

TABLE OF CONTENTS  
PART V

SECTION

2022

5.1           **GENERAL**

- 5.1.1       Materials Control Functions of the Secretary of Transportation
- 5.1.2       Materials Control Functions of the Bureau of Construction and Materials

5.2           **QUALITY CONTROL/QUALITY ASSURANCE**

- 5.2.1       Statistics
- 5.2.2       Rounding Off and Random Sampling
  - 5.2.2.1     Rounding Off of Numbers
  - 5.2.2.2     Random Sampling
- 5.2.3       Reasons for Quality Control/Quality Assurance (QC/QA) and the Certified Inspection and Testing Training Program (CIT<sup>2</sup>).
- 5.2.4       Procedures for Quality Assurance
- 5.2.5       Quality Control/Quality Assurance (QC/QA) Tests
- 5.2.6       Comparison of Quality Control and Verification Tests
- 5.2.7       Contractor's Quality Control Plan
  - 5.2.7.1     HMA: Contractor's Quality Control Plan
  - 5.2.7.2     Guide for Quality Control and Acceptance Requirements for HMA
  - 5.2.7.3     Example of a Laboratory Quality Manual For HMA
  - 5.2.7.4     Concrete: Contractor's Quality Control Plan
  - 5.2.7.5     Example of a Laboratory Quality Manual for Concrete
  - 5.2.7.6     Concrete Structures: Contractor's Quality Control Plan
  - 5.2.7.7     Example of a Contractor's Concrete Structures Quality Control Plan for Controlling Evaporation
  - 5.2.7.8     Cement Treated Base: Contractor's Quality Control Plan (CTB)
  - 5.2.7.8.1   Example of a Laboratory Quality Manual for CTB

5.3           **MIX DESIGN METHODS**

- 5.3.1       Concrete Mix Design
- 5.3.2       Bituminous Mix Design
- 5.3.3       Superpave Mix Design
- 5.3.4       Mix Design Procedures for CIR (Cold in Place Recycling) Material

5.4           **LABORATORY AND SAMPLE IDENTIFICATION**

- 5.4.1       Laboratory Identification
- 5.4.2       Sample Identification
- 5.4.3       Sample Identification Forms

5.5           **REQUIRED SAMPLE SIZES**

TABLE OF CONTENTS  
PART V

2022

SECTION

5.6	<b>AGGREGATES</b>
5.6.1	General
5.6.2	Types of Production
5.6.3	Inspection Responsibilities
5.6.4	Approval of Deposits
5.6.5	Inspection, Sampling and Testing
5.7	<b>INSPECTION AND SAMPLING OF MATERIALS</b>
5.7.1	Asphalt Materials
5.7.2	Brick and Concrete Masonry Units
5.7.3	Concrete Curing Materials
5.7.4	Joint Sealing and Joint Filler Materials
5.7.5	Miscellaneous Materials
5.7.6	Miscellaneous Metals
5.7.7	Bridge Paints and Pavement Marking Materials
5.7.8	Culvert, Sewer and Underdrain Pipe
5.7.9	Cementitious Material
5.7.10	Materials for Roadside Improvements
5.7.11	Steel and Iron
5.7.12	Timber, Lumber, Piling and Posts
5.7.13	Water for Use with Portland Cement
5.8	<b>NUCLEAR GAUGE</b>
5.8.1	1.13.2 SOM - RADIOLOGICAL SAFETY GUIDELINES
5.8.2	Independent Assurance Replicate (ASR) Check for Nuclear Density Gauges
5.8.3	Segregation Check Using the Nuclear Density Gauge
5.8.4	Joint Density Evaluation Using the Nuclear Density Gauge
5.9	<b>SAMPLING AND TEST METHODS FOREWORD</b>
5.9.01	KT-01 Sampling and Splitting of Aggregates
5.9.02	KT-02 Sieve Analysis of Aggregates
5.9.03	KT-03 Material Passing No. 200 (75 $\mu$ m) Sieve by the Wash Method
5.9.04	KT-04 Percent Retained on the No. 200 (75 $\mu$ m) Sieve by Dry Screening
5.9.05	KT-05 Unit Weight of Aggregate
5.9.06	KT-06 Specific Gravity and Absorption of Aggregates
5.9.07	KT-07 Clay Lumps and Friable Particles in Aggregate
5.9.08	KT-08 Shale or "Shalelike" Materials in Aggregate
5.9.10	KT-10 Plasticity Tests
5.9.11	KT-11 Moisture Tests
5.9.12	KT-12 Standard Compaction Test

TABLE OF CONTENTS

PART V

2022

SECTION

5.9.13	KT-13	Field Density Tests of Soils, Treated Base Courses and Water Bound Base Courses
5.9.14	KT-14	Marshall Tests of Bituminous Mixes
5.9.15	KT-15	Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)
5.9.16	KT-16	Deleted
5.9.17	KT-17	Sampling Freshly Mixed Concrete
5.9.18	KT-18	Air Content of Freshly Mixed Concrete by the Pressure Method
5.9.19	KT-19	Air Content of Freshly Mixed Concrete by the Volumetric Method
5.9.20	KT-20	Mass Per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete
5.9.21	KT-21	Slump of Portland Cement Concrete
5.9.22	KT-22	Making and Curing Compression and Flexural Test Specimens in the Field
5.9.23	KT-23	Flexural Strength of Concrete (Third-Point Loading Method)
5.9.24	KT-24	Determination of Free Moisture or Absorption of Aggregate for Use in Concrete
5.9.25	KT-25	Sampling and Splitting Plant Mixed Asphalt Mixtures
5.9.26	KT-26	Sampling Asphalt Materials
5.9.27	KT-27	Sampling Joint Compound Materials
5.9.28	KT-28	Sampling Bridge Paint
5.9.29	KT-29	Field Sampling of Portland Cement, Lime and Fly Ash
5.9.30	KT-30	Field Sampling of Thermoplastic Pavement Marking Material
5.9.31	KT-31	Determination of Percentage of Crushed Particles in Crushed Gravel AKA: Coarse Aggregate Angularity
5.9.32	KT-32	Method of Test for Density of Compacted Asphalt Mixtures by Nuclear Method
5.9.33	KT-33	Deleted See KTMR-39
5.9.34	KT-34	Sieve Analysis of Extracted Aggregate
5.9.35	KT-35	Sticks in Aggregate
5.9.36	KT-36	Density of Freshly Mixed Concrete in Bridge Deck Overlays by Nuclear Gauge
5.9.37	KT-37	Making, Curing and Testing Cement Treated and Unbound Bases
5.9.38	KT-38	Density of Freshly Mixed Concrete in Pavement by Nuclear Method
5.9.39	KT-39	Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures
5.9.41	KT-41	Determination of Density and Moisture Content of Portland Cement Treated Bases, Aggregate Bases and Aggregate Shoulders by Nuclear Method
5.9.42	KT-42	Sieve Analysis for Acceptance of Lime or Cement Treated Soils
5.9.43	KT-43	Moisture Content of Asphalt Mixtures or Mineral Aggregates - Microwave Oven Method
5.9.44	KT-44	Method of Testing the Strength of Portland Cement Concrete Using the Maturity Method
5.9.45	KT-45	Determination of Dry Paint Film Thickness with the Magnetic Gauge
5.9.46	KT-46	Determination of Pavement Profile with the Profilograph
5.9.47	KT-47	Depth Determination of Hot-in-Place Recycled Asphalt Pavement (HIR)
5.9.49	KT-49	Method for Obtaining and Testing Drilled Cores from PCCP and Precast Girders
5.9.50	KT-50	Uncompacted Void Content of Fine Aggregate
5.9.51	KT-51	Field Density and Moisture Tests of Soils by Nuclear Gauge
5.9.54	KT-54	Deleted See KT-46
5.9.55	KT-55	Plastic Fines in Combined Aggregates by Use of the Sand Equivalent Test
5.9.56	KT-56	Resistance of Compacted Asphalt Mixture to Moisture Induced Damage

TABLE OF CONTENTS  
PART V

SECTION

2022

5.9.57	KT-57	Determination of Asphalt Content and Gradation of Hot Mix Asphalt Concrete by the Ignition Method
5.9.58	KT-58	Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor
5.9.59	KT-59	Flat and Elongated Particles in Coarse Material Test
5.9.60	KT-60	Indirect Tensile Test
5.9.61	KT-61	Raveling Test on Recycled Asphalt Specimens
5.9.62	KT-62	Percent Solids of Lime Slurry
5.9.63	KT-63	Method for Determining Draindown Characteristics in Uncompacted Asphalt Mixtures
5.9.64	KT-64	Method for Determining Volume of Voids in Compacted Filler or Fines
5.9.65	KT-65	Sampling and Splitting Cement Treated Base Mixtures
5.9.66	KT-66	Sampling Epoxy Pavement Marking/Multi-Component Pavement Marking
5.9.67	KT-67	Sampling Glass Beads
5.9.68	KT-68	Sampling Traffic Paint
5.9.69	KT-69	Relative Density
5.9.70	KT-70	Method for Testing Polymer Overlays for Surface Preparation and Adhesion
5.9.71	KT-71	Air-Void Analyzer
5.9.72	KT-72	Measuring Flowing Concrete
5.9.73	KT-73	Density, Absorption and Voids in Hardened Concrete
5.9.76	KT-76	Method for Testing the Compressive Strength of Molded Cylindrical Concrete Specimens
5.9.77	KT-77	Method for Capping Cylindrical Concrete Specimens
5.9.78	KT-78	Method for Determining the Tensile Adhesive Strength of Asphalt Pavement Tack Coat
5.9.79	KT-79	Surface Resistivity of Concrete
5.9.80	KT-80	Uncompacted Void Content of Coarse Aggregate
5.9.81	KT-81	Sampling Cold Plastic Pavement Marking, Patterned Cold Plastic Pavement Marking Tape and High Durability Pavement Marking Tape
5.9.82	KT-82	Determination of Excessive Moisture in Concrete Surfaces
5.9.83	KT-83	Strand Bond in Prestressed Concrete Members
5.9.84	KT-84	Sampling Nuts, Bolts and Washers
5.9.85	KT-85	Procedures for Evaluating the Movement, Rotation, and Sound Generation of Portable Temporary Rumble Strips
5.9.86	KT-86	Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method (Super Air Meter – SAM)
5.10	<b>CALCULATIONS</b>	
5.10.1	Absolute Volume and Percent of Voids in a Unit Volume of Aggregate	
5.10.2	Theoretical Specific Gravity of a Combination of Aggregates	
5.10.3	Volume of Asphalt Materials	
5.10.4	Calculations for the Marshall Mix Design of Bituminous Mixtures	
5.10.5	Fineness Modulus of Aggregates (Gradation Factor)	

TABLE OF CONTENTS  
PART V

2022

SECTION

**APPENDICIES**

- Appendix A Sampling and Testing Frequency Chart – **Non Quality Control/Quality Assurance Specifications**
- Appendix B Sampling and Testing Frequency Chart – **Quality Control/Quality Assurance Specifications**
- Appendix C Test Procedure Criteria for the Independent Assurance Program
- Appendix D Policy and Procedure Manual for the Inspection of Kansas Department of Transportation District Laboratories



## **PART V – MATERIALS CONTROL**

### **5.1. GENERAL**

#### **5.1.1. MATERIALS CONTROL FUNCTIONS OF THE SECRETARY OF TRANSPORTATION**

By state statute, the Secretary of Transportation has the power, duty, authority and jurisdiction “to inspect and test all materials...used for state highway purposes or highway projects involving federal funds, and to develop methods and procedures for this purpose.” (K.S.A. 68-404(h)). The Secretary’s inspection and testing of materials and the methods and procedures employed to conduct this inspection and testing are for the Department’s benefit. They are not for the benefit of contractors, producers, or suppliers.

Part V of this Manual and KDOT’s Standard Specifications are two means by which the Secretary fulfills the Secretary’s statutory obligations. Nothing in Part V or KDOT’s Standard Specifications shall be construed to limit KDOT’s discretion to adopt and/or revise standards, specifications, test procedures, removal procedures, or other policies and procedures applicable to the materials used for highway construction/maintenance. Nothing in Part V or KDOT’s Standard Specifications, including without limitation, prequalification or preapproval of materials/sources of material, is a guarantee to contractors, producers, or suppliers that a given material/source of material for highway construction/maintenance will be approved by or remain approved by KDOT, be accepted by KDOT, or be purchased by KDOT or others.

Part V and KDOT’s Standard Specifications include provisions for the Department’s Quality Control/Quality Assurance Program (QC/QA Program), which is required by FHWA to assure the quality of materials and construction in all Federal-aid highway projects and as a condition precedent to use of federal funds. The Department administers its state program in the same manner as its federal program. The Secretary has delegated to the Bureau of Construction and Materials the responsibility for the establishment and administration of the materials’ portion of the Department’s QC/QA Program.

#### **5.1.2. MATERIALS CONTROL FUNCTIONS OF THE BUREAU OF CONSTRUCTION AND MATERIALS**

The Bureau of Construction and Materials has responsibility for the establishment and administration of the materials portion of the Department’s Quality Control/Quality Assurance (QC/QA) Program.

The Bureau develops standards and specifications for materials, establishes sampling procedures and frequencies, and establishes testing procedures that are used in the laboratory and the field in order to assure compliance with specifications. The fact that KDOT develops objective specifications and testing criteria and approves or preapproves materials is not intended to limit the Department’s discretion regarding the inspection, sampling, testing and acceptance of materials for highway construction/maintenance.

The Bureau performs materials testing to assist the districts in administering quality assurance functions of the QC/QA Program. Such testing includes tests on materials purchased by

contractors or the State for use in maintenance or construction activities. This testing is for KDOT's benefit not to ensure contractors' quality control. The Bureau also conducts tests on concrete, bituminous mixtures and numerous other specialized materials, the results of which are used by others. KDOT has no control over or responsibility for the use of KDOT's materials testing by other entities and no legal duties to such entities.

The responsibility of the Bureau extends to all materials used or proposed for use in State and Federal-aid highway construction and maintenance.

On "full oversight" and "certification acceptance" projects involving Federal funds, the Bureau of Construction and Materials must certify to the Federal Highway Administration as to the quality of each type of material used on each project before the State is completely reimbursed by the Federal Government. On all other projects the bureau reviews project materials records and advises the District Engineer of materials status prior to contract finalization.

To accomplish its various objectives, duties and responsibilities, the Bureau organization consists of the Headquarters Administration office, the Materials and Research Center (MRC), and Regional Laboratories. It also has the assistance of a District Laboratory in each District.



## 5.2. QUALITY CONTROL /QUALITY ASSURANCE

### 5.2.1. STATISTICS

#### 1. ACKNOWLEDGEMENT

This paper has been copied directly from the HMA Manual with a few modifications from the original version. The original version was prepared by Dr. Mustaque Hossain. Ph. D., P.E., Kansas State University.

#### 2. BACKGROUND

**2.1.** American industries have defined the Quality Control/Quality Assurance (QC/QA) concept to fit within their particular application and there is no doubt that the “working” definition differs from industry to industry. In the highway community those Contractors, suppliers, and Public Agencies (Agency) that have implemented a QC/QA program probably have their own definition as well. It is important that a concise and logical definition of QC/QA be adopted and be supported by all members within a single industry. For the highway community the QC/QA concept must be defined so that Contractors, suppliers and Agencies can identify with a basic concept and proceed to establish their respective programs. The American Association of State Highway and Transportation Officials (AASHTO) has defined QC/QA in AASHTO R 10 in the following manner:

**2.2. Quality Control:** The system used by a contractor to monitor, assess and adjust their production or placement processes to ensure that the final product will meet the specified level of quality. Quality control includes sampling, testing, inspection and corrective action (where required) to maintain continuous control of a production or placement process.

**2.3. Quality Assurance:** All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service; or (2) making sure the quality of a product is what it should be.

#### 3. STANDARD DEFINITIONS FOR QC/QA APPLICATIONS

The following terms are defined in the AASHTO R 10 *except Agency*. All other shall be consistent with the **2020 AASHTO Guide Specifications For Highway Construction**.

**3.1. Agency:** The State Highway or Transportation Department, Commission, or other organization, constituted under State or Commonwealth laws, that administers highway or transportation work.

The term Agency was chosen for the purpose of consistency, as this document is intended for use by any governing organization attempting to prepare specifications for the purpose of highway or transportation work.

**3.2. Acceptable Quality Level (AQL):** The level of established actual quality for a quality characteristic that is fully acceptable.

**3.3. Buyer:** See *Agency* above.

**3.4. Buyer’s Risk:** Also called *agency’s risk*, or *risk of a Type II or beta ( $\beta$ ) error*. It is the risk to the agency of accepting rejectable quality level (*RQL*) material or workmanship.

**3.5. Certified Technician:** A technician certified by some agency as proficient in performing certain duties.

**3.6. Disincentive:** A pre-established decrease in payment to the contractor applied to a contract bid item for which the level of materials quality and workmanship, determined by statistical means, does not meet the specified acceptable quality level (*AQL*). The disincentive is usually expressed as a percentage of the original Contract bid-price.

**3.7. Incentive/disincentive provision (for quality):** A pay adjustment schedule which functions to motivate the contractor to provide a high level of quality.

**3.8. Lower Specification Limit (LSL):** The lower statistically based limiting value associated with a quality characteristic and used to evaluate the acceptability of a lot.

**3.9. Percent Within Limits (PWL):** The percentage of the lot falling above a lower specification limit, beneath an upper specification limit, or between upper and lower specification limits.

**3.10. Quality Assurance:** All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service; or (2) making sure the quality of a product is what it should be.

**3.11. Quality Control:** Also called *process control*. The system used by a contractor to monitor, assess and adjust their production or placement processes to ensure that the final product will meet the specified level of quality. Quality control includes sampling, testing, inspection and corrective action (where required) to maintain continuous control of a production or placement process.

**3.12. Quality Control Plan:** A project-specific document prepared by the contractor that identifies all QC personnel and procedures that will be used to maintain all production and placement processes "in control" and meet the agency specification requirements. The document also addresses actions to be taken in the event that a process goes "out of control".

**3.13. Quality Level Analysis:** A statistical procedure that provides an estimate of the percentage of a given lot that is within specification limits (*PWL*) or outside specifications limits (*PD*).

**3.14. Rejectable Quality Level (RQL):** The level of established actual quality for a quality characteristic that is rejectable when using a particular quality measure.

**3.15. Seller's Risk ( $\alpha$ ):** Also called *contractor's risk*, or *risk of a type 1 or alpha ( $\alpha$ ) error*. The risk to the contractor of having acceptable quality level (*AQL*) material or workmanship rejected.

**3.16. Target Value:** The value that is placed on a quality characteristic that represents the mean of the expected distribution of the specified population.

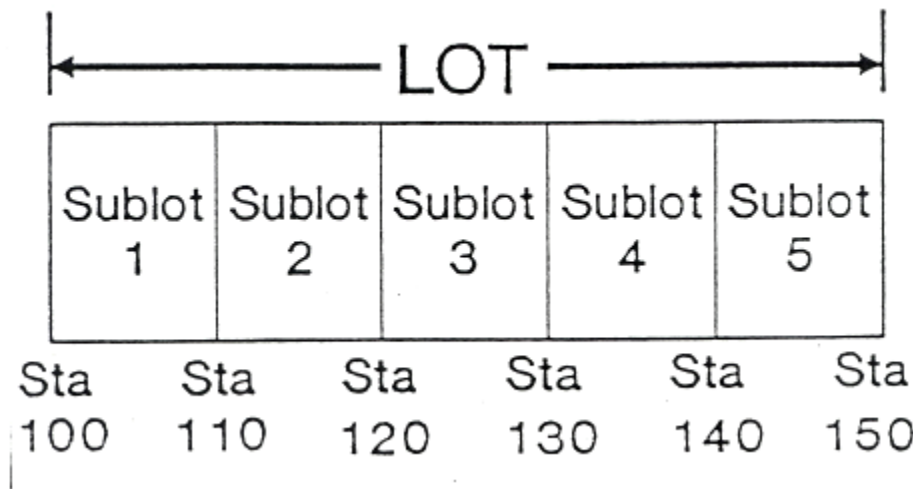
**3.17. Upper Specification Limit (USL):** The upper statistically based limiting value associated with a quality characteristic and used with a quality measure to evaluate the quality of a lot.

#### **4. MISCELLANEOUS DEFINITIONS RELATED TO QC/QA**

**4.1. Lot:** An isolated quantity of material which is produced from a single source under similar conditions. A lot is a measured amount of construction assumed to be produced by the same process. For example, the placement of 4,000 tons of hot-mix asphalt (HMA) or one days production for concrete paving. Also referred to as population in statistical analysis.

**4.2. Sublot:** Sublots are equal divisions (i.e. portions) of a lot. A lot is divided into sublots for sampling purposes. For example, if a lot is considered to be 4,000 tons of HMA and the specification requires that the lot be divided into four sublots, the size of each sublot would be 1,000 tons (4,000 /4). For concrete paving, a lot is considered to be one day's production and the specification requires that the lot be subdivided into five sublots as shown in **Figure 1**.

**4.3. Sample:** Each individual quantity of material collected for test. A portion of lot.



**Figure 1. Lot and sublots in a highway construction setting**

## 5. INTRODUCTORY STATISTICAL TERMS

**5.1. Average or Mean ( $\bar{x}$ ):** Arithmetic mean or average determined for a number of variables ( $x_i$ ) as below:

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n} = \frac{\sum x_i}{n} \quad (1)$$

**5.1.1. Example:** Find the arithmetic mean or average for the asphalt content of six Superpave mix sublots given as: 5.4, 5.8, 6.2, 5.4, 5.4 and 6.0%.

$$\bar{x} = \frac{5.4 + 5.8 + 6.2 + 5.4 + 5.4 + 6.0}{6} = \frac{34.2}{6} = 5.7$$

**5.1.2. Example:** Find the arithmetic mean or average for the percent air in the concrete mix of six sublots given as: 6.6, 6.2, 5.5, 7.8, 6.9 and 6.6%.

$$\bar{x} = \frac{6.6 + 6.2 + 5.5 + 7.8 + 6.9 + 6.6}{6} = \frac{39.6}{6} = 6.6$$

**5.2. Moving Average:** Average computed based on a fixed set of continuous data points. For KDOT, the  $w$  represents the number of tests within a lot:

$$x_{ma} = \frac{x_{i-3} + x_{i-2} + x_{i-1} + x_i}{w} \quad (2)$$

**5.2.1. Example:** Find the 4-point moving average for the above asphalt content data:

<u>Asphalt content (%)</u>	<u>4-point moving average</u>
5.4	-
5.8	-
6.2	-
5.4	5.7
5.4	5.7
6.0	5.8

**5.2.2. Example:** Find the 4-point moving average for the above percent air content data:

<u>Air content (%)</u>	<u>4-point moving average</u>
6.6	-
6.2	-
5.5	-
7.8	6.5
6.9	6.6
6.6	6.7

**5.3. Range (R):** Range is the difference between the largest and smallest values. A simple measure of variability.

$$R = x_{\max} - x_{\min} \quad (3)$$

**5.3.1. Example:** Find the Range (R) for the asphalt content data in 5.2.1. above:

$$R = 6.2 - 5.4 = 0.8\%$$

**5.3.2. Example:** Find the Range (R) for the air content data in 5.2.2. above:

$$R = 7.8 - 5.5 = 2.3\%$$

**5.4. Sample Standard Deviation (s):** Standard deviation is the root mean square of the deviation from the mean. This is a better measure of variability than range and is computed as below:

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \quad (4)$$

where, n is the sample size.

**5.4.1. Example:** Find the standard deviation for the asphalt content data given below:

$x_i$	$\bar{x}$	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
5.4	5.7	-0.3	0.09
5.8	5.7	0.1	0.01
6.2	5.7	0.5	0.25
5.4	5.7	-0.3	0.09
5.4	5.7	-0.3	0.09
6.0	5.7	0.3	0.09
-----			-----
n = 6			$\Sigma = 0.62$

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{0.62}{6-1}} = 0.35$$

**5.4.2. Example:** Find the standard deviation for the air content data given below:

$x_i$	$\bar{x}$	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
6.6	6.6	0.0	0.00
6.2	6.6	-0.4	0.16
5.5	6.6	-1.1	1.21
7.8	6.6	1.2	1.44
6.9	6.6	0.3	0.09
6.6	6.6	0.0	0.00
-----			-----
n = 6			$\Sigma = 2.90$

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{2.90}{6-1}} = 0.76$$

**5.5. Population Standard Deviation ( $\sigma$ ):** When the sample size  $n$  is large (usually greater than 30), the standard deviation obtained is for the population. The equation is same as in (4) except that the denominator is replaced by  $n$ .

**5.6. Variance ( $s^2$ ):** Sample variance is simply the square of the sample standard deviation.

**5.6.1. Example:** Find the variance of the asphalt content data given above:

$$s = 0.35; \qquad s^2 = (0.35)^2 = 0.123$$

**5.6.2. Example:** Find the variance of the air content data given above:

$$s = 0.76; \qquad s^2 = (0.76)^2 = 0.578$$

**5.7. Coefficient of Variation (COV):** The coefficient of variation is defined as the standard deviation as a percentage of the mean. It is an additional measure of variability and is calculated as:

$$C.O.V.(%) = \frac{s}{\bar{x}} \times 100 \qquad (5)$$

**5.7.1. Example:** Find the coefficient of variation of the asphalt content data given above:

$$C.O.V.(%) = \frac{0.35}{5.7} \times 100 = 6.1\%$$

**5.7.2. Example:** Find the coefficient of variation of the asphalt content data given above:

$$C.O.V.(%) = \frac{0.76}{6.6} \times 100 = 11.5\%$$

5.8. Normal Distribution Curve: It is a typical "bell-shaped" symmetrical curve which usually will describe the distribution of engineering measurements, e.g. test results of HMA or concrete mixes. Figures 2, 3 and 4 show various examples of normal distribution curves and how they vary but are interrelated.

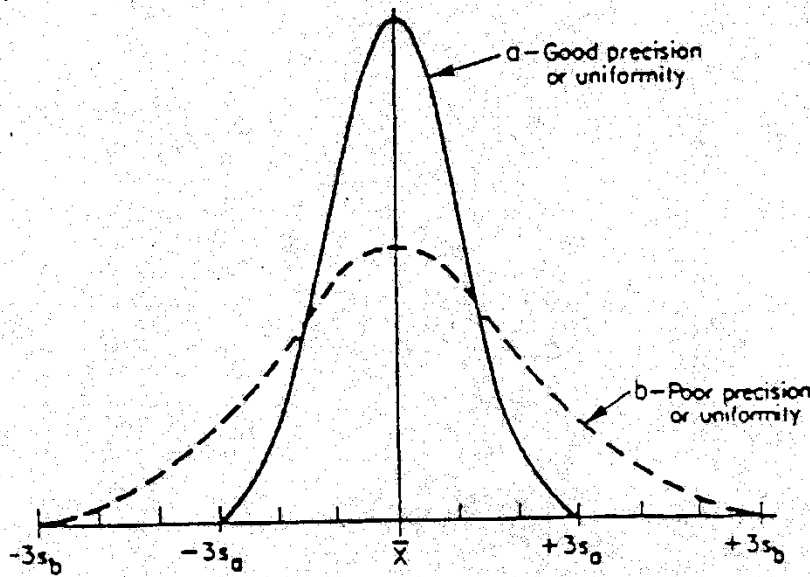


Figure 2. Normal distribution curves

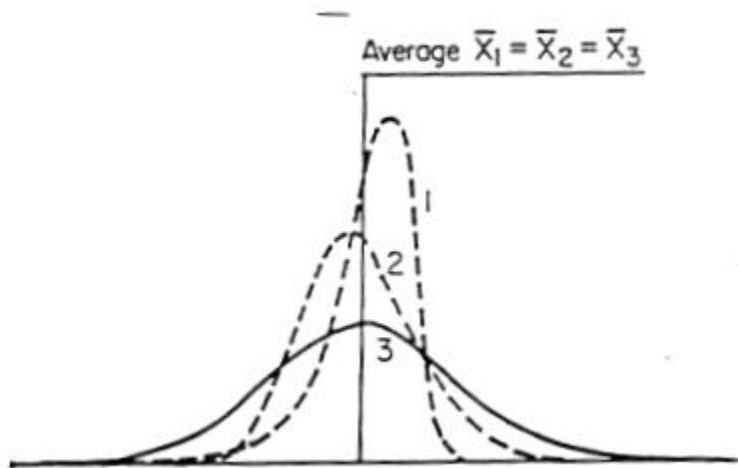
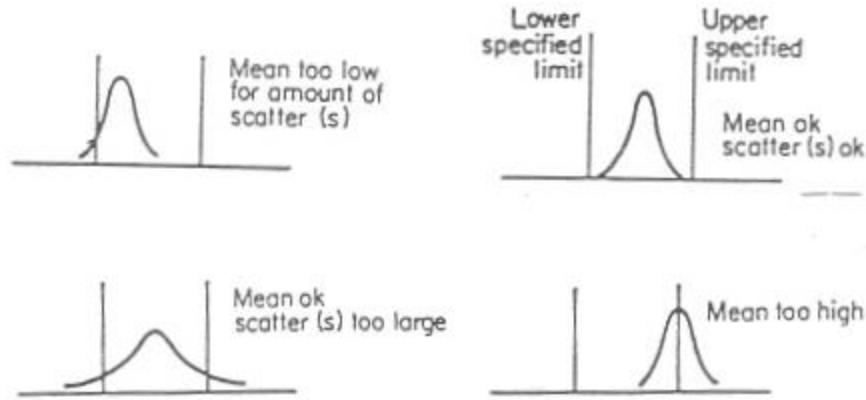
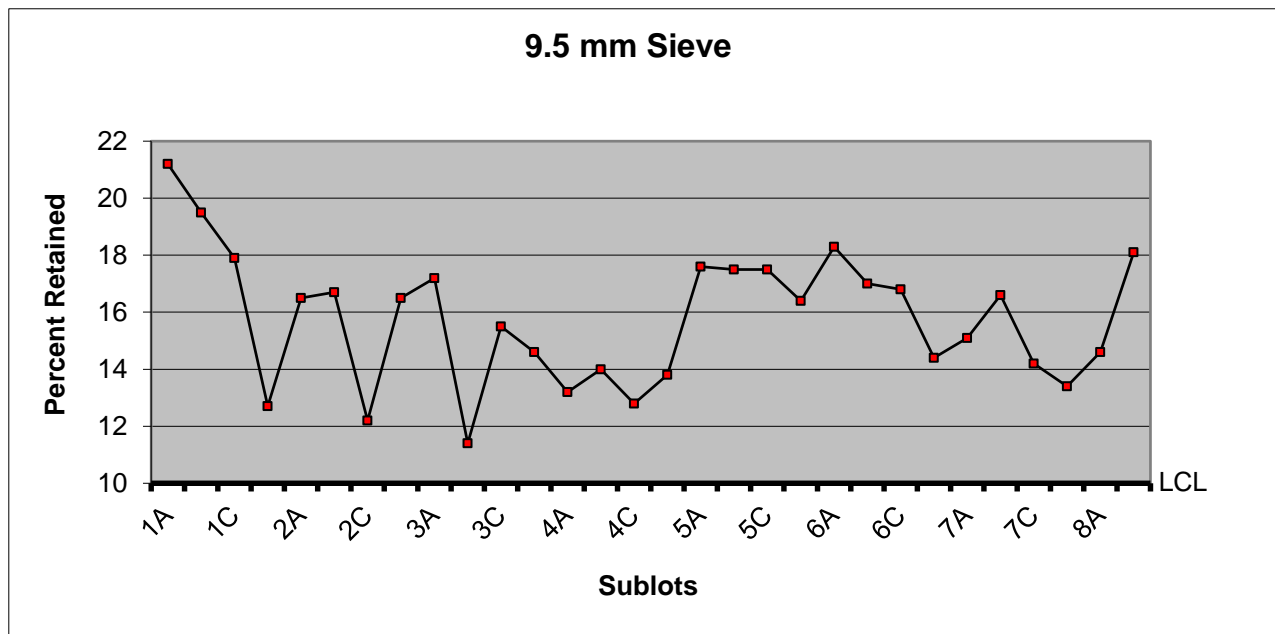


Figure 3. Quite different distributions may have the same average



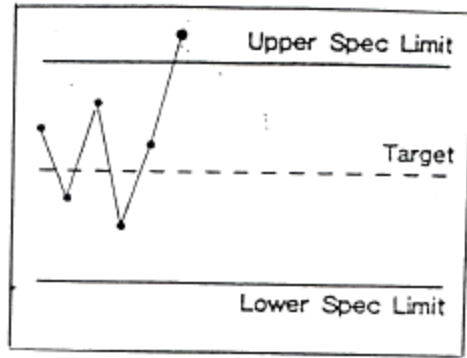
**Figure 4. Process control related to specification limits**

**5.9. Control charts:** Control charts are horizontal line charts. The horizontal lines (for single test results or for "average" type charts) generally consist of a central line at the specified average and an upper line at the specified upper acceptance limit and a lower line at the lower acceptance limit (if both are applicable) - for an "acceptance" control chart. **Figure 5** shows a typical control chart for average 9.5 mm aggregate size (percent retained). Control charts are very helpful for identifying possible problems. Examples are provided in **Figures 6, 7, 8, and 9**. It is to be noted that if these charts are plotted using individual test results, then the chance causes cannot be distinguished from assignable causes. However, the moving average tends to smooth out chance variations and a control chart based on moving averages can be used to indicate significant trends due to variation in materials and processes.

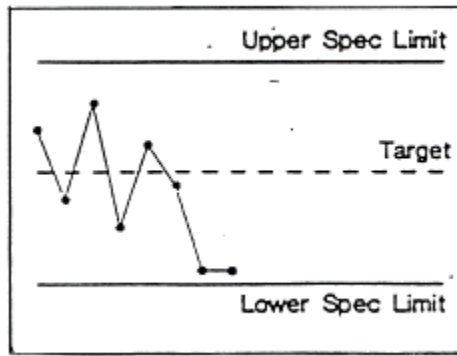


**Figure 5. A typical control chart**

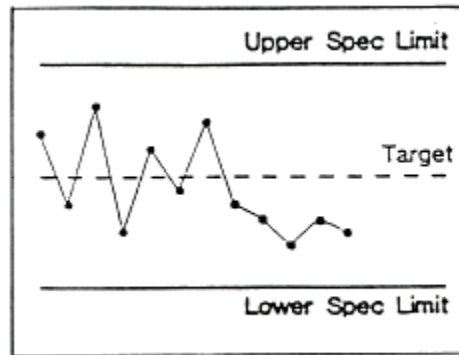




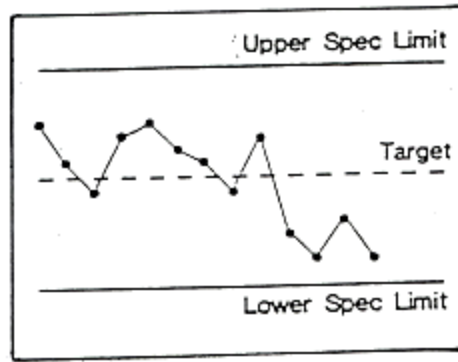
**Figure 6. A point outside the upper specification limits**



**Figure 7. Two consecutive points near the upper or lower specification limits**



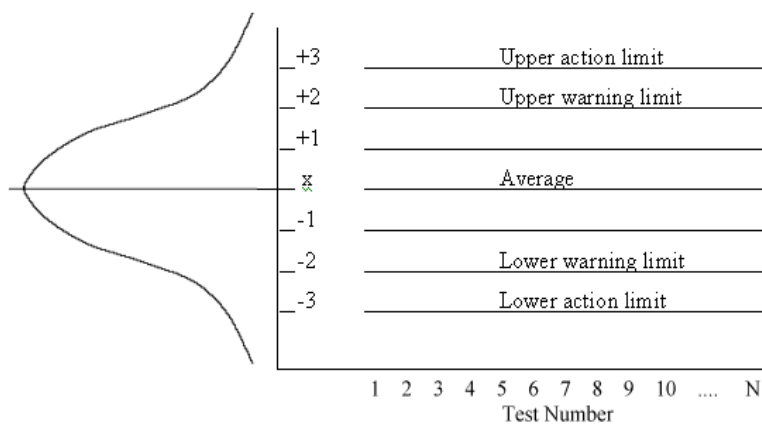
**Figure 8. Five consecutive points on one side of the center target value**



**Figure 9. A sudden change in the level of results**

**5.10. Statistical Control charts:** It is to be noted that regardless of the shape of the normal curve and spread ( $s$ ), 68.26% of the test results will be within  $\pm 1s$ , 95.44% within  $\pm 2s$  and 99.74% within  $\pm 3s$ . Thus, it is apparent that a control chart based on the test statistics ( $\bar{x}$  and  $s$ ) could be easily developed. The center line could be the mean of  $k$  sample means, each based on tests. The Upper Specification Limit (USL) and the Lower Specification Limit (LSL) can be fixed based on multiples of  $s$  resulting in a typical statistical control chart as shown in **Figure 10**.

**5.11. Random Number:** A number selected entirely by chance as from a table of random numbers as shown in **Table 1 of the KDOT Construction Manual Section 5.2.2.2**. (A scientific calculator can also generate random number; however, this method needs to be approved by the District Materials Engineer).



**Figure 10. Statistical control chart**

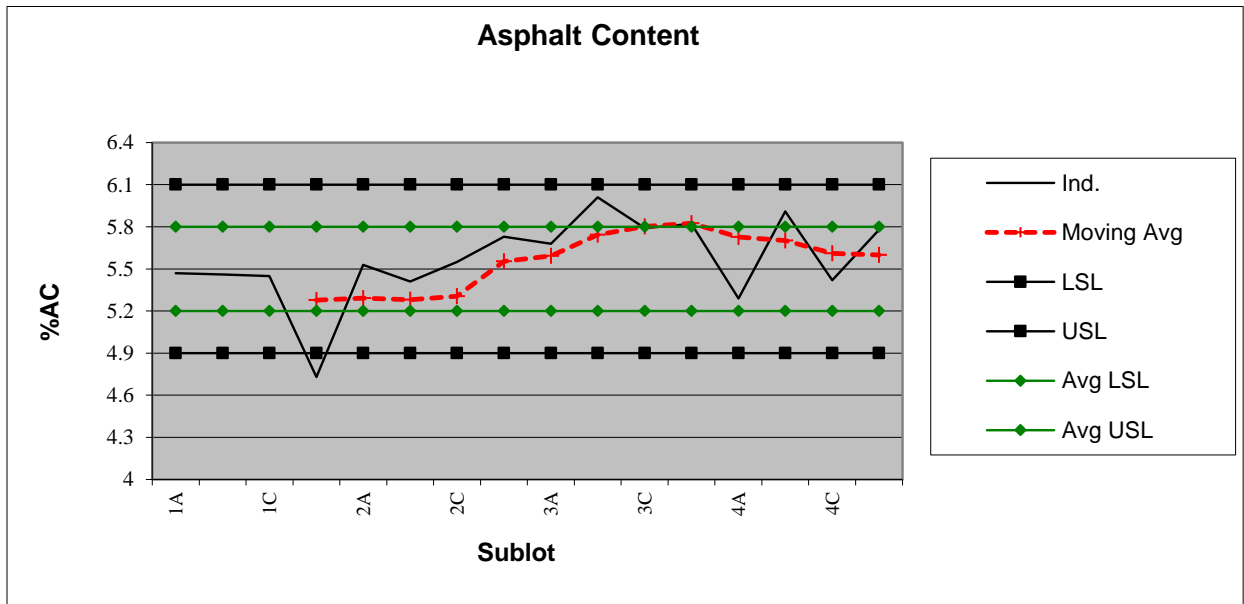
### 5.12. Moving Average

Within KDOT’s QC/QA specifications, moving averages are to be plotted on the same chart as the individual test results. This is a simple process to include on the graphs. The number of tests in each average will be dictated by the specifications for the project. For the following illustration, a 4-point moving average will be considered.

**Table 1: Individual Asphalt Content Test Data**

Sublot	AC%	
1A	5.47	
1B	5.46	
1C	5.45	
1D	4.73	1st avg = ( 5.47 + 5.46 + 5.45 + 4.73 )/4 = 5.28
2A	5.53	2nd avg = ( 5.46 + 5.45 + 4.73 + 5.53 )/4 = 5.29
2B	5.41	3rd avg = ( 5.45 + 4.73 + 5.53 + 5.41 )/4 = 5.28
2C	5.55	4th avg = ( 4.73 + 5.53 + 5.41 + 5.55 )/4 = 5.31
2D	5.73	5th avg = ( 5.53 + 5.41 + 5.55 + 5.73 )/4 = 5.56
3A	5.68	6th avg = ( 5.41 + 5.55 + 5.73 + 5.68 )/4 = 5.59
3B	6.01	7th avg = ( 5.55 + 5.73 + 5.68 + 6.01 )/4 = 5.74
3C	5.79	8th avg = ( 5.73 + 5.68 + 6.01 + 5.79 )/4 = 5.80
3D	5.82	9th avg = ( 5.68 + 6.01 + 5.79 + 5.82 )/4 = 5.83
4A	5.29	10th avg = ( 6.01 + 5.79 + 5.82 + 5.29 )/4 = 5.73
4B	5.91	11th avg = ( 5.79 + 5.82 + 5.29 + 5.91 )/4 = 5.70
4C	5.42	12th avg = ( 5.82 + 5.29 + 5.91 + 5.42 )/4 = 5.61
4D	5.78	13th avg = ( 5.29 + 5.91 + 5.42 + 5.78 )/4 = 5.60

When starting out, the first four tests (1 thru 4) will be used to determine the average. As the fifth test becomes available for plotting, a second 4-point moving average becomes available by taking the average of the 2<sup>nd</sup> thru 5<sup>th</sup> tests. This process continues as additional tests become available. Using the test data from **Table 1**, a clear pattern emerges for calculating the averages.



## MOVING AVERAGE

Notice how the individual test result fails in subplot 1D which exceeded the single lower specification limit (LSL). There is also a failure of the moving average in 3D. Read the specifications to determine what, if any, lower and upper specification limits exist for test results and what action is warranted when such an event occurs.

### 6. QUALITY LEVEL ANALYSIS

**6.1.** *Quality Level Analysis* is a statistical procedure that provides a method of estimating the percentage of each lot or subplot of material, product item of construction, or completed construction that may be expected to be within specified tolerance limits. This percent within limits is represented by the unshaded areas under the normal curves in **Figure 11**.

**6.2.** When the specifications require that the percent within limits be established by Quality Level Analysis, the following procedure shall apply:

Terminology:

**6.2.1.**  $x_i$  = the individual values under consideration

**6.2.2.**  $n$  = the number of individual values under consideration

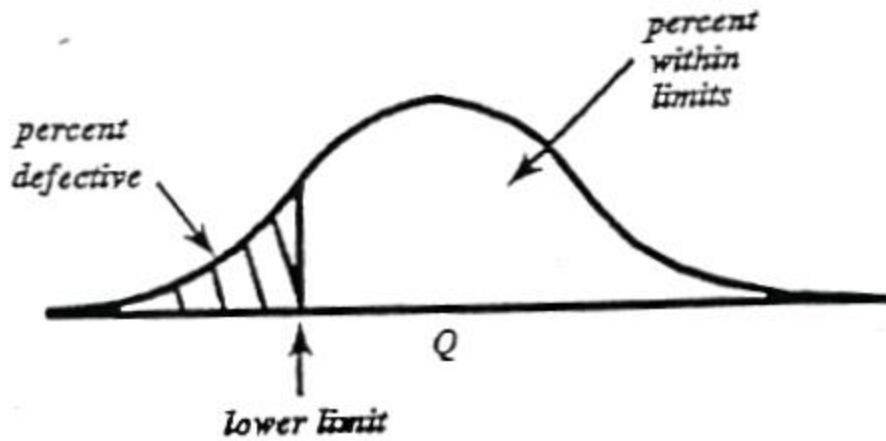
**6.2.3.**  $\bar{X}$  = the arithmetic mean or average of values under consideration.  $\bar{X}$  may be expressed as  $\Sigma x_i/n$ , or the sum of the individual values divided by the number of individual values.

**6.2.4.**  $Q_U$  = Upper Quality Index. Found by subtracting the average  $\bar{X}$  from the Upper Specification Limit (USL) and dividing by the sample standard deviation(s).

**6.2.5.**  $Q_L$  = Lower Quality Index. Found by subtracting the Lower Specification Limit (LSL) from the average  $\bar{X}$  and dividing by the sample standard deviation (s).

## SINGLE-LIMIT SPECIFICATION

DISTRIBUTION OF CHARACTERISTIC OF INTEREST



## DOUBLE-LIMIT SPECIFICATION

DISTRIBUTION OF CHARACTERISTIC OF INTEREST

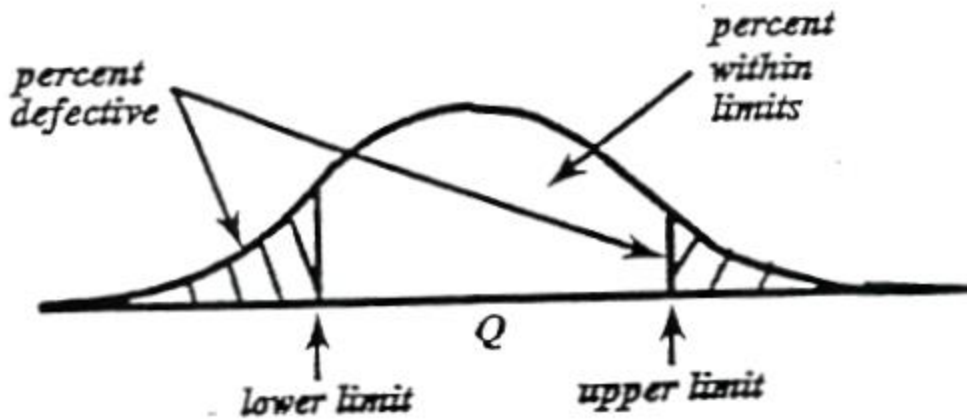


Figure 11. Concept of Percent Defective

6.3. Steps in Analysis for a double-limit specification:

6.3.1. Locate “n” sampling positions on the lot or subplot in a random manner.

6.3.2. Make a measurement at each sample position or take a test portion and make the measurement on the test portion.

**6.3.3.** Average all measurements to find  $\bar{X}$ .

**6.3.4.** Compute the sample standard deviation using:

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n - 1}}$$

**6.3.5.** Find the Upper Quality Index ( $Q_U$ ) by subtracting the average ( $\bar{X}$ ) from the Upper Specification Limit (USL) and dividing the result by  $s$ .

$$Q_U = \frac{(USL - \bar{x})}{s}$$

**6.3.6.** Find the Lower Quality Index ( $Q_L$ ) by subtracting the Lower Specification Limit (LSL) from the average ( $\bar{X}$ ) and dividing the result by  $s$ .

$$Q_L = \frac{(\bar{x} - LSL)}{s}$$

**6.3.7.** Estimate the percentage that will fall below the Upper Specification limit ( $PWL_U$ ). This is done by referring to **Table 2** with the computed value of  $Q_U$  and then reading the appropriate  $PWL_U$  value.

**6.3.8.** Estimate the percentage that will fall above the Lower Specification Limit ( $PWL_L$ ).

**6.3.9.** Determine the Quality Level stated as percent within limits (PWL).

$$PWL = (PWL_U + PWL_L) - 100$$

**6.4.** Steps in Analysis for a single-limit specification with lower-limit specified:

**6.4.1.** Locate “n” sampling positions on the lot or subplot in a random manner.

**6.4.2.** Make a measurement at each sample position or take a test portion and make the measurement on the test portion.

**6.4.3.** Average all measurements to find  $\bar{X}$ .

**6.4.4.** Compute the sample standard deviation using:

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n - 1}}$$

**6.4.5.** Find the Quality Index (Q) by subtracting the Lower Specification Limit (LSL) from the average ( $\bar{x}$ ) and dividing the result by s.

$$Q = \frac{(\bar{x} - LSL)}{s}$$

**6.4.6.** Estimate the percentage that will fall above the Specification limit (PWL). This is done by referring to **Table 2** with the computed value of Q and then reading the appropriate PWL value.

**6.5. Quality Level Analysis: Example Problem for double-limit specification**

A contractor has run air voids tests on five lots of SM-19B. The specification limits for air voids are  $4 \pm 1.25$  %. This sets the lower specification limit (LSL) at 2.75 % ( $4 - 1.25$  %) air voids and the upper specification limit (USL) at 5.25 % ( $4 + 1.25$  %) air voids. Conduct a Quality Level Analysis and compute the percent within limits.

Lot	Sublot	Percent Air Voids
1	1A	4.30
	1B	3.77
	1C	4.05
	1D	4.80
2	2A	4.90
	2B	5.07
	2C	3.82
	2D	3.53
3	3A	2.67
	3D	2.09
	3C	2.92
	3D	2.56
4	4A	2.39
	4B	2.87
	4C	5.56
	4D	4.74
5	5A	2.36
	5B	2.00
	5C	5.99
	5D	3.73

Solution:

$$\text{Lot 1: } \bar{X} = 4.23, s_x = 0.437, n = 4$$

$$Q_U = \frac{5.25 - 4.23}{0.437} = 2.33 \quad \text{from Table 2 PWLU} = 100 \%$$

$$Q_L = \frac{4.23 - 2.75}{0.437} = 3.39 \quad \text{from Table 2 PWLL} = 100 \%$$

$$\text{PWL} = (100 + 100) - 100 = 100 \%$$

$$\text{Lot 2: } \bar{X} = 4.33, s_x = 0.769, n = 4$$

$$Q_U = \frac{5.25 - 4.33}{0.769} = 1.20 \quad \text{from Table 2 PWLU} = 90 \%$$

$$Q_L = \frac{4.33 - 2.75}{0.769} = 2.05 \quad \text{from Table 2 PWLL} = 100 \%$$

$$\text{PWL} = (90 + 100) - 100 = 90 \%$$

$$\text{Lot 3: } \bar{X} = 2.56, s_x = 0.348, n = 4$$

$$Q_U = \frac{5.25 - 2.56}{0.348} = 7.73 \quad \text{from Table 2 PWLU} = 100 \%$$

$$Q_L = \frac{2.56 - 2.75}{0.348} = -0.55 \quad \text{from Table 2 PWL Table} = 68.33 \%$$

If  $Q_L$  is a negative number, the PWL is equal to  $100 \%$  - (value looked up in **Table 2**)

$$\text{PWL}_L = (100 - 68.33) = 31.67 \%$$

$$\text{PWL} = (100 + 31.67) - 100 = 31.67 \%$$

$$\text{Lot 4: } \bar{X} = 3.89, s_x = 1.506, n = 4$$

$$Q_U = \frac{5.25 - 3.89}{1.506} = 0.90 \quad \text{from Table 2 PWLU} = 80.0 \%$$

$$Q_L = \frac{3.89 - 2.75}{1.506} = 0.76 \quad \text{from Table 2 PWLL} = 75.33 \%$$

$$\text{PWL} = (80.0 + 75.33) - 100 = 55.33 \%$$



Lot 5:  $\bar{x} = 3.52, s_x = 1.807, n = 4$

$$Q_U = \frac{5.25 - 3.52}{1.807} = 0.96 \quad \text{from Table 2 PWLU} = 82.0 \%$$

$$Q_L = \frac{3.52 - 2.75}{1.807} = 0.43 \quad \text{from Table 2 PWL}_L = 64.33 \%$$

$$PWL = (82.0 + 64.33) - 100 = 46.33 \%$$

### 6.6. Quality Level Analysis: Example Problem for single-limit specification

A contractor has made thickness cores on three lots of concrete pavement. The lower specification limit (LSL) is 275 mm. Conduct a Quality Level Analysis and compute the percent within limits.

Lot	Sublot	Thickness (mm)
1	1A	278
	1B	274
	1C	276
	1D	280
	1E	280
2	2A	261
	2B	284
	2C	275
	2D	269
	2E	281
3	3A	293
	3B	288
	3C	297
	3D	299
	3E	290

Solution:

Lot 1:  $\bar{x} = 277.6, s_x = 2.608, n = 5$

$$Q = \frac{277.6 - 275}{2.608} = 0.997 \quad \text{from Table 2. PWL} = 83.64 \%$$

Lot 2:  $\bar{x} = 274.0, s_x = 9.274, n = 5$

$$Q = \frac{274 - 275}{9.274} = -0.11 \quad \text{from Table 2. PWL}_{\text{Table}} = 53.91 \%$$

If Q is a negative number, the PWL is equal to 100 % - (value looked up in Table 2.)  
 $PWL = (100.0 - 53.91) = 46.09 \%$

Lot 3:  $\bar{x} = 293.4, s_x = 4.615, n = 5$

$$Q = \frac{293.4 - 275}{4.615} = 3.99 \quad \text{from Table 2. PWL} = 100.00 \%$$

**Table 2 for Estimation of Lot Percent Within Limits  
Variability Unknown Procedure  
Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
0.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
0.01	50.28	50.33	50.36	50.37	50.37	50.38	50.38	50.38	50.39	50.39	50.40	50.40	50.40
0.02	50.55	50.67	50.71	50.73	50.75	50.76	50.76	50.77	50.78	50.79	50.79	50.79	50.80
0.03	50.83	51.00	51.07	51.10	51.12	51.14	51.15	51.15	51.17	51.18	51.19	51.19	51.19
0.04	51.10	51.33	51.42	51.47	51.50	51.51	51.53	51.54	51.56	51.57	51.58	51.59	51.59
0.05	51.38	51.67	51.78	51.84	51.87	51.89	51.91	51.92	51.95	51.96	51.98	51.98	51.99
0.06	51.65	52.00	52.13	52.20	52.24	52.27	52.29	52.30	52.34	52.36	52.37	52.38	52.39
0.07	51.93	52.33	52.49	52.57	52.62	52.65	52.67	52.69	52.73	52.75	52.76	52.78	52.78
0.08	52.21	52.67	52.85	52.94	52.99	53.03	53.05	53.07	53.12	53.14	53.16	53.17	53.18
0.09	52.48	53.00	53.20	53.30	53.37	53.41	53.43	53.46	53.51	53.53	53.55	53.57	53.58
0.10	52.76	53.33	53.56	53.67	53.74	53.78	53.82	53.84	53.90	53.92	53.95	53.96	53.97
0.11	53.04	53.67	53.91	54.04	54.11	54.16	54.20	54.22	54.29	54.31	54.34	54.36	54.37
0.12	53.31	54.00	54.27	54.40	54.49	54.54	54.58	54.60	54.67	54.70	54.73	54.75	54.76
0.13	53.59	54.33	54.62	54.77	54.86	54.92	54.96	54.99	55.06	55.09	55.12	55.14	55.16
0.14	53.87	54.67	54.98	55.14	55.23	55.29	55.34	55.37	55.45	55.48	55.52	55.54	55.55
0.15	54.15	55.00	55.33	55.50	55.60	55.67	55.71	55.75	55.84	55.87	55.91	55.93	55.95
0.16	54.42	55.33	55.69	55.87	55.97	56.04	56.09	56.13	56.22	56.26	56.30	56.32	56.34
0.17	54.70	55.67	56.04	56.23	56.35	56.42	56.47	56.51	56.61	56.65	56.69	56.71	56.73
0.18	54.98	56.00	56.40	56.60	56.72	56.79	56.85	56.89	56.99	57.04	57.08	57.11	57.12
0.19	55.26	56.33	56.75	56.96	57.09	57.17	57.23	57.27	57.38	57.43	57.47	57.50	57.52
0.20	55.54	56.67	57.10	57.32	57.46	57.54	57.60	57.65	57.76	57.81	57.85	57.89	57.91
0.21	55.82	57.00	57.46	57.69	57.83	57.92	57.98	58.03	58.15	58.20	58.24	58.27	58.30
0.22	56.10	57.33	57.81	58.05	58.20	58.29	58.36	58.40	58.53	58.58	58.63	58.66	58.69
0.23	56.38	57.67	58.16	58.41	58.56	58.66	58.73	58.78	58.91	58.97	59.01	59.05	59.07
0.24	56.66	58.00	58.52	58.78	58.93	59.03	59.11	59.16	59.29	59.35	59.40	59.44	59.46
0.25	56.95	58.33	58.87	59.14	59.30	59.41	59.48	59.53	59.67	59.73	59.78	59.82	59.85
0.26	57.23	58.67	59.22	59.50	59.67	59.78	59.85	59.91	60.05	60.11	60.17	60.21	60.23
0.27	57.51	59.00	59.57	59.86	60.03	60.15	60.23	60.28	60.43	60.49	60.55	60.59	60.62
0.28	57.80	59.33	59.92	60.22	60.40	60.52	60.60	60.66	60.81	60.87	60.93	60.97	61.00
0.29	58.08	59.67	60.28	60.58	60.77	60.89	60.97	61.03	61.19	61.25	61.31	61.35	61.38
0.30	58.37	60.00	60.63	60.94	61.13	61.25	61.34	61.40	61.56	61.63	61.69	61.73	61.76
0.31	58.65	60.33	60.98	61.30	61.50	61.62	61.71	61.77	61.94	62.01	62.07	62.11	62.14
0.32	58.94	60.67	61.33	61.66	61.86	61.99	62.08	62.14	62.31	62.38	62.45	62.49	62.52
0.33	59.23	61.00	61.68	62.02	62.22	62.35	62.45	62.51	62.69	62.76	62.82	62.87	62.90
0.34	59.51	61.33	62.03	62.38	62.58	62.72	62.81	62.88	63.06	63.13	63.20	63.25	63.28
0.35	59.80	61.67	62.38	62.73	62.94	63.08	63.18	63.25	63.43	63.51	63.57	63.62	63.65
0.36	60.09	62.00	62.72	63.09	63.31	63.45	63.54	63.62	63.80	63.88	63.95	63.99	64.03
0.37	60.38	62.33	63.07	63.45	63.67	63.81	63.91	63.98	64.17	64.25	64.32	64.37	64.40
0.38	60.67	62.67	63.42	63.80	64.02	64.17	64.27	64.35	64.54	64.62	64.69	64.74	64.77
0.39	60.97	63.00	63.77	64.16	64.38	64.53	64.63	64.71	64.90	64.98	65.06	65.11	65.14
0.40	61.26	63.33	64.12	64.51	64.74	64.89	65.00	65.07	65.27	65.35	65.42	65.47	65.51
0.41	61.55	63.67	64.46	64.86	65.10	65.25	65.36	65.43	65.63	65.72	65.79	65.84	65.88
0.42	61.85	64.00	64.81	65.21	65.45	65.61	65.71	65.79	66.00	66.08	66.15	66.21	66.24
0.43	62.15	64.33	65.15	65.57	65.81	65.96	66.07	66.15	66.36	66.44	66.52	66.57	66.61
0.44	62.44	64.67	65.50	65.92	66.16	66.32	66.43	66.51	66.72	66.80	66.88	66.93	66.97

**Table 2 for Estimation of Lot Percent Within Limits  
 Variability Unknown Procedure  
 Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
0.45	62.74	65.00	65.84	66.27	66.51	66.67	66.79	66.87	67.08	67.16	67.24	67.29	67.33
0.46	63.04	65.33	66.19	66.62	66.87	67.03	67.14	67.22	67.43	67.52	67.60	67.65	67.69
0.47	63.34	65.67	66.53	66.96	67.22	67.38	67.49	67.58	67.79	67.88	67.96	68.01	68.05
0.48	63.65	66.00	66.88	67.31	67.57	67.73	67.85	67.93	68.15	68.23	68.31	68.37	68.40
0.49	63.95	66.33	67.22	67.66	67.92	68.08	68.20	68.28	68.50	68.59	68.67	68.72	68.76
0.50	64.25	66.67	67.56	68.00	68.26	68.43	68.55	68.63	68.85	68.94	69.02	69.07	69.11
0.51	64.56	67.00	67.90	68.35	68.61	68.78	68.90	68.98	69.20	69.29	69.37	69.43	69.46
0.52	64.87	67.33	68.24	68.69	68.96	69.13	69.24	69.33	69.55	69.64	69.72	69.77	69.81
0.53	65.18	67.67	68.58	69.04	69.30	69.47	69.59	69.68	69.90	69.99	70.07	70.12	70.16
0.54	65.49	68.00	68.92	69.38	69.64	69.82	69.93	70.02	70.24	70.33	70.41	70.47	70.51
0.55	65.80	68.33	69.26	69.72	69.99	70.16	70.28	70.36	70.59	70.68	70.76	70.81	70.85
0.56	66.12	68.67	69.60	70.06	70.33	70.50	70.62	70.71	70.93	71.02	71.10	71.15	71.19
0.57	66.43	69.00	69.94	70.40	70.67	70.84	70.96	71.05	71.27	71.36	71.44	71.49	71.53
0.58	66.75	69.33	70.27	70.74	71.01	71.18	71.30	71.39	71.61	71.70	71.78	71.83	71.87
0.59	67.07	69.67	70.61	71.07	71.34	71.52	71.64	71.72	71.95	72.04	72.11	72.17	72.21
0.60	67.39	70.00	70.95	71.41	71.68	71.85	71.97	72.06	72.28	72.37	72.45	72.50	72.54
0.61	67.72	70.33	71.28	71.75	72.02	72.19	72.31	72.40	72.61	72.70	72.78	72.84	72.87
0.62	68.04	70.67	71.61	72.08	72.35	72.52	72.64	72.73	72.95	73.04	73.11	73.17	73.20
0.63	68.37	71.00	71.95	72.41	72.68	72.85	72.97	73.06	73.28	73.37	73.44	73.50	73.53
0.64	68.70	71.33	72.28	72.74	73.01	73.18	73.30	73.39	73.61	73.69	73.77	73.82	73.86
0.65	69.03	71.67	72.61	73.08	73.34	73.51	73.63	73.72	73.93	74.02	74.10	74.15	74.18
0.66	69.37	72.00	72.94	73.40	73.67	73.84	73.96	74.04	74.26	74.34	74.42	74.47	74.51
0.67	69.70	72.33	73.27	73.73	74.00	74.17	74.28	74.37	74.58	74.67	74.74	74.79	74.83
0.68	70.04	72.67	73.60	74.06	74.32	74.49	74.61	74.69	74.90	74.99	75.06	75.11	75.14
0.69	70.39	73.00	73.93	74.39	74.65	74.81	74.93	75.01	75.22	75.30	75.38	75.43	75.46
0.70	70.73	73.33	74.26	74.71	74.97	75.14	75.25	75.33	75.54	75.62	75.69	75.74	75.77
0.71	71.08	73.67	74.59	75.04	75.29	75.46	75.57	75.65	75.85	75.94	76.01	76.05	76.09
0.72	71.43	74.00	74.91	75.36	75.61	75.77	75.89	75.97	76.17	76.25	76.32	76.36	76.40
0.73	71.78	74.33	75.24	75.68	75.93	76.09	76.20	76.28	76.48	76.56	76.63	76.67	76.70
0.74	72.14	74.67	75.56	76.00	76.25	76.41	76.51	76.59	76.79	76.87	76.93	76.98	77.01
0.75	72.50	75.00	75.89	76.32	76.56	76.72	76.83	76.90	77.10	77.17	77.24	77.28	77.31
0.76	72.87	75.33	76.21	76.63	76.88	77.03	77.14	77.21	77.40	77.48	77.54	77.58	77.61
0.77	73.24	75.67	76.53	76.95	77.19	77.34	77.44	77.52	77.70	77.78	77.84	77.88	77.91
0.78	73.61	76.00	76.85	77.26	77.50	77.65	77.75	77.82	78.01	78.08	78.14	78.18	78.21
0.79	73.98	76.33	77.17	77.58	77.81	77.96	78.06	78.13	78.30	78.37	78.43	78.47	78.50
0.80	74.36	76.67	77.49	77.89	78.12	78.26	78.36	78.43	78.60	78.67	78.73	78.77	78.79
0.81	74.75	77.00	77.81	78.20	78.42	78.56	78.66	78.73	78.90	78.96	79.02	79.06	79.08
0.82	75.14	77.33	78.13	78.51	78.73	78.86	78.96	79.02	79.19	79.25	79.31	79.35	79.37
0.83	75.53	77.67	78.44	78.82	79.03	79.16	79.25	79.32	79.48	79.54	79.60	79.63	79.65
0.84	75.93	78.00	78.76	79.12	79.33	79.46	79.55	79.61	79.77	79.83	79.88	79.91	79.94
0.85	76.33	78.33	79.07	79.43	79.63	79.76	79.84	79.90	80.06	80.11	80.16	80.20	80.22
0.86	76.74	78.67	79.38	79.73	79.93	80.05	80.13	80.19	80.34	80.40	80.44	80.47	80.49
0.87	77.16	79.00	79.69	80.03	80.22	80.34	80.42	80.48	80.62	80.68	80.72	80.75	80.77
0.88	77.58	79.33	80.00	80.33	80.52	80.63	80.71	80.77	80.90	80.95	81.00	81.02	81.04
0.89	78.01	79.67	80.31	80.63	80.81	80.92	81.00	81.05	81.18	81.23	81.27	81.30	81.31

**Table 2 for Estimation of Lot Percent Within Limits  
Variability Unknown Procedure  
Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
0.90	78.45	80.00	80.62	80.93	81.10	81.21	81.28	81.33	81.46	81.50	81.54	81.57	81.58
0.91	78.89	80.33	80.93	81.22	81.39	81.49	81.56	81.61	81.73	81.77	81.81	81.83	81.85
0.92	79.34	80.67	81.23	81.51	81.67	81.77	81.84	81.89	82.00	82.04	82.08	82.10	82.11
0.93	79.81	81.00	81.54	81.81	81.96	82.05	82.12	82.16	82.27	82.31	82.34	82.36	82.37
0.94	80.27	81.33	81.84	82.10	82.24	82.33	82.39	82.44	82.54	82.57	82.60	82.62	82.63
0.95	80.75	81.67	82.14	82.39	82.52	82.61	82.67	82.71	82.80	82.84	82.86	82.88	82.89
0.96	81.25	82.00	82.45	82.67	82.80	82.88	82.94	82.97	83.06	83.10	83.12	83.13	83.14
0.97	81.75	82.33	82.75	82.96	83.08	83.15	83.21	83.24	83.32	83.35	83.37	83.39	83.39
0.98	82.26	82.67	83.04	83.24	83.35	83.43	83.47	83.51	83.58	83.61	83.63	83.64	83.64
0.99	82.79	83.00	83.34	83.52	83.63	83.69	83.74	83.77	83.84	83.86	83.88	83.88	83.89
1.00	83.33	83.33	83.64	83.80	83.90	83.96	84.00	84.03	84.09	84.11	84.12	84.13	84.13
1.01	83.89	83.67	83.93	84.08	84.17	84.22	84.26	84.28	84.34	84.36	84.37	84.37	84.38
1.02	84.47	84.00	84.22	84.36	84.44	84.49	84.52	84.54	84.59	84.60	84.61	84.62	84.62
1.03	85.07	84.33	84.52	84.63	84.70	84.75	84.77	84.79	84.83	84.85	84.85	84.85	84.85
1.04	85.69	84.67	84.81	84.91	84.97	85.00	85.03	85.04	85.08	85.09	85.09	85.09	85.09
1.05	86.34	85.00	85.09	85.18	85.23	85.26	85.28	85.29	85.32	85.33	85.33	85.32	85.32
1.06	87.02	85.33	85.38	85.45	85.49	85.51	85.53	85.54	85.56	85.56	85.56	85.55	85.55
1.07	87.73	85.67	85.67	85.71	85.74	85.76	85.78	85.78	85.80	85.80	85.79	85.78	85.78
1.08	88.49	86.00	85.95	85.98	86.00	86.01	86.02	86.03	86.03	86.03	86.02	86.01	86.00
1.09	89.29	86.33	86.24	86.24	86.25	86.26	86.27	86.27	86.26	86.26	86.25	86.23	86.23
1.10	90.16	86.67	86.52	86.50	86.51	86.51	86.51	86.50	86.49	86.48	86.47	86.46	86.45
1.11	91.11	87.00	86.80	86.76	86.75	86.75	86.74	86.74	86.72	86.71	86.69	86.68	86.66
1.12	92.18	87.33	87.07	87.02	87.00	86.99	86.98	86.97	86.95	86.93	86.91	86.89	86.88
1.13	93.40	87.67	87.35	87.28	87.25	87.23	87.21	87.20	87.17	87.15	87.13	87.11	87.09
1.14	94.92	88.00	87.63	87.53	87.49	87.46	87.45	87.43	87.39	87.37	87.34	87.32	87.30
1.15	97.13	88.33	87.90	87.78	87.73	87.70	87.68	87.66	87.61	87.58	87.55	87.53	87.51
1.16	100.00	88.67	88.17	88.03	87.97	87.93	87.90	87.88	87.82	87.79	87.76	87.74	87.72
1.17	100.00	89.00	88.44	88.28	88.21	88.16	88.13	88.10	88.04	88.00	87.97	87.94	87.92
1.18	100.00	89.33	88.71	88.53	88.44	88.39	88.35	88.32	88.25	88.21	88.18	88.15	88.12
1.19	100.00	89.67	88.98	88.77	88.67	88.61	88.57	88.54	88.46	88.42	88.38	88.35	88.32
1.20	100.00	90.00	89.24	89.01	88.90	88.83	88.79	88.76	88.66	88.62	88.58	88.54	88.52
1.21	100.00	90.33	89.50	89.25	89.13	89.06	89.00	88.97	88.87	88.82	88.78	88.74	88.71
1.22	100.00	90.67	89.77	89.49	89.35	89.27	89.22	89.18	89.07	89.02	88.97	88.93	88.91
1.23	100.00	91.00	90.03	89.72	89.58	89.49	89.43	89.39	89.27	89.22	89.16	89.12	89.09
1.24	100.00	91.33	90.28	89.96	89.80	89.70	89.64	89.59	89.47	89.41	89.36	89.31	89.28
1.25	100.00	91.67	90.54	90.19	90.02	89.91	89.85	89.79	89.66	89.60	89.54	89.50	89.47
1.26	100.00	92.00	90.79	90.42	90.23	90.12	90.05	90.00	89.85	89.79	89.73	89.68	89.65
1.27	100.00	92.33	91.04	90.64	90.45	90.33	90.25	90.19	90.04	89.98	89.91	89.87	89.83
1.28	100.00	92.67	91.29	90.87	90.66	90.53	90.45	90.39	90.23	90.16	90.10	90.05	90.01
1.29	100.00	93.00	91.54	91.09	90.87	90.74	90.65	90.58	90.42	90.34	90.28	90.22	90.18
1.30	100.00	93.33	91.79	91.31	91.07	90.94	90.84	90.78	90.60	90.52	90.45	90.40	90.36
1.31	100.00	93.67	92.03	91.52	91.28	91.13	91.04	90.97	90.78	90.70	90.63	90.57	90.53
1.32	100.00	94.00	92.27	91.74	91.48	91.33	91.23	91.15	90.96	90.88	90.80	90.74	90.70
1.33	100.00	94.33	92.51	91.95	91.68	91.52	91.41	91.34	91.14	91.05	90.97	90.91	90.87
1.34	100.00	94.67	92.75	92.16	91.88	91.71	91.60	91.52	91.31	91.22	91.14	91.08	91.03

**Table 2 for Estimation of Lot Percent Within Limits  
 Variability Unknown Procedure  
 Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
1.35	100.00	95.00	92.98	92.37	92.08	91.90	91.78	91.70	91.48	91.39	91.31	91.24	91.19
1.36	100.00	95.33	93.21	92.58	92.27	92.09	91.96	91.88	91.65	91.56	91.47	91.40	91.35
1.37	100.00	95.67	93.44	92.78	92.46	92.27	92.14	92.05	91.82	91.72	91.63	91.56	91.51
1.38	100.00	96.00	93.67	92.98	92.65	92.45	92.32	92.23	91.99	91.88	91.79	91.72	91.67
1.39	100.00	96.33	93.90	93.18	92.83	92.63	92.49	92.40	92.15	92.04	91.95	91.88	91.82
1.40	100.00	96.67	94.12	93.37	93.02	92.81	92.67	92.56	92.31	92.20	92.10	92.03	91.98
1.41	100.00	97.00	94.34	93.57	93.20	92.98	92.83	92.73	92.47	92.36	92.26	92.18	92.13
1.42	100.00	97.33	94.56	93.76	93.38	93.15	93.00	92.90	92.63	92.51	92.41	92.33	92.27
1.43	100.00	97.67	94.77	93.95	93.55	93.32	93.17	93.06	92.78	92.66	92.56	92.48	92.42
1.44	100.00	98.00	94.98	94.13	93.73	93.49	93.33	93.22	92.93	92.81	92.70	92.62	92.56
1.45	100.00	98.33	95.19	94.32	93.90	93.65	93.49	93.37	93.08	92.96	92.85	92.76	92.70
1.46	100.00	98.67	95.40	94.50	94.07	93.81	93.65	93.53	93.23	93.10	92.99	92.90	92.84
1.47	100.00	99.00	95.61	94.67	94.23	93.97	93.80	93.68	93.37	93.25	93.13	93.04	92.98
1.48	100.00	99.33	95.81	94.85	94.40	94.13	93.96	93.83	93.52	93.39	93.27	93.18	93.12
1.49	100.00	99.67	96.01	95.02	94.56	94.29	94.11	93.98	93.66	93.52	93.40	93.31	93.25
1.50	100.00	100.00	96.20	95.19	94.72	94.44	94.26	94.13	93.80	93.66	93.54	93.45	93.38
1.51	100.00	100.00	96.39	95.36	94.87	94.59	94.40	94.27	93.94	93.80	93.67	93.58	93.51
1.52	100.00	100.00	96.58	95.53	95.03	94.74	94.55	94.41	94.07	93.93	93.80	93.71	93.64
1.53	100.00	100.00	96.77	95.69	95.18	94.88	94.69	94.55	94.20	94.06	93.93	93.83	93.76
1.54	100.00	100.00	96.95	95.85	95.33	95.03	94.83	94.69	94.33	94.19	94.05	93.96	93.89
1.55	100.00	100.00	97.13	96.00	95.48	95.17	94.97	94.82	94.46	94.31	94.18	94.08	94.01
1.56	100.00	100.00	97.31	96.16	95.62	95.31	95.10	94.95	94.59	94.44	94.30	94.20	94.13
1.57	100.00	100.00	97.48	96.31	95.76	95.44	95.23	95.08	94.71	94.56	94.42	94.32	94.25
1.58	100.00	100.00	97.65	96.46	95.90	95.58	95.36	95.21	94.84	94.68	94.54	94.44	94.36
1.59	100.00	100.00	97.81	96.60	96.04	95.71	95.49	95.34	94.96	94.80	94.66	94.55	94.48
1.60	100.00	100.00	97.97	96.75	96.17	95.84	95.62	95.46	95.08	94.92	94.77	94.67	94.59
1.61	100.00	100.00	98.13	96.89	96.31	95.97	95.74	95.59	95.19	95.03	94.88	94.78	94.70
1.62	100.00	100.00	98.28	97.03	96.43	96.09	95.86	95.70	95.31	95.14	94.99	94.89	94.81
1.63	100.00	100.00	98.43	97.16	96.56	96.21	95.98	95.82	95.42	95.25	95.10	94.99	94.92
1.64	100.00	100.00	98.58	97.29	96.69	96.33	96.10	95.94	95.53	95.36	95.21	95.10	95.02
1.65	100.00	100.00	98.72	97.42	96.81	96.45	96.22	96.05	95.64	95.47	95.32	95.21	95.13
1.66	100.00	100.00	98.85	97.55	96.93	96.57	96.33	96.16	95.75	95.57	95.42	95.31	95.23
1.67	100.00	100.00	98.98	97.67	97.05	96.68	96.44	96.27	95.85	95.68	95.52	95.41	95.33
1.68	100.00	100.00	99.11	97.79	97.16	96.79	96.55	96.38	95.95	95.78	95.62	95.51	95.43
1.69	100.00	100.00	99.23	97.91	97.27	96.90	96.66	96.48	96.06	95.88	95.72	95.61	95.53
1.70	100.00	100.00	99.34	98.02	97.38	97.01	96.76	96.59	96.16	95.98	95.82	95.70	95.62
1.71	100.00	100.00	99.45	98.13	97.49	97.11	96.86	96.69	96.25	96.07	95.91	95.80	95.71
1.72	100.00	100.00	99.55	98.24	97.59	97.21	96.97	96.79	96.35	96.17	96.01	95.89	95.81
1.73	100.00	100.00	99.64	98.34	97.70	97.31	97.06	96.89	96.44	96.26	96.10	95.98	95.90
1.74	100.00	100.00	99.73	98.45	97.80	97.41	97.16	96.98	96.54	96.35	96.19	96.07	95.99
1.75	100.00	100.00	99.81	98.55	97.89	97.51	97.25	97.07	96.63	96.44	96.28	96.16	96.07
1.76	100.00	100.00	99.88	98.64	97.99	97.60	97.35	97.17	96.72	96.53	96.37	96.24	96.16
1.77	100.00	100.00	99.94	98.73	98.08	97.69	97.44	97.26	96.80	96.62	96.45	96.33	96.24
1.78	100.00	100.00	99.98	98.82	98.17	97.78	97.53	97.34	96.89	96.70	96.53	96.41	96.33
1.79	100.00	100.00	100.00	98.91	98.26	97.87	97.61	97.43	96.97	96.79	96.62	96.49	96.41

**Table 2 for Estimation of Lot Percent Within Limits  
 Variability Unknown Procedure  
 Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
1.80	100.00	100.00	100.00	98.99	98.35	97.96	97.70	97.51	97.06	96.87	96.70	96.57	96.49
1.81	100.00	100.00	100.00	99.07	98.43	98.04	97.78	97.60	97.14	96.95	96.78	96.65	96.57
1.82	100.00	100.00	100.00	99.15	98.51	98.12	97.86	97.68	97.21	97.02	96.85	96.73	96.64
1.83	100.00	100.00	100.00	99.22	98.59	98.20	97.94	97.75	97.29	97.10	96.93	96.81	96.72
1.84	100.00	100.00	100.00	99.29	98.66	98.28	98.02	97.83	97.37	97.18	97.01	96.88	96.79
1.85	100.00	100.00	100.00	99.36	98.74	98.35	98.09	97.91	97.44	97.25	97.08	96.95	96.87
1.86	100.00	100.00	100.00	99.43	98.81	98.42	98.16	97.98	97.52	97.32	97.15	97.03	96.94
1.87	100.00	100.00	100.00	99.49	98.88	98.49	98.24	98.05	97.59	97.39	97.22	97.10	97.01
1.88	100.00	100.00	100.00	99.54	98.94	98.56	98.30	98.12	97.66	97.46	97.29	97.17	97.08
1.89	100.00	100.00	100.00	99.60	99.01	98.63	98.37	98.19	97.72	97.53	97.36	97.23	97.15
1.90	100.00	100.00	100.00	99.65	99.07	98.69	98.44	98.25	97.79	97.60	97.43	97.30	97.21
1.91	100.00	100.00	100.00	99.70	99.13	98.76	98.50	98.32	97.86	97.66	97.49	97.37	97.28
1.92	100.00	100.00	100.00	99.74	99.19	98.82	98.56	98.38	97.92	97.73	97.55	97.43	97.34
1.93	100.00	100.00	100.00	99.78	99.24	98.88	98.63	98.44	97.98	97.79	97.62	97.49	97.40
1.94	100.00	100.00	100.00	99.82	99.30	98.93	98.68	98.50	98.04	97.85	97.68	97.55	97.46
1.95	100.00	100.00	100.00	99.85	99.35	98.99	98.74	98.56	98.10	97.91	97.74	97.61	97.52
1.96	100.00	100.00	100.00	99.88	99.40	99.04	98.80	98.62	98.16	97.97	97.80	97.67	97.58
1.97	100.00	100.00	100.00	99.91	99.44	99.09	98.85	98.67	98.22	98.03	97.86	97.73	97.64
1.98	100.00	100.00	100.00	99.93	99.49	99.14	98.90	98.73	98.27	98.08	97.91	97.79	97.70
1.99	100.00	100.00	100.00	99.95	99.53	99.19	98.95	98.78	98.33	98.14	97.97	97.84	97.75
2.00	100.00	100.00	100.00	99.97	99.57	99.24	99.00	98.83	98.38	98.19	98.02	97.90	97.81
2.01	100.00	100.00	100.00	99.98	99.61	99.28	99.05	98.88	98.43	98.24	98.07	97.95	97.86
2.02	100.00	100.00	100.00	99.99	99.64	99.33	99.10	98.93	98.48	98.29	98.13	98.00	97.91
2.03	100.00	100.00	100.00	100.00	99.68	99.37	99.14	98.97	98.53	98.34	98.18	98.05	97.96
2.04	100.00	100.00	100.00	100.00	99.71	99.41	99.18	99.02	98.58	98.39	98.23	98.10	98.01
2.05	100.00	100.00	100.00	100.00	99.74	99.45	99.23	99.06	98.63	98.44	98.27	98.15	98.06
2.06	100.00	100.00	100.00	100.00	99.77	99.48	99.27	99.10	98.67	98.49	98.32	98.20	98.11
2.07	100.00	100.00	100.00	100.00	99.79	99.52	99.30	99.14	98.72	98.53	98.37	98.24	98.16
2.08	100.00	100.00	100.00	100.00	99.82	99.55	99.34	99.18	98.76	98.58	98.41	98.29	98.21
2.09	100.00	100.00	100.00	100.00	99.84	99.58	99.38	99.22	98.80	98.62	98.46	98.34	98.25
2.10	100.00	100.00	100.00	100.00	99.86	99.61	99.41	99.26	98.84	98.66	98.50	98.38	98.29
2.11	100.00	100.00	100.00	100.00	99.88	99.64	99.45	99.29	98.88	98.70	98.54	98.42	98.34
2.12	100.00	100.00	100.00	100.00	99.90	99.67	99.48	99.33	98.92	98.74	98.58	98.46	98.38
2.13	100.00	100.00	100.00	100.00	99.92	99.70	99.51	99.36	98.96	98.78	98.62	98.50	98.42
2.14	100.00	100.00	100.00	100.00	99.93	99.72	99.54	99.39	99.00	98.82	98.66	98.54	98.46
2.15	100.00	100.00	100.00	100.00	99.94	99.74	99.57	99.42	99.03	98.86	98.70	98.58	98.50
2.16	100.00	100.00	100.00	100.00	99.95	99.77	99.59	99.45	99.07	98.90	98.74	98.62	98.54
2.17	100.00	100.00	100.00	100.00	99.96	99.79	99.62	99.48	99.10	98.93	98.78	98.66	98.58
2.18	100.00	100.00	100.00	100.00	99.97	99.81	99.64	99.51	99.13	98.97	98.81	98.70	98.61
2.19	100.00	100.00	100.00	100.00	99.98	99.83	99.67	99.54	99.17	99.00	98.85	98.73	98.65
2.20	100.00	100.00	100.00	100.00	99.99	99.84	99.69	99.56	99.20	99.03	98.88	98.77	98.69
2.21	100.00	100.00	100.00	100.00	99.99	99.86	99.71	99.59	99.23	99.06	98.91	98.80	98.72
2.22	100.00	100.00	100.00	100.00	99.99	99.87	99.73	99.61	99.26	99.10	98.95	98.83	98.75
2.23	100.00	100.00	100.00	100.00	100.00	99.89	99.75	99.63	99.29	99.13	98.98	98.87	98.79
2.24	100.00	100.00	100.00	100.00	100.00	99.90	99.77	99.66	99.31	99.15	99.01	98.90	98.82

**Table 2 for Estimation of Lot Percent Within Limits  
 Variability Unknown Procedure  
 Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
2.25	100.00	100.00	100.00	100.00	100.00	99.91	99.79	99.68	99.34	99.18	99.04	98.93	98.85
2.26	100.00	100.00	100.00	100.00	100.00	99.92	99.80	99.70	99.37	99.21	99.07	98.96	98.88
2.27	100.00	100.00	100.00	100.00	100.00	99.93	99.82	99.71	99.39	99.24	99.10	98.99	98.91
2.28	100.00	100.00	100.00	100.00	100.00	99.94	99.83	99.73	99.42	99.26	99.12	99.02	98.94
2.29	100.00	100.00	100.00	100.00	100.00	99.95	99.85	99.75	99.44	99.29	99.15	99.05	98.97
2.30	100.00	100.00	100.00	100.00	100.00	99.96	99.86	99.77	99.46	99.32	99.18	99.07	99.00
2.31	100.00	100.00	100.00	100.00	100.00	99.96	99.87	99.78	99.48	99.34	99.20	99.10	99.03
2.32	100.00	100.00	100.00	100.00	100.00	99.97	99.89	99.80	99.51	99.36	99.23	99.13	99.05
2.33	100.00	100.00	100.00	100.00	100.00	99.98	99.90	99.81	99.53	99.39	99.25	99.15	99.08
2.34	100.00	100.00	100.00	100.00	100.00	99.98	99.91	99.82	99.55	99.41	99.28	99.18	99.10
2.35	100.00	100.00	100.00	100.00	100.00	99.98	99.92	99.84	99.57	99.43	99.30	99.20	99.13
2.36	100.00	100.00	100.00	100.00	100.00	99.99	99.92	99.85	99.58	99.45	99.32	99.22	99.15
2.37	100.00	100.00	100.00	100.00	100.00	99.99	99.93	99.86	99.60	99.47	99.34	99.25	99.18
2.38	100.00	100.00	100.00	100.00	100.00	99.99	99.94	99.87	99.62	99.49	99.37	99.27	99.20
2.39	100.00	100.00	100.00	100.00	100.00	100.00	99.95	99.88	99.64	99.51	99.39	99.29	99.22
2.40	100.00	100.00	100.00	100.00	100.00	100.00	99.95	99.89	99.65	99.53	99.41	99.31	99.25
2.41	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.90	99.67	99.55	99.43	99.33	99.27
2.42	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.91	99.68	99.56	99.44	99.35	99.29
2.43	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.92	99.70	99.58	99.46	99.37	99.31
2.44	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.92	99.71	99.60	99.48	99.39	99.33
2.45	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.93	99.73	99.61	99.50	99.41	99.35
2.46	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.94	99.74	99.63	99.52	99.43	99.37
2.47	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.94	99.75	99.64	99.53	99.45	99.38
2.48	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.95	99.76	99.66	99.55	99.46	99.40
2.49	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.95	99.77	99.67	99.56	99.48	99.42
2.50	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.79	99.68	99.58	99.50	99.44
2.51	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.80	99.70	99.59	99.51	99.45
2.52	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.81	99.71	99.61	99.53	99.47
2.53	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.82	99.72	99.62	99.54	99.49
2.54	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.83	99.73	99.63	99.56	99.50
2.55	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.83	99.74	99.65	99.57	99.52
2.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.84	99.75	99.66	99.59	99.53
2.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.85	99.76	99.67	99.60	99.54
2.58	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.86	99.77	99.68	99.61	99.56
2.59	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.87	99.78	99.70	99.62	99.57
2.60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.87	99.79	99.71	99.64	99.59
2.61	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.88	99.80	99.72	99.65	99.60
2.62	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.89	99.81	99.73	99.66	99.61
2.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.89	99.82	99.74	99.67	99.62
2.64	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.90	99.83	99.75	99.68	99.63
2.65	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.91	99.84	99.76	99.69	99.65
2.66	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.91	99.84	99.77	99.70	99.66
2.67	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.92	99.85	99.78	99.71	99.67
2.68	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.92	99.86	99.78	99.72	99.68
2.69	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.93	99.86	99.79	99.73	99.69

**Table 2 for Estimation of Lot Percent Within Limits  
Variability Unknown Procedure  
Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
2.70	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.93	99.87	99.80	99.74	99.70
2.71	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.94	99.88	99.81	99.75	99.71
2.72	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.94	99.88	99.82	99.76	99.72
2.73	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.94	99.89	99.82	99.77	99.73
2.74	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.95	99.89	99.83	99.78	99.73
2.75	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.95	99.90	99.84	99.78	99.74
2.76	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.95	99.90	99.84	99.79	99.75
2.77	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.91	99.85	99.80	99.76
2.78	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.91	99.86	99.81	99.77
2.79	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.96	99.92	99.86	99.81	99.77
2.80	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.92	99.87	99.82	99.78
2.81	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.93	99.87	99.83	99.79
2.82	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.93	99.88	99.83	99.80
2.83	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.93	99.88	99.84	99.80
2.84	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.97	99.94	99.89	99.84	99.81
2.85	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.94	99.89	99.85	99.82
2.86	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.94	99.90	99.86	99.82
2.87	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.95	99.90	99.86	99.83
2.88	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.95	99.91	99.87	99.83
2.89	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.95	99.91	99.87	99.84
2.90	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.95	99.91	99.88	99.84
2.91	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.92	99.88	99.85
2.92	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.92	99.88	99.86
2.93	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.92	99.89	99.86
2.94	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.93	99.89	99.87
2.95	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.93	99.90	99.87
2.96	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.93	99.90	99.87
2.97	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.94	99.90	99.88
2.98	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.94	99.91	99.88
2.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.94	99.91	99.89
3.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.95	99.92	99.89
3.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.95	99.92	99.89
3.02	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.95	99.92	99.90
3.03	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.95	99.93	99.90
3.04	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.95	99.93	99.91
3.05	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.96	99.93	99.91
3.06	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.96	99.93	99.91
3.07	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.96	99.94	99.92
3.08	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.94	99.92
3.09	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.96	99.94	99.92
3.10	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.94	99.92
3.11	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.95	99.93
3.12	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.95	99.93
3.13	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.95	99.93
3.14	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.95	99.93



**Table 2 for Estimation of Lot Percent Within Limits  
 Variability Unknown Procedure  
 Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
3.15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.95	99.94
3.16	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96	99.94
3.17	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96	99.94
3.18	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96	99.94
3.19	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96	99.95
3.20	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96	99.95
3.21	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96	99.95
3.22	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97	99.95
3.23	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97	99.95
3.24	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.97	99.96
3.25	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.98	99.97	99.96
3.26	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.96
3.27	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.96
3.28	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.97	99.96
3.29	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96
3.30	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.96
3.31	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.32	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.33	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.34	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.35	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.36	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.37	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.38	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.97
3.39	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98	99.98
3.40	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99	99.98
3.41	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99	99.98
3.42	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99	99.98
3.43	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99	99.98
3.44	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99	99.98
3.45	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98
3.46	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98
3.47	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98
3.48	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98
3.49	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98
3.50	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.98
3.51	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.52	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.53	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.54	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.55	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.56	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.57	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.58	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.59	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99

**Table 2 for Estimation of Lot Percent Within Limits  
 Variability Unknown Procedure  
 Standard Deviation Method**

Quality Index Qu or Ql	Percent Within Limits for Selected Sample Sizes												
	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10	N=15	N=20	N=30	N=50	N=100
3.60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99	99.99
3.61	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.62	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.63	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.64	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.65	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.66	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.67	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.68	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.69	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.70	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.71	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.72	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.73	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.74	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.75	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	99.99
3.76	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The estimates of lot percent within limits (PWL) provided in the tables are obtained by numerically integrating the beta distribution function corresponding to Quality Index (Q) and Sample Size (N).

To find PWL from the tables, compute Q from the sample mean and sample standard deviation with unknown population variability, and the lower or upper specification limits.

To find the PWL for a negative Quality Index, first get the PWL for the positive value of the Quality Index from the tables and subtract the result from 100.

## 5.2.2. ROUNDING OFF AND RANDOM SAMPLING

### 5.2.2.1. ROUNDING OFF OF NUMBERS

#### 1. SCOPE

This procedure applies to all specified limits in the specifications. For the purpose of determining conformance with the specifications and observed or calculated value shall be rounded off to the same place as used in expressing the limiting value, in accordance with the following.

#### 2. REFERENCED DOCUMENTS

2.1. None.

#### 3. PROCEDURE

3.1. Determine the last significant digit to be retained.

3.1.1. When the digit next beyond the last place to be retained is less than 5, retain unchanged the digit in the last place retained.

3.1.2. When the digit next beyond the last place to be retained is greater than 5, increase by 1 the digit in the last place retained.

3.1.3. When the digit next beyond the last place to be retained is 5, and there are no digits beyond this 5, or only zeros, increase by 1 the digit in the last place retained if it is odd, leave the digit unchanged if it is even. Increase by 1 the digit in the last place retained, if there are digits beyond this 5.

3.1.4. This rounding procedure may be restated simply as follows: When rounding a number to one having a specified number of significant digits, choose that which is nearest. If two choices are possible, as when the digits dropped are exactly a 5 or a 5 followed only by zeros, choose that ending in an even digit.

3.1.5. Examples: The following table indicates correct rounding-off procedures.

#### Examples of Rounding Off

Specified Limit	Observed or Calculated Value	Rounded to nearest percent	Rounded Off Value to be used for Purpose of Determining Conformance	Conform with a Specified Value
Nickel 57% min.	56.4	1	56	No
	56.5	1	56	No
	56.6	1	57	Yes
Sodium Bicarbonate 0.5% max.	0.54	0.1	0.5	Yes
	0.55	0.1	0.6	No
	0.56	0.1	0.6	No

The rounded-off value should be obtained in one step by direct rounding off of the most precise value available and not in two or more successive roundings. For example, 89,490 rounded off to the nearest 1000 is 89,000; it would be incorrect to round off first to the nearest 100, giving 89,500 and then to the nearest 1000 giving 90,000.

## **5.2.2.2. RANDOM SAMPLING**

### **1. SCOPE**

This method covers procedures for securing random samples from a lot by the use of random numbers obtained from tables or generated by other methods.

Nothing in this method is intended to preclude additional testing if failing or suspect materials or construction is encountered. Testing that is additional to the scheduled testing should occur immediately if failing test results occur or if materials or work appears to be substandard.

### **2. DEFINITIONS**

**2.1.** Lot: An isolated or defined quantity of material from a single source or a measured amount of construction assumed to be produced by the same process. Specified amounts of asphalt concrete mix, a stockpile of aggregates, or linear feet of roadway constructed in a day are examples of a lot.

**2.1.1.** Sublot: A portion of a lot. When it is not convenient to sample the entire lot, such as a specified amount of hot mix, then it can be divided into equal sized sublots. The sublots, when combined, would constitute the entire lot.

**2.1.2.** Random: Without aim or pattern, depending entirely on chance alone (not to be construed as haphazard).

**2.1.3.** Sample: A small part of a lot or sublot which represents the whole. A sample may be made up of one or more increments or test portions.

**2.1.4.** Random number: A number selected entirely by chance. Random numbers may be generated electronically such as with a random number function on a calculator or spreadsheet or selected from a table of random numbers (See **Table 1**).

**2.1.5.** Seed number: A number to provide a starting point for selection of the random numbers. The seed number may be generated from an odometer reading, random number function on a calculator or spreadsheet, or by pointing at the random number table.

### **3. USE OF RANDOM NUMBERS IN SAMPLING**

**3.1.** Most sampling and testing for construction materials should be randomized to prevent any unintentional bias of the results. Randomization of sampling times or locations is accomplished by using a set of random numbers to determine the time or location for the sample. A table of random numbers is included below.

**3.1.1.** Example 1: Determining when to sample.

**3.1.1.1.** As an example, assume ten trucks carrying equal loads are going to be used to deliver concrete during a bridge deck placement. Select which truck to sample for compressive strength cylinders to be molded.

In cases such as number of trucks or tons of production, etc. round up to the next whole number because there will not be a truck “0”. In cases involving things such as stationing there is a zero point so rounding to the nearest number may be justified.

Generate a random number using one of the methods below. Use .456 in this example. Multiply .456 by 10 (the number of trucks) for a result of 4.56. Round this result up to a whole number, 5 in this case. Take the concrete sample from the fifth truck.

This method can be used to select a time of day or the day of the week. If production was to occur during an 8 hour day, multiply 8 by the selected random number, .456, to obtain a result of 3.648. If rounding is used the sample should be taken in the fourth hour of production. Refinement could be used to select a time down to the nearest minute if needed by using the integer, three in this case, as the hour and then multiplying the decimal by 60 to obtain the minute,  $60 \times .648$  or  $\pm 39$  in this case. Sampling would occur three hours thirty nine minutes into production. Use the number seven multiplied by a random number to determine a day of the week. Sampling during production according to units, such as tons of material produced, can be handled in the same fashion. Multiply the lot or subplot size, as required, by the random number selected.

### 3.2. Example 2: Determining location for sampling.

#### 3.2.1. Given random numbers selected:

X	Y
0.338	0.922
0.763	0.198
0.043	0.737
0.810	0.747

#### ENGLISH EXAMPLE:

Sampling a large lot may require division into sublots to ensure all portions of a lot are represented. Stratification into sublots is accomplished by dividing the “Lot” material (in this case, a mile of construction or 5280 feet, 12’6” wide) into “four sublots” (each of 1320’ or 1/4 mile).

To locate a sample point station in subplot No. 1, the length of that subplot is multiplied by the “X” coordinate for the “subplot” and the product added to the beginning station for that subplot.

$$\begin{array}{l} \text{Starting Station} = 486 + 15 \\ (X_1)(1320) = (0.338)(1320) = 446' \\ \text{Sample Station} = \end{array} \qquad \begin{array}{r} 486 + 15 \\ \underline{4 + 46} \\ 490 + 61 \end{array}$$

The sample point distance from the base line (generally centerline or the edge of pavement) is determined by multiplying  $Y_1$  by the available width, in this case, 12.5 feet.

$$(Y_1)(12.5') = (0.922)(12.5') = 11.5' \text{ from base line.}$$

Thus the sample location is Sta. 490 + 61, 11.5’ from base line. Keeping in mind that the second subplot begins at station 499 + 35 (sta. 486 + 15 + 1320’), the second, third and fourth locations are determined by the same technique. These values are:

Sublot # 2 Sta. 509 + 42, 2.5' from base line.  
 Sublot # 3 Sta. 513 + 12, 9.2' from base line.  
 Sublot # 4 Sta. 536 + 44, 9.3' from base line.

**SI EXAMPLE:**

Stratification into sublots is accomplished by dividing the “Lot” material (in this case, 2,000 meters) into “four sublots” [each of 500 meters (2,000/4) long].

To locate a sample point station in subplot No. 1, the length of that subplot is multiplied by the “X” coordinate for the “subplot” and the product added to the beginning station for that subplot.

Starting Station = 1 + 525	1 + 525
$(X_1)(500) = (0.338)(500) = 169$ meters	<u>169</u>
Sample Station =	1 + 694

The sample point distance from the base line (generally centerline or the edge of pavement) is determined by multiplying  $Y_1$  by the available width.

$(Y_1)(3.7 \text{ m}) = (0.922)(3.7 \text{ m}) = 3.4 \text{ m from base line.}$

Thus the sample location is Sta. 1 + 694, 3.4 m from base line. Keeping in mind that the second subplot begins at station 2 + 025 (sta. 1 + 525 + 500 m), the second, third and fourth locations are determined by the same technique. These values are:

Sublot # 2 Sta. 2 + 407, 0.7 m from base line.  
 Sublot # 3 Sta. 2 + 547, 2.7 m from base line.  
 Sublot # 4 Sta. 3 + 430, 2.8 m from base line.

**4. Methods for selection of random numbers.**

**4.1. Use of calculators or spreadsheet functions.**

**4.1.1.** Many calculators have a random function. Review the manual for a given calculator to determine how to access this function. Sets of random numbers may be generated directly from the calculator by repeated use of this function.

**4.1.2.** Most spreadsheets also have a function to generate random numbers. Insert the random number function into a cell and press enter. A random number will be generated. Copy that cell as needed to produce the required quantity of random numbers. It may be necessary to reformat the cells to have only three decimal places. Read the manual for the specific spreadsheet for more detail on use.

**NOTE:** The District Materials Engineer may require a different method of generating random numbers to be used if an electronic method is determined to not be truly random.

**4.2. Use of the Random Number Table (Table 1).**

**4.2.1.** Use of the random number table requires the use of “seed” numbers to provide starting points for selection of the random numbers. A seed number can be obtained by several methods including odometer

readings, generation by a random number function of a calculator or spreadsheet or by “pointing” if necessary.

**4.2.1.1.** Using an odometer reading such as 78642 as a seed number, use the digit farthest to the right (2) to select the column in the table. Use the next two digits to the left (64) to select the row.

In this case finding the intersection of the row and the column yields the number 0.338. Use this as a starting position and count down the column for the required number of samples. Selecting numbers for an X coordinate for three samples yields 0.338, 0.763 and 0.043.

If a Y coordinate is also required use the fourth digit from the right for the column and the next two digits to the left, for the row. In this example that would yield column 8 and row 07 producing a starting point at number 0.521. If a total of three samples are required, counting down two more places yields numbers 0.937 and 0.912.

Using this example, pairs of numbers for determining three X and Y coordinates are obtained, (0.338, 0.521), (0.763, 0.937) and (0.043, 0.912). Any amount of numbers required may be selected this way. If ten samples are required count down the column until ten numbers are selected.

Once the bottom of a column has been reached go to the top of the next column to the right and countdown to obtain more numbers, if the bottom of column 10 is reached go to the top of column 1.

**If the column value from the seed number 0, then use column 10. If the row value from the seed number is 00, then use row 100.**

Use of the odometer to generate seed numbers is not recommended if more than one set of X and Y pairs of random numbers is required in a relatively short period of time due to the slow change of the left odometer numbers.

**4.2.1.2.** Seed numbers may be obtained by using the random number function of a calculator or spreadsheet. In the above example the same results would have occurred if a calculator returned .264 for the first seed number. Use the first digit (2) to select a column and the second two digits (64) for the row. If using the random number function again produced 0.837, and then the same numbers would have been generated for the Y coordinate as in Example 2.

**4.2.1.3.** Seed numbers may be obtained by “pointing” also. Lay copies of both pages of **Table 1** side by side and with eyes closed place a pointer on the table to select a seed number. Use this number as in the above example. Suitable pointers would be any device with a small tip such as a pin or a mechanical pencil.



**Table 1 Random Numbers**

Table 1 (Cont)

	1	2	3	4	5	6	7	8	9	10
1	0.293	0.971	0.892	0.865	0.500	0.652	0.058	0.119	0.403	0.234
2	0.607	0.840	0.428	0.857	0.125	0.143	0.562	0.692	0.743	0.306
3	0.161	0.182	0.544	0.646	0.548	0.384	0.347	0.330	0.869	0.958
4	0.856	0.103	0.019	0.990	0.370	0.094	0.967	0.642	0.332	0.717
5	0.779	0.795	0.262	0.276	0.236	0.537	0.465	0.712	0.358	0.090
6	0.036	0.475	0.100	0.813	0.191	0.581	0.350	0.429	0.768	0.574
7	0.028	0.569	0.915	0.344	0.009	0.523	0.520	0.521	0.002	0.970
8	0.442	0.320	0.084	0.623	0.859	0.608	0.714	0.937	0.559	0.943
9	0.045	0.878	0.108	0.876	0.466	0.117	0.005	0.912	0.150	0.887
10	0.625	0.906	0.957	0.145	0.616	0.606	0.279	0.207	0.337	0.242
11	0.962	0.457	0.424	0.102	0.462	0.885	0.710	0.352	0.617	0.781
12	0.938	0.696	0.085	0.916	0.844	0.281	0.254	0.528	0.470	0.267
13	0.431	0.960	0.653	0.256	0.944	0.928	0.809	0.543	0.739	0.776
14	0.755	1.000	0.072	0.501	0.805	0.884	0.322	0.235	0.348	0.900
15	0.139	0.365	0.993	0.091	0.599	0.954	0.693	0.249	0.925	0.637
16	0.064	0.040	0.219	0.199	0.055	0.732	0.105	0.505	0.661	0.579
17	0.701	0.450	0.950	0.218	0.067	0.531	0.979	0.783	0.934	0.096
18	0.659	0.406	0.800	0.525	0.339	0.936	0.719	0.029	0.825	0.215
19	0.804	0.580	0.754	0.690	0.629	0.794	0.841	0.131	0.388	0.168
20	0.261	0.456	0.158	0.774	0.673	0.289	0.982	0.371	0.666	0.121
21	0.604	0.471	0.020	0.870	0.624	0.349	0.426	0.529	0.634	0.214
22	0.587	0.083	0.635	0.038	0.767	0.473	0.939	0.647	0.449	0.691
23	0.947	0.292	0.217	0.183	0.366	0.172	0.156	0.570	0.583	0.185
24	0.351	0.025	0.224	0.432	0.752	0.636	0.664	0.582	0.622	0.213
25	0.165	0.184	0.516	0.099	0.353	0.920	0.097	0.519	0.197	0.126
26	0.725	0.931	0.309	0.436	0.782	0.389	0.707	0.297	0.709	0.803
27	0.253	0.506	0.656	0.343	0.974	0.898	0.162	0.879	0.393	0.231
28	0.498	0.414	0.576	0.427	0.662	0.345	0.877	0.385	0.122	0.051
29	0.104	0.301	0.346	0.905	0.918	0.572	0.838	0.092	0.282	0.260
30	0.035	0.075	0.518	0.280	0.115	0.611	0.362	0.062	0.578	0.567
31	0.503	0.421	0.697	0.610	0.147	0.049	0.545	0.452	0.852	0.497
32	0.274	0.205	0.778	0.472	0.245	0.951	0.671	0.932	0.713	0.731
33	0.314	0.032	0.468	0.493	0.252	0.833	0.812	0.445	0.904	0.324
34	0.400	0.422	0.592	0.854	0.832	0.527	0.605	0.797	0.089	0.455
35	0.807	0.593	0.989	0.997	0.910	0.722	0.645	0.534	0.021	0.327
36	0.118	0.377	0.711	0.871	0.024	0.251	0.433	0.814	0.577	0.216
37	0.007	0.288	0.372	0.727	0.014	0.259	0.037	0.922	0.460	0.230
38	0.476	0.011	0.265	0.188	0.317	0.603	0.981	0.198	0.853	0.977
39	0.275	0.700	0.745	0.535	0.179	0.902	0.706	0.737	0.133	0.748
40	0.721	0.237	0.283	0.070	0.644	0.614	0.942	0.747	0.123	0.880
41	0.980	0.716	0.819	0.079	0.526	0.071	0.828	0.536	0.463	0.909
42	0.359	0.789	0.135	0.555	0.394	0.444	0.775	0.269	0.510	0.845
43	0.733	0.598	0.059	0.921	0.816	0.381	0.454	0.477	0.596	0.250
44	0.192	0.968	0.430	0.699	0.295	0.383	0.266	0.401	0.542	0.286
45	0.354	0.799	0.004	0.232	0.633	0.682	0.638	0.897	0.485	0.695
46	0.496	0.012	0.243	0.985	0.355	0.612	0.315	0.760	0.392	0.541
47	0.494	0.113	0.773	0.867	0.824	0.976	0.323	0.134	0.761	0.911
48	0.780	0.687	0.318	0.202	0.331	0.264	0.670	0.848	0.114	0.495
49	0.023	0.027	0.930	0.031	0.843	0.730	0.919	0.858	0.866	0.360
50	0.086	0.335	0.631	0.247	0.120	0.965	0.675	0.999	0.601	0.948

	1	2	3	4	5	6	7	8	9	10
51	0.940	0.312	0.994	0.564	0.946	0.886	0.016	0.112	0.169	0.241
52	0.547	0.336	0.382	0.017	0.836	0.632	0.175	0.053	0.441	0.821
53	0.376	0.620	0.399	0.765	0.618	0.203	0.530	0.124	0.132	0.326
54	0.586	0.268	0.109	0.378	0.434	0.734	0.551	0.894	0.464	0.321
55	0.018	0.409	0.539	0.144	0.703	0.180	0.478	0.688	0.929	0.674
56	0.588	0.227	0.896	0.758	0.826	0.504	0.512	0.026	0.863	0.481
57	0.305	0.689	0.137	0.319	0.558	0.418	0.277	0.992	0.766	0.447
58	0.831	0.899	0.208	0.698	0.676	0.195	0.808	0.759	0.738	0.439
59	0.626	0.827	0.959	0.440	0.411	0.861	0.850	0.686	0.159	0.374
60	0.201	0.895	0.480	0.270	0.369	0.407	0.082	0.749	0.057	0.435
61	0.030	0.167	0.509	0.419	0.508	0.181	0.490	0.875	0.830	0.482
62	0.136	0.065	0.416	0.116	0.907	0.556	0.095	0.110	0.395	0.736
63	0.591	0.600	0.405	0.657	0.013	0.651	0.225	0.340	0.146	0.155
64	0.487	0.338	0.170	0.006	0.263	0.173	0.228	0.008	0.010	0.313
65	0.364	0.763	0.391	0.790	0.589	0.003	0.998	0.257	0.984	0.437
66	0.996	0.043	0.793	0.522	0.705	0.248	0.924	0.609	0.639	0.423
67	0.063	0.810	0.189	0.769	0.488	0.152	0.221	0.978	0.329	0.229
68	0.513	0.333	0.540	0.160	0.461	0.683	0.285	0.750	0.557	0.311
69	0.176	0.054	0.341	0.484	0.860	0.046	0.278	0.244	0.222	0.864
70	0.549	0.835	0.398	0.829	0.459	0.153	0.728	0.822	0.106	0.756
71	0.298	0.514	0.945	0.648	0.784	0.154	0.499	0.415	0.397	0.255
72	0.888	0.764	0.602	0.220	0.684	0.081	0.868	0.272	0.987	0.802
73	0.654	0.995	0.073	0.655	0.041	0.811	0.367	0.226	0.438	0.107
74	0.650	0.467	0.210	0.204	0.762	0.420	0.680	0.334	0.723	0.446
75	0.039	0.022	0.823	0.087	0.076	0.568	0.515	0.223	0.561	0.316
76	0.291	0.791	0.788	0.396	0.212	0.138	0.357	0.304	0.575	0.342
77	0.834	0.373	0.584	0.694	0.613	0.817	0.129	0.546	0.425	0.290
78	0.511	0.375	0.048	0.923	0.001	0.088	0.258	0.166	0.787	0.837
79	0.538	0.174	0.068	0.052	0.640	0.148	0.093	0.553	0.565	0.862
80	0.560	0.724	0.975	0.818	0.796	0.379	0.069	0.034	0.792	0.757
81	0.492	0.820	0.489	0.872	0.770	0.991	0.704	0.050	0.874	0.621
82	0.890	0.356	0.451	0.554	0.649	0.507	0.061	0.479	0.211	0.273
83	0.966	0.798	0.917	0.141	0.368	0.193	0.443	0.751	0.458	0.746
84	0.517	0.715	0.777	0.742	0.839	0.307	0.246	0.956	0.665	0.111
85	0.786	0.328	0.015	0.643	0.882	0.815	0.963	0.590	0.855	0.891
86	0.047	0.702	0.287	0.177	0.164	0.552	0.296	0.413	0.941	0.849
87	0.681	0.678	0.563	0.851	0.726	0.801	0.573	0.056	0.140	0.641
88	0.404	0.842	0.412	0.893	0.935	0.744	0.386	0.299	0.178	0.881
89	0.033	0.042	0.753	0.660	0.685	0.171	0.408	0.060	0.550	0.302
90	0.128	0.658	0.667	0.926	0.239	0.127	0.903	0.483	0.300	0.597
91	0.973	0.933	0.361	0.595	0.186	0.901	0.914	0.190	0.303	0.098
92	0.672	0.729	0.163	0.310	0.196	0.964	0.486	0.308	0.735	0.474
93	0.524	0.402	0.628	0.410	0.846	0.206	0.585	0.566	0.044	0.627
94	0.720	0.157	0.238	0.078	0.233	0.771	0.533	0.986	0.077	0.101
95	0.983	0.669	0.927	0.066	0.080	0.740	0.969	0.630	0.619	0.200
96	0.294	0.387	0.988	0.961	0.913	0.679	0.284	0.949	0.380	0.785
97	0.668	0.149	0.972	0.187	0.151	0.502	0.718	0.453	0.953	0.491
98	0.130	0.708	0.417	0.594	0.209	0.663	0.908	0.271	0.532	0.741
99	0.883	0.677	0.615	0.469	0.363	0.142	0.952	0.325	0.194	0.847
100	0.889	0.772	0.390	0.571	0.873	0.806	0.448	0.955	0.240	0.074

### **5.2.3. REASONS FOR QUALITY CONTROL/QUALITY ASSURANCE (QC/QA) AND THE CERTIFIED INSPECTOR TRAINING AND TESTING PROGRAM (CIT<sup>2</sup>)**

#### **1. Compliance with Specifications.**

The primary reason for requiring inspection, sampling and testing of materials, through an adequate and effective QC/QA system for materials used in a project, is for KDOT to verify that all materials furnished by the contractor and incorporated into the work and the completed work itself meet the requirements of the contract documents (plans, specifications, special provisions and other supplemental documents).

Specifications and plans have been prepared to require the use of materials that are expected to perform satisfactorily with minimal maintenance throughout the life of the facility. Any material that deviates from specification or plan limits will not perform as expected, and, in all probability, will shorten the life of the facility or add appreciably to the cost of its maintenance. Inspectors are expected to review the applicable clauses and covenants of the Standard Specifications at regular intervals.

#### **2. Uniform Relations with Contractors and Producers.**

The contract documents provide an equitable basis for bidding by contractors since they define the requirements that are to be met. The contractors who bid the work and producers supplying material to the contractors commit to KDOT to furnish materials and completed work that will equal or exceed such requirements.

The Engineer must determine, through quality assurance measures that the contractor is providing and the State is receiving what is specified under the contract. The Engineer should accept nothing less for the use of taxpayer funds.

It is essential that quality assurance be applied uniformly by all engineers and inspectors from project to project so that all contractors and suppliers are treated alike. This manual provides guidance to the Engineer and inspector on interpretation of the specifications and the application of quality assurance, so no contractors or producers are given an unfair advantage over other contractors and producers.

#### **3. Documentation of Expenditure of Public Funds.**

When payment is to be made to the contractor for materials furnished and work performed, the duly designated state official must authorize disbursement of public funds for this purpose. The disbursing officer must depend upon others for evidence to support the expenditure. Through the materials quality assurance system, the Field Engineer will acquire substantiating data in the form of test results, inspection records and measurements to justify acceptance of the contractor's work. Thus, the Engineer can assure and furnish documentation to the officials responsible for authorizing payment that the contractor has fulfilled its obligation and is entitled to full or adjusted payment as provided for in the contract documents.

In case of failure to meet the minimum requirements, quality assurance data will constitute the basis for rejection of work as unacceptable.

Complete records, including test and inspection reports covering acceptance or rejection, should be maintained in the Engineer's project files while the necessary copies should be furnished to the appropriate headquarters personnel as needed for verification and as supporting evidence for payment documents.

#### **4. Compliance with Federal Regulations**

Title 23, Chapter 1, Part 637 of the Code of Federal Regulations includes many requirements which must be adhered to for Federal-aid highway construction. Some of these requirements include:

- State Transportation Departments have a Quality Assurance program in place.
- Testing of highway materials is performed by Qualified Laboratories.
- State Transportation Departments have an Independent Assurance program in place.
- Sampling of materials used in highway construction is accomplished in a Random manner.
- Qualified personnel are used for sampling and testing of materials used in highway construction.

Part 637 defines Quality Assurance as “All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality”. A Quality Assurance Program is required under 637.205 which states in part: “Each STD (State Transportation Department) shall develop a quality assurance program which will assure that the materials and workmanship incorporated into each Federal-aid highway construction project on the NHS are in conformity with the requirements of the approved plans and specifications”.

Other requirements and definitions can be found on the Government Printing Office website: <http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR>. KDOT administers its state quality program in accordance with federal regulations and requirements.

##### 5. Reasons for the Certified Inspection and Testing Training Program (CIT<sup>2</sup>).

As noted above, the use of qualified personnel is required for sampling and testing of materials used in highway construction. This requirement is expressed in 637.209(b) “Sampling and testing personnel. After June 29, 2000, all sampling and testing data to be used in the acceptance decision or the IA program shall be executed by qualified sampling and testing personnel.” The State defines qualified personnel as those certified through the Certified Inspection and Testing Training Program (CIT<sup>2</sup>).

The following is an excerpt from the CIT<sup>2</sup> manual giving an overview of the program:

“The Kansas Department of Transportation (KDOT) has established this training program to educate, test and certify those individuals responsible for performing inspection and testing functions on KDOT construction projects. KDOT’s Bureau of Construction and Materials has responsibility for the establishment and administration of the materials portion of the KDOT’s Quality Control/Quality Assurance (QC/QA) Program. The Bureau develops standards and specifications for materials, establishes sampling procedures and frequencies, and test procedures used in the laboratory and the field in order to assure compliance with specifications. It performs materials testing to assist each of the six KDOT districts in administering quality assurance functions of the QC/QA Program. Such testing includes tests on materials purchased by contractors or the State for use in maintenance or construction activities. The Bureau also conducts tests on soils, concrete, bituminous mixtures and numerous other specialized materials, the results of which are used by others for a variety of reasons.”

“Quality control and quality assurance activities involve the routine sampling, testing and analysis of various materials to determine the quality of a given product and to attain a quality product. The goal of the Certified Inspection and Testing Training Program (CIT<sup>2</sup>) is to provide persons engaged in the inspection and/or testing of KDOT construction projects specific training in, but not limited to, soils, aggregates, and concrete and/or asphalt disciplines.”

“Each student is required to demonstrate specific abilities as defined by the training modules described in the CIT<sup>2</sup> manual.” The manual can be found online at:  
<http://www.ksdot.org/descons.asp#CIT>.”



## 5.2.4. PROCEDURES FOR QUALITY ASSURANCE

### 1. General

KDOT has two procedures for assuring quality on project produced materials. The two Sampling and Testing Frequency Charts in Appendix A and B help clarify some of the differences between the two procedures.

**1.1.** The older of the two is “Method Specs”. Under this procedure, KDOT’s test results are used as the basis of acceptance for project produced materials, and the contractor is not required to conduct quality control testing, although the contractor may choose to do so.

**1.2.** A more current procedure is “QC/QA” specifications. Under this method of quality assurance, the contractor conducts quality control testing, and these test results can be used as a basis of acceptance, provided KDOT’s quality assurance verifies the results.

### 2. Authorized Personnel.

**2.1.** Under a “method spec”, all inspection, sampling and testing for acceptance must be performed by an authorized representative of the Kansas Department of Transportation. The representative may be an employee of the Kansas Department of Transportation, an employee of another highway agency or an employee of a commercial testing laboratory or inspection agency. The contractor’s/producer’s process control test results may be used for partial acceptance when allowed by the contract documents. (See basis of acceptance.)

Arrangements for inspection and sampling of materials by agencies other than the Department are made by the Chief, Bureau of Construction and Materials.

Samples submitted to the laboratory for tests by unauthorized individuals or agencies will not be tested except by authorization of the Chief, Bureau of Construction and Materials.

**2.2.** Under “QC/QA” specifications, all technicians must demonstrate qualifications for each Test Group in which they wish to conduct materials sampling and testing. These qualifications include some type of certificate for the completion of a training program or a combination of demonstration of the test procedures and completion of written exams covering the group of test methods. For a list of Test Groups, see **Appendix C**. Acceptable certifications include KDOT training and testing, training conducted at KSU-Salina or Manhattan, American Concrete Institute certification, or a certificate of completion from a program similar to those described and issued or approved by another state’s DOT. KDOT has final judgment on a technician’s qualifications.

Certification in one group may be required before attendance in the certification course of another group. For example, Aggregate Field is required before a technician may attend the Superpave Field training.

All contractors conducting QC/QA sampling and testing for KDOT projects are responsible for the annual calibration and verification of their equipment by an AASHTO Accredited Laboratory, calibration service, or the equipment manufacturer using NIST traceable equipment, or by some other NIST traceable source (see **Appendix C** for calibration and verification frequencies). Calibrations and verifications required more often than every 12 months may be conducted by the contractor if the equipment is checked annually by an AASHTO Accredited Laboratory, calibration service or the equipment manufacturer. Equipment will be made available to the District Materials Engineer for spot checks of the calibrations when necessary.

**2.3.** All technicians conducting sampling and testing for the State of Kansas projects are given a unique number for tracking in AASHTOWare Project (AWP). The system also lists the group of tests that the technician is authorized or qualified to conduct.

The contractor and KDOT Construction Offices must submit a list of qualified technicians that will be conducting sampling and testing on a project to the District Materials Engineer before work begins on the project. Include each technician's AWP identification number and the possible group of tests to be conducted by the technician on the list. The District Materials Engineer will run a sort against AWP to determine if Independent Assurance requirements have been completed for each technician during that calendar year. They will make an attempt to schedule such activity during the course of the project if required.

### **3. Inspection and Sampling Procedures.**

**3.1. Contract Requirements:** The first activity in the inspection and sampling of a product is to determine the specified requirements for the material. The project listing issued by the Bureau of Construction and Materials and the contract documents should be reviewed to determine if there are special provisions covering the product. If there are none, then the plans and Standard Specifications are applicable. If dimensions and other details are not covered by the Standard Specifications and special provisions, then the necessary information must be obtained from the plans.

When reviewing contract requirements for a product, the following statement from the Standard Specifications should be kept in mind: "In case of discrepancy, calculated dimensions will govern over scaled dimensions; Plans will govern over Standard Specifications; Special Provisions will govern over Plans; and Project Special Provisions will govern over Special Provisions."

The applicable specifications, special provisions and plans must be carefully studied and notes outlining pertinent requirements should be made for reference during the actual inspection procedure.

**3.2. Visual Inspection:** To prevent incorporation of "out of specification" material into the work and to prevent an injustice to the producer or the supplier by rejecting "specification material," it is essential that each sample truly represent the material being inspected. Therefore, before most material is sampled, it must be subjected to a careful visual inspection. If the material to be sampled involves many individual units such as concrete blocks, culvert pipe, bolts and nuts, castings, etc., the entire lot offered for inspection must be carefully examined for workmanship, defects, dimensions if specified, finish and uniformity.

Any units which visual inspection shows to be outside specified limits should be immediately rejected and not sampled. It is emphasized that the Department is not a "culling" agency and if it is found that more than 10 to 15% of the units in a lot fall outside the specified limits, the entire lot should be rejected. If the producer or supplier elects to cull the lot and remove all non-specification units, the new lot may be re-inspected and sampled.

**3.3. Sampling:** When sampling materials, refer to **section 5.9.** for specific instructions on sampling procedures for specific materials. In situations not covered by **section 5.9,** contact the District Materials Engineer for assistance.

**3.4. Identification of Materials:** It is essential that all material be properly marked for identification when the material is inspected and sampled. The identification must be such that the Field Engineer can readily associate the material with the inspection and/or test report for the lot of material covered by the inspection.



If the number of units is not too large, each unit must be tagged or stenciled with a laboratory or other number assigned by the inspector. When a large number of units are involved in a lot, identification is placed on a number of units on a random basis.

**3.5. Identification of Samples:** Properly executed AWP-Sample ID screens or information sheets must be prepared for each sample or group of samples submitted to the laboratory for test. All appropriate items on the sheet or screen must be filled out so that the sample will be identified with the lot of material that it represents. It is especially important that the quantity of material represented by each sample be shown in order for the Field Engineer to account for all materials received on the project. Further details are set forth in **section 5.4.** of this manual.

**3.6. Inspection at Destination:** All materials that arrive on the project are to be inspected by the Engineer prior to being incorporated into the work and all such inspections should be carefully documented. It must be understood that the final acceptance or rejection of all materials should be made at the project site just prior to incorporation of the material in the work.

Subject items that have previously been inspected, tested and accepted to visual inspection to ascertain possible damage during shipment, laboratory numbers or other identification assigned during the initial inspection and general conformance with dimensional requirements.

Visually examine all items accepted by certification at destination to ensure conformance with dimensional and/or other requirements, to ensure that the identification on the material correspond with the identification on the certifications, and to ensure that the material was not damaged during shipment.



## **5.2.5. QUALITY CONTROL/QUALITY ASSURANCE (QC/QA) TESTS**

### **1. General**

This section establishes terminology and procedures for the various tests that are included in the QC/QA system.

### **2. Definitions**

**2.1. Acceptance Program** - All factors that comprise the State's determination of the degree of compliance with contract requirements and value of a product. These factors include the State's sampling, testing and inspection, and validated results of contractor sampling and testing.

**2.2. Assurance Sampling and Testing** - Split or replicate samples used as an independent check of the sampling and testing procedures and equipment. These samples are to assure testing is being performed properly by both the contractor's and the State's personnel. The results of assurance tests are not to be used as a basis of material acceptance.

**2.3. Dispute Resolution** - The procedure used to resolve conflicts resulting from discrepancies between the State's verification results and the Contractor's quality control results of sufficient magnitude to impact payment. Any laboratory used for dispute resolution must be accredited by the AASHTO Accreditation program for the tests to be performed.

**2.4. Independent Assurance (IA)** - IA is an unbiased and independent verification of the Quality Assurance system used and of the reliability of the test results obtained in the regular sampling and testing activities. KDOT's IA will consist of observations by independent personnel to assure that specified procedures are followed (witnessing), and split or replicate sampling and testing.

**2.5. Quality Assurance (QA)** - All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality. QA activities include: acceptance, independent assurance, verification, and prequalification sampling and testing; inspection; reporting of results; and any follow up that may be necessary due to test failure. Without these actions, it would be impossible for the Engineer to accurately verify compliance or in many cases the level of compliance with the requirements of the contract documents.

**2.6. Quality Control (QC)** - The sum total of operational techniques and activities performed or conducted by the contractor and/or producer to make sure that a product meets contract specification requirements. QC activities generally are outlined in a contractor's process control plan which lists such items as types of tests to be performed, sampling locations, sampling frequencies, equipment calibration procedures and frequencies, and documentation procedures.

**2.7. Qualified Laboratories** - Laboratories used for sampling and testing of materials are those approved through appropriate programs as determined by KDOT.

**2.8. Qualified Technician** - Personnel who are certified through appropriate programs as determined by KDOT.

**2.9. Replicate Tests** - Tests performed by independent assurance personnel using equipment other than that used by project personnel, but performed on a portion of the sample used by project personnel.

**2.10. Split Samples** - Sampling and splitting of the material by project personnel with a portion tested by the contractor, a portion tested by KDOT field personnel and a portion tested by independent assurance personnel. Tests performed by KDOT designated independent assurance personnel use equipment other than that used by project personnel.

**2.11. Verification Sampling and Testing** - Sampling and testing performed to validate the quality of the product or to check the adequacy of mix designs. If quality control sampling and testing is used in the acceptance program, verification sampling and testing will also be used to validate the quality control sampling and testing. Verification samples are independent samples obtained by KDOT.

**2.11.1. On Grade Concrete Aggregate (OGCA) Production Samples** - Sampling and testing procedures utilized to verify that the production of OGCA complies with the specification quality requirements

**2.12. Other** - sampling and testing by the District Materials laboratories not otherwise designated in this instruction or specified in the Sampling and Testing Frequency Chart, such as determination of asphalt content in maintenance mixes, or a Marshall design.

### **3. Independent Assurance**

KDOT uses a systems-wide approach to Independent Assurance Sampling and Testing of project produced materials. Each test is included in one of the following Groups according to the type of material: Aggregates, Concrete, Asphalt Mixes, and Soils. A breakdown of requirements for each Group is provided in **Appendix C**. Independent assurance will be conducted once per calendar year per technician per group of tests performed by that technician during that year. It may not be possible to witness all the tests within a group during the assurance process. There are, however, critical Core Tests within each group that must be witnessed before annual Independent Assurance requirements are completed by a technician for that group of tests. These Core Tests are marked with a double asterisk (\*\*) on the list in **Appendix C**.

KDOT's MRC at 2300 Van Buren is AASHTO Accredited. District Materials personnel are responsible for conducting the independent assurance witnessing and testing. The equipment that the Districts use to conduct independent assurance testing is calibrated or verified annually by the MRC personnel, by another AASHTO Accredited Laboratory, calibration service, or equipment manufacturer using NIST traceable sources.

Independent Assurance consists of witnessing the technician properly conduct the test and split or replicate samples. The District conducts the split or replicate testing whenever possible

during the independent assurance process. KDOT may hire, train, and evaluate personnel from independent laboratories to conduct independent assurance witnessing for KDOT. KDOT will still conduct the split sample testing. The independent laboratory need not be AASHTO Accredited since the personnel would be acting on behalf of KDOT.

#### 4. Comparison Procedures

**4.1. Assurance Samples.** Acceptable variations for between laboratory reproducibility are listed in **Appendix C**. Precision statements from **ASTM** or **AASHTO** test procedures are used when available, and these statements are included in the **KT Methods**. Where precision statements are not available the standard deviations from the last 10 AMRL Proficiency Samples are used to calculate the 95% reproducibility limit (between laboratories) – d2s as defined in **ASTM E177**. These calculated values are reviewed annually for applicability and may be adjusted when warranted. Where precision statements and AMRL Samples are not available, the Engineer will use the Engineer’s discretion to determine acceptable variations. The comparisons are made by personnel who are knowledgeable of testing variation and who have the authority to resolve any problems in equipment, procedures, etc.

**4.2.** Under a “method spec” the numerical results obtained on Verification Samples are compared promptly with the specifications, or certified results, as applicable. Appropriate action is taken by the person responsible for making comparisons in each case. In the case of verification sample test results obtained at the MRC, the Engineer of Tests informs the district of any test results which do not comply with specifications and retains the reports pending receipt of information from the district regarding its investigation of circumstances for non-compliance and corrective action taken, if needed, resulting from its investigation.

Under QC/QA specifications, Verification test results are statistically compared to the contractor’s test results by the use of the F & t tests outlined in **section 5.2.6**. or some other statistically valid practice. Use F & t tests only when enough verification results are available. KDOT prefers results from at least 3 to 5 verification tests for statistical comparisons. If the data passes the T test, use the contractor’s numbers to calculate pay quantities. If the data fails the t test, use KDOT’s numbers to calculate pay quantities.

**4.3.** Reports of Verification Samples shall show sufficient information to facilitate comparison with the corresponding Acceptance Test, related certifications, or producer's test results.

**4.3.1.** When statistical comparisons are made, include a comment in the report similar to one of the following:

**4.3.1.1.** "Statistical comparison of results indicates it is reasonable to assume all associated samples came from the same population."

**4.3.1.2.** "Statistical comparison of results indicates it is reasonable to assume all associated samples did not come from the same population (or lot)."

**4.3.2.** When no statistical comparison can be made, include a comment in the report similar to one of the following:

**4.3.2.1.** "The results of this test appear to agree reasonably well with data reported previously for this project.

**4.3.2.2.** "Comparison of these data with data reported previously for this product indicates that further monitoring or corrective action is merited."

## 5. Dispute resolution

If a dispute exists between the Engineer and the contractor about the validity of the other's test results, the KDOT Materials Research Center will perform referee testing. If one of the disputed Department test results was generated at the MRC, then an Independent AASHTO Accredited Laboratory agreeable to both parties will be selected. If referee testing indicates that the department's test results are correct then the contractor pays for the additional testing, including referee testing performed at the MRC. If the referee testing indicates that the contractor's test results are correct then the Department pays for the additional testing.

## 6. Sampling and Testing Frequency

**6.1.** The two **Sampling and Testing Frequency Charts (Appendix A and Appendix B)** reflect the minimum rate for sampling and testing. It is understood that if a problem occurs, more samples or tests may be necessary.

**6.1.1.** It is also intended that Verification and Assurance Samples may be used for items other than those required by the Sample and Testing Frequency Chart. However, Assurance Samples will never be used for Acceptance.

## 7. Reporting Procedures

**7.1.** Assurance Samples are reported in AWP on the data input screen appropriate for the item being tested. Identify the individual tests by AWP ID nos. or by the Assurance Sample Number (assigned by the District Materials Engineer), the name of the person requesting the sample, and the appropriate sample number used by the group performing the test or a notation as to which group performed each test.

When entering split and replicate samples into AWP the contractor's or field personnel's results are entered as Sample A and the District's or MRC's results are entered as Sample B under the same AWP sample ID number.

**7.2.** Contractors do not currently have access to AWP. District or field personnel are responsible for entering Acceptance and Verification test results into AWP. When test results on Acceptance Samples fall outside of the specification limits, underline or circle in red the points of noncompliance. This option is not available in AWP.

**7.3.** Number of copies and distributions:

### Non AWP

Bureau of Construction and Materials - 1 copy

District Engineer - 1 copy

Field Engineer - 1 copy

### AWP

In AWP it is the users' responsibility to identify the need for information and obtain such information. Information can be obtained using on-line service or ordering reports.

## 8. Responsibility

The Chief of Construction and Materials will maintain a complete file of non-AWP reports on Assurance Samples, Acceptance Samples, Verification Samples and other tests. District Materials Engineers are responsible for forwarding these reports to the Bureau of Construction and Materials.

**8.1.** The District Materials Engineer is responsible for reporting the results on all Assurance Samples performed in the District and may be required to perform Acceptance Tests shown on the **Sampling and Testing Frequency Chart in Appendix A** or **Verification Tests shown in Appendix B**. In addition, performance of additional tests such as, but not limited to, Marshall Designs, Soil Compaction Standards, and Asphalt Extractions will be required.

**8.2.** The Engineer of Tests is responsible for reporting results on samples that are submitted to the Materials and Research Center for Test.

**8.3.** The Field Engineer is normally responsible for the Acceptance Tests shown on the **Sample and Testing Frequency Chart in Appendix A** or the **Verification Tests shown in Appendix B**.





## 5.2.6 COMPARISON OF QUALITY CONTROL AND VERIFICATION TESTS

This procedure is carried out to compare two different sets of multiple test results for finding the same parameter. Typical example would be comparing contractor QC test results and KDOT verification test results to determine if the material under test came from the same population. The statistical test which would be used to compare two means would be popularly known as Student's t-test or simply t-tests for testing a null hypothesis ( $H_0$ ) with certain confidence (e.g. 99%) or level of significance (risk of rejecting a null hypothesis when it is true, e.g., 1%) is as follows:

$H_0$  : There is no difference in the sample means, ie. the means are statistically equal

If the test results do not support this hypothesis than an alternate hypothesis ( $H_a$ ) is accepted as:

$H_a$ : The means are different, ie. the means are not statistically equal

This test is generally applicable when the number of tests (or observations as is known in Statistics) is less than or equal to 30. However, since the approach used in the t-test is dependent upon whether or not the variances (square of the sample standard deviation) are equal for the two sets of data, it is necessary to test the variances of the test results before comparing the means of the test results.

### F-test for the Sample Variances

The F-test determines whether the difference in the variability of the contractor's QC tests and that of KDOT's verification tests is larger than might be expected from chance if they came from the same population. In this case, a hypothesis testing is done at a certain level of significance. The null hypothesis in the test is:

$H_0$ : There is no difference in the sample variances, ie. the variances are statistically equal

If the test results do not support this hypothesis than an alternate hypothesis is accepted as:

$H_a$ : The variances are different, i.e. the variances are not statistically equal

The following steps need to be followed in doing an F-test:

- i) Compute the variance (the standard deviation squared) for the QC tests,  $s_c^2$ , and the KDOT verification tests,  $s_v^2$
- ii) Compute F statistic as:

$$F = s_c^2 / s_v^2 \text{ or } s_v^2 / s_c^2$$

***Always use the larger of the two variances in the numerator.***

- iii) Choose the level of significance,  $\alpha$ , for the test. The recommended  $\alpha$  is 1%.

iv) Find the critical F value  $F_{crit}$ , **from the Table 1** using the degrees of freedom associated with each set of test results. The degrees of freedom for each set of results is the number of test results in the set, less one. If the number of QC tests is  $n_c$  and the number of verification tests is  $n_v$ , then the degrees of freedom associated with  $s_c^2$  is  $(n_c-1)$  and the degrees of freedom associated with  $s_v^2$  is  $(n_v-1)$ . The values in Table 5.17.08-1 are tabulated to test if there is a difference (either larger or smaller) between two variance estimates. This is known as a two-sided or two-tailed test. Care must be taken when using other tables of the F distribution, since they are usually based on a one-tailed test, i.e., testing specifically whether one variance is larger than another. When finding  $F_{crit}$  be sure that the appropriate degrees of freedom for the numerator and denominator are used.

v) Find the value for  $F_{crit}$  from **Table 1**.

vi) If  $F \geq F_{crit}$ , then the null hypothesis is rejected i.e. the two sets of tests have significantly different variabilities. If  $F < F_{crit}$  then there is no reason to believe that the variabilities are significantly different.

### **t-test for Sample Means**

Once the variances have been tested and been assumed to be either equal or not equal, the means of the test results can be tested to determine whether they differ from one another or can be assumed equal. The desire is to determine whether it is reasonable to assume that the QC tests came from the same population as the verification tests. As mentioned before, a t-test is used to compare the sample means. Two approaches for the t-test are necessary.

If the sample variances are assumed equal, then the t-test is conducted based on the two samples using a *pooled estimate for the variance* ( $s_p^2$ ) and the pooled degrees of freedom. If the sample variances are found to be different in the F-test, the t-test is conducted using the individual sample variances, the individual sample sizes, and the effective degrees of freedom (estimated from the sample variances and sample sizes).

In either of the two cases discussed earlier, the null hypothesis used is:

$$H_o : \quad \text{There is no difference in the sample means, i.e. the means are statistically equal}$$

If the test results do not support this hypothesis than an alternate hypothesis is accepted as:

$$H_a: \quad \text{The means are different, i.e. the means are not statistically equal}$$

**Table 1 Critical Values,  $F_{crit}$  for the F-test for a Level of Significance,  $\alpha = 1\%$**

DEGREES OF FREEDOM FOR NUMERATOR

DEGREES OF FREEDOM FOR DENOMINATOR

	1	2	3	4	5	6	7	8	9	10	11	12
1	16200	20000	21600	22500	23100	23400	23700	23900	24100	24200	24300	24400
2	198	199	199	199	199	199	199	199	199	199	199	199
3	55.6	49.8	47.5	46.2	45.4	44.8	44.4	44.1	43.9	43.7	43.5	43.4
4	31.3	26.3	24.3	23.2	22.5	22.0	21.6	21.4	21.1	21.0	20.8	20.7
5	22.8	18.3	16.5	15.6	14.9	14.5	14.2	14.0	13.8	13.6	13.5	13.4
6	18.6	14.5	12.9	12.0	11.5	11.1	10.8	10.6	10.4	10.2	10.1	10.0
7	16.2	12.4	10.9	10.0	9.52	9.16	8.89	8.68	8.51	8.38	8.27	8.18
8	14.7	11.0	9.60	8.81	8.30	7.95	7.69	7.50	7.34	7.21	7.10	7.01
9	13.6	10.1	8.72	7.96	7.47	7.13	6.88	6.69	6.54	6.42	6.31	6.23
10	12.8	9.43	8.08	7.34	6.87	6.54	6.30	6.12	5.97	5.85	5.75	5.66
11	12.2	8.91	7.60	6.88	6.42	6.10	5.86	5.68	5.54	5.42	5.32	5.24
12	11.8	8.51	7.23	6.52	6.07	5.76	5.52	5.35	5.20	5.09	4.99	4.91
15	10.8	7.70	6.48	5.80	5.37	5.07	4.85	4.67	4.54	4.42	4.33	4.25
20	9.94	6.99	5.82	5.17	4.76	4.47	4.26	4.09	3.96	3.85	3.76	3.68
24	9.55	6.66	5.52	4.89	4.49	4.20	3.99	3.83	3.69	3.59	3.50	3.42
30	9.18	6.35	5.24	4.62	4.23	3.95	3.74	3.58	3.45	3.34	3.25	3.18
40	8.83	6.07	4.98	4.37	3.99	3.71	3.51	3.35	3.22	3.12	3.03	2.95
60	8.49	5.80	4.73	4.14	3.76	3.49	3.29	3.13	3.01	2.90	2.82	2.74
120	8.18	5.54	4.50	3.92	3.55	3.28	3.09	2.93	2.81	2.71	2.62	2.54
$\infty$	7.88	5.30	4.28	3.72	3.35	3.09	2.90	2.74	2.62	2.52	2.43	2.36

**NOTE :** This is for a *two-tailed test* with the null and alternate hypotheses shown below:

$$H_0 : s^2_c = s^2_v$$

$$H_a : s^2_c \neq s^2_v$$

**Table 1**

**Critical Values,  $F_{crit}$ , for the F-test for a Level of Significance,  $\alpha = 1\%$  (contd..)**

DEGREES OF FREEDOM FOR NUMERATOR

DEGREES OF FREEDOM FOR DENOMINATOR	15	20	24	30	40	50	60	100	120	200	500	$\infty$	
	1	24600	24800	24900	25000	25100	25200	25300	25300	25400	25400	25400	25500
	2	199	199	199	199	199	199	199	199	199	199	199	200
	3	43.1	42.8	42.69	42.5	42.3	42.2	42.1	42.0	42.0	41.9	41.9	41.8
	4	20.4	20.2	20.0	19.9	19.8	19.7	19.6	19.5	19.5	19.4	19.4	19.3
	5	13.1	12.9	12.8	12.7	12.5	12.5	12.4	12.3	12.3	12.2	12.2	12.1
	6	9.81	9.59	9.47	9.36	9.24	9.17	9.12	9.03	9.00	8.95	8.91	8.88
	7	7.97	7.75	7.65	7.53	7.42	7.35	7.31	7.22	7.19	7.15	7.10	7.08
	8	6.81	6.61	6.50	6.40	6.29	6.22	6.18	6.09	6.06	6.02	5.98	5.95
	9	6.03	5.83	5.73	5.62	5.52	5.45	5.41	5.32	5.30	5.26	5.21	5.19
	10	5.47	5.27	5.17	5.07	4.97	4.90	4.86	4.77	4.75	4.71	4.67	4.64
	11	5.05	4.86	4.76	4.65	4.55	4.49	4.45	4.36	4.34	4.29	4.25	4.23
	12	4.72	4.53	4.43	4.33	4.23	4.17	4.12	4.04	4.01	3.97	3.93	3.90
15	4.07	3.88	3.79	3.69	3.59	3.52	3.48	3.39	3.37	3.33	3.29	3.26	
20	3.50	3.32	3.22	3.12	3.02	2.96	2.92	2.83	2.81	2.76	2.72	2.69	
24	3.25	3.06	2.97	2.87	2.77	2.70	2.66	2.57	2.55	2.50	2.46	2.43	
30	3.01	2.82	2.73	2.63	2.52	2.46	2.42	2.32	2.30	2.25	2.21	2.18	
40	2.78	2.60	2.50	2.40	2.3	2.23	2.18	2.09	2.06	2.01	1.96	1.93	
60	2.57	2.39	2.29	2.19	2.08	2.01	1.96	1.86	1.83	1.78	1.73	1.69	
120	2.37	2.19	2.09	1.98	1.87	1.80	1.75	1.64	1.61	1.54	1.48	1.43	
$\infty$	2.19	2.00	1.90	1.79	1.67	1.59	1.53	1.40	1.36	1.28	1.17	1.00	

**NOTE :** This is for a *two-tailed test* with the null and alternate hypotheses shown below:

$$H_0 : s^2_c = s^2_v$$

$$H_a : s^2_c \neq s^2_v$$

### Case 1: Sample Variances Assumed to Be Equal

a) To conduct the t-test when the sample variances are assumed equal, Equation 1 is used to calculate the t value from which the decision is reached.

$$t = \frac{|\bar{X}_c - \bar{X}_v|}{\sqrt{\frac{s_p^2}{n_c} + \frac{s_p^2}{n_v}}} \quad (1)$$

where:

- $\bar{X}_c$  = mean of QC tests
- $\bar{X}_v$  = mean of verification tests
- $s_p^2$  = pooled estimate for the variance (described below)
- $n_c$  = number of QC tests
- $n_v$  = number of verification tests

b) The pooled variance, which is the weighted average, using the degrees of freedom for each sample as the weighting factor, is computed from the sample variances using Equation 2.

$$s_p^2 = \frac{s_c^2(n_c - 1) + s_v^2(n_v - 1)}{n_c + n_v - 2} \quad (2)$$

Where:

- $s_p^2$  = pooled estimate for the variance
- $n_c$  = number of QC tests
- $n_v$  = number of verification tests
- $s_c^2$  = variance of the QC tests
- $s_v^2$  = variance of the verification tests

- c) Once the pooled variance is estimated, the value of t is computed using equation 1.
- d) To determine the critical t value against which to compare the computed t value, it is necessary to select the level of significance,  $\alpha$ . *A value of  $\alpha = 1\%$  is recommended.*
- e) Determine the critical t value,  $t_{crit}$ , from **Table 2** for the pooled degrees of freedom. The pooled degrees of freedom for the case where the sample variances are assumed equal is  $(n_c + n_v - 2)$ .
- f) If  $t \geq t_{crit}$ , then decide that the two sets of tests have significantly different means. If  $t < t_{crit}$ , then decide that there is no reason to believe that the means are significantly different.

**Case 2: Sample Variances Assumed to Be Not Equal**

- a) To conduct the t-test when the sample variances are assumed not equal, Equation 3 is used to calculate the t value from which the decision is reached.

$$t = \frac{|\bar{X}_c - \bar{X}_v|}{\sqrt{\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}}} \quad (3)$$

- where:
- $\bar{X}_c$  = mean of QC tests
  - $\bar{X}_v$  = mean of verification tests
  - $s_c^2$  = variance of the QC tests
  - $s_v^2$  = variance of the verification tests
  - $n_c$  = number of QC tests
  - $n_v$  = number of verification tests

- b) To determine the critical t value against which to compare the computed t value, it is necessary to select the level of significance,  $\alpha$ . A value of  $\alpha = 1\%$  is recommended.
- c) The effective degrees of freedom,  $f'$ , for the case where the sample variances are assumed not equal is determined from Equation 4 (*the calculated effective degrees of freedom is rounded down to a whole number*).

$$f' = \frac{\left(\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}\right)^2}{\left(\frac{\left(\frac{s_c^2}{n_c}\right)^2}{n_c + 1} + \frac{\left(\frac{s_v^2}{n_v}\right)^2}{n_v + 1}\right)} - 2 \quad (4)$$

where all the symbols are as described previously.

- d) Determine the critical t value,  $t_{crit}$ , from **Table 2** for the effective degrees of freedom determined by Equation 4.
- e) If  $t \geq t_{crit}$ , then decide that the two sets of tests have significantly different means. If  $t < t_{crit}$ , then decide that there is no reason to believe that the means are significantly different.

**Table 2 Critical t values**

degrees of freedom	$\alpha = 0.01$	$\alpha = 0.05$	$\alpha = 0.10$
1	63.657	12.706	6.314
2	9.925	4.303	2.920
3	5.841	3.182	2.353
4	4.604	2.776	2.132
5	4.032	2.571	2.015
6	3.707	2.447	1.943
7	3.499	2.365	1.895
8	3.355	2.306	1.860
9	3.250	2.262	1.833
10	3.169	2.228	1.812
11	3.106	2.201	1.796
12	3.055	2.179	1.782
13	3.012	2.160	1.771
14	2.977	2.145	1.761
15	2.947	2.131	1.753
16	2.921	2.120	1.746
17	2.898	2.110	1.740
18	2.878	2.101	1.734
19	2.861	2.093	1.729
20	2.845	2.086	1.725
21	2.831	2.080	1.721
22	2.819	2.074	1.717
23	2.807	2.069	1.714
24	2.797	2.064	1.711
25	2.787	2.060	1.708
26	2.779	2.056	1.706
27	2.771	2.052	1.703
28	2.763	2.048	1.701
29	2.756	2.045	1.699
30	2.750	2.042	1.697
40	2.704	2.021	1.684
60	2.660	2.000	1.671
120	2.617	1.980	1.658
$\infty$	2.576	1.960	1.645

**NOTE :** This is for a two-tailed test with the null and alternate hypotheses shown below :

$$H_0 : \bar{X}_c = \bar{X}_v$$

$$H_a : \bar{X}_c \neq \bar{X}_v$$

### Example Problem 1-Concrete

A contractor has run 21 QC tests for compressive strength and KDOT has run 5 verification tests over the same period of time. The results are shown below. Is it likely that the tests came from the same population?

Contractor QC Test Results (%)	KDOT Verification Test Results (%)
36.40	36.10
36.65	30.00
32.69	37.00
38.05	32.80
38.54	<u>30.60</u>
37.59	$\bar{X}_v = 33.300$
36.57	
42.48	
36.99	
38.20	
37.53	
36.00	
41.28	
40.00	
38.37	
38.72	
40.36	
30.37	
34.87	
35.62	
<u>36.06</u>	
$\bar{X}_c = 37.302$	

A t-test between the means of these two sets of results can be used to test whether the mean results of the tests done by the contractor and KDOT are statistically different. If they are not different, then it is likely that they came from the same population. However, first the F-test needs to be done to determine whether or not to assume the variance of the QC test results differs from the KDOT verification tests.

<b>Step 1.</b>	Compute the mean and standard deviation for each set of data:	
	<u>QC test results</u>	<u>KDOT Verification test results</u>
	$\bar{X}_c = 37.302$	$\bar{X}_v = 33.300$
	$s_c = 2.736$	$s_v = 3.161$

**Step 2.** Compute variance,  $s^2$ , for each set of test results (variance is square of the standard deviation):



QC test results

KDOT Verification test results

$$s_c^2 = 7.431$$

$$s_v^2 = 9.992$$

**Step 3.** Compute F, using the largest  $s^2$  in the numerator.

$$F = \frac{s_v^2}{s_c^2} = \frac{9.992}{7.431} = 1.34$$

**Step 4.** Determine  $F_{crit}$  from **Table 1** being sure to use the correct degrees of freedom for the numerator ( $n_v - 1 = 5 - 1 = 4$ ) and the denominator ( $n_c - 1 = 21 - 1 = 20$ ).

From Table 5.17.08-1, at  $\alpha = 1\%$ ,

$$F_{crit} = 5.17$$

**Conclusion:** Since  $F < F_{crit}$  (i.e.,  $1.34 < 5.17$ ), there is no reason to believe that the two sets of tests have different variabilities. That is, they could have come from the same population. Since we can assume that the variances are equal, we can use *the pooled variance* to calculate the t-test statistic, and *the pooled degrees of freedom* to determine the critical t value,  $t_{crit}$ .

**Step 5.** Compute the pooled variance,  $s_p^2$ , using the sample variances from above.

$$s_p^2 = \frac{s_c^2(n_c - 1) + s_v^2(n_v - 1)}{n_c + n_v - 2}$$
$$s_p^2 = \frac{(7.431)(20) + (9.992)(4)}{21 + 5 - 2} = 7.86$$

**Step 6.** Compute the t-test statistic, t.

$$t = \frac{|\bar{X}_c - \bar{X}_v|}{\sqrt{\frac{s_p^2}{n_c} + \frac{s_p^2}{n_v}}}$$
$$t = \frac{|37.302 - 33.300|}{\sqrt{\frac{7.86}{21} + \frac{7.86}{5}}} = \frac{4.002}{\sqrt{1.946}} = 2.87$$

**Step 7.** Determine the critical t value,  $t_{crit}$ , for the pooled degrees of freedom degrees of freedom =  $(n_c + n_v - 2) = (21 + 5 - 2) = 24$ .

From **Table 2**,

for  $\alpha = 1\%$  and degrees of freedom = 24,

$$t_{\text{crit}} = 2.80.$$

**Conclusion:** Since  $2.87 > 2.80$ , we assume that the sample means are not equal. It is therefore probable that the two sets of test results did not come from the same population (or lot).

### Example Problem - Case 2-Asphalt

A contractor has run 10 QC tests and KDOT has run 5 verification tests over the same period of time for the asphalt pavement density (%G<sub>mm</sub>). The results are shown below. Is it likely that the test came from the same population or lot?

#### Contractor QC Test Results

93.0  
92.4  
92.9  
93.6  
92.9  
92.9  
92.4  
93.4  
92.9  
92.4  
 $\bar{X}_c = 92.88$

#### KDOT Verification Test Results

95.5  
93.3  
94.1  
92.5  
92.7  
 $\bar{X}_v = 93.62$

A t-test between the means of these two sets of results can be used to test whether the mean results of the %G<sub>mm</sub> done by the contractor and KDOT are statistically different. If they are not different, then it is likely that they came from the same population. First, we have to determine whether the variance of the QC tests differ from the verification tests using F-test.

**Step 1.** Compute the mean and standard deviation for each set of data:

#### QC test results

$$\bar{X}_c = 92.88$$

$$s_c = 0.408$$

#### KDOT Verification test results

$$\bar{X}_v = 93.62$$

$$s_v = 1.221$$

**Step 2.** Compute the variance,  $s^2$ , for each set of tests (variance is the square of the standard deviation):

$$s_c^2 = 0.166$$

$$s_v^2 = 1.491$$

**Step 3.** Compute F, using the largest  $s^2$  in the numerator.

$$F = \frac{s_v^2}{s_c^2} = \frac{1.491}{0.166} = 8.98$$

**Step 4.** Determine  $F_{\text{crit}}$  from **Table 1** (be sure to use the correct degrees of freedom for the numerator ( $n_v - 1 = 5 - 1 = 4$ ) and the denominator ( $n_c - 1 = 10 - 1 = 9$ )).

From **Table 1**, at  $\alpha = 1\%$ ,  $F_{\text{crit}} = 7.96$

**Conclusion:** Since  $F > F_{\text{crit}}$  (i.e.,  $8.98 > 7.96$ ), there is reason to believe that the two sets of tests have different variabilities. Thus, it is likely that they came from populations with different variances. Since we CAN NOT assume that the variances are equal, we cannot use the pooled variance to calculate the t-test statistic, and the pooled degrees of freedom to determine the critical t value,  $t_{\text{crit}}$ .

**Step 5.** Compute the t-test statistic, t.

$$t = \frac{|\bar{X}_c - \bar{X}_v|}{\sqrt{\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}}}$$

$$t = \frac{|92.88 - 93.62|}{\sqrt{\frac{0.166}{10} + \frac{1.491}{5}}} = \frac{0.74}{\sqrt{0.315}} = 1.32$$

**Step 6.** Determine the critical t value,  $t_{\text{crit}}$ , for the approximate degrees of freedom (the calculated effective degrees of freedom is rounded down to a whole number).

$$f' = \frac{\left(\frac{s_c^2}{n_c} + \frac{s_v^2}{n_v}\right)^2}{\left(\frac{\left(\frac{s_c^2}{n_c}\right)^2}{n_c + 1} + \frac{\left(\frac{s_v^2}{n_v}\right)^2}{n_v + 1}\right)} - 2$$

$$f' = \frac{\left( \frac{0.166}{10} + \frac{1.491}{5} \right)^2}{\left( \frac{\left( \frac{0.166}{10} \right)^2}{11} + \frac{\left( \frac{1.491}{5} \right)^2}{6} \right)} - 2 = \frac{(0.315)^2}{0.0148} - 2 = 4.7$$

From **Table 2**,  
for  $\alpha = 1\%$  and degrees of freedom = 4 (rounded down to the nearest whole number)

$$t_{\text{crit}} = 4.60$$

**Conclusion:** Since  $t < t_{\text{crit}}$ , (i.e.,  $1.32 < 4.60$ ), there is no reason to assume that the sample means are not equal. It is, therefore, reasonable to assume that the sets of test results came from populations that had the same mean.

### Asphalt Paving Excel Spreadsheet

The Air Voids F & t portion of the EXCEL spreadsheet compares the Contractor's Quality Control (QC) results and KDOT's verification results using the following process:

In lots 1 and 2, the mean and standard deviation of the QC results are calculated and compared to the mean of the verification results. The comparison is considered to be satisfactory (Pass) if the mean of the verification results for that lot is within the greater of:

1. the mean of the QC results  $\pm$  three standard deviations of the QC results for that lot
2. one percent of the mean of the QC results for that lot

Starting with lot 3, the F & t tests are used to compare the QC results and verification results. All of the QC results and verification results are used in the comparison for lots 3, 4 and 5. Starting with lot 6, all of the QC results and verification results for the last five lots are used in the comparison. For example, the test results from lots 2-6 are used in the comparison for lot 6.

The maximum specific gravity ( $G_{\text{mm}}$ ) F & t portion of the EXCEL spreadsheet compares the QC results and verification results using the follow process:

In lots 1 and 2, the mean and standard deviation of the QC results are calculated and compared to the mean of the verification results. The comparison is considered to be satisfactory (Pass) if the mean of the verification results for that lot is within the greater of :

1. the mean of the QC results  $\pm$  three standard deviations of the QC results for that lot
2. 0.02 of the mean of the QC results for that lot

Starting with lot 3, the F & t tests are used to compare the QC results and verification results. All of the QC results and verification results are used in the comparison for lots 3, 4 and 5. Starting with lot 6, all of the QC results and verification results for the last five lots are used in the comparison. For example, the test results from lots 2-6 are using in the comparison for lot 6.

If the results of comparison of the  $G_{mm}$  QC and verification results for a lot are satisfactory (Pass), the QC  $G_{mm}$  results should be used in the calculation of % $G_{mm}$  for both the QC and verification Density results. If the results of the comparison of the  $G_{mm}$  QC and verification results for a lot are not satisfactory (Fail), the verification  $G_{mm}$  results should be used in the calculation of % $G_{mm}$  for both the QC and verification Density results.

The Density F & t portion of the EXCEL spreadsheet compares the QC results and verification results using the follow process:

All of a lot's QC results and verification results are used in the comparison for that lot. Each lot stands on its own for the Density F & t comparison.

For the Air Voids,  $G_{mm}$  and Density F & t comparisons, the results are considered satisfactory (Pass) if the t-test shows that the Contractor's QC results and KDOT's QA results are from the same population with a  $\alpha$  of 1%.

### **Concrete Paving Excel Spreadsheet**

The Compressive Strength and Thickness F & t portions of the EXCEL spreadsheet compare the Contractor's Quality Control (QC) results and KDOT's verification results using the following process:

All of a lot's QC results and verification results are used in the comparison for that lot. Each lot stands on its own for the Compressive Strength F & t comparison and the Thickness F & t comparison.

For the Compressive Strength and Thickness F & t comparisons, the results are considered satisfactory (Pass) if the t-test shows that the Contractor's QC results and KDOT's QA results are from the same population with a  $\alpha$  of 1%.

### F&t Air Void Spreadsheet

HMA Overlay 602		15-06007-R01	BTH 07/28/17		updated 1/10/2020					
Lots:	1	6	Project #s	I70-85 KA 5664-01		Name of QC Tester		Junior Samples		
Dates:	8/14/2020	8/26/2020	Contract #s	520056242		Certification # of QC Tester		BR-549		
Mix Type	SR-12.5A		70-28	HMA Overlay	Contract Line #s 6					
Metric/English:	E			Placement	ML					
Target Air Voids	3.00%									
Air Voids										
Lot	Date	Contractor Quality Control Tests (%)	KDOT Verification Test (%)	Number of Contractor Tests	Number of KDOT Tests	t Test	t(crit)	Are Means The Same?	Use Contractor Test Results?	Comments
1A	8/14/2020	3.05	3.49						Yes	
1B	8/14/2020	3.55								
1C	8/15/2020	3.30								
1D	8/15/2020	3.34								
1E										
1F					4	1				
2A	8/17/2020	3.06	2.96						Yes	
2B	8/17/2020	2.80								
2C	8/17/2020	2.47								
2D	8/18/2020	3.67								
2E										
2F					4	1				
3A	8/18/2020	3.26	3.46						Yes	
3B	8/19/2020	3.10								
3C	8/19/2020	3.43								
3D	8/20/2020	3.58								
3E										
3F					12	3	0.39	3.01		
4A	8/20/2020	3.01	4.36						Yes	
4B	8/20/2020	3.87								
4C	8/21/2020	4.53								
4D	8/21/2020	2.77								
4E										
4F					16	4	0.95	2.88		
5A	8/24/2020	3.28	3.13						Yes	
5B	8/24/2020	3.08								
5C	8/24/2020	3.54								
5D	8/25/2020	3.00								
5E										
5F					20	5	0.84	2.81		

## F&t Density Spreadsheet

HMA Overlay 602 15-06007-R01													
Lots:		1	10	Project #		I70-85 KA 5664-01		Name of QC Tester		Junior Samples			
Dates:		8/14/2020	8/26/2020	Contract #		520056242		Certification # of QC Tester		BP-549			
Mix Type		SR-12.5A		HMA Overlay		Contract Line #s		6					
Target Air Voids		3.00%		Increased Density?		No		Select 'Yes' if the target air voids is 3.00% and there are increased density (compact					
Lot	Date	Contractor Test Results (lb/ft <sup>3</sup> )	Gam	Contractor Quality Control Tests (%Gam)	KDOT Test Results (lb/ft <sup>3</sup> )	KDOT Verification Tests (%Gam)	Number of Contractor Tests	Number of KDOT Tests	t Test	t(crit)	Arc Meas The Same?	Use Contractor Test Results?	Comments
1A1	8/14/2020	137.4	2.396	92.13	140.0	93.88	10	5	0.98	3.01	Pass	Yes	
1A2		142.6		95.62		93.88							
1B1		140.3		94.08		91.26							
1B2		138.7		93.00		136.1							
1C1		138.4		92.90		93.34							
1C2		139.8		93.74									
1D1		136.6		91.60		92.40							
1D2		138.7		93.00									
1E1		137.9		92.47		92.47							
1E2		140.7		94.34		137.9							
2A1	8/15/2020	140.1	2.394	94.02	139.8	93.82	10	5	1.04	3.01	Pass	Yes	
2A2		141.6		95.03		93.82							
2B1		139.3		93.48		139.8							
2B2		138.8		93.15		93.15							
2C1		140.7		94.42		93.15							
2C2		138.5		92.95		138.6							
2D1		140.1		94.02		92.81							
2D2		140.8		94.49		138.3							
2E1		139.4		93.55		93.95							
2E2		139.3		93.48		140.0							
3A1	8/17/2020	139.3	2.390	93.64	143.4	96.40	10	5	1.49	3.01	Pass	Yes	
3A2		140.1		94.18		96.40							
3B1		139.7		93.91		95.19							
3B2		141.7		95.25		141.6							
3C1		139.6		93.84		94.31							
3C2		140.4		94.38		140.3							
3D1		140.6		94.51		96.06							
3D2		138.1		92.83		142.9							
3E1		143.2		96.26		93.64							
3E2		140.1		94.18		139.3							
4A1	8/18/2020	137.7	2.394	92.41	137.2	92.07	10	5	3.30	3.01	Fail	No	
4A2		139.8		93.82		92.48							
4B1		140.6		94.36		92.48							
4B2		139.0		93.28		91.74							
4C1		138.6		93.01		136.7							
4C2		139.9		93.89		93.42							
4D1		138.6		93.01		139.2							
4D2		138.4		92.88		93.42							
4E1		140.4		94.22		91.54							
4E2		139.8		93.82		136.4							
5A1	8/19/2020	137.0	2.402	91.63	140.2	93.77	10	5	0.11	3.01	Pass	Yes	
5A2		139.1		93.04		93.51							
5B1		139.6		93.37		139.8							
5B2		139.3		93.17		92.90							
5C1		139.7		93.44		92.90							
5C2		141.4		94.58		138.9							
5D1		142.1		95.05		94.11							
5D2		138.5		92.64		140.7							
5E1		139.4		93.24		92.57							
5E2		139.1		93.04		138.4							

### F&t Gmm Spreadsheet

HMA Overlay 602 15-06007-R01										
Lots:		1	6	Project #s		170-85 KA 5664-01	Name of QC Tester		Junior Samples	
Dates:		8/14/2020	8/26/2020	Contract #s		520056242	Certification # of QC Tester		BR-549	
Mix Type:		SR-12.5A	70-28	HMA Overlay						
Gmm										
Lot	Date	Contractor Quality Control Tests (Gmm)	KDOT Verification Test (Gmm)	Number of Contractor Tests	Number of KDOT Tests	t Test	t(crit)	Are Means The Same?	Use Contractor Test Results?	Comments
1A	8/14/2020	2.398	2.406	1	0				Yes	
1B	8/14/2020	2.393		2	1			Pass		
1C	8/15/2020	2.392		3	1					
1D	8/15/2020	2.393		4	1			Pass		
1E										
1F										
2A	8/17/2020	2.387	2.402	5	1				Yes	
2B	8/17/2020	2.397		6	1					
2C	8/17/2020	2.386		7	2			Pass		
2D	8/18/2020	2.398		8	2					
2E										
2F										
3A	8/18/2020	2.396	2.397	9	2			Pass	Yes	
3B	8/19/2020	2.389		10	2					
3C	8/19/2020	2.391		11	3	3.20	3.05	Fail		
3D	8/20/2020	2.404		12	3	2.43	3.01			
3E										
3F										
4A	8/20/2020	2.391	2.410	13	3	2.58	2.98		Yes	
4B	8/20/2020	2.404		14	3	2.15	2.95	Pass		
4C	8/21/2020	2.407		15	4	2.49	2.90			
4D	8/21/2020	2.382		16	4	2.53	2.88	Pass		
4E										
4F										
5A	8/24/2020	2.405	2.397	17	4	2.29	2.86		Yes	
5B	8/24/2020	2.399		18	4	2.28	2.85			
5C	8/24/2020	2.400		19	5	2.08	2.82	Pass		
5D	8/25/2020	2.400		20	5	2.05	2.81			
5E										
5F										



### F&t Compressive Strength Spreadsheet

SS2015 Section 501 (RAB 07/20/15)										
Lots:		1	50	Project #	KA-1234-56		Name of QC Tester		Junior Samples	
Dates:		5/4/2015	1/18/2015	Contract #	123456798		Certification # of QC Test		BR-549	
Compressive Strength Comparison										
Lot	Date	Corrected Contractor Compressive Strength (psi)	Corrected KDOT Compressive Strength (psi)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?	Use Contractor Test Results?	Comments
1A1	5/4/2015	3711								
1A2	5/4/2015	3994	4468							
1B1	5/4/2015	4296								
1B2	5/4/2015	4695	4810							
1C1	5/4/2015	4593								
1C2	5/4/2015	4639	4381							
1D1	5/4/2015	4557								
1D2	5/4/2015	4023	4675							
1E1	5/4/2015	3858								
1E2	5/4/2015	4621	4700	10	5	1.74	3.01	Pass	Yes	
2A1	5/5/2015	4266								
2A2	5/5/2015	4208	2913							
2B1	5/5/2015	3887								
2B2	5/5/2015	3746	4358							
2C1	5/5/2015	3765								
2C2	5/5/2015	4451	3914							
2D1	5/5/2015	4659								
2D2	5/5/2015	4695	4557							
2E1	5/5/2015	4372								
2E2	5/5/2015	4719	5239	10	5	0.26	3.01	Pass	Yes	
3A1	5/6/2015	4328								
3A2	5/6/2015	3914	5750							
3B1	5/6/2015	3881								
3B2	5/6/2015	4034	3911							
3C1	5/6/2015	4627								
3C2	5/6/2015	3989	5377							
3D1	5/6/2015	4181								
3D2	5/6/2015	4084	3062							
3E1	5/6/2015	4191								
3E2	5/6/2015	3852	2828	10	5	0.19	3.01	Pass	Yes	
4A1	5/7/2015	4463								
4A2	5/7/2015	3677	4006							
4B1	5/7/2015	3926								
4B2	5/7/2015	4332	4802							
4C1	5/7/2015	3692								
4C2	5/7/2015	4124	4709							
4D1	5/7/2015	4560								
4D2	5/7/2015	4225	5459							
4E1	5/7/2015	3714								
4E2	5/7/2015	4590	5135	10	5	2.97	3.01	Pass	Yes	
5A1	5/8/2015	4284								
5A2	5/8/2015	4507	5340							
5B1	5/8/2015	3821								
5B2	5/8/2015	4029	5281							
5C1	5/8/2015	4486								
5C2	5/8/2015	4682	4724							
5D1	5/8/2015	4205								
5D2	5/8/2015	4230	3280							
5E1										
5E2				8	4	1.07	3.17	Pass	Yes	

### F&t Thickness Spreadsheet

SS2015 Section 501 (RAB 07/20/15)										
Lots:		1	50	Project #	KA-1234-56	Name of QC Tester		Junior Samples		
Dates:		5/4/2015	1/18/2015	Contract #	123456798	Certification # of QC Tes		BR-549		
Concrete Thickness Comparison										
Lot	Date	Contractor Core Length (in)	KDOT Core Length (in)	Number of Contractor Tests	Number of KDOT Tests	T Test	T(crit)	Are Means The Same?	Use Contractor Test Results?	Comments
1A1	5/4/2015	12.66								
1A2	5/4/2015	11.89	11.50							
1B1	5/4/2015	11.29								
1B2	5/4/2015	12.42	12.00							
1C1	5/4/2015	13.01								
1C2	5/4/2015	11.48	11.80							
1D1	5/4/2015	11.26								
1D2	5/4/2015	12.87	11.50							
1E1	5/4/2015	11.52								
1E2	5/4/2015	12.26	11.90	10	5			Pass	Yes	
2A1	5/5/2015	12.11								
2A2	5/5/2015	11.59	12.91							
2B1	5/5/2015	12.83								
2B2	5/5/2015	12.56	11.49							
2C1	5/5/2015	12.26								
2C2	5/5/2015	11.70	12.81							
2D1	5/5/2015	12.76								
2D2	5/5/2015	11.14	12.39							
2E1	5/5/2015	12.06								
2E2	5/5/2015	11.25	12.84	10	5			Pass	Yes	
3A1	5/6/2015	11.30								
3A2	5/6/2015	12.95	12.04							
3B1	5/6/2015	12.37								
3B2	5/6/2015	12.62	11.77							
3C1	5/6/2015	13.03								
3C2	5/6/2015	11.35	12.98							
3D1	5/6/2015	11.39								
3D2	5/6/2015	11.53	12.05							
3E1	5/6/2015	11.09								
3E2	5/6/2015	12.08	12.38	30	15	0.71	2.70	Pass	Yes	
4A1	5/7/2015	11.90								
4A2	5/7/2015	11.43	12.24							
4B1	5/7/2015	12.78								
4B2	5/7/2015	11.79	11.99							
4C1	5/7/2015	12.09								
4C2	5/7/2015	11.16	12.52							
4D1	5/7/2015	12.19								
4D2	5/7/2015	11.84	11.20							
4E1	5/7/2015	12.56								
4E2	5/7/2015	13.02	11.25	40	20	0.26	2.66	Pass	Yes	
5A1	5/8/2015	12.45								
5A2	5/8/2015	11.12	11.88							
5B1	5/8/2015	11.93								
5B2	5/8/2015	12.12	13.01							
5C1	5/8/2015	12.50								
5C2	5/8/2015	12.60	11.33							
5D1	5/8/2015	12.69								
5D2	5/8/2015	11.19	11.37							
5E1										
5E2				48	24	0.04	2.65	Pass	Yes	

## 5.2.7 CONTRACTOR'S QUALITY CONTROL PLAN

### 1. SCOPE

The following subsections provide guidance for contractors to maintain quality control laboratories and personnel for QC/QA designated projects.

- 5.2.7.1. **HMA:** Contractor's Quality Control plan
- 5.2.7.2. Guide for Quality Control and Acceptance Requirements for HMA
- 5.2.7.3. Example of a Laboratory Quality Manual for HMA
- 5.2.7.4. **Concrete:** Contractor's Quality Control Plan
- 5.2.7.5. Example of a Laboratory Quality Manual for Concrete
- 5.2.7.6. **Concrete Structures:** Contractor's Quality Control Plan
- 5.2.7.7. Example of Contractor's Concrete Structures Quality Plan for Controlling Evaporation
- 5.2.7.8 **Cement Treated Base:** Contractor's Quality Control Plan (CTB)



## 5.2.7.1. HMA: CONTRACTOR'S QUALITY CONTROL PLAN

### 1. QUALITY CONTROL

The Contractor shall provide and maintain a Quality Control (QC) Plan that will assure all materials and products submitted to KDOT for acceptance will conform to the contract requirements whether manufactured or processed by the contractor, or procured from suppliers, subcontractors, or vendors. The contractor shall perform or have performed the inspections and tests required to substantiate product conformance to contract document requirements. The contractor shall also perform or have performed all inspections and tests otherwise required by the contract. The contractor's quality control inspections and tests shall be documented and provided to KDOT. The contractor shall maintain adequate records of all inspections and tests. The records shall include the nature, number, and type of deficiencies found; the quantities rejected by the contractor; and the nature of corrective action taken, as appropriate. The contractor shall maintain standard equipment and qualified personnel as required by the Specifications to assure conformance to contract requirements. Procedures will be subject to approval by KDOT before work is started.

The contractor shall prepare a QC Plan detailing the type and frequency of inspection, sampling, and testing deemed necessary to measure and control the various properties of materials and construction governed by the Specifications. The QC Plan shall be submitted in writing to KDOT at the preconstruction conference. This plan shall include the following:

- Construction items covered by the plan
- Tests and Test Frequency to be performed
  - \* Part V; Appendix B
- Sampling locations and techniques
- Documentation procedures, including:
  - \*Identify the QC laboratory to be used and its credentials
  - \*Identify the QC personnel and their qualifications
  - \*Inspection and test records
  - \*Temperature measurements
  - \*Accuracy and readability, calibration, or re-calibration checks performed on production or testing equipment.
  - \*Control charts

The Plan shall identify the personnel responsible for the contractor's quality control. This shall include the name of the company official who will act as liaison with KDOT personnel and the names of the Certified Technicians who will direct and conduct the inspection program. The contractor shall provide a testing facility or laboratory.

**NOTE:** Guide for Quality Control and Acceptance Requirements for HMA, will help define the minimum contents necessary for an acceptable Quality Control Plan.

### 2. SAMPLES, TESTS AND REFERENCED CITED SPECIFICATIONS

The contractor shall be responsible for the quality of construction and materials incorporated into the contract. The contractor shall perform all necessary quality control inspection, sampling and testing. All materials will be approved for acceptance through KDOT's acceptance procedures. KDOT has the responsibility for determining the acceptability of the construction and materials incorporated therein. KDOT may use the results of the contractor's inspection, approved quality control program. To eliminate confusion when transferring information, provide all critical information as outlined in **Table 1**.

**Table 1  
Request Report Requirements**

a. Name and address of the testing laboratory
b. Identification of the report and the date issued
c. Project number and contract number
d. Description and identification of the test sample (including subplot numbers)
e. Date(s) of receipt of the test
f. Date(s) of test performance
g. Identification of the standard test method used and a notation of all known deviations from the test method
h. Test results and other pertinent data required by the standard test method
i. Identification of any test results obtained from test performed by a subcontractor
j. Name and certification number of the person (s) technically responsible for the test report

### **3. QUALIFIED TESTING LABORATORY**

The Materials and Research Center is accredited through the **AASHTO Accreditation Program (AAP)**. If the contractor’s QC laboratory is not participating in the AAP, then the contractor shall have an AAP approved laboratory or a manufacturer certified technician inspect the QC laboratory’s equipment and perform calibrations and verifications annually. The contractor may perform the inspection, calibrations and verifications annually if the QC laboratory is participating in the AAP. The inspection, calibrations and verifications shall include all equipment necessary to perform testing on specified types of material related to the contract; base and grading, aggregate, HMA and concrete.

The contractor’s QC laboratory shall be furnished and maintained with adequate ventilation, heat, light, water, sink and drainage, electrical or gas outlets or both, work tables, shelves, and supply cabinets. The laboratory shall be supplied with equipment and materials necessary to perform all tests required by the specifications and shall be maintained in such condition that the equipment will meet the applicable requirements of KDOT.

KDOT will annually inspect and document the acceptability of the sampling and testing equipment. This includes sampling and testing equipment owned by contractors, consultants or vendors. Checks on equipment during the life of a project should be accomplished by project sampling and testing personnel as well as KDOT personnel.

#### 4. EQUIPMENT CALIBRATION AND VERIFICATION

The QC laboratory shall have all significant testing equipment calibrated or verified that is associated with tests covered by the scope of this standard which the QC laboratory performs. Copies of all current equipment calibration records shall be maintained in a Quality Manual and stored in the laboratory. As a minimum, the equipment listed in **Table 2** shall be included if it is associated with tests performed by the QC laboratory. Applicable equipment shall be calibrated or verified at the intervals specified in the QC Laboratory's Quality Manual. The intervals specified in the Quality Manual shall be no greater than those indicated in **Table 2**. Newly acquired equipment without manufacturer's certification and equipment that has not been calibrated or verified because it has been removed from service shall be calibrated or verified before being placed in service. The QC laboratory shall have detailed written procedures for all in-house calibration and verification activities not addressed in standards. These procedures shall indicate the equipment required to perform the calibration or verification.

Certain items in **Table 2** can be verified by the contractor's QC certified technician. These items are; mechanical shakers, ovens, sieves and weighted foot.

**NOTE:** Example of a Laboratories Quality Manual will provide examples of equipment procedures to verify that equipment is in proper condition. Also, examples of records for calibrating/verifying equipment are presented.

#### 5. TECHNICIAN CERTIFICATION

KDOT requires that all individuals be certified who perform one or more of the actual sampling testing and inspection functions for KDOT, Contractor or private laboratories. A certification program helps to assure the qualifications of sampling and testing personnel and increases pride in the work performed.

Certified sampling and testing personnel provide added assurances that the sampling and testing will be performed correctly and that the results will be valid.

The individuals performing any sampling and testing of materials must be knowledgeable in the sampling and testing procedures that have been specified by KDOT.

Certification programs recognized by KDOT should be one or more of the following:

Certified Inspector Training Program

For additional information concerning an acceptable certification program, contact the Bureau of Construction and Materials, CIT Program Administrator.

Sampling may be performed by an uncertified individual if the person demonstrates proficiency in the procedure in **KT-25** and has been witnessed by District Materials personnel during the same calendar year.

**Table 2**  
**HMA Materials Test Equipment**

Equipment –Test Method	Requirements	Interval (months)
Mechanical Shakers	Check Sieving Thoroughness	12
General Purpose Balances, Scales and Masses – <b>AASHTO M 231</b>	Calibrate	12
Test Thermometers –KT-15, KT-39, KT-56, KT-58	Standardize	12
Compression Testing Machine	Verify Load and Calibrate	12
Ovens	Standardize Thermostat	12
Vacuum System KT-39	Standardize	12
Coarse Sieves (openings $\geq$ No. 4 [4.75 mm])	Check Physical Condition and Dimensions of Openings	12
Fine Sieves (openings $<$ No. 4 [4.75 mm])	Check Physical Condition	12
Nuclear Density Gauge KT-32	Calibration	12
Weighted Foot Assembly KT-55	Check Mass of Assembly	12
Gyratory Compactor KT-58	Verify and/or Calibrate Ram Pressure, Angle of Gyration, Frequency of Gyration, Height	12
Gyratory Compactor Mold KT-58	Check Critical Dimensions	12

**NOTE: Section 5.2.7.2** of this manual, Guide for Quality Control and Acceptance Requirements for HMA, will help to define the minimum contents necessary for an acceptable Quality Control Plan.

**Section 5.2.7.3** of this manual, Example of a Laboratories Quality Manual, will provide examples of equipment procedures to verify that equipment is in proper condition. Also, examples of records for calibrating/verifying equipment are presented



## GUIDE FOR QUALITY CONTROL AND ACCEPTANCE REQUIREMENTS FOR HMA

### 1. Purpose

The purpose of this guide is to establish minimum requirements for the Contractor's quality control system for use in QC/QA Projects. It is intended that these requirements be used as a procedural guide in detailing the inspection, sampling and testing deemed necessary to maintain compliance with the specification requirements.

### 2. Scope

This procedure is applicable to the production and construction of HMA.

### 3. Requirements

#### 3.1. General

As stated in the specifications, a Quality Control Plan must be developed by the producer and submitted in writing to the Engineer at the pre-construction conference. Acceptance of the Quality Control Plan by the Engineer will be contingent upon its conformance with these guidelines. For this reason, the plan shall clearly describe the methods by which the quality control program will be conducted. For example, the items to be controlled, tests to be performed, testing frequencies, sampling locations and techniques all shall be included and each item shall be listed separately. Also include a table stating what actions will occur when test results indicate specification limits are approached or exceeded. See **Table 1** at end of this guide for an example. Also, a detailed plan of action regarding disposition of non-specification material shall be included. Such a plan shall provide for immediate notification of all parties involved in the event nonconforming situations are detected. **Example 1. HMA Quality Control Plan** may be used as an example for a Quality Control Plan.

Inspection and testing records shall be maintained, kept current, and made available for review by KDOT personnel throughout the life of the Contract. All other documentation, such as date of inspections, tests performed, temperature measurements, and accuracy, calibration or re-calibration checks performed on production of testing equipment shall be recorded.

The Contractor shall maintain standard equipment and qualified personnel in accordance with Contract and specification requirements for the item(s) being produced.

#### 3.2. Quality Control Plan

Operation Quality Control Plans shall be submitted for each Project to the District Engineer where the Project is located. Distribution of the approved Quality Control Plans will be made by the Engineer.

#### **4. Acceptance Sampling and Testing**

KDOT is responsible for sampling, testing, and determining the acceptability of the material produced, except for furnishing of necessary materials for testing. Acceptance of the material is based on the inspection of the construction, monitoring of the Contractor's quality control program, verification test results, and the comparison of the verification test results to the quality control test results. The Engineer may use the results of the Quality Control Plan as part of the acceptance procedures, providing:

- 1) The Engineer's inspection and monitoring activities indicate that the Contractor is following the approved Quality Control Plan; and
- 2) The results from the Contractor's quality control sampling and testing compare with the verification tests.

KDOT's test results will be used on a comparative basis as part of its overall verification program with testing done at the frequency listed in the Sampling and Testing Frequency Chart. Some of the verification sampling and testing will be conducted independently from the Contractor's activities, including test equipment.

Unless split samples are used, results from verification tests will be evaluated in accordance with KDOT specifications. If a dissimilarity is detected, an investigation shall be immediately initiated to determine the cause of the dissimilarity.

**EXAMPLE**

**HMA Quality Control Plan**

To: (DISTRICT ENGINEER)

From: (CONTRACTOR(S) NAME)

Subject: HMA Quality Control Plan.

1. We are submitting our HMA Quality Control Plan, developed in accordance with the Contractor's Quality Control Plan for:

Project(s):  
Contract(s):

2. Plant Information:

2.1. General Information:

KDOT ID #:  
Make:  
Type: \_\_\_\_\_  
Location of Plant: \_\_\_\_\_

2.2. Current calibration and verification status of plant and history of plant inspection program attached.

- 2.3. RAP: Describe how the feed is controlled
- 2.4. RAS: Describe how the feed is controlled
- 2.5. Anti-strip: Describe how the dosage is controlled
- 2.6. Mud Balls, Clumping of RAS, RAP, and Virgin Aggregates: Action to take when these are present in the asphalt mixture.
- 2.7. Asphalt Binder: Describe the method for heating and circulating.
- 2.8. Asphalt Release Agent: Name of Product on PQL 27.
- 2.9. Scale Checks: Describe the method and frequency.
- 2.10. In-Place Density: Method(s) to control.

3. Lab Personnel:

3.1. The quality control program is under the direction of (NAME OF PERSON) who can be contacted at (ADDRESS AND TELEPHONE).

3.2. Sampling and testing will be the responsibility of (NAME OF PERSON(S)), HMA technician number (CERTIFICATE NUMBER(S)).

3.3. Mix Designs will be the responsibility of (NAME OF PERSON(s)), HMA design technician number (CERTIFICATE NUMBER(s)).

4. Field Personnel:

4.1. The field operation is under the direction of (NAME) who can be contacted at (ADDRESS AND TELEPHONE).

4.2. (NAMES) will be responsible for ensuring that all items of work will comply with KDOT Specifications and is responsible to halt production when work does not meet KDOT specifications.

4.3. (NAME) is the designated Compaction Foreman.

4.4. During the placement operations of the HMA pavement we will perform at a minimum quality control tests per Part V of the Construction Manual or attached schedule. Sampling and testing will be the responsibility of (NAME(s)), certification number (CERTIFICATE NUMBER(s)).

5. The HMA design(s) to be used are:  
(MIX DESIGN DESIGNATION)

6. Prior to production, (NAME),(CERTIFICATE NUMBER), will submit our HMA Design for each type of mix in accordance with specifications by (DATE). Only approved materials will be incorporated in the mix.

7. During the production operations of the HMA (NAMES) will perform, at a minimum, quality control tests in accordance with Part V of the Construction Manual or the attached schedule. Also attached are the proposed methods to select random locations for sampling.

8. All testing and evaluation will be completed by (NAME) within (HOURS) hours of sampling and all documentation will be completed and submitted to the Engineer on approved processing forms within (HOURS) hours according to specifications or production will be halted until these items are current. Example forms are attached.

9. Equipment - As a minimum provide the Manufacturer, Model, and Capacity/Weight for the following:

- 9.1 Paver
- 9.2 Distributor
- 9.3 Material Transfer Device

10. Any material found to be noncomplying shall be addressed by (NAME) who will notify the Engineer immediately. (STATE THE PROCESS FOR DISPOSITION OF NONCONFORMING MATERIAL)

11. (NAME) will notify all appropriate KDOT personnel at least 24 hours before the scheduled work is to begin.

12. (NAME) will sign the end of day quantities document and provide it to the Engineer.

**Table 1: Example of QC Actions to Implement When Approaching or Exceeding Specification Limits**

Test Description	Test Method	Specification		Situation		Action
		Single Test	4-Point Moving Avg. or Daily Avg.	Single Test	4-Point Moving Avg. or Daily Avg.	
Binder Content	KT-57	+/-0.6	+/-0.3	Approaching limit	Approaching Limit	Discuss with hot mix plant, operator, and may suspend construction process
Aggregate Gradation	KT-02	NA	>=min. <=max.	4 point on +#4 2 points on -#4	Approaching Limit	Increase frequency of tests and prepare for process modification
Air Voids @ N <sub>des</sub>	KT-58	+/-2%	NA	2 tests over +/-1%	NA	Initiate JMF Modifications
VMA	5.10.04	<=1% min.	>=min.	3 tests over +/-1%	>=min. <=max.	Discuss with the Engineer & Process Modification
VFA	5.10.04	NA	>=min. <=max.	Over Limit once	Approaching Limit	Notify the Engineer, modify JMF
Density @ N <sub>ini</sub> and N <sub>max</sub>	KT-58	NA	>=min.	Approaching Limit Over once	Approaching Limit	Notify the Engineer, modify process
Coarse Aggregate Angularity	KT-31	>=min.	NA	Approaching limit	NA	Modify JMF or Redesign
Fine Aggregate Angularity	KT-50	>=min.	NA	Approaching limit	NA	Notify the Engineer, modify JMF
Sand Equivalent	KT-55	>=min.	NA	Approaching limit	NA	Notify the Engineer, modify JMF
TSR	KT-56	>=min.	NA	Approaching limit	NA	Discuss with the Engineer & initiate investigation, modification, or redesign
Dust to Binder Ratio		NA	>=min. <=max.	Approaching limit	Approaching Limit	Modify JMF
Flat & Elongated	KT-59	>=min.	NA	Approaching limit	NA	Modify JMF or Redesign
Roadway Density	KT-32	NA	>=min.	Approaching <91%	<= 100% Pay	Notify the Engineer & Construction Manager

NOTE: Whenever two consecutive test results fail or if any of the four-point moving average values fail, production will be suspended and the situation discussed with the Engineer and Construction Manager. The process will be corrected before production resumes.



### 5.2.7.3 EXAMPLE OF A LABORATORY QUALITY MANUAL FOR HMA

This example is designed to provide the contractor with general guidelines in creating and maintaining a contractor's Quality Manual. The QC process requires records for equipment calibrations/verifications. Maintaining records in an orderly manner will assist the District Materials Engineer in quickly determining if the laboratory meets QC/QA requirements. Having the field laboratory fully prepared and the Quality Manual properly maintained represent two items that can keep the start of a project on schedule. It also aids in demonstrating the contractor's commitment to the QC process.

The following records are presented to illustrate what is required in the Quality Manual. Records need not be exactly as illustrated but should supply all necessary information concerning the equipment calibration/verification.

**NOTE:** After calibrating any force-load testing equipment (stability machine, gyratory, etc.) a copy of the certification for the calibration device (proving ring, load cell, etc.) shall be attached to the calibration record.

**NOTE:** All equipment shall be verified immediately after repairs (this may include new or replacement parts, or mechanical or electrical adjustments) that may in any way affect the ability of the equipment to provide accurate readings as established during the calibration/verification process.

**DISCLAIMER:** It is not the intent of these guidelines to endorse manufacturers, suppliers, calibrating services, etc. The examples are used to provide guidance in establishing a thoroughly developed Quality Manual.



**LABORATORY QUALITY MANUAL**  
**TABLE OF CALIBRATION/VERIFICATION DATES**  
**Revision Date 04/01/14**

<b>ITEM</b>	<b>CAL/VER INTERVAL (MONTHS)</b>	<b>NEXT CAL/VER</b>
SIEVES	_____	_____
MECH. SIEVE SHAKER	_____	_____
THERMOMETER	_____	_____
OVENS	_____	_____
VACUUM SYS.	_____	_____
M/D GAUGE	_____	_____
STABILITY MACHINE	_____	_____
BALANCES	_____	_____
WEIGHTED FOOT	_____	_____
GYRATORY	_____	_____

June 15, 2022

**VERIFICATION PROCEDURE FOR SIEVES**  
**(Page 1/2)**

**Purpose:**

This method provides instructions for checking the physical condition of laboratory tests sieves ranging in size 3 in. (75 mm) to #200 (0.075 mm).

**Inspection Equipment Required:**

1. A caliper readable to 0.01 mm (use for #4 or coarser).

**Tolerances:**

Sieves shall meet physical requirements specified in ASTM E11.

**Procedure:**

(Steps 1 & 2 apply to sieves having openings greater than 4.75 mm)

1. Select an adequate number of individual sieve openings (3 or 4) along a 45° line. Measure and record the sieve openings to verify that the size opening indicated on the label is correct.
2. Repeat step 1, rotating the sieve 90°.
3. Inspect the general condition of the sieve. Check the frame and solder joints for cracks or holes (check for pin holes in the finer sieves).
4. Make sure the sieves have an appropriate label.
5. Check for tightness of the wires on each individual sieve.

June 15, 2022

**VERIFICATION RECORD FOR SIEVES  
(Page 2/2)**

Inspected by: \_\_\_\_\_ Date: \_\_\_\_/\_\_\_\_/\_\_\_\_

Identification No. \_\_\_\_\_ Verification Frequency:

Previous Verification Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment Used: See verification procedure for sieves

Verification Procedure Used: See verification procedure for sieves

Opening Size: Step 1

1. \_\_\_\_\_ mm

2. \_\_\_\_\_ mm

3. \_\_\_\_\_ mm

4. \_\_\_\_\_ mm

Opening Size: Step 2

1. \_\_\_\_\_ mm

2. \_\_\_\_\_ mm

3. \_\_\_\_\_ mm

4. \_\_\_\_\_ mm

General Condition of Sieve:

Label Correct:\_\_\_\_ Wires Tight:

Action Recommended: Replace \_\_\_\_ None

Comments:

June 15, 2022

**VERIFICATION PROCEDURE FOR MECHANICAL SIEVE SHAKER  
(Page 1/2)**

**Purpose:** This method provides instructions for checking the length of time the mechanical sieving device must run. This reflects the procedure in **KT-02 9**.

**Inspection Equipment Required:**

1. Set of 8" dia. sieves (4, 8, 16, 30, 50, 100, 200)
2. Timer
3. Balance, readable to 0.1 g.
4. Sample of fine aggregate.

**Efficiency:**

The difference between two percent retained values on any sieve shall not exceed 0.5 percent by mass.

**Procedure (See KT-02 Section 9.):**

1. Determine the initial mass of the sample.
2. Place sample of aggregate in nested sieves. Fit the sieve nest with a lid and a pan.
3. Place sieves in shaker & set timer for 6 minutes.
4. Determine and record the percent retained of each sieve size.
5. Collect and recombine all of the material.
6. Place sieves in shaker & set timer for 7 minutes.
7. Determine and record the percent retained of each sieve size.
8. If the difference between two percent retained values on any sieve does not exceed 0.5 percent by mass, then the mechanical sieve shake is verified. If not, repeat the procedure for 2 longer time periods or repair/replace the mechanical sieve shaker.

June 15, 2022

**VERIFICATION RECORD FOR MECHANICAL SHAKER  
(Page 2/2)**

Inspected by: \_\_\_\_\_ Date:

Identification Number: \_\_\_\_\_ Verification Frequency:\_\_\_\_\_.

Previous Verification Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment Used: See Verification Procedure For Mechanical Shaker.

Verification Procedure: See Verification Procedure For Mechanical Shaker.

Original Dry Mass (ODM) \_\_\_\_\_

Mass Retained on Each Sieve

	#4	#8	#16	#30	#50	#100	#200
1st Run							
2nd Run							
Difference							
% of ODM							

**VERIFICATION PROCEDURE FOR THERMOMETERS**  
**(Page 1/2)**

**FORM DATE:** \_\_\_\_\_

**Purpose:**

This method provides instructions for verifying the settings on general-purpose thermometers.

**Inspection Equipment Required:**

1. A calibrated thermometer graduated in 2.0°F (1.0°C) increments having a range which includes the temperature range to be checked.
2. A clothes pin to hold the thermometer in such a manner as to enable the operator to read the scale easily.
3. A container well to retain heat for constant temperature readings.
4. A hot plate to heat the liquid (oil) in the container well.

**Procedure:**

1. Place the thermometer inside the container well with the clothes pin attached to the thermometer.
2. Take the first reading when the temperature has stabilized.
3. Take as many readings as necessary to determine the "laboratory thermometer setting" vs "actual calibrated reading."

**VERIFICATION RECORD FOR THERMOMETERS**  
**(Page 2/2)**

**Specification Interval:** \_\_\_\_\_

**Model No.** \_\_\_\_\_ see below \_\_\_\_\_

**Serial No .** \_\_\_\_\_ see below \_\_\_\_\_

**Date :** \_\_\_\_\_

**Calibration/Verification Performed by :** \_\_\_\_\_

**Cal./Ver. Procedure Reference:** See Verification Procedure for Thermometers

**Previous Calibration/Verification Date :** \_\_\_\_\_

**Next Calibration/Verification Due Date :** \_\_\_\_\_

**Calibration/Verification Equipment Used :** \_\_\_\_\_

**Model/Serial No. of C/V Equipment Used :** \_\_\_\_\_ see below \_\_\_\_\_

1. Equipment thermometer reading \_\_\_\_\_ see below \_\_\_\_\_

2. Calibrated thermometer reading \_\_\_\_\_ see below \_\_\_\_\_

<u>Equipment Thermometer Designation</u>	<u>Equipment Thermometer Reading</u>	<u>Calibrated Thermometer Designation</u>	<u>Calibrated Thermometer Reading</u>
--	--	---	---

# VERIFICATION PROCEDURE FOR OVENS (Page 1/2)

Form Date: \_\_\_\_\_

## **Purpose:**

This method provides instructions for verifying the accuracy of the temperature settings and the tolerance on ovens.

## **Inspection Equipment Required:**

1. A calibrated thermometer graduated in 2.0°F (1.0°C) increments having a range that includes the temperature range to be checked.
2. A brass thermometer well to retain heat while the oven door is open. This is essential for a constant temperature reading.
3. A clothes pin to hold the thermometer in such a manner as to enable the operator to read the scale easily from outside or inside the oven.

## **Tolerance:**

Drying ovens shall be capable of maintaining a constant temperature range listed in the appropriate test methods.

## **Procedure:**

1. Place the thermometer inside the brass well with the clothes pin attached to the thermometer. Position the thermometer on the shelf where the samples are normally dried.
2. Take the first reading at least 1 hour after closing the oven (oven should remain undisturbed).
3. Take as many readings as necessary to determine if the temperature range is within the specified tolerance (three consecutive readings, taken no less than 1/2 hr apart, within tolerance allowed are adequate).
4. Adjust the temperature of the oven if an observed temperature reading is outside the tolerance specified (allow at least 1/2 hr for the temperature to stabilize between each adjustment). Return to step 3.



Form Date \_\_\_\_\_

**VERIFICATION RECORD FOR OVENS**  
**(Page 2/2)**

Verified by \_\_\_\_\_ Date \_\_\_\_\_

Verif. Frequency \_\_\_\_\_

Identification No.: \_\_\_\_\_

Prev. Verif. Date: \_\_\_\_\_ Next Due Date : \_\_\_\_\_

Verif. Equip. Used Cal. Therm. Verif. Procedure Verification Procedure for Ovens

Temperature Range

Temperature*	Oven Dial Reading	Correction Factor
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Action Recommended: Repair \_\_\_\_ Replace \_\_\_\_ None X

\*This thermometer has been tested by comparison with standards certified by NIST. If the correction is “+” the true temperature is higher than the thermometer reading. If the correction is “-” the true temperature is lower than the thermometer reading

## VERIFICATION PROCEDURE FOR VACUUM SYSTEM (Page 1/2)

**Form Date:** \_\_\_\_\_

**Purpose:**

This method provides instructions for checking the vacuum pressure.

**Inspection Equipment Required:**

1. Absolute pressure gauge or manometer.
2. Water vapor trap.
3. Hoses, connectors, tools, misc.

**Tolerance:**

Equipment shall be capable of applying the vacuum specified in the applicable test method (usually 30 mm Absolute Vacuum)

**Procedure:**

1. Connect the gauge to the system with the trap in-line between the system and the gauge.
2. Make sure all connections are air-tight.
3. Open the number of lines normally used in testing, then read and record the pressure indicated on the gauge.

**VERIFICATION RECORD FOR VACUUM SYSTEM**  
**(Page 2/2)**

Verified By \_\_\_\_\_ Date \_\_\_\_\_

Verif. Frequency \_\_\_\_\_

Identification No. \_\_\_\_\_

Previous Verif. Date \_\_\_\_\_ Next Due Date \_\_\_\_\_

Verif. Equip. Used ABSOLUTE GAUGE Verif. Procedure: Verification Procedure for Vac. Sys.

Vacuum 15 mm of Hg vacuum is available at the end of the vacuum line

Action Recommended: Repair \_\_\_\_ Replace \_\_\_\_ None \_\_\_\_\_

Comments:

# MOISTURE/DENSITY GAUGE CALIBRATION

Troxler Electronic Laboratories, Inc.

Page 1/2

Gauge model -3440  
Serial-19627

Ref standard count:density - 2365.525  
moisture- 686. 05

Source type- Cs-137 Am-241/Be  
Serial- 50-09352 47-15173

Calib date: 3-19-2004 Bay-4  
Print date: 3-19-2004

\*\*\* Density calibration count data \*\*\*

Depth	Magnes	Mag/Al	Alumin
	1784.0	2217.0	2715.0
-----	-----	-----	-----
BS	1061	700	482
2	3662	2311	1467
4	3754	2227	1310
6	3020	1665	911
8	2083	1062	533

\*\*\* Density performance parameters \*\*\*

Pos	A	B*1000	C	'Y'	Slope	Prec
---	-----	-----	-----	-----	-----	-----
BS	4.930	1.52416	-0.11248	2217.0	0.8	8.51
2	16.750	1.44684	-0.24045	2217.0	3.2	4.15
4	21.332	1.54070	-0.17553	2217.0	3.6	3.67
6	24.074	1.72200	-0.11952	2217.0	3.1	3.67
8	22.955	1.89212	-0.06308	2217.0	2.3	3.99

\*\*\* Moisture calibration count data \*\*\*

Mag	Mag/poly	S R
0.0	553.0	
---	-----	---
20	406	398

Moisture performance parameters \*\*\*

E	F*1000	Rat	Prec	S R	Exerr
-----	-----	----	----	---	----
0.02915	1.01743	3.21	5.00	-11.5	12.6

Density Standard Decay Sheet

Gauge model -3440  
Serial-19627

Calib date: 3-19-2004  
Print date: 3-19-2004

Ref. std. cnt. 2365.525

Range of projected density standard counts at future dates

Date	Lower Limit of Projected density Standard Count	Upper Limit of Projected density Standard Count
04-01-1996	2340	2387
05-01-1996	2336	2383
06-01-1996	2331	2378
07-01-1996	2327	2374
08-01-1996	2322	2369
09-01-1996	2318	2364
10-01-1996	2313	2360
11-01-1996	2309	2355
12-01-1996	2304	2351
01-01-1997	2300	2346
02-01-1997	2295	2342
03-01-1997	2291	2338
04-01-1997	2287	2333

# STABILITY MACHINE

## Proving Ring Calibration Certificate

**SATEC** Materials Testing Equipment

SATEC Systems, Inc.  
900 Liberty Street  
Grove City, PA 16127-9005  
1-800-726-8378

### Report and Certificate of Verification

This is to certify that the following described machine has been verified in accordance with ASTM E4-89 and was found to be within a tolerance of +/- 1.0 %.

Location: **Kansas Dept. of Transportation**  
2300 Van Buren Street  
Topeka, KS 66611

Machine: **Rainhart**  
Model: **Compression Tester**  
Serial No: **BLH #56264**

Mode of Verification: **Compression**  
Next Verification Due: **04/24/97**

Attn: **Larry Schroeder**

Range Verified: **1000** to **10000** Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Unit	%	
1000	997	3	0.33	2
2000	1999	1	0.05	3
4000	3989	11	0.28	3
6000	5954	46	0.78	3
8000	7937	63	0.79	3
10000	9924	76	0.77	3

Range Verified: **500** to **5000** Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Unit	%	
500	498.6	1.4	0.28	1
1000	1007.5	-7.5	0.74	2
2000	2005.0	-5.0	0.25	3
3000	2995.4	3.6	0.12	3
4000	3979.4	20.6	0.52	3
5000	4982.2	7.8	0.16	3

Range Verified: **250** to **2500** Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Unit	%	
250	249.46	0.54	0.21	1
500	500.24	-0.24	0.05	1
1000	1001.27	-1.27	0.13	2
1500	1497.33	2.67	0.18	3
2000	1991.80	8.20	0.41	3
2500	2501.67	-1.67	0.07	3

Range Verified: \_\_\_\_\_ to \_\_\_\_\_

Machine Reading	Device Reading	Machine Error		C.D. Code
		Unit	%	

LOAD VALUES CORRECTED FOR A TEMPERATURE OF 72 DEGREES FAHRENHEIT.

Verification Method Used  
 Follow-the-Force Method  
 Set-the-Load Method

Load Indicating Device Mfg. Strainsense  
Device Serial Number: 920302  
Load Indicating Device Verified 04/19/96

**SATEC Verification Equipment Information:**

C.D. Code	Serial Number	Manufacturer	Verification High Value	Loading Range Class A Value	Calibration Date	Calibration Agency Laboratory Number
1	950411A	STRAINSENSE	600	34.35	04/21/95	SJT.01/106121
2	920302B	STRAINSENSE	6000	525.6	04/19/95	SJT.01/106121
3	920302C	STRAINSENSE	20000	1040	04/25/95	SJT.01/106121
4	920302D	STRAINSENSE	120000	8820	04/25/95	SJT.01/106121
5	920302F	STRAINSENSE	600000	16760	07/06/94	SJT.01/106099
6	0090	RICE LAKE - Weights	50	0.01	03/17/92	NIST 781/24697
7						

Method of verification and pertinent data in accordance with ASTM Specification E4-89 and SATEC Systems, Inc. "Procedure for Calibration Tension and Compression Testing Machines." The Testing Device(s) used for this verification have been calibrated per ASTM Specification E74 and are traceable to the National Institute of Standards Technology.

Date of Verification: **04/24/96**

Verified By: \_\_\_\_\_

*Richard H. Hestness*  
Richard H. Hestness

Service Engineer - Satec Systems, Inc.

Witness: \_\_\_\_\_

# CALIBRATION OF BALANCES

Page 1/4

March 30, 2004

ALFIE PACKERS INC.

SCOPE OF WORK FOR LABORATORY BALANCES:

Definitions are on next page.

1. The weighing environment is checked for anything that would affect the ability of the balance to weigh accurately for example: direct air currents, direct sunlight, objects stuck under the balance or magnets in close proximity to the balance.
2. The balance is checked for errors in zero, sensitivity, calibration, corner load, linearity, repeatability and tare accuracy. Any errors are noted.
3. The balance is thoroughly cleaned and disassembled. Parts subject to wear or damage are inspected. On mechanical balances, this includes but is not limited to knife edges, arrestment mechanism, switches, pan brake assemblies and weight lifting assemblies. On electronic balances, the measuring cell and flexures are inspected. Circuit boards and switches are inspected for contamination and corrosion.
4. Any errors noted in step two are corrected through adjustments or replacement of minor parts. If the balance cannot be returned to factory specifications through this method, the using personnel are consulted as to the need for further repairs.
5. The balance is reassembled and final checks are made as in step two. Final calibration adjustments are made.
6. Applicable GLP log books are annotated.
  - A. All tests are performed with Class 1 stainless steel weights traceable to the NIST and are calibrated at least annually.
  - B. A certificate of weight traceability to the NIST is provided to each functional area. This certificate lists all the balances serviced in that area and the serial number of the weights used, their calibration date, the NIST trace number and the technician calibration number.

Page 2/4

## DEFINITIONS:

Balance = Weighing device, generally with a resolution of 1 part in 12,000 or greater. Top loading balances will have a resolution of up to 1 part in 1,200,000 and sensitivity down to 1 milligram i.e. 1200.000 gram  $\pm$  .001 gram. Analytical balances will have a resolution of up to 1 part in 4,100,000 and sensitivity down to .01 milligram i.e. 41.00000 gram  $\pm$  .00001 gram. Micro-balances will have a resolution of up to 1 part in 200,000,000 sensitivity down to .0000001 gram.

Calibration = The accuracy of the balance, usually at full capacity, as compared to known standards.

Class 1 = A published standard for weights from the NIST. The standard dictates the materials, configuration and tolerance of the weights.

Corner loads = The deviation of the indicated weight between the center of the pan and the front, rear, left and right of the pan. This test is performed at 2/3 of maximum capacity.

Electronic Balance = A balance deriving its indicated weight from a force restoration coil measuring cell or high resolution load cell.

Factory specifications = The balance manufacturer's specifications for all adjustments, usually  $\pm$  1 final count (least significant digit).

Flexure = Parts of the measuring cell. The accuracy of all adjustments is dependent on the condition of these parts.

GLP = Acronym. Stands for Good Laboratory Practices. Laboratories under this standard must establish a plan for weighing accuracy control.

Knife edges = The pivot points of the balance beam in mechanical balances.

Mechanical Balance = A high resolution balance deriving its indicated readout from the mechanical movement of a balance beam and a system of built-in standard comparison weights.

NIST = Acronym. Stands for the National Institute for Standards and Technology. This is the new name for the National Bureau of Standards (NBS).

Pan brake = Part of a mechanical analytical balance used to stop pan swing when the balance is arrested.



## DEFINITIONS, CONTINUED

Repeatability = Test performed on all balances to determine if it indicates the same weight and returns to zero every time a weight is applied to and removed from the pan. This test is normally performed with a weight that is near the normal usage of the balance if known or near the mid-range of the balance. The weight is placed on the balance a minimum of three times to get a plus or minus reading.

Sensitivity = On mechanical balances this test determines the accuracy of the beam travel or optical range of the balance. On electronic balances this is the lightest weight that the balance will accurately respond to.

Tare accuracy = This test is used on mechanical balances to determine if the balance reads the same with or without the tare.



# Certificate of Weight Traceability

To: KANSAS DEPARTMENT OF TRANSPORTATION  
2300 VAN BUREN TOPEKA KANSAS

The following balances have been calibrated on SEE BELOW

Service representative: M.J. Aluma

Balance	Serial Number	
<u>3/17/95 OHAUS E4000S</u>	<u>2274</u>	<u>Agg. CONCRETE</u>
<u>3/17/95 METTLER P10</u>	<u>192446</u>	<u>Agg CONCRETE</u>
<u>3/17/95 A&amp;D FW-100KA1</u>	<u>05707023</u>	<u>CONCRETE</u>
<u>3/17/95 A&amp;D EP-6000</u>	<u>6401205</u>	<u>METALS</u>
<u>3/17/95 SARTORIUS I8100P</u>	<u>40210240</u>	<u>Cement CONCRETE</u>
<u>3/27/95 SHIMADZU AEG-220</u>	<u>D400400141</u>	<u>Cement CONCRETE</u>
<u>3/27/95 A&amp;D EP-20KB</u>	<u>3808903</u>	<u>Agg. CONCRETE</u>
<u>3/27/95 A&amp;D EP-20KB</u>	<u>3809190</u>	<u>Agg. CONCRETE</u>

Serial number of mass standards:  
E136/AP-9MAY/AP-9JUN/AP-9JUL/AP-9AUG/AP-9SEP/AP-9OCT/AP-9NOV/AP-9DEC  
 Calibration date: MAY 4, 1994 / SEPTEMBER 26, 1994  
 NIST test number: 732/246308/94-0107  
 State certification number: 5146-141 KS.  
 Date of issue: 3/30/95

**Alfie Packers Inc.**  
**8901 J Street**  
**Omaha Ne. 68127**  
**402-592-9102**

**VERIFICATION PROCEDURE FOR SAND EQUIVALENT**  
**(Page 1/2)**

(DATE) \_\_\_\_\_

Equipment Checked:     **WEIGHTED FOOT ASSEMBLY**

Purpose:

This method provides instructions for verifying the critical mass of the weighted foot assembly.

Inspection Equipment Required:

1. Balance, capacity 6100 g, readable to 0.1 g, repeatability to 0.05 g.

Tolerance:

Equipment shall meet the mass tolerances specified in the applicable test method.

Procedure:

1. Place the weighted foot assembly on the scale.
2. Record the mass to the nearest 0.1 g.
3. The mass shall be  $1000 \pm 5$  g.

**VERIFICATION RECORD FOR SAND EQUIVALENT**  
**Page 2/2**

The only item to be systematically inspected for KT-55 is the weighted foot assembly. The assembly is to be inspected annually. The assembly is to have a mass of  $1000 \pm 5$  g and shall be verified on calibrated scales.

Information concerning KT-55 is as follows:

1. Model and Serial Number.

\_\_\_\_\_

2. Name of worker.

\_\_\_\_\_

3. ID of Calibration/Verification (C/V) equipment used.

\_\_\_\_\_  
Serial Number \_\_\_\_\_  
Maximum Load \_\_\_\_\_g  
Readability 0.1 g

4. Date of work done.

\_\_\_\_\_

5. Next Due Date.

\_\_\_\_\_

6. Previous C/V date.

New Equipment

7. Detailed results.

The mass of the weighted foot was \_\_\_\_\_ grams.

8. Reference to procedure used.

See Page 2/2.

# CAL/VER PROCEDURE FOR GYRATORY

(Page 1/4)

## Purpose:

This method provides instructions for calibrating the load (pressure) and verifying the angle, rotation and height on the Superpave Gyratory. Use the proper equipment designated by the manufacturer when calibrating or verifying the Gyratory.

## Inspection Equipment required:

A certified load cell or proving ring to calibrate the load readings. Digital stopwatch required to determine the rotational speed. Manufacturer's recommended equipment for determining proper angle. Certified blocks for determining accuracy of height reading.

## Tolerances:

Meet all requirements as specified:

Gyratory:

Capable of applying a pressure of  $600 \pm 6$  kPa

Capable of applying an angle of  $1.16 \pm 0.02$  degrees

Gyrates specimen molds at  $30 \pm 0.5$  rev./minute

Records height of specimen to 0.05 mm during compaction once per gyration

Molds - 150 mm (nominal 6 in):

Inside diameter of molds 149.90 to 150.20 mm

At least 250 mm high

Walls at least 8.5 mm thick

Ram base and base plate faces shall be ground flat and have a diameter of 149.50 to 149.75 mm

Molds - 100 mm (nominal 4 in):

Inside diameter of molds 99.90 to 100.00 mm

At least 250 mm high

Walls at least 8.5 mm thick

Ram base and base plate faces shall be ground flat and have a diameter of 99.70 to 99.75 mm

## Procedures:

Follow the calibration procedures set forth in the manufacturer's manual to meet the tolerances established above.

**CAL/VER RECORD FOR GYRATORY**  
**(Page 2/4)**

Inspected by: \_\_\_\_\_ Date: \_\_\_\_\_

Identification Number: \_\_\_\_\_ Verification Frequency: \_\_\_\_\_

Previous Verification Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment and Procedure Used: See Manufacturers Manual.

**Calibration Results:**

**Angle Set at:** \_\_\_\_\_

**Revolutions Per Minute :** \_\_\_\_\_

**Height at a specific location :**

	Actual (mm)	Gyratory (mm)	% Error ( ± 0.05 mm)
1 .	_____	_____	_____
2 .	_____	_____	_____
3 .	_____	_____	_____

**Load at 3 (minimum) specific locations:**

	Actual (N/lbs )	Gyratory (N/lbs)	% Error = $\frac{100 (\text{Gyratory} - \text{Actual})}{\text{Actual}}$
1 .	_____	_____	_____
2 .	_____	_____	_____
3 .	_____	_____	_____
4 .	_____	_____	_____
5 .	_____	_____	_____

## VERIFICATION OF INSIDE DIAMETERS FOR GYRATORY MOLDS





Verified By: \_\_\_\_\_ Date: \_\_\_\_\_

Equipment: Gyratory Compaction Molds Verif. Frequency: \_\_\_\_\_

Equipment Identification: \_\_\_\_\_ See Below

Previous Verif. Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment Used: \_\_\_\_\_

Verif. Equipment Identification: \_\_\_\_\_

Verif. Procedure Used: \_\_\_\_\_

**Tolerance of Molds:** 5.902 to 5.913 in (149.90 to 150.20 mm)

**Bore Gauge Readings:**

Mold Number <u>1</u>					
Orientation	Reading 1	Reading 2	Reading 3	Ave. of Readings	Average Diameter
Top					
Middle					
Bottom					

Average Inside Diameter: \_\_\_\_\_

Action Recommended: Repair  Replace  None

Comments \_\_\_\_\_

Mold Number <u>2</u>					
Orientation	Reading 1	Reading 2	Reading 3	Ave. of Readings	Average Diameter
Top					
Middle					
Bottom					

Average Inside Diameter: \_\_\_\_\_

Action Recommended: Repair  Replace  None

Comments \_\_\_\_\_

**CAL/VER RECORD FOR GYRATORY**  
**(Page 4/4)**

# Proving Ring Calibration Certificate

## Certificate of Calibration and Traceability to the United States National Institute of Standards & Technology

Pine Instrument Company  
10,000 lbf Capacity Proving Ring  
Serial No.: 1306

The above identified instrument was calibrated as a limited load instrument according to ASTM specification E74-91, "Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines."

Following are the units and loads of force applied to the instrument during three separate calibration runs, the deflection in divisions as read on the indicator for each applied load, and the average deflection in divisions for each load.

Applied Load LBF	Compression Mode Indicator Readings			Average DIV
	Run 1 DIV	Run 2 DIV	Run 3 DIV	
0	0.0	0.0	0.0	0.0
350	35.0	35.0	35.0	35.0
500	50.0	50.0	50.0	50.0
1000	100.0	100.0	100.0	100.0
1500	149.0	149.0	149.0	149.0
2000	199.5	199.5	199.5	199.5
2500	250.0	250.0	250.0	250.0
3000	300.0	300.0	300.0	300.0
4000	403.5	403.0	403.0	403.2
5000	507.0	507.0	507.0	507.0
6000	608.5	608.0	607.5	608.0
7000	714.5	714.0	714.0	714.2
8000	817.0	817.0	816.5	816.8
9000	921.0	920.5	920.5	920.7
10000	1028.0	1027.5	1028.0	1027.8

Temperature During Calibration: 22 °C      Calibration Date: 8/17/85  
 Humidity: 38 %      Recalibration Date: 8/18/86  
 Uncertainty of Standard: +/- 0.02%      Due Date: 12/19/86  
 Standard Used: 10K LB. LOAD CELL S/N 77107  
 NIST No.: 822.07/250325

Approved By: MPC *[Signature]*



#### **5.2.7.4 CONCRETE: CONTRACTOR'S QUALITY CONTROL PLAN**

**NOTE:** This document is generally written in the imperative mood. The subject, "the *Contractor*" is implied. Also implied in this language are "*shall*", "*shall be*", or similar words and phrases. The word "*will*" generally pertains to decisions or actions of the Kansas Department of Transportation.

##### **1. GENERAL**

Provide qualified personnel and sufficient equipment meeting the requirements listed in the Department's Construction Manual to conduct quality control testing which conforms with the Sampling and Testing Frequency Chart for Portland Cement Concrete Pavement for Quality Control/Quality Assurance Projects in Appendix B of this Manual.

Calibrate and correlate the testing equipment with prescribed procedures and conduct tests in conformance with specified testing procedures as listed in the Department's Construction Manual. As a minimum, meet the calibration schedule as outlined in **Table 1, Concrete Materials Test Equipment**.

Maintain control charts on an ongoing basis.

File all reports, records, and diaries developed during the progress of construction activities as directed by the Engineer. Files become the property of the Engineer.

Provide the following:

- Make copies of all test results and control charts readily available to the Engineer at the project site.
- Copies of all failing test results (based on a moving average of four tests, when appropriate) and summary sheet sent on a daily basis to the Construction Engineer.

##### **2. QUALITY CONTROL ORGANIZATION**

Submit a listing of the names and phone numbers of individuals and alternates responsible for quality control administration and inspection along with the proposed mix design data. Provide an organizational chart that shows the specified lines of authority relating both to mix design and quality control operations during production. Post a copy of the organizational chart in the Contractor's test facility.

The Contractor's quality control organization or private testing firms representing the Contractor must include individuals who are certified by KDOT, or a State approved equivalent, for the appropriate test methods. Only technicians certified in accordance with KDOT requirements may perform process control testing on the project.

##### **3. QUALITY CONTROL PLAN**

Prepare a Quality Control Plan detailing the type and frequency of inspection, sampling and testing deemed necessary to measure and control the various properties of materials and construction governed by the Specifications. As a minimum, detail sampling location and techniques, and test frequency to be utilized in the sampling and testing plan. The Department may utilize quality control sampling and testing performed by the Contractor for acceptance. Submit the Quality Control Plan to the Engineer in writing at the pre-construction meeting.

**3.1.** Identify the personnel responsible for the Contractor's quality control in the plan. This shall include the company official who will act as liaison with Department personnel, as well as the Certified Technician who will direct the inspection program. The class or classes of concrete involved will be listed separately. If existing mix designs are to be utilized, list the mix design numbers. Quality control sampling, testing, and inspection shall be an integral part of the Contractor's quality control system. In addition to the above requirements, the Contractor's quality control system shall document the quality control requirements considered to be normal activities necessary to control the production and placing of a given product or material at an acceptable quality level. Retain the latest ten gradation samples for use by the Engineer. It is intended that sampling and testing be in accordance with standard methods and procedures, and that measuring and testing equipment be standard, properly calibrated and documented in the Quality Manual. Detail in the Quality Control Plan any alternative sampling method, procedure and inspection equipment to be used.

**3.1.1.** Elements of the Plan. Include all elements that affect the quality of the PCCP including, but not limited to the following:

- Mix Designs
- Aggregate Production
- Quality of Components
- Stockpile Management
- Proportioning, including added water
- Mixing and transportation, including time from batching to completion of delivery
- Initial mix properties, including temperature, air content, and consistency
- Placement and consolidation, including a schedule for calibrating and checking vibrators
- Concrete yield versus Plan quantity records
- Compressive strength
- Finishing and curing

**3.1.2.** Personnel Requirements:

Detail in the Plan:

- The frequency of sampling and testing, coordination of activities, corrective actions to be taken, and documentation.
- How the duties and responsibilities are to be accomplished and documented, and whether more than one Certified Technician is required.
- The criteria utilized by the Technician to correct or reject unsatisfactory materials.

Certified Technicians required duties:

- Perform and utilize quality control tests and other quality control practices to assure that delivered materials and proportioning meet the requirements of the mix designs, including temperature, slump, air content, and strength. Be available on the project site whenever concrete is being produced for use on or being placed on the project site.
- Periodically inspect all equipment utilized in transporting, proportioning, mixing, placing, consolidating, finishing, and curing to assure it is operating properly and that placement, consolidation, finishing, and curing conform to the mix design and other Contract requirements.

#### 4. DOCUMENTATION

Maintain adequate records of all inspections and tests. Indicate the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and the nature of corrective action taken as appropriate in the records. The Contractor's documentation procedures will be subject to approval of the Engineer before the start of the work and to compliance checks during the progress of the work.

Charts and Forms.

Keep all conforming and non-conforming inspections and test results complete and available at all times to the Engineer during the performance of the work. Provide forms on a computer-acceptable medium where required. Document batch tickets and gradation data in accordance with Department requirements.

Chart test data for portland cement concrete in accordance with the applicable requirements.

The Contractor may use other types of control charts as deemed appropriate. It is normally expected that testing and charting will be completed within 1 working day after sampling.

All charts and records documenting the Contractor's quality control inspections and tests become property of the Department upon completion of the work.

#### 5. CORRECTIVE ACTION

Notify the Engineer when the moving average test result trend line for any property approaches the specification limits. Cease operations if two consecutive moving average points fall outside the Specification limits. Ceasing operations is the Contractor's responsibility. Quality control tests for this determination includes aggregate gradation, compliance with the mix design band, entrained air content, concrete unit mass, and density of fresh concrete in place. Production will be suspended pending the satisfactory results of a pre-production sample, unless waived by the District Materials Engineer.

Failure to cease operations for the conditions cited above will subject all subsequent material to rejection by the Engineer, or acceptance at a reduced price, as determined by the Engineer.

The Engineer may examine materials represented by individual test results which lie beyond the Contractor's normal quality control testing variation. The investigation may be based on either Contractor's test results or the Department's test results. The information from additional testing (including testing of in place pavement) may be used to define unacceptable work according to **Standard Specifications For State Road And Bridge Construction Subsection 105.5 and Subsection 106.10**, and apply appropriate price reductions or initiate corrective action as determined by the Engineer.

For any test, if a dispute exists between the Engineer and the Contractor about the validity of the others' test results, the KDOT Materials and Research Center (MRC) will perform referee testing. If one of the disputed Department test result was generated at the MRC, then an Independent Laboratory agreeable to both parties will be selected. The selected Laboratory must be approved by the AASHTO Accreditation Program for the appropriate test procedure. If referee testing indicates that the Department's test results are correct, then the Contractor pays for the additional testing, including referee testing performed at the MRC. If the referee testing indicates that the Contractor's test results are correct then the Department pays for the additional testing.

**6. Non-Conforming Materials.** Establish and maintain an effective and positive system for controlling non-conforming material, including procedures for its identification, isolation and disposition. Reclaim or rework non-conforming materials in accordance with procedures acceptable to the Engineer.

Positively identify all non-conforming materials and products to prevent use, shipment, and intermingling with conforming materials and products. Provide holding areas, mutually agreeable to the Engineer and the Contractor.

**7. Testing Facilities.** Locate the Contractor's testing facility at the plant site or at the project site. Obtain approval of the facility by the Engineer before the commencement of mixture production. Any other laboratory location requires approval by the District Materials Engineer. Provide suitable space and specified testing equipment for use by the Contractor's quality control personnel to perform tests as required.

KDOT's Materials and Research Center is Accredited through the AASHTO Accreditation Program (AAP). If the contractor's QC laboratory is not participating in the AAP, then the contractor shall have an AAP approved laboratory or a manufacturer certified technician inspect the QC laboratory's equipment and perform calibrations and verifications annually. The contractor may perform the inspection, calibrations and verifications annually if the QC laboratory is participating in the AAP. The inspection, calibrations and verifications shall include all equipment necessary to perform testing on specified types of material related to this contract; base and grading, aggregate, HMA and concrete.

Maintain a Quality Manual showing all calibrations performed on all test equipment and when next calibration is due for that equipment. As a minimum, follow the calibration/verification interval established in **Table 1, Concrete Materials Test Equipment**.

To facilitate communication between the Contractor and the Engineer regarding quality control, equip the Contractor's testing facility with the following:

- A telephone with a private line for the exclusive use of the testing facility's quality control personnel.
- A copying machine.
- A facsimile machine for use by contractor personnel and the Engineer.

**Table 1, Concrete Materials Test Equipment**

Equipment – Test Method	Requirements	Interval (months)
Mechanical Shakers – KT-02	Check Sieving Thoroughness.	12
General Purpose Balances, Scales and Masses – AASHTO M 231	Calibrate	12
Test Thermometers – KT-17, KT-22 & KT-73	Standardize	12
Compression Testing Machine –KT-49 & KT-76	Standardize	12
	Verify plane of bearing blocks	12
	Clean and lubricate upper bearing block	6
Beam Breaker – KT-23	Standardize	12
	Clean and lubricate	6
Sieves – AASHTO M 92	Check Physical Conditions.	12
Water tanks – AASHTO M 201	Cleaned and refilled with 3 g/L of hydrated lime (calcium hydroxide).	24
	Verify recording thermometer.	6
Pressure Meter – KT-18	Standardize	3
Volumetric Meter – KT-19	Standardize	12
Slump Cones- KT-21	Check Critical Dimensions.	12
Unit Mass – KT-20	Standardize	12
Capping Material – KT-77	Check Strength.	3
Reusable Molds – KT-23	Check Critical Dimensions.	12
Nuclear Density Gauge – KT-36 & 38	Check for Uniformity	12

**8. Testing Requirements.** Take all samples for tests at random locations, selected as specified in the Contractor’s quality control plan and at the rates specified in the Sampling and Testing Frequency Chart for Portland Cement Concrete Pavement for Quality Control/Quality Assurance Projects in Appendix B-of Part V of this manual. Record and document all test results and calculations on data sheets that are acceptable to the Engineer. Record specific test results on a daily summary sheet approved by the Engineer to facilitate the computation of moving test averages. Base moving averages on 4 consecutive test results. Include a description of quality control actions taken (adjustment of aggregate or additive proportions in the mix, moisture adjustments, etc.) in the Daily Quality Control Summary Sheet. Post quality control charts and keep current, show both individual test results and moving average values. Plot the single test values and the 4-test moving average values on approved control charts.

Plot individual test results in black for each test point. Connect points with a solid black line. Plot the moving average for each test variable in red starting with the fourth test. Connect the points with a dashed red line. Plot the Department's verification test results with green asterisks. Do not include the Department's verification tests in the moving average.

Indicate specification working range limits for single test results on the control charts using a dotted green line and for four point moving average results with a solid green line.

**NOTE: Section 5.2.7.5** of this manual, Example of a Laboratories Quality Manual, will provide examples of equipment procedures to verify that equipment is in proper condition. Also, examples of records for calibrating/verifying equipment are presented.





#### **5.2.7.5. EXAMPLE OF A LABORATORY QUALITY MANUAL FOR CONCRETE**

This example is designed to provide the contractor with general guidelines in creating and maintaining a contractor's Quality Manual. The QC process requires records for equipment calibrations/verifications. Maintaining records in an orderly manner will assist the District Materials Engineer in quickly determining if the laboratory meets QC/QA requirements. Having the field laboratory fully prepared and the Quality Manual properly maintained represent two items that can keep the start of a project on schedule. It also aids in demonstrating the contractor's commitment to the QC process.

The following records are presented to illustrate what is required in the Quality Manual. Records need not be exactly as illustrated but should supply all necessary information concerning the equipment calibration/verification.

**NOTE:** After calibrating any force-load testing equipment (compression machine) a copy of the certification for the calibration device (proving ring, load cell, etc.) shall be attached to the calibration record.

**NOTE:** All equipment shall be verified immediately after repairs (this may include new or replacement parts, or mechanical or electrical adjustments) that may in any way affect the ability of the equipment to provide accurate readings as established during the calibration/verification process.

**DISCLAIMER:** It is not the intent of these guidelines to endorse manufacturers, suppliers, calibrating services, etc. The examples are used to provide guidance in establishing a thoroughly developed Quality Manual.

# LABORATORY QUALITY MANUAL

## TABLE OF CALIBRATION/VERIFICATION DATES

**Revision Date 2021**

Equipment – Test Method	Calibration/Verification Intervals (months)	Next Due Date
Mechanical Shakers – KT-02		
General Purpose Balances, Scales and Masses – AASHTO M 231		
Test Thermometers – KT-17, KT-22 & KT-77		
Testing Machine –KT-23, KT-49 & KT-76		
Sieves – ASTM E11		
Water tanks – AASHTO M 201 (clean)		
Pressure Meter – KT-18		
Volumetric Meter – KT-19		
Slump – KT-21		
Unit Mass – KT-20		
Capping Material – KT-77		
Reusable Molds – KT-23		

May 23, 2022

**VERIFICATION PROCEDURE FOR MECHANICAL SIEVE SHAKER  
(Page 1/2)**

**Purpose:** This method provides instructions for checking the length of time the mechanical sieving device must run. This reflects the procedure in **KT-02 Section 9**

**Inspection Equipment Required:**

1. Set of 8" dia. sieves (4, 8, 16, 30, 50, 100, 200)
2. Timer
3. Balance, readable to 0.1 g.
4. Sample of fine aggregate.

**Efficiency:**

The difference between two percent retained values on any sieve shall not exceed 0.5 percent by mass.

**Procedure (See KT-02 Section 9.):**

1. Determine the initial mass of the sample.
2. Place sample of aggregate in nested sieves. Fit the sieve nest with a lid and a pan.
3. Place sieves in shaker & set timer for 6 minutes.
4. Determine and record the percent retained of each sieve size.
5. Collect and recombine all of the material.
6. Place sieves in shaker & set timer for 7 minutes.
7. Determine and record the percent retained of each sieve size.
8. If the difference between two percent retained values on any sieve does not exceed 0.5 percent by mass, then the mechanical sieve shake is verified. If not, repeat the procedure for 2 longer time periods or repair/replace the mechanical sieve shaker.

May 23, 2022

**VERIFICATION RECORD FOR MECHANICAL SHAKER**  
**(Page 2/2)**

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** \_\_\_\_\_ Mechanical Shaker \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

Original Dry Mass (ODM) \_\_\_\_\_

Mass Retained on Each Sieve

	#4	#8	#16	#30	#50	#100	#200
1st Run							
2nd Run							
Difference							
% of ODM							

# CALIBRATION OF BALANCES

Page 1/3

March 30, 1995

ABC PACKERS INC.

SCOPE OF WORK FOR LABORATORY BALANCES:

Definitions are on next page.

1. The weighing environment is checked for anything that would effect the ability of the balance to weigh accurately for example: direct air currents, direct sunlight, objects stuck under the balance or magnets in close proximity to the balance.
2. The balance is checked for errors in zero, sensitivity, calibration, comer load, linearity, repeatability and tare accuracy. Any errors are noted.
3. The balance is thoroughly cleaned and disassembled. Parts subject to wear or damage are inspected. On mechanical balances, this includes but is not limited to knife edges, arrestment mechanism, switches, pan brake assemblies and weight lifting assemblies. On electronic balances, the measuring cell and flextures are inspected. Circuit boards and switches are inspected for contamination and corrosion.
4. Any errors noted in step two are corrected through adjustments or replacement of minor parts. If the balance cannot be returned to factory specifications through this method, the using personnel are consulted as to the need for further repairs.
5. The balance is reassembled and final checks are made as in step two. Final calibration adjustments are made.
6. Applicable GLP log books are annotated.
  - A. All tests are performed with Class 1 stainless steel weights traceable to the NIST and are calibrated at least annually.
  - B. A certificate of weight traceability to the NIST is provided to each functional area. This certificate lists all the balances serviced in that area and the serial number of the weights used, their calibration date, the NIST trace number and the technician calibration number.

DEFINITIONS:

Balance = Weighing device, generally with a resolution of 1 part in 12,000 or greater. Top loading balances will have a resolution of up to 1 part in 1,200,000 and sensitivity down to 1 milligram i.e. 1200.000 gram  $\pm$  .001 gram. Analytical balances will have a resolution of up to 1 part in 4,100,000 and sensitivity down to .0 1 milligram i.e. 41.00000 gram  $\pm$  .00001 gram. Micro-balances will have a resolution of up to 1 part in 200,000,000 sensitivity down to .0000001 gram.

Calibration = The accuracy of the balance, usually at full capacity, as compared to known standards.

Class 1 = A published standard for weights from the NIST. The standard dictates the materials, configuration and tolerance of the weights.

Corner loads = The deviation of the indicated weight between the center of the pan and the front, rear, left and right of the pan. This test is performed at 2/3 of maximum capacity.

Electronic Balance = A balance deriving its indicated weight from a force restoration coil measuring cell or high resolution load cell.

Factory specifications = The balance manufacturers specifications for all adjustments, usually  $\pm$  1 final count (least significant digit).

Flexure = Parts of the measuring cell. The accuracy of all adjustments is dependent on the condition of these parts.

GLP = Acronym. Stands for Good Laboratory Practices. Laboratories under this standard must establish a plan for weighing accuracy control.

Knife edges = The pivot points of the balance beam in mechanical balances.

Mechanical Balance = A high resolution balance deriving its indicated readout from the mechanical movement of a balance beam and a system of built in standard comparison weights.

NIST = Acronym. Stands for the National Institute for Standards and Technology. This is the new name for the National Bureau of Standards (NBS).

Pan brake = Part of a mechanical analytical balance used to stop pan swing when the balance is arrested.

DEFINITIONS, CONTINUED

Repeatability = Test performed on all balances to determine if it indicates the same weight and returns to zero every time a weight is applied to and removed from the pan. This test is normally performed with a weight that is near the normal usage of the balance if known or near the mid-range of the balance. The weight is placed on the balance a minimum of three times to get a plus or minus reading.

Sensitivity = On mechanical balances this test determines the accuracy of the beam travel or optical range of the balance. On electronic balances this is the lightest weight that the balance will accurately respond to.

Tare accuracy = This test is used on mechanical balances to determine if the balance reads the same with or without the tare.

**Certificate of Weight Traceability**

To: KANSAS DEPARTMENT OF TRANSPORTATION  
2300 VAN BUREN TOPEKA KANSAS

The following balances have been calibrated on SEE BELOW

Service representative: M. J. Gillman

Balance	Serial Number	
<u>3/17/95 OHAUS E4000I</u>	<u>2274</u>	<u>Agg.</u> <del>CONCRETE</del>
<u>3/17/95 METTLER P10</u>	<u>192446</u>	<u>Agg</u> <del>CONCRETE</del>
<u>3/17/95 A&amp;D FW-100KA1</u>	<u>C.5707023</u>	<u>CONCRETE</u>
<u>3/17/95 A&amp;D EP-6000</u>	<u>6401205</u>	<del>METALS</del>
<u>3/17/95 SARTORIUS I8100P</u>	<u>40210240</u>	<u>Cement</u> <del>CONCRETE</del>
<u>3/27/95 SHIMADZU AEG-220</u>	<u>D400400141</u>	<u>Cement</u> <del>CONCRETE</del>
<u>3/27/95 A&amp;D EP-20KB</u>	<u>3808903</u>	<u>Agg.</u> <del>CONCRETE</del>
<u>3/27/95 A&amp;D EP-20KB</u>	<u>3809190</u>	<u>Agg.</u> <del>CONCRETE</del>

Serial number of mass standards:  
E136/AP-9M01/AP-3M01/AP-9M04/AP-9Q94  
 Calibration date: MAY 4, 1994 / SEPTEMBER 26, 1994  
 NIST test number: 732/246308/94-0107  
 State certification number: 3146-141 KS.  
 Date of issue: 3/30/95

**Alfie Packers Inc.**  
 8901 J Street  
 Omaha Ne. 68127  
 402-592-9102



May 23, 2022

**VERIFICATION PROCEDURE FOR THERMOMETERS  
(Page 1/2)**

**FORM DATE:** March 29, 1996

**Purpose:**

This method provides instructions for verifying the settings on general-purpose thermometers.

**Inspection Equipment Required:**

1. A calibrated thermometer graduated in 2.0°F (1.0°C) increments having a range which includes the temperature range to be checked.
2. A clothespin to hold the thermometer in such a manner as to enable the operator to read the scale easily.
3. A container well to retain heat for constant temperature readings.
4. A hot plate to heat the liquid (oil) in the container well.

**Procedure:**

1. Place the thermometer inside the container well with the clothespin attached to the thermometer.
2. Take the first reading when the temperature has stabilized.
3. Take as many readings as necessary to determine the "laboratory thermometer setting" vs "actual calibrated reading."



# REPORT FORM FOR COMPRESSION MACHINE

(Page 1/2)

Calibration performed according to ASTM E 4 (latest publication).

- Must provide Load Cell readings, Compression Machine readings and percent error for each force reading.

CONTRACTOR: \_\_\_\_\_ DATE: \_\_\_\_\_

LOCATION: \_\_\_\_\_

CALIBRATION SERVICE NAME: \_\_\_\_\_

CALIBRATOR: \_\_\_\_\_

NEXT LOAD CELL/RING CALIBRATION DATE: \_\_\_\_\_

LOWER RANGE OF DEVICE (CLASS A VALUE): \_\_\_\_\_

UPPER RANGE OF DEVICE: \_\_\_\_\_

TEMPERATURE CORRECTION FACTOR USED: \_\_\_\_\_

TESTING MACHINE MANUFACTURER: \_\_\_\_\_

TESTING MACHINE SERIAL NUMBER: \_\_\_\_\_

CALIBRATION WITNESS: \_\_\_\_\_

CALIBRATOR SIGNATURE: \_\_\_\_\_

CHECK PLANE OF BEARING BLOCKS?: Y/N \_\_\_\_\_

CLEAN/LUBRICATE UPPER BEARING BLOCK?: Y/N \_\_\_\_\_

COMMENTS: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**EXAMPLE FOR VERIFICATION RECORD OF TESTING MACHINE**  
(Page 2/2)

**SATEC** Materials Testing Equipment

SATEC Systems, Inc.  
800 Liberty Street  
Croydon City, PA 17021-5006  
1-800-798-8379

**Report and Certificate of Verification**

This is to certify that the following described machine has been verified in accordance with ASTM E4-84 and has found to be within a tolerance of ±1.0 %

Location: Kansas Dept. of Transportation  
2500 Van Buren Street  
Topeka, KS 66611

Machine: Balance  
Model: Compression Tester  
Serial No: 84249864

Mode of Verification: Compression  
Next Verification Due: 04/04/97

By: Larry Belkroeder

Range Verified: 1000 to 10000 Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	
1000	997	3	0.30	2
2000	1998	1	0.05	3
4000	3998	11	0.28	3
6000	5994	6	0.10	3
8000	7997	3	0.38	3
10000	9994	6	0.60	3

Range Verified: 500 to 5000 Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	
500	498.8	1.2	0.24	1
1000	1007.5	-7.5	0.75	2
2000	2008.0	-8.0	0.40	3
3000	2998.4	1.6	0.53	3
4000	3999.4	0.6	0.15	3
5000	4993.2	6.8	0.14	3

Range Verified: 250 to 2500 Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	
250	249.46	0.54	0.21	1
500	500.24	-0.24	0.05	1
1000	1001.27	-1.27	0.13	2
1500	1497.28	1.72	0.11	3
2000	1999.50	0.50	0.04	3
2500	2501.36	-1.36	0.05	3

Range Verified: 0

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	

LOAD VALUES CORRECTED FOR A TEMPERATURE OF 72 DEGREES FAHRENHEIT.

APPROXIMATE METHOD USED:  
 Follows the Force Method  
 Set the Load Method

Used Indicating Device No. 1: Strainometer  
 Device Serial Number: 84249864  
 Used Indicating Device Verified: 04/04/95

**SATEC Verified Equipment Information:**

C.C. Code	Serial Number	MANUFACTURE	Verification High Value	Location - High Class # Status	Verification Date	Location/ Agency Inventory Number
1	350411A	STRAINHEAD SC	400	3436	04/01/96	BJT-INT-0810
2	320000E	STRAINHEAD SC	2000	5200	04/18/95	BJT-INT-0810
3	320000C	STRAINHEAD SC	2000	1149	04/05/95	BJT-INT-0810
4	4000011	STRAINHEAD SC	10000	8920	04/05/95	BJT-INT-0810
5	320000F	STRAINHEAD SC	2000	18780	07/06/94	BJT-INT-0810
6	0600	TRUCK LANE - Weight	50	901	02/12/95	HSBT/PA-00001
T						

Maintained and/or repaired in accordance with ASTM Specification E4-89 and SATEC Systems, Inc. Procedure for Calibration Function and Compression Fatigue Machines. The Testing Device(s) used for this verification have been calibrated per ASTM Specification E7-91 and are traceable to the NATIONAL BUREAU OF STANDARDS technology.

Date of Verification: 04/04/96

Verified By:



Service Engineer - SATEC Systems, Inc.

Witness: \_\_\_\_\_

## **VERIFICATION PROCEDURE FOR SIEVES**

**(Page 1/2)**

### **Purpose:**

This method provides instructions for checking the physical condition of laboratory tests sieves ranging in size 3 in. (75 mm) to #200 (0.075 mm).

### **Inspection Equipment Required:**

1. A caliper readable to 0.01 mm (use for #4 or coarser).

### **Tolerances:**

Sieves shall meet physical requirements specified in **ASTM E11**.

### **Procedure:**

(Steps 1 & 2 apply to sieves having openings greater than 4.75 mm)

1. Select an adequate number of individual sieve openings (3 or 4) along a 45° line. Measure and record the sieve openings to verify that the size opening indicated on the label is correct.
2. Repeat step 1, rotating the sieve 90°.
3. Inspection the general condition of the sieve. Check the frame and solder joints for cracks or holes (check for pinholes in the finer sieves).
4. Make sure the sieves have an appropriate label.
5. Check for tightness of the wires on each individual sieve.



**VERIFICATION PROCEDURE FOR WATER TANKS**  
**(Page 1/2)**

**Purpose:**

This method provides instructions for checking water storage tanks.

**Inspection Equipment Required:**

1. Calibrated thermometer, graduated in 0.5°C divisions.

**Tolerances:**

1. Storage Tanks shall meet the tolerances specified in the test method.

**Procedure:**

(Tanks)

Drain and clean the water storage tanks in intervals not to exceed 24 months.

1. Visually inspect the tanks, note any crack or holes observed, and repair as needed.
2. Refill each tank with water containing 3 g/L of calcium hydroxide.
3. Thoroughly stir the water in the tanks at intervals not to exceed one month to help replace calcium ions that have depleted. - Record the date stirred.

(Recording Thermometer)

1. Check the recording thermometer for accuracy at least every six months.
2. Place calibrated thermometer in water adjacent to the recording thermometer.
3. Correction factor shall be provided if differences in the observed readings exceed 1°C. Record this verification of the thermometer as described in the section covering verification of thermometers.

**VERIFICATION RECORD FOR WATER TANKS**  
(Page 2/2)

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** \_\_\_\_\_ **Water Tanks** \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

**Water Stirred in Tanks**

1 <sup>st</sup> year		2 <sup>nd</sup> year
	Month 1	
	Month 2	
	Month 3	
	Month 4	
	Month 5	
	Month 6	
	Month 7	
	Month 8	
	Month 9	
	Month 10	
	Month 11	
	Month 12	

**Tanks Drained and Cleaned:** \_\_\_\_\_

**Condition of tanks** \_\_\_\_\_

**Refilled with 3 g/L hydrated lime (calcium hydroxide)** \_\_\_\_\_

**Was the thermometer checked for accuracy every six months?** \_\_\_\_\_



**VERIFICATION PROCEDURE FOR PRESSURE METER**  
**(Page 1/2)**

**Purpose:**

This method provides instructions for checking the Type B pressure meter.

**Inspection Equipment Required:**

1. Calipers or ruler readable to 0.01 in.
2. Gauge for measuring hemispherical end of tamping rod.
3. Scale accurate to 0.1% of the weight of the bowl filled with water.
4. Calibration vessel.
5. Glass plate.

**Tolerance:**

The pressure meter shall comply with **KT-18** for dimensions and materials.

**Procedure:**

1. Determine the weight of water required to fill the calibration vessel. Record weight as  $w$ .
2. Determine the weight of water required to fill the bowl. Record the weight as  $W$ .
3. Determine  $R = w/W$ .
4. Determine the calibration factor  $K$ , where  $K=R$ .
5. Assemble water filled meter and calibrate the pressure gauge as outlined in **KT-18**.



## **VERIFICATION PROCEDURE FOR VOLUMETRIC METER**

**(Page 1/2)**

### **Purpose:**

This method provides instructions for checking the volumetric meter.

### **Inspection Equipment Required:**

1. Calipers or ruler readable to 0.01 in.
2. Gauge for measuring hemispherical end of tamping rod.
3. Scale accurate to 0.1 % of the weight of the bowl filled with water.
4. Calibrated cup.
5. Thermometer

### **Tolerance:**

The volumetric meter shall comply with **KT-20** for dimensions and materials.

### **Procedure:**

1. Determine the volume of the bowl, with an accuracy of at least 0.1 % by weighing the amount of water required to fill it at room temperature, and dividing this weight by the unit weight of water at the same temperature.
2. Determine the accuracy of the gradations on the neck, by filling the assembled meter with water to a pre-selected air-content gradation and then determining the quantity of 21.1°C (70°F) water required to fill the meter to the zero mark. The added water shall be within  $\pm 0.1$  % volume of the measuring bowl. Repeat this procedure 3 times.
3. Determine the volume of the calibrated cup by the method outlined in **KT-20**.

**VERIFICATION RECORD FOR VOLUMETRIC METER**  
(Page 2/2)

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** Volumetric meter **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

---

**Volume of bowl:** \_\_\_\_\_

**Volume of calibrated cup:** \_\_\_\_\_

**Neck gradations accurate** \_\_\_\_\_ Yes / no

**Gradations checked 3 times** \_\_\_\_\_ Yes / no

**Tamping Rod**

**Diameter, inches** 1) \_\_\_\_\_ 5/8"

2) \_\_\_\_\_

**Length, inches** \_\_\_\_\_ At least 12"

**Hemispherical end** \_\_\_\_\_ Yes / no

**Action recommended** \_\_\_\_\_

**VERIFICATION PROCEDURE FOR SLUMP**  
**(Page 1/2)**

**Purpose:**

This method provides instructions for checking the critical dimensions of the slump cone.

**Inspection Equipment Required:**

1. Calipers or ruler readable to 0.01 in.
2. Straightedge or ruler.
3. Digital micrometer.
4. Gauge for measuring hemispherical end of tamping rod.

**Tolerance:**

Equipment shall meet the dimensional tolerances specified in the test method.

**Procedure:**

*(CONE)*

1. Measure the inside diameter at the top of the cone to the nearest 0.01 in. by taking two readings 90° apart using the calipers and record the results.
2. Invert the cone and repeat the procedure.
3. Place the cone on a flat surface. Measure and record the depth of the cone by using the calipers and a straightedge and record the results.
4. Measure the thickness of the cone to the nearest 0.001 in. by taking 2 readings 90° apart at the bottom of the cone & record the results.

*(TAMPER)*

1. Measure the diameter of the tamping rod to the nearest millimeter by taking two readings 90° apart using the micrometer and record the results. Measure the length of the rod to the nearest 0.1 in. and record the results.
2. Measure the hemispherical end of the rod and record the results.

**VERIFICATION RECORD FOR SLUMP**  
(Page 2/2)

Verified By: \_\_\_\_\_ Date: \_\_\_\_\_

Equipment: Slump Cone and Tamping Rod Verif. Frequency: \_\_\_\_\_

Previous Verif. Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment Used: \_\_\_\_\_

Verif. Equipment Identification: \_\_\_\_\_

Verif. Procedure Used: \_\_\_\_\_

	<u>Cone</u>		Specification
Top inside diameter, inches	1)	_____	4" +/- 1/8"
	2)	_____	
Bottom inside diameter, inches	1)	_____	8" +/- 1/8"
	2)	_____	
Depth of Cone , inches	1)	_____	12" +/- 1/8"
Wall thickness, inches	1)	_____	Not less than 0.045"
	2)	_____	
<u>Tamping Rod</u>			
Diameter, inches	1)	_____	5/8"
	2)	_____	
Length, inches		_____	Approx. 24"
Hemispherical end		_____	Yes / no
Action recommended		_____	

## VERIFICATION PROCEDURE FOR UNIT MASS (Page 1/2)

### **Purpose:**

This method provides instructions for calibrating measures used in obtaining unit mass.

### **Inspection Equipment Required:**

1. Balance conforming to **Part V 5.9. Sampling and Test Methods Forward**
2. 0.01 in (0.25 mm) feeler gauge.
3. 1/4 in (6 mm) thick glass plate at least 1 in (25 mm) larger than the measure.
4. Water pump or chassis grease.
5. Thermometer.

### **Tolerance:**

The bowls and measures shall conform to the dimensions found in **KT-20**.

### **Procedure:**

1. Place glass plate on rim and attempt to insert feeler gauge.
2. Fill measure with room temperature water and cover in such a way as to dispel air bubbles and excess water.
3. Determine the mass of water in the measure.
4. Determine the temperature of the water, and obtain its density from **KT-15**.
5. Calculate the volume,  $V$ , of the measure by dividing the mass of the water required to fill the measure by its density.
6. Calculate the factor for the measure ( $1/V$ ) by dividing the density of the water by the mass required to fill the measure.

**VERIFICATION RECORD FOR UNIT MASS**  
(Page 2/2)

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** Measure for Unit Mass \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

---

	<b>Specification</b>
<b>Glass 6 mm thick and 25 mm larger than measure</b>	<b>Yes / no</b>
<b>Rim plane to 0.25 mm</b>	<b>Yes / no</b>
<b>Temperature of water taken</b>	<b>Yes / no</b>
<b>Density obtained KT 20</b>	<b>Yes / no</b>
<b>Volume and measure factor determined</b>	<b>Yes / no</b>
<b>Action recommended</b> _____	



**VERIFICATION PROCEDURE FOR CAPPING MATERIAL**  
**(Page 1/3)**

**Purpose:**

To ensure that capping material meets Quality requirements.

**Inspection Equipment Required:**

1. Testing Machine
2. Melting Pot capable of holding a temperature between 265 to 290°F (129 to 143°C)
3. Three 2-inch (50 mm) cube molds
4. Ladle or other suitable pouring device
5. .002 feeler gauge and bar
6. Mineral oil
7. Straight bar

**Tolerance:**

All capping material shall conform to the following strength and thickness requirements:

Cylinder Compressive Strength psi (MPa)	Minimal Strength of Capping Material	Maximum Average Thickness of Cap	Maximum Thickness of Any Part of the Cap
500 to 7000 psi (3.5 to 50 MPa)	5000 psi (35 MPa) or cylinder strength, whichever is greater	1/4 inch (6 mm)	5/16 inch (8 mm)
Greater than 7000 psi (50 MPa)	Compressive strength not less than cylinder strength	1/8 inch (3 mm)	3/16 inch (5 mm)

**VERIFICATION PROCEDURE FOR CAPPING MATERIAL**  
**(Page 2/3)**

**Procedure:**

1. Melt sufficient capping material in melting pot until it reaches between 265 to 290°F (129 to 143°C).
2. Bring the mold parts to 68 to 86°F (20 to 30°C).
3. Coat all surfaces of cube molds with mineral oil.
4. After stirring thoroughly, use Ladle to begin casting the cubes. Quickly fill all three molds until the molten material reaches the top of the filling hole.
5. Allow time for maximum shrinkage to occur due to cooling and solidification to occur (approximately 15 minutes) and refill each mold with molten material.
6. After solidification occurs remove the cubes from the molds without breaking off the knob.
7. Remove oil, sharp edges, and fins from cubes.
8. Allow cubes to harden for a minimum of two hours before breaking.
9. Test the cubes in the compression machine and calculate the compressive strength.

**VERIFICATION RECORD FOR CAPPING MATERIAL**  
**(Page 3/3)**

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** Capping Material \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

**Compressive Strength at 2 hours (average of three), PSI** \_\_\_\_\_

**Material Meets specification requirements as outlined in Page 1/3.** \_\_\_\_\_

**VERIFICATION PROCEDURE FOR REUSABLE MOLDS**  
**(Page 1/2)**

**Purpose:**

This method provides instructions for checking all types of reusable molds.

**Inspection Equipment Required:**

1. Calipers or ruler readable 0.01 in.
2. Aggregate for dry rodding, (cylinder molds)
3. Supply of water for leak testing
4. Triangle for checking right angles

**Tolerance:**

Molds shall meet the dimensional requirements of **AASHTO M 205** for cylinder molds, and **KT-22** for beam molds.

**Procedure:**

1. Reusable plastic molds shall be dry rodded and checked for damage, as stated in **AASHTO M 205**.
2. All reusable molds shall be filled 90 - 95% of capacity with water and subjected to jarring and tapping.
3. After standing for a minimum of one hour, check molds for visible leakage.

**VERIFICATION RECORD FOR REUSABLE MOLDS**  
(Page 2/2)

Verified By: \_\_\_\_\_ Date: \_\_\_\_\_

Equipment: Reusable Molds \_\_\_\_\_ Verif. Frequency: \_\_\_\_\_

Previous Verif. Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment Used: \_\_\_\_\_

Verif. Equipment Identification: \_\_\_\_\_

Verif. Procedure Used: \_\_\_\_\_

**Inside Diameter**

**Inside Height**

**Top and Bottom Planes Perpendicular to Axis**

**Diameter Variation Within  $\pm 2\%$  (% of variation)**

**Satisfactory condition after dry rodding**

**Leakage**

**Materials React With or Injurious to Concrete**

### 5.2.7.6. CONCRETE STRUCTURES: CONTRACTOR'S QUALITY CONTROL PLAN

**NOTE:** This document is generally written in the imperative mood. The subject, "the *Contractor*" is implied. Also implied in this language are "shall", "shall be", or similar words and phrases. The word "will" generally pertains to decisions or actions of the Kansas Department of Transportation.

**1. General.** Provide equipment meeting the requirements listed below to conduct quality control testing. Verify the testing equipment with prescribed procedures. As a minimum, meet the verification schedule as outlined in **Table 1, Concrete Structures Evaporation Test Equipment**.

File all reports, records, and diaries developed during the progress of construction activities as directed by the Engineer. Files become the property of the Department.

Provide the following test data: Air temperature, concrete temperature, relative humidity, wind velocity and evaporation rate.

- Make copies of all test results and control charts readily available to the Engineer at the project site.

**Table 1: Concrete Structures Evaporation Test Equipment**

Equipment	Requirements (Range) [Accuracy]	Interval (months)
Relative Humidity	Verify (10 to 90%) [ $\pm 3\%$ ]	12
Wind Velocity	Verify (2 to 90 mph) [ $\pm 5\%$ ]	12
Thermometers (Air and Concrete)	Standardize (-20 to 60°C or -5 to 140°F) [ $\pm 1^\circ\text{C}$ or $2^\circ\text{F}$ ]	6

**2. Quality Control Organization.** Submit a listing of the names and phone numbers of individuals and alternates responsible for quality control administration and inspection. Provide an organizational chart that shows the specified lines of authority relating to quality control operations during production. Provide a copy of the organizational chart at the pre-construction conference.

**3. Quality Control Plan.** Prepare a Quality Control Plan detailing the monitoring of evaporation rate and actions to be taken once the evaporation rate exceeds the maximum stated within the specifications. As a minimum, provide:

- The name of the individual(s) responsible to initiate the plan
- The name of the individual(s) performing the tests and frequency of tests that will be performed
- Number of individuals to assist in the fogging operation
- Experience of individuals with fogging bridge decks
- Type of fogging equipment
- Curing procedure to be used

**4. Documentation.** Maintain adequate records of all tests. Indicate the nature and number of observations made. The Contractor's documentation procedures will be subject to approval of the Engineer before the start of the work and to compliance checks during the progress of the work.

**NOTE:** Section 5.2.7.7., Example of a Contractor's Concrete Structures Quality Control Plan for Controlling Evaporation, will provide the contractor a basic outline for the Quality Control Plan.



**5.2.7.7. EXAMPLE OF A CONTRACTOR'S CONCRETE STRUCTURES QUALITY CONTROL PLAN FOR CONTROLLING EVAPORATION**

To: (DISTRICT ENGINEER)

From: (CONTRACTOR(s) NAME)

Subject: Concrete Structures Quality Control Plan for Controlling Evaporation.

1. We are submitting our Concrete Structures Quality Control Plan, developed for:

Project No.:

Contract No.:

2. Evaporation Equipment calibration/verification papers are attached.

3. Quality Control Personnel:

3.1. The quality control program is under the direction of (NAME OF PERSON) who can be contacted at (ADDRESS AND TELEPHONE). This individual is responsible for initiating the fogging procedures to control the evaporation rate on the bridge deck.

3.2. Testing will be the responsibility of (NAME OF PERSON(s)). Testing will be performed every (HOURS) hours at (HOW MANY) locations across the bridge deck.

3.3. The following list are individuals (with the number of years of experience) assisting in the fogging operation:

4. Quality Control Equipment:

4.1. Type of fogging equipment is as follows:

4.2. The curing procedure to be used is as follows:

5. (NAME) will notify all appropriate KDOT personnel at least 24 hours before the scheduled work is to begin.





### **5.2.7.8 CEMENT TREATED BASE: CONTRACTOR'S QUALITY CONTROL PLAN (CTB)**

**NOTE:** This document is generally written in the imperative mood. The subject, "the *Contractor*" is implied. Also implied in this language are "*shall*", "*shall be*", or similar words and phrases. The word "*will*" generally pertains to decisions or actions of the Kansas Department of Transportation.

#### **1. GENERAL**

Provide qualified personnel and equipment meeting the requirements listed in the Department's Construction Manual to conduct quality control testing which conforms with the Sampling and Testing Frequency Chart for Cement Treated Base for Quality Control/Quality Assurance Projects in Appendix B of this Manual.

Calibrate and correlate the testing equipment with prescribed procedures and conduct tests in conformance with specified testing procedures as listed in the Department's Construction Manual. As a minimum, meet the calibration schedule as outlined in **Table 1, Cement Treated Base Materials Test Equipment**.

Maintain control charts on an ongoing basis.

File all reports, records, and diaries developed during the progress of construction activities as directed by the Engineer. Files become the property of the Department.

Provide the following:

- Make copies of all test results and control charts readily available to the Engineer at the project site.
- Copies of all failing test results (based on a moving average of four tests, when appropriate) and summary sheet sent by on a daily basis to the Construction Engineer.

#### **2. QUALITY CONTROL ORGANIZATION**

Submit a listing of the names and phone numbers of individuals and alternates responsible for quality control administration and inspection along with the proposed mix design data. Provide an organizational chart that shows the specified lines of authority relating both to mix design and quality control operations during production. Post a copy of the organizational chart in the Contractor's test facility.

The Contractor's quality control organization or private testing firms representing the Contractor must include individuals who are certified by KDOT, or a State approved equivalent, for the appropriate test methods. Only technicians certified in accordance with KDOT requirements may perform process control testing on the project.

#### **3. QUALITY CONTROL PLAN**

Prepare a Quality Control Plan detailing the type and frequency of inspection, sampling and testing deemed necessary to measure and control the various properties of materials and construction governed by the Specifications. As a minimum, detail sampling location and techniques, and test frequency to be utilized in the sampling and testing plan. The Department may utilize quality control sampling and testing performed by the Contractor for acceptance. Submit the Quality Control Plan to the Engineer in writing at the pre-construction meeting.

**3.1.** Identify the personnel responsible for the Contractor's quality control in the plan. This shall include the company official who will act as liaison with Department personnel, as well as the Certified Technician who will direct the inspection program. Quality control sampling, testing, and inspection shall be an integral part of the Contractor's quality control system. In addition to the above requirements, the Contractor's quality control system shall document the quality control requirements considered to be normal activities necessary to control the production and placing of a given product or material at an acceptable quality level. Retain the latest ten gradation samples for use by the Engineer. It is intended that sampling and testing be in accordance with standard methods and procedures, and that measuring and testing equipment be standard, properly calibrated and documented in the Quality Manual. Detail in the Quality Control Plan any alternative sampling method, procedure and inspection equipment to be used.

**3.1.1.** Elements of the Plan. Include all elements that affect the quality of the CTB including, but not limited to the following:

- Mix Designs
- Aggregate Production
- Quality of Components
- Stockpile Management
- Proportioning, including added water
- Mixing and transportation, including time from batching to completion of delivery
- Initial mix properties, including temperature and consistency
- Placement and consolidation
- Compressive strength
- Finishing and curing

**3.1.2.** Personnel Requirements:

Detail in the Plan:

- The frequency of sampling and testing, coordination of activities, corrective actions to be taken, and documentation.
- How the duties and responsibilities are to be accomplished and documented, and whether more than one Certified Technician is required.
- The criteria utilized by the Technician to correct or reject unsatisfactory materials.

Certified Technicians required duties:

- Perform and utilize quality control tests and other quality control practices to assure that delivered materials and proportioning meet the requirements of the mix designs, including temperature, slump and strength. Be available on the project site whenever CTB is being produced for use on or being placed on the project site.
- Periodically inspect all equipment utilized in transporting, proportioning, mixing, placing, consolidating, finishing, and curing to assure it is operating properly and that placement, consolidation, finishing, and curing conform to the mix design and other Contract requirements.

#### 4. DOCUMENTATION

Maintain records of all inspections and tests. Specify the nature and number of observations made, the number and type of deficiencies found, the quantities approved and rejected, and the nature of corrective action taken as appropriate in the records. The Contractor's documentation procedures will be subject to approval of the Engineer before the start of the work and to compliance checks during the progress of the work.

Charts and Forms.

Keep all conforming and non-conforming inspections and test results complete and available at all times to the Engineer during the performance of the work. Provide forms on a computer-acceptable medium where required. Document batch tickets and gradation data in accordance with Department requirements.

Chart test data for cement treated base, including gradation of combined aggregates, in-place CTB moisture, dry density and compressive strength, in accordance with the applicable requirements.

The Contractor may use other types of control charts as deemed appropriate. It is normally expected that testing and charting will be completed within 1 working day after testing.

All charts and records documenting the Contractor's quality control inspections and tests become property of the Department upon completion of the work.

#### 5. CORRECTIVE ACTION

Notify the Engineer when the moving average test result trend line for any property approaches the specification limits. Cease operations when 2 consecutive moving average points fall outside the specification limits, or 2 consecutive single compressive strength tests exceed the specification limits. Ceasing operations is the Contractor's responsibility. Quality control tests for this determination include aggregate gradation, compliance with the mix design band and in-place density of CTB.

Failure to cease operations for the conditions cited above will subject all subsequent material to rejection by the Engineer or acceptance at a reduced price, as determined by the Engineer.

The Engineer may examine materials represented by individual test results which lie beyond the Contractor's normal quality control testing variation. The investigation may be based on either Contractor or KDOT test results. The information from additional testing (including testing of in-place CTB) may be used to define unacceptable work according to **subsection 105.5d**. The Engineer will apply appropriate price reductions or initiate corrective action as determined by the Engineer.

If a dispute exists between the Engineer and Contractor about the validity of any test results, the MRC will perform referee testing. If 1 of the disputed KDOT test results was generated at the MRC, an Independent Laboratory agreeable to both parties shall be selected. The Independent Laboratory shall be approved by the AASHTO Accreditation Program for the tests being refereed. If referee testing indicates that the KDOT test results are correct, the Contractor is responsible for the cost of additional testing, including referee testing performed at the MRC. If the referee testing indicates that the Contractor test results are correct, KDOT is responsible for the cost of additional testing.

**6. Non-Conforming Materials.** Identify all non-conforming materials and products to prevent use, shipment and intermingling with conforming materials and products. Provide holding areas, mutually agreeable to the Engineer and Contractor.

The Engineer will determine if reclaiming or reworking of non-conforming materials is allowed rather than rejection of non-conforming materials.

**7. Testing Facilities.** Locate the Contractor's testing facility at the plant site or at the project site. Obtain approval of the facility by the Engineer before the commencement of mixture production. Any other laboratory location requires approval by the District Materials Engineer. Provide suitable space and specified testing equipment for use by the Contractor's quality control personnel to perform tests as required.

KDOT's Materials and Research Center is Accredited through the AASHTO Accreditation Program (AAP). If the contractor's QC laboratory is not participating in the AAP, then the contractor shall have an AAP approved laboratory or a manufacturer certified technician inspect the QC laboratory's equipment and perform calibrations and verifications annually. The contractor may perform the inspection, calibrations and verifications annually if the QC laboratory is participating in the AAP. The inspection, calibrations and verifications shall include all equipment necessary to perform testing on cement treated base.

Maintain a Quality Manual showing all calibrations performed on all test equipment and when next calibration is due for that equipment. As a minimum, follow the calibration/verification interval established in **Table 1, Cement Treated Base Materials Test Equipment**.

To facilitate communication between the Contractor and the Engineer regarding quality control, equip the Contractor's testing facility with the following:

- A telephone with a private line for the exclusive use of the testing facility's quality control personnel.
- A copying machine.
- A facsimile machine for use by contractor personnel and the Engineer.

**Table 1, Cement Treated Base Materials Test Equipment**

Equipment – Test Method	Requirements	Interval (months)
Mechanical Shakers – KT-02	Check Sieving Thoroughness.	12
General Purpose Balances, Scales and Masses – AASHTO M 231	Calibrate	12
Compression Testing Machine –KT-76	Standardize	12
	Verify plane of bearing blocks	12
	Clean and lubricate upper bearing block	6
Sieves – AASHTO M 92	Check Physical Conditions.	12
Slump Cones- KT-21	Check Critical Dimensions.	12
Unit Mass – KT-20	Standardize	12
Capping Material –KT-77	Check Strength.	3
Reusable Molds – KT-37	Calibrate	12
Nuclear Density Gauge – KT-36 & 38	Check for Uniformity	12
Ovens	Calibrate	12
Thermometers	Standardize	12

**8. Testing Requirements.** Take all samples for tests at random locations, selected as specified in the Contractors quality control plan and at the rates specified in the Sampling and Testing Frequency Chart for Portland Cement Concrete Pavement for Quality Control/Quality Assurance Projects in Appendix B-of Part V of this manual. Record and document all test results and calculations on data sheets that are acceptable to the Engineer. Record specific test results on a daily summary sheet approved by the Engineer to facilitate the computation of moving test averages. Base moving averages on 4 consecutive test results. Include a description of quality control actions taken (adjustment of aggregate or additive proportions in the mix, moisture adjustments, etc.) in the Daily Quality Control Summary Sheet. Post quality control charts and keep them current, showing both individual test results and moving average values. As a minimum, plot the single test values and the 4-test moving average values on approved control charts for the following properties:

- In-place moisture.
- Dry Density.
- Compressive strength including separate graph for PWL.
- Gradation of combined aggregates.

Plot individual test results in black for each test point. Connect points with a solid black line. Plot the moving average for each test variable in red starting with the fourth test. Connect the points with a dashed red line. Plot the Department's verification test results with green asterisks. Do not include the Department's verification tests in the moving average.

Indicate specification working range limits for single test results on the control charts using a dotted green line and for four point moving average results with a solid green line.

**NOTE: Section 5.2.7.9** of this manual, Example of a Laboratories Quality Manual for Cement Treated Base, will provide examples of equipment procedures to verify that equipment is in proper condition. Also, examples of records for calibrating/verifying equipment are presented.



#### **5.2.7.8.1. EXAMPLE OF A LABORATORY QUALITY MANUAL FOR CEMENT TREATED BASE**

This example is designed to provide the contractor with general guidelines in creating and maintaining a contractor's Quality Manual. The QC process requires records for equipment calibrations/verifications. Maintaining records in an orderly manner will assist the District Materials Engineer in quickly determining if the laboratory meets QC/QA requirements. Having the field laboratory fully prepared and the Quality Manual properly maintained represent two items that can keep the start of a project on schedule. It also aids in demonstrating the contractor's commitment to the QC process.

The following records are presented to illustrate what is required in the Quality Manual. Records need not be exactly as illustrated but should supply all necessary information concerning the equipment calibration/verification.

**NOTE:** After calibrating any force-load testing equipment (compression machine) a copy of the certification for the calibration device (proving ring, load cell, etc.) shall be attached to the calibration record.

**NOTE:** All equipment shall be verified immediately after repairs that may in any way affect the ability of the equipment to provide accurate readings as established during the calibration/verification process. Repairs may include new or replacement parts or mechanical or electrical adjustments, among other items.

**DISCLAIMER:** It is not the intent of these guidelines to endorse manufacturers, suppliers, calibrating services, etc. The examples are used to provide guidance in establishing a thoroughly developed Quality Manual.



# LABORATORY QUALITY MANUAL

## TABLE OF CALIBRATION/VERIFICATION DATES

**Revision Date 2018**

Equipment – Test Method	Calibration/Verification Intervals (months)	Next Due Date
Mechanical Shakers – KT-02		
General Purpose Balances, Scales and Masses – AASHTO M 231		
Compression Testing Machine –KT-76		
Sieves – ASTM E11		
Slump Cones- KT-21		
Unit Mass – KT-20		
Capping Material – KT-77		
Reusable Molds – KT-37		
Nuclear Density Gauge – KT-41		
Ovens		
Thermometers		

May 23, 2022

**VERIFICATION PROCEDURE FOR MECHANICAL SIEVE SHAKER  
(Page 1/2)**

**Purpose:** This method provides instructions for checking the length of time the mechanical sieving device must run. This reflects the procedure in to meet the tolerances as specified in **KT-02 9**.

**Inspection Equipment Required:**

1. Set of 8" dia. sieves (4, 8, 16, 30, 50, 100, 200)
2. Timer
3. Balance, readable to 0.1 g.
4. Sample of fine aggregate.

**Efficiency:**

The difference between two percent retained values on any sieve shall not exceed 0.5 percent by mass.

**Procedure (See KT-02 Section 9.):**

1. Determine the initial mass of the sample.
2. Place sample of aggregate in nested sieves. Fit the sieve nest with a lid and a pan.
3. Place sieves in shaker & set timer for 6 minutes.
4. Determine and record the percent retained of each sieve size.
5. Collect and recombine all of the material.
6. Place sieves in shaker & set timer for 7 minutes.
7. Determine and record the percent retained of each sieve size.
8. If the difference between two percent retained values on any sieve does not exceed 0.5 percent by mass, then the mechanical sieve shake is verified. If not, repeat the procedure for 2 longer time periods or repair/replace the mechanical sieve shaker.

May 23, 2022

**VERIFICATION RECORD FOR MECHANICAL SHAKER**  
**(Page 2/2)**

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** \_\_\_\_\_ Mechanical Shaker \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

Original Dry Mass (ODM) \_\_\_\_\_

Mass Retained on Each Sieve

	#4	#8	#16	#30	#50	#100	#200
1st Run							
2nd Run							
Difference							
% of ODM							

# CALIBRATION OF BALANCES

Page 1/3

March 30, 1995

ABC PACKERS INC.

SCOPE OF WORK FOR LABORATORY BALANCES:

Definitions are on next page.

1. The weighing environment is checked for anything that would effect the ability of the balance to weigh accurately for example: direct air currents, direct sunlight, objects stuck under the balance or magnets in close proximity to the balance.
2. The balance is checked for errors in zero, sensitivity, calibration, comer load, linearity, repeatability and tare accuracy. Any errors are noted.
3. The balance is thoroughly cleaned and disassembled. Parts subject to wear or damage are inspected. On mechanical balances, this includes but is not limited to knife edges, arrestment mechanism, switches, pan brake assemblies and weight lifting assemblies. On electronic balances, the measuring cell and flextures are inspected. Circuit boards and switches are inspected for contamination and corrosion.
4. Any errors noted in step two are corrected through adjustments or replacement of minor parts. If the balance cannot be returned to factory specifications through this method, the using personnel are consulted as to the need for further repairs.
5. The balance is reassembled and final checks are made as in step two. Final calibration adjustments are made.
6. Applicable GLP log books are annotated.
  - A. All tests are performed with Class 1 stainless steel weights traceable to the NIST and are calibrated at least annually.
  - B. A certificate of weight traceability to the NIST is provided to each functional area. This certificate lists all the balances serviced in that area and the serial number of the weights used, their calibration date, the NIST trace number and the technician calibration number.

## DEFINITIONS:

Balance = Weighing device, generally with a resolution of 1 part in 12,000 or greater. Top loading balances will have a resolution of up to 1 part in 1,200,000 and sensitivity down to 1 milligram i.e. 1200.000 gram  $\pm$  .001 gram. Analytical balances will have a resolution of up to 1 part in 4,100,000 and sensitivity down to .01 milligram i.e. 41.00000 gram  $\pm$  .00001 gram. Micro-balances will have a resolution of up to 1 part in 200,000,000 sensitivity down to .0000001 gram.

Calibration = The accuracy of the balance, usually at full capacity, as compared to known standards.

Class 1 = A published standard for weights from the NIST. The standard dictates the materials, configuration and tolerance of the weights.

Corner loads = The deviation of the indicated weight between the center of the pan and the front, rear, left and right of the pan. This test is performed at 2/3 of maximum capacity.

Electronic Balance = A balance deriving its indicated weight from a force restoration coil measuring cell or high resolution load cell.

Factory specifications = The balance manufacturers specifications for all adjustments, usually  $\pm$  1 final count (least significant digit).

Flexure = Parts of the measuring cell. The accuracy of all adjustments is dependent on the condition of these parts.

GLP = Acronym. Stands for Good Laboratory Practices. Laboratories under this standard must establish a plan for weighing accuracy control.

Knife edges = The pivot points of the balance beam in mechanical balances.

Mechanical Balance = A high resolution balance deriving its indicated readout from the mechanical movement of a balance beam and a system of built in standard comparison weights.

NIST = Acronym. Stands for the National Institute for Standards and Technology. This is the new name for the National Bureau of Standards (NBS).

Pan brake = Part of a mechanical analytical balance used to stop pan swing when the balance is arrested.

DEFINITIONS, CONTINUED

Repeatability = Test performed on all balances to determine if it indicates the same weight and returns to zero every time a weight is applied to and removed from the pan. This test is normally performed with a weight that is near the normal usage of the balance if known or near the mid-range of the balance. The weight is placed on the balance a minimum of three times to get a plus or minus reading.

Sensitivity = On mechanical balances this test determines the accuracy of the beam travel or optical range of the balance. On electronic balances this is the lightest weight that the balance will accurately respond to.

Tare accuracy = This test is used on mechanical balances to determine if the balance reads the same with or without the tare.

**Certificate of Weight Traceability**

To: KANSAS DEPARTMENT OF TRANSPORTATION  
2300 VAN BUREN TOPEKA KANSAS

The following balances have been calibrated on SEE BELOW

Service representative: M. J. Gillman

Balance	Serial Number	
<u>3/17/95 OHAUS E4000I</u>	<u>2274</u>	<u>Agg. CONCRETE</u>
<u>3/17/95 METTLER P10</u>	<u>192446</u>	<u>Agg. CONCRETE</u>
<u>3/17/95 A&amp;D FW-100KA1</u>	<u>C.5707023</u>	<u>CONCRETE</u>
<u>3/17/95 A&amp;D EP-6000</u>	<u>6401205</u>	<u>METALS</u>
<u>3/17/95 SARTORIUS I8100P</u>	<u>40210240</u>	<u>Cement CONCRETE</u>
<u>3/27/95 SHIMADZU AEG-220</u>	<u>D400400141</u>	<u>Cement CONCRETE</u>
<u>3/27/95 A&amp;D EP-20KB</u>	<u>3808903</u>	<u>Agg. CONCRETE</u>
<u>3/27/95 A&amp;D EP-20KB</u>	<u>3809190</u>	<u>Agg. CONCRETE</u>

Serial number of mass standards:  
E136/AP-9M01/AP-3M01/AP-9M04/AP-9Q94  
 Calibration date: MAY 4, 1994 / SEPTEMBER 26, 1994  
 NIST test number: 732/246308/94-0107  
 State certification number: 5146-141 KS.  
 Date of issue: 3/30/95

**Alfie Packers Inc.**  
 8901 J Street  
 Omaha Ne. 68127  
 402-592-9102

May 23, 2022

## REPORT FORM FOR COMPRESSION MACHINE

(Page 1/2)

Calibration performed according to ASTM E 4 (latest publication).

- Must provide Load Cell readings, Compression Machine readings and percent error for each force reading.

CONTRACTOR: \_\_\_\_\_ DATE: \_\_\_\_\_

LOCATION: \_\_\_\_\_

CALIBRATION SERVICE NAME: \_\_\_\_\_

CALIBRATOR: \_\_\_\_\_

NEXT LOAD CELL/RING CALIBRATION DATE: \_\_\_\_\_

LOWER RANGE OF DEVICE (CLASS A VALUE): \_\_\_\_\_

UPPER RANGE OF DEVICE: \_\_\_\_\_

TEMPERATURE CORRECTION FACTOR USED: \_\_\_\_\_

TESTING MACHINE MANUFACTURER: \_\_\_\_\_

TESTING MACHINE SERIAL NUMBER: \_\_\_\_\_

CALIBRATION WITNESS: \_\_\_\_\_

CHECK PLANE OF BEARING BLOCKS?: Y/N \_\_\_\_\_

CLEAN/LUBRICATE UPPER BEARING BLOCK?: Y/N \_\_\_\_\_

CALIBRATOR SIGNATURE: \_\_\_\_\_

COMMENTS: \_\_\_\_\_

**EXAMPLE FOR VERIFICATION RECORD OF TESTING MACHINE**  
(Page 2/2)

**SATEC** Materials Testing Equipment

SATEC Systems, Inc.  
800 Liberty Street  
Croydon City, PA 17021-5006  
1-800-798-8379

**Report and Certificate of Verification**

This is to certify that the following described machine has been verified in accordance with ASTM E4-84 and has found to be within a tolerance of ±1.0 %

Location: Kansas Dept. of Transportation  
2500 Van Buren Street  
Topeka, KS 66611

Machine: Balance  
Model: Compression Tester  
Serial No: 84249864

Mode of Verification: Compression  
Next Verification Due: 04/04/97

By: Larry Belkroeder

Range Verified: 1000 to 10000 Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	
1000	997	3	0.3%	2
2000	1998	1	0.05	3
4000	3998	11	0.28	3
6000	5994	6	0.1%	3
8000	7997	3	0.4%	3
10000	9994	78	0.77	3

Range Verified: 500 to 5000 Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	
500	498.8	1.2	0.24	1
1000	1007.5	-7.5	-0.7%	2
2000	2008.9	-1.0	0.05	3
3000	2998.4	1.6	0.52	3
4000	3999.4	0.6	0.15	3
5000	4993.2	6.8	0.14	3

Range Verified: 250 to 2500 Lbs.

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	
250	249.46	0.54	0.21	1
500	500.24	-0.24	0.05	1
1000	1001.27	-1.27	0.13	2
1500	1497.28	2.72	0.18	3
2000	1997.50	2.50	0.12	3
2500	2501.36	-1.36	0.05	3

Range Verified: 0

Machine Reading	Device Reading	Machine Error		C.D. Code
		Lbs.	%	

LOAD VALUES CORRECTED FOR A TEMPERATURE OF 72 DEGREES FAHRENHEIT.

APPROXIMATE METHOD USED:  
Y Follows the Force Method  
S Set the Load Method

Used Following Device No. 1: Strain Gage  
Device Serial Number: 84249864  
Load Following Device Verified: 04/19/95

**SATEC Verified Equipment Information:**

C.D. Code	Serial Number	MANUFACTURE	Verification High Value	Location - High Class # Status	Verification Date	Location of Agency Issuance/Number
1	350411A	STRAINHEAD SC	400	3436	04/01/96	BJT 011 0812
2	320000E	STRAINHEAD SC	2000	5200	04/18/95	BJT 011 0812
3	320000C	STRAINHEAD SC	2000	1149	04/05/95	BJT 011 0812
4	4000011	STRAINHEAD SC	10000	8920	04/05/95	BJT 011 0812
5	320000F	STRAINHEAD SC	2000	18780	07/06/94	BJT 011 0808
6	0900	TRIC LANE - Weigh In	50	901	02/12/95	HSBT 011 0808
T						

Maintained and/or repaired in accordance with ASTM Specification E4-89 and SATEC Systems, Inc. Procedure for Calibration Function and Compression Fatigue Machines. The Testing Device(s) used for this verification have been calibrated per ASTM Specification E4-89 and are traceable to the NATIONAL BUREAU OF STANDARDS technology.

Date of Verification: 04/04/96

Verified By:



Service Engineer - SATEC Systems, Inc.

Witness: \_\_\_\_\_



## **VERIFICATION PROCEDURE FOR SIEVES**

**(Page 1/2)**

### **Purpose:**

This method provides instructions for checking the physical condition of laboratory tests sieves ranging in size 3 in. (75 mm) to #200 (0.075 mm).

### **Inspection Equipment Required:**

1. A caliper readable to 0.01 mm (use for #4 or coarser).

### **Tolerances:**

Sieves shall meet physical requirements specified in **AASHTO M 92 (ASTM E11)**.

### **Procedure:**

(Steps 1 & 2 apply to sieves having openings greater than 4.75 mm)

1. Select an adequate number of individual sieve openings (3 or 4) along a 45° line. Measure and record the sieve openings to verify that the size opening indicated on the label is correct.
2. Repeat step 1, rotating the sieve 90°.
3. Inspection the general condition of the sieve. Check the frame and solder joints for cracks or holes (check for pinholes in the finer sieves).
4. Make sure the sieves have an appropriate label.
5. Check for tightness of the wires on each individual sieve.



## VERIFICATION PROCEDURE FOR SLUMP (Page 1/2)

### **Purpose:**

This method provides instructions for checking the critical dimensions of the slump cone.

### **Inspection Equipment Required:**

1. Calipers or ruler readable to 0.01 in.
2. Straightedge or ruler.
3. Digital micrometer.
4. Gauge for measuring hemispherical end of tamping rod.

### **Tolerance:**

Equipment shall meet the dimensional tolerances specified in the test method.

### **Procedure:**

#### *(CONE)*

1. Measure the inside diameter at the top of the cone to the nearest 0.01 in. by taking two readings 90° apart using the calipers and record the results.
2. Invert the cone and repeat the procedure.
3. Place the cone on a flat surface. Measure and record the depth of the cone by using the calipers and a straightedge and record the results.
4. Measure the thickness of the cone to the nearest 0.001 in. by taking 2 readings 90° apart at the bottom of the cone & record the results.

#### *(TAMPER)*

1. Measure the diameter of the tamping rod to the nearest millimeter by taking two readings 90° apart using the micrometer and record the results. Measure the length of the rod to the nearest 0.1 in. and record the results.
2. Measure the hemispherical end of the rod and record the results.

**VERIFICATION RECORD FOR SLUMP**  
(Page 2/2)

Verified By: \_\_\_\_\_ Date: \_\_\_\_\_

Equipment: Slump Cone and Tamping Rod Verif. Frequency: \_\_\_\_\_

Previous Verif. Date: \_\_\_\_\_ Next Due Date: \_\_\_\_\_

Verification Equipment Used: \_\_\_\_\_

Verif. Equipment Identification: \_\_\_\_\_

Verif. Procedure Used: \_\_\_\_\_

	<u>Cone</u>		Specification
Top inside diameter, inches	1)	_____	4" +/- 1/8"
	2)	_____	
Bottom inside diameter, inches	1)	_____	8" +/- 1/8"
	2)	_____	
Depth of Cone , inches	1)	_____	12" +/- 1/8"
Wall thickness, inches	1)	_____	Not less than 0.045"
	2)	_____	
<u>Tamping Rod</u>			
Diameter, inches	1)	_____	5/8"
	2)	_____	
Length, inches		_____	Approx. 24"
Hemispherical end		_____	Yes / no
Action recommended		_____	

## VERIFICATION PROCEDURE FOR UNIT MASS (Page 1/2)

### **Purpose:**

This method provides instructions for calibrating measures used in obtaining unit mass.

### **Inspection Equipment Required:**

1. Balance conforming to **Part V 5.9. Sampling and Test Methods Forward**
2. 0.01 in (0.25 mm) feeler gauge.
3. 1/4 in (6 mm) thick glass plate at least 1 in (25 mm) larger than the measure.
4. Water pump or chassis grease.
5. Thermometer.

### **Tolerance:**

The bowls and measures shall conform to the dimensions found in **KT-20**.

### **Procedure:**

1. Place glass plate on rim and attempt to insert feeler gauge.
2. Fill measure with room temperature water and cover in such a way as to dispel air bubbles and excess water.
3. Determine the mass of water in the measure.
4. Determine the temperature of the water, and obtain its density from **KT-15**.
5. Calculate the volume,  $V$ , of the measure by dividing the mass of the water required to fill the measure by its density.
6. Calculate the factor for the measure ( $1/V$ ) by dividing the density of the water by the mass required to fill the measure.

**VERIFICATION RECORD FOR UNIT MASS**  
(Page 2/2)

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** Measure for Unit Mass **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

---

	<b>Specification</b>
<b>Glass 6 mm thick and 25 mm larger than measure</b>	<b>Yes / no</b>
<b>Rim plane to 0.25 mm</b>	<b>Yes / no</b>
<b>Temperature of water taken</b>	<b>Yes / no</b>
<b>Density obtained KT 20</b>	<b>Yes / no</b>
<b>Volume and measure factor determined</b>	<b>Yes / no</b>
<b>Action recommended</b> _____	

**VERIFICATION PROCEDURE FOR CAPPING MATERIAL**  
**(Page 1/3)**

**Purpose:**

To ensure that capping material meets Quality requirements.

**Inspection Equipment Required:**

1. Testing Machine
2. Melting Pot capable of holding a temperature between 265 to 290°F (129 to 143°C)
3. Three 2-inch (50 mm) cube molds
4. Ladle or other suitable pouring device
5. .002 feeler gauge and bar
6. Mineral oil
7. Straight bar

**Tolerance:**

All capping material shall conform to the following strength and thickness requirements:

Cylinder Compressive Strength psi (MPa)	Minimal Strength of Capping Material	Maximum Average Thickness of Cap	Maximum Thickness of Any Part of the Cap
500 to 7000 psi (3.5 to 50 MPa)	5000 psi (35 MPa) or cylinder strength, whichever is greater	1/4 inch (6 mm)	5/16 inch (8 mm)
Greater than 7000 psi (50 MPa)	Compressive strength not less than cylinder strength	1/8 inch (3 mm)	3/16 inch (5 mm)

**VERIFICATION PROCEDURE FOR CAPPING MATERIAL**  
**(Page 2/3)**

**Procedure:**

1. Melt sufficient capping material in melting pot until it reaches between 265 to 290°F (129 to 143°C).
2. Bring the mold parts to 68 to 86°F (20 to 30°C).
3. Coat all surfaces of cube molds with mineral oil.
4. After stirring thoroughly, use Ladle to begin casting the cubes. Quickly fill all three molds until the molten material reaches the top of the filling hole.
5. Allow time for maximum shrinkage to occur due to cooling and solidification to occur (approximately 15 minutes) and refill each mold with molten material.
6. After solidification occurs remove the cubes from the molds without breaking off the knob.
7. Remove oil, sharp edges, and fins from cubes.
8. Allow cubes to harden for a minimum of two hours before breaking.
9. Test the cubes in the compression machine and calculate the compressive strength.



**VERIFICATION RECORD FOR CAPPING MATERIAL**  
**(Page 3/3)**

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** Capping Material \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Verification Equipment Used:** \_\_\_\_\_

**Verif. Equipment Identification:** \_\_\_\_\_

**Verif. Procedure Used:** \_\_\_\_\_

**Compressive Strength at 2 hours (average of three), PSI** \_\_\_\_\_

**Material Meets specification requirements as outlined in Page 1/3.** \_\_\_\_\_

**VERIFICATION PROCEDURE FOR REUSABLE MOLDS**  
**(Page 1/2)**

**Purpose:**

This method provides instructions for checking all types of reusable molds.

**Inspection Equipment Required:**

1. Cup grease or Vaseline
2. Two glass plates great than 6 inches square
3. Water
4. Triangle for checking right angles

**Tolerance:**

Molds shall meet the dimensional requirements of **KT-37** for cylinder molds.

**Procedure:**

1. Coat one end of the mold without the collar with cup grease or Vaseline to form a seal and then placing it on a glass plate which should be placed in a level position on a scale.
2. Coat the other end of the mold with cup grease or Vaseline and then the mold and two glass plates are weighed.
3. Fill the mold with  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ) water after which the second glass plate should be placed on top of the mold in such a way as to eliminate air bubbles and excess water.
4. Remove any excess water by carefully wiping off the mold and plates.
5. Determine the final weight of the mold, water and glass plates.
6. Calculate the volume of the mold using  $62.243 \text{ lb/ft}^3$  ( $997 \text{ kg/m}^3$ ) as the density of water.

Calculation:

Mass of water = mass of mold, plates and water – mass of mold and plates

Volume ( $\text{ft}^3$ ) = mass of water (lbs.)/62.243

**VERIFICATION RECORD FOR REUSABLE MOLDS**  
(Page 2/2)

**Verified By:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Equipment:** Reusable Molds \_\_\_\_\_ **Verif. Frequency:** \_\_\_\_\_

**Previous Verif. Date:** \_\_\_\_\_ **Next Due Date:** \_\_\_\_\_

**Volume:**

**VERIFICATION PROCEDURE FOR THERMOMETERS**  
**(Page 1/2)**

**FORM DATE:** \_\_\_\_\_

**Purpose:**

This method provides instructions for verifying the settings on general-purpose thermometers.

**Inspection Equipment Required:**

1. A calibrated thermometer graduated in 2.0°F (1.0°C) increments having a range which includes the temperature range to be checked.
2. A clothes pin to hold the thermometer in such a manner as to enable the operator to read the scale easily.
3. A container well to retain heat for constant temperature readings.
4. A hot plate to heat the liquid (oil) in the container well.

**Procedure:**

1. Place the thermometer inside the container well with the clothes pin attached to the thermometer.
2. Take the first reading when the temperature has stabilized.
3. Take as many readings as necessary to determine the "laboratory thermometer setting" vs "actual calibrated reading."

**VERIFICATION RECORD FOR THERMOMETERS**  
**(Page 2/2)**

**Specification Interval:** \_\_\_\_\_

**Model No.** \_\_\_\_\_ see below \_\_\_\_\_

**Serial No .** \_\_\_\_\_ see below \_\_\_\_\_

**Date :** \_\_\_\_\_

**Calibration/Verification Performed by :** \_\_\_\_\_

**Cal./Ver. Procedure Reference:** See Verification Procedure for Thermometers

**Previous Calibration/Verification Date :** \_\_\_\_\_

**Next Calibration/Verification Due Date :** \_\_\_\_\_

**Calibration/Verification Equipment Used :** \_\_\_\_\_

**Model/Serial No. of C/V Equipment Used :** \_\_\_\_\_ see below \_\_\_\_\_

1. Equipment thermometer reading \_\_\_\_\_ see below \_\_\_\_\_

2. Calibrated thermometer reading \_\_\_\_\_ see below \_\_\_\_\_

<u>Equipment Thermometer Designation</u>	<u>Equipment Thermometer Reading</u>	<u>Calibrated Thermometer Designation</u>	<u>Calibrated Thermometer Reading</u>
--	--	---	---

# VERIFICATION PROCEDURE FOR OVENS (Page 1/2)

Form Date: \_\_\_\_\_

## **Purpose:**

This method provides instructions for verifying the accuracy of the temperature settings and the tolerance on ovens.

## **Inspection Equipment Required:**

1. A calibrated thermometer graduated in 2.0 °F (1.0°C) increments having a range that includes the temperature range to be checked.
2. A brass thermometer well to retain heat while the oven door is open. This is essential for a constant temperature reading.
3. A clothes pin to hold the thermometer in such a manner as to enable the operator to read the scale easily from outside or inside the oven.

## **Tolerance:**

Drying ovens shall be capable of maintaining a constant temperature range listed in the appropriate test methods.

## **Procedure:**

1. Place the thermometer inside the brass well with the clothes pin attached to the thermometer. Position the thermometer on the shelf where the samples are normally dried.
2. Take the first reading at least 1 hour after closing the oven (oven should remain undisturbed).
3. Take as many readings as necessary to determine if the temperature range is within the specified tolerance (three consecutive readings, taken no less than 1/2 hr apart, within tolerance allowed are adequate).
4. Adjust the temperature of the oven if an observed temperature reading is outside the tolerance specified (allow at least 1/2 hr for the temperature to stabilize between each adjustment). Return to step 3.

Form Date \_\_\_\_\_

**VERIFICATION RECORD FOR OVENS**  
**(Page 2/2)**

Verified by \_\_\_\_\_ Date \_\_\_\_\_

Verif. Frequency \_\_\_\_\_

Identification No.: \_\_\_\_\_

Prev. Verif. Date: \_\_\_\_\_ Next Due Date : \_\_\_\_\_

Verif. Equip. Used Cal. Therm. Verif. Procedure Verification Procedure for Ovens

Temperature Range

Temperature*	Oven Dial Reading	Correction Factor
--------------	-------------------	-------------------

_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Action Recommended: Repair \_\_\_\_ Replace \_\_\_\_ None X

\*This thermometer has been tested by comparison with standards certified by NIST. If the correction is “+” the true temperature is higher than the thermometer reading. If the correction is “-” the true temperature is lower than the thermometer reading

## 5.3 MIX DESIGN METHODS

### 5.3.1 CONCRETE MIX DESIGN

#### 1. Scope.

This method covers the procedure for designing concrete mixes and is based on the absolute volumes of the various components of the mix, i.e.: the absolute volumes of cementitious materials, aggregate, water and air in one cubic yard of concrete.

#### 2. Procedure.

2.1. Specifications govern the following elements of concrete mixtures:

2.1.1. Minimum Cement Content or "Cement Factor" (CF) expressed as pounds per cubic yard of concrete.

2.1.2. Maximum allowable water content or water-cement ratio (W/C) expressed as pounds of water per pound of cement.

2.1.3. When air entrained concrete is specified, the air content is expressed as percent of the volume of the concrete.

NOTE: When air entrained concrete is not specified, a percentage of entrapped air is used during design. Experience has shown that the entrapped air is usually between 2% and 4%.

Since the quantities of cementitious materials, water and air are limited by specifications, the volumes occupied by each of these elements are calculated. Calculations are then made to determine the quantity of aggregate required, when added to the combined volumes of other ingredients, to result in a cubic yard of mixed concrete.

#### 3. Calculations.

3.1. Secure one or more copies of **KDOT Form No. 694, CONCRETE MIX DESIGN**. (See Example.)

3.2. Complete Part I of the form. This includes the class of concrete, the aggregate designation, the water-cement ratio, specified minimum cement factor, percent air, and the specific gravity (Bulk, Saturated Surface Dry Basis) of each aggregate.

The specific gravity is determined by tests conducted on samples obtained from project stockpiles. Due to differences in processing and gradation, there may be an appreciable difference between the specific gravity of the aggregate submitted to the Laboratory and the specific gravity of the aggregate in the project stockpiles.

3.3. Complete Part II of the form by calculating the volume, in cubic feet, occupied by the cementitious materials, water and air in a cubic yard of the mixture. Then subtract the sum of these values from 27 to determine the volume of aggregate that must be added to produce a cubic yard of concrete.

3.4. Complete Part III as follows:



**3.4.1.** Calculate the volume occupied by 100 lbs. of combined aggregate.

**3.4.2.** Using simple proportioning, calculate the number of pounds of combined aggregate required to produce the volume of aggregate determined in Part II.

NOTE: The basic formula in Parts II and III is:

$$\text{Absolute volume (cu. ft. )} = \frac{\text{Weight (lbs. )}}{\text{spec. grav.} \times 62.4}$$

**3.5.** Complete Part IV to determine the weight in pounds of each ingredient in one cubic yard of concrete.

Calculate the saturated, surface dry weight of each individual aggregate in the batch by multiplying the total weight of aggregate as determined in Part III by the design percentage for each aggregate.

**3.6.** If the aggregate contains free moisture, as determined by **KT-24**, the initial batch weight is multiplied by the percent of free moisture in the aggregate and this quantity is added to the initial batch weight. An equivalent amount must then be deducted from the pounds of water computed under Part IV. If the aggregate is absorptive, as determined by **KT-24**, the aggregate weight must be reduced by the percent of absorption and the computed water requirement must be increased by a like amount. Since moisture conditions of aggregates may change throughout a given pour, the initial moisture conditions will govern only as long as the moisture content remains the same. The batch weights thus determined can easily be converted from pounds per cubic yard to pounds per sack or any other convenient unit required for the batching operation.

**3.7.** Complete the last page to determine the combined aggregate gradation. Include the percent retained for each sieve and the cumulative percent retained as determined in accordance with **KT-02**.

Calculate the gradation parameters of the mixture.

**KANSAS DOT  
CONCRETE MIX DESIGN**

**PRINT ALL REQUIRED PAGES**

Project Number \_\_\_\_\_ Spec Max W/C \_\_\_\_\_ \* Design Air \_\_\_\_\_  
 Contract Number \_\_\_\_\_ \* Design W/C \_\_\_\_\_ Design Slump \_\_\_\_\_  
 Concrete Class \_\_\_\_\_ Spec Min CF \_\_\_\_\_  
 Concrete Producer \_\_\_\_\_ \* Design CF \_\_\_\_\_ (includes all cementitious)  
 Aggregate Designation \_\_\_\_\_ \*Fields are required for batch calculations.

	Material Type or Name	Producer		Official Quality	Amount in Mix*	Specific Gravity
		Name	ID Number			
Aggregate No. 1						
Aggregate No. 2						
Aggregate No. 3						
Aggregate No. 4						
Cement						
Other Cementitious No. 1						
Other Cementitious No. 2						
Water						
Air Entraining Admixture						
Admixture No. 1						
Admixture No. 2						
Admixture No. 3						

\* Amount in Mix column: Use whole number percentages (i.e. 40 or 15) for aggregates and cementitious materials; assume oz/cy for admixtures.

Note: Water adjustments should be made when admixtures are used at large dosages (i.e. dosages of accelerators, corrosion inhibitors, SRAs, etc.)

Mix Design Used Previous: \_\_\_\_\_ KDOT Mix Design Number \_\_\_\_\_ (if known) Date Last Used \_\_\_\_\_

Please include the following information along with this completed form:

- Materials Certifications
- Compressive Strength Results (KT-76)
- Permeability Test Results (KT-73, KT-79, or AASHTO T-277)
- Reactivity Test Results (ASTM C 1567, if SCMs are used)

Please fill in the table to the right with the test results, in addition to providing hard copies of the actual test reports

MIX DESIGN TEST RESULTS	
Air Content, %	
Slump, in.	
Compressive Strength (28 day)	
Only one of _____ KT-73	
the three is _____ KT-79	
required: AASHTO T-277	
ASTM C 1567 (if necessary)	

**NOT VALID UNTIL SIGNED**

**CLICK TO SIGN**

NOTE: Please make sure that when this form is submitted to the construction or district office, ensure that all three (3) pages are included.

**ABSOLUTE VOLUME METHOD FOR ONE CUBIC YARD**

*Determine the Absolute Volume of Aggregates Required*

Cement Volume	$\frac{\text{Design CF} \times \% \text{ Cement}}{\text{S.G.} \times 62.243} = \frac{0 \times 0.0\%}{0.00 \times 62.243} =$	-	cu. ft.
Other Cementitious Volume	$\frac{\text{Design CF} \times \% \text{ Other}}{\text{S.G.} \times 62.243} = \frac{0 \times 0.0\%}{0.00 \times 62.243} =$	-	cu. ft.
Other Cementitious Volume	$\frac{\text{Design CF} \times \% \text{ Other}}{\text{S.G.} \times 62.243} = \frac{0 \times 0.0\%}{0.00 \times 62.243} =$	-	cu. ft.
Total Cementitious Volume	=	-	cu. ft.
Water Volume	$\frac{\text{Design CF} \times \text{Design w/c}}{62.243} = \frac{0 \times 0.00}{62.243} =$	-	cu. ft.
Air Volume (Entrained and Entrapped)	0.0% X 27 =	-	cu. ft.
Absolute Volume of Cementitious, Water, Air, and Admixtures	=	-	cu. ft.
Absolute Volume of Aggregate Required	27.00 - - =	27.0000	cu. ft.

*Determine the Absolute Volume of 100 lb of Combined Aggregates*

$\frac{\% \text{ Aggregate No. 1} \times 100 \text{ lb}}{\text{S.G. No. 1} \times 62.243} = \frac{0\% \times 100}{0.00 \times 62.243} =$	-	cu. ft.	
$\frac{\% \text{ Aggregate No. 2} \times 100 \text{ lb}}{\text{S.G. No. 2} \times 62.243} = \frac{0\% \times 100}{0.00 \times 62.243} =$	-	cu. ft.	
$\frac{\% \text{ Aggregate No. 3} \times 100 \text{ lb}}{\text{S.G. No. 3} \times 62.243} = \frac{0\% \times 100}{0.00 \times 62.243} =$	-	cu. ft.	
$\frac{\% \text{ Aggregate No. 4} \times 100 \text{ lb}}{\text{S.G. No. 4} \times 62.243} = \frac{0\% \times 100}{0.00 \times 62.243} =$	-	cu. ft.	
	cu. ft. =	-	cu. ft.
Total Aggregate Required for One Cubic Yard	$= \frac{100 \times 27.00}{0.0000} =$	#DIV/0!	lbs.

*Batch Weights*

Cement	0 X 0.0% =	-	lbs.
Other Cementitious	0 X 0.0% =	-	lbs.
Other Cementitious	0 X 0.0% =	-	lbs.
Water (total free water)	0 X 0.00 =	-	lbs.
	(	-	gallons)
Aggregate No. 1	#DIV/0! X 0.0% =	#DIV/0!	lbs.
Aggregate No. 2	#DIV/0! X 0.0% =	#DIV/0!	lbs.
Aggregate No. 3	#DIV/0! X 0.0% =	#DIV/0!	lbs.
Aggregate No. 4	#DIV/0! X 0.0% =	#DIV/0!	lbs.
Weight for One Cubic Yard	=	#DIV/0!	lbs.
Concrete Unit Weight	=	#DIV/0!	lbs./cu.ft.
Air Free Unit Weight	=	#DIV/0!	lbs./cu.ft.

### AGGREGATE GRADATION

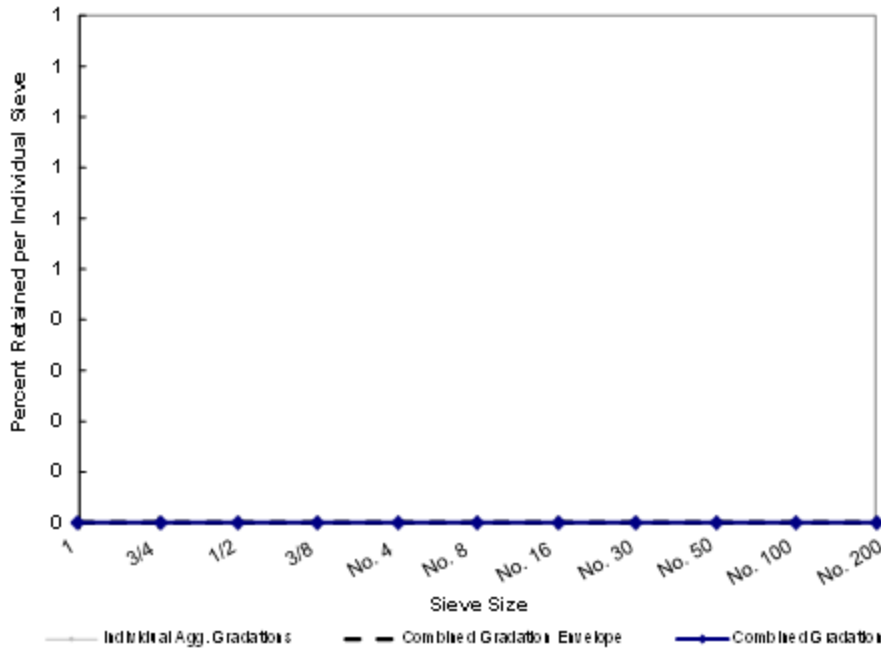
Sieve Size (inches)	Aggregate No. 1	Aggregate No. 2	Aggregate No. 3	Aggregate No. 4	Cum. % retained	% retained per sieve	Gradation Envelope	
	N/A	N/A	N/A	N/A			0	
1					0	0	UPPER	LOWER
3/4					0	0	N/A	N/A
1/2					0	0	N/A	N/A
3/8					0	0	N/A	N/A
No. 4					0	0	N/A	N/A
No. 8					0	0	N/A	N/A
No. 16					0	0	N/A	N/A
No. 30					0	0	N/A	N/A
No. 50					0	0	N/A	N/A
No. 100					0	0	N/A	N/A
No. 200					0	0.0	N/A	N/A

Fineness Modulus    0.00    0.00    0.00    0.00    0.00    TOTAL

NOTE: Gradation envelope will not be shown on the graph for following gradations:

MA-5    MA-7

**Gradation Distribution Chart**



#### Gradation Parameters

Coarseness Factor	#DIV/0!	Percent Mortar < 6 mm	-
Workability	100	Percent Mortar < No. 8	-
Target Workability	#DIV/0!	Percent Paste	-
Workability Difference	#DIV/0!		



### 5.3.2. BITUMINOUS MIX DESIGN

#### (a) Mixtures Containing Asphalt Cement.

##### (1) Scope.

This method covers the procedure for determining the optimum amount of asphalt cement in a given aggregate mixture. Since bituminous mixtures vary by type, and to some extent within type, these instructions must be considered as a general commentary. Judgment and experience must be used in interpreting the design information obtained by this method.

##### (2) General.

- a. **Marshall Tests:** Conduct tests on mixtures of aggregate and asphalt using Marshall apparatus as described in Kansas Test Method **KT-14**, and plot the resulting data on **KDOT Form No. 702**, "Asphaltic Concrete Design Mix Curves." Report percent asphalt on a dry weight basis.
- b. **Interpretation of Test Results:** Experience has shown that the results of Marshall tests can be excellent guidelines to use when determining the optimum asphalt content for a given mix. The mix designer must become familiar with Marshall criteria, learn to judge the significance of each parameter and be able to analyze the characteristics of the mixture from the results of the design calculations and test values. Marshall curves alone should not be used to determine the design asphalt content, but should be used in analyzing the characteristics of the mixture. When deciding upon the optimum asphalt content for a mixture, do not select a value that is obviously not in conformity with some portions of the data in question or with other values derived from the test.

##### (3) Significance of Properties:

It should remain foremost in the thinking of the mix designer that the design data consists of two general areas - volumetric and physical.

##### a. Volumetric Considerations:

Voids in Mineral Aggregate (VMA). The VMA generally decreases to a minimum value then increases with increasing asphalt contents. As far as possible, the mixtures with higher VMA should be preferred because of the following advantages:

1. More asphalt can be incorporated in the mixture to increase durability.
2. Lower sensitivity to variation in asphalt content during production.
3. Mixtures with low VMA will flush if slightly excessive in asphalt content, and will be dry and brittle if slightly deficient in asphalt content.

Voids Filled with Asphalt (VFA). The VFA increases with increasing asphalt content. There is a maximum VFA for each aggregate blend and compaction effort. The VFA can not be increased above this maximum without increasing or otherwise changing the compaction effort. The VFA curve is usually convex upwards.

% Voids - Total Mixture. The percent of air voids decreases with increasing asphalt content, ultimately approaching a minimum void content in much the same manner as the VFA discussed above approaches a maximum value. The air voids curve is usually concave upwards. Voids are the air spaces within the mixture. It is important that a mixture contains sufficient voids to provide spaces for expansion of bitumen and a slight amount of additional densification (compaction) under traffic. Aggregate size, shape and gradation have an effect on the amount of voids developed in a mixture and in the amount of bitumen that a mixture can contain. The voids should be held to a minimum, consistent with the aggregate, yet large enough to permit expansion.

b. Physical Considerations:

Unit Weight (specimen). The Unit Weight of the compacted specimen increases with increasing asphalt content up to a certain point, after which it decreases.

Stability. The stability value increases with increasing asphalt content up to a maximum after which the stability decreases. The peak of the stability curve is normally (but not always) at a slightly lower asphalt content than the peak of the Unit Weight curve. Cases are not uncommon where no stability peak is obtained. Stability is a measure of resistance to deformation. It is necessary to have sufficient stability to meet the requirements of traffic without mat distortion or displacement. There are two forms of resistance, frictional or interlocking and cohesive resistance. Frictional or interlocking resistance is dependent on the aggregate framework. Cohesive resistance develops in the bitumen-binder portion of the mixture. It depends on the rate of loading, load and temperature. High stability is undesirable if it is due to high density and low voids. Mixtures of this type have an excess of filler and are deficient in bitumen. Such surfaces will have low resistance to cracking, are brittle in the winter, and tend to ravel under traffic.

Flow. This is an index of plasticity or the resistance to distortion. The amount of bitumen that fills the aggregate voids affects the flow. The flow value increases as the bitumen content of the mixture increases. Mixtures which contain high air voids usually develop excessive flow values before reaching the bitumen content which will produce a satisfactory density. Flow values will increase rapidly with small increases in asphalt in mixtures which contain a large amount of filler.

c. Generalized "Need" of a Durable Pavement:

Workability. This is a term which generally describes the spreadability and compactability of the mixture. Decreasing the percentage retained on the No. 8 (2.36 mm) sieve will reduce harshness. Decreasing the percentage of sand and filler will reduce stiffness. Reducing the bitumen content and filler content will reduce gumminess.

Skid Resistance. A measure of the sliding force exerted on a tire when the brakes are locked. Bituminous wearing courses must have the highest possible skid resistance obtainable. The type of aggregate used has a great effect on skid resistance.

Durability. A measure of resistance to disintegration by weather or traffic conditions. The most important factor with respect to durability is the amount of bitumen. A bituminous mixture is resistant to the action of air and water in direct proportion to the

degree that they are kept out of the mixture. If the voids are completely filled with bitumen, the surfaces will become plastic and flushing will occur. It is, however, desirable that the mixture should contain as high a bitumen content as possible that is consistent with stability and voids. This will give the pavement maximum durability and prevent raveling because of a deficiency of bitumen. An asphalt content set totally on durability may produce a slippery surface. Therefore, a compromise between durability and skid resistance must often be accepted.

Flexibility. The ability of the bituminous mixture to bend repeatedly without cracking and to conform to changes in the base course. To have flexibility, a mixture must contain the proper amount of bitumen. Open graded mixtures are more flexible than dense graded mixtures. Flexibility decreases as the paving layer thickness increases. Flexibility increases with an increase of temperature.

#### (4) Types of Mixtures:

The types of mixtures encountered will generally fall within one of the following categories:

- a. **Balanced Mixture:** The Marshall curves for a balanced mixture show that the maximum unit weight and maximum stability occur at nearly the same asphalt content.
- b. **Open Graded Mixture:** This type of mixture has an open texture, low unit weight and a high percent of voids due to the type, particle shape and gradation of the aggregate. The maximum unit weight and maximum stability can occur at the same asphalt content, which will be much higher than for a balanced mixture.
- c. **Dense Graded Mixture:** This type of mixture has high unit weight, low percentage of voids and often has no indicated stability peak. This is caused by the proportioning of graded coarse and fine aggregates to produce a mixture that will have maximum density and minimum voids.

**Form 707** allows the gradation of the mix to be visually shown. **Form 707** (Gradation Chart for Marshall Design, Sieve Sizes Raised to 0.45 Power) is completed as listed below and shown in the example at the end of this section (**5.3.2**).

- a. Plot the Marshall Job Mix Single Point (for recycle mixes plot the Theoretical Combined Gradation, RAP Extracted Gradation, and the Virgin Aggregate Job Mix Single Point).
- b. Determine the first sieve size with more than 10 percent retained in the Job Mix Single Point. (For recycle mixes determine the first sieve size with more than 10 percent retained on the Theoretical Combined Gradation).
- c. Determine the Maximum Sieve Size. This is two sieve sizes larger than the first sieve with more than 10% retained.
- d. Draw the maximum density line. This is a line drawn from the origin of the 0.45 power chart (lower left) to the point at which the Maximum Sieve Size intersects the 0 percent retained (100% passing) line.
- e. Determine if the mix VMA falls in Zone 1 or Zone 2 using the instructions on **Form 707**.



- f. Terminology definition - Normal Maximum Size is one sieve size smaller than the Maximum Size. This is also one size larger than the first sieve size with more than 10% retained on the Job Mix Single Point (Theoretical Combined Gradation for recycle mixes.)

(5) Asphalt Content Determination:

- a. The recommended asphalt content should be one which best fits or satisfies the volumetric and physical parameters desired. Information needed for asphalt content selection may be found in the project specifications or plans when Marshall control is specified. When Marshall control is not specified, the best engineering practices should govern the selection.

For guidance, the following table may be used:

Traffic Category*	EAL<140		EAL 141-274		EAL>275	
	Min.	Max.	Min.	Max.	Min.	Max.
Number of Blows	50		50 (Note 3)		75 (Note 1)	
Test Property	Min.	Max.	Min.	Max.	Min.	Max.
Stability Newtons** (lbs.)	3336 (750)		5338 (1200)		8006 (1800)	
Flow, 0.25mm (0.01")	8	18	8	16	8	14
Air Voids, %	3	5	3	5	3	5
VMA, %	(Note 2)		(Note 2)		(Note 2)	
VFA, %	70	80	65	78	65	75
Bearing Capacity						
kPa	690	1,725	1,035	2,070	1,205	2,070
(PSI)	(100)	(250)	(150)	(300)	(175)	(300)

\* EAL values will be taken from the latest issue of the NOS condition survey.

\*\* Stability values shown reflect the most recent data published by the Asphalt Institute. These values are considered valid only for those mixes with VMA values in Zone 1, **KDOT Form No. 707**. For those mixes with VMA values in Zone 2, **KDOT Form No. 707**, higher stabilities may be required to provide resistance to plastic deformation.

**Note** - Use 75 blows for the top 100mm (4") of new construction in traffic lanes. Use 75 blows for all overlays, including hot recycle, in traffic lanes. Use 50 blows for all other lifts of new construction. (If 75 blow Marshall is required, it is to be specified in the contract.)

**Note** - Zone 1, **KDOT Form No. 707**, corresponds to mixes which are considered to have sufficient aggregate voids space to provide both adequate room for asphalt and

sufficient remaining air voids to prevent flushing. Zone 2 mixtures would be considered as potentially at risk of flushing due to lack of aggregate void space to accommodate sufficient asphalt for durability and insufficient air voids remaining to prevent flushing.

**Note** - Use 75 blows for overlays on PCCP and composite pavements. (If 75 blow Marshall is required, it is to be specified in the contract.)

- b. Using the data previously determined, the bar chart portion of **KDOT Form No. 701** is utilized as follows:

Step 1. Indicate by a horizontal line the range of asphalt contents which include the desired (or specified) properties.

Step 2. Indicate by vertical lines the area of "best convergence" of asphalt contents which satisfy the desirable (or specified) properties.

Step 3. Indicate by vertical line the computed value of  $P_b'$ max as shown in the supplemental calculations, Section **5.10.4 (g) (3)**.

Step 4. Select tentative asphalt content within the "best convergence" zone, but not exceeding the value of  $P_b'$ max.

Step 5. Show this value (the tentative asphalt content) as the "Recommended % Asphalt."

Step 6. Show values for VMA, Air Voids, etc. corresponding to the "Recommended % Asphalt" in the last column at the right side of the bar chart.

A completed bar chart is shown as an example at the end of this section.

- (b) Mixtures Containing Cutback Asphalt.

- (1) Formulas:

A number of formulas have been devised to calculate the percent of cutback asphalt to be added to aggregate that is to be road-mixed. Two of these, the Nebraska and the New Mexico formulas are used in combination for work in Kansas. The asphalt content as calculated by these formulas will be a good indication of the proper value to use at the start of the work. It may be necessary to make adjustments based on judgment, and past experience in order to provide sufficient asphalt to coat the aggregate particles. Care must be taken not to have an excess amount of asphalt as this can result in an unstable pavement. The quantities of cutback asphalt should be increased to compensate for the amount of diluent that will be lost during mixing, aeration and curing.

a. New Mexico Formula:

$$P = 0.02a + 0.07b + 0.15c + 0.20d$$

Where:

P = Percent of bituminous material by weight of dry aggregate.

a = Percent of material retained on the No. 50 (300 $\mu$ m) sieve.

b = Percent of material between No. 50 (300 $\mu$ m) and No. 100 (150 $\mu$ m) sieves.

c = Percent of material between No. 100 (150 $\mu$ m) and No. 200 (75 $\mu$ m) sieves.

d = Percent of material passing the No. 200 (75 $\mu$ m) sieve.

When aggregates with an appreciable amount of water absorption are used, the amount of cutback asphalt added to the mixture should be increased by approximately two-thirds (2/3) of the amount of water absorbed by the aggregate.

b. Nebraska Formula:

$$P = AG(0.02a) + 0.06b + 0.10c + Sd$$

Where:

P = Percent of bituminous material by weight of dry aggregate.

A = Absorption factor, equal to 1 for sand-gravel and 1 + 2/3 the water absorption of other aggregates.

G = Specific Gravity Correction Factor. This factor equals 1.0 for aggregate mixtures that have a average specific gravity of 2.61. For aggregate mixtures having a different average specific gravity, this factor is inversely proportional to the average specific gravity of the combined aggregate.

a = Percent of material retained on No. 50 (300 $\mu$ m) sieve.

b = Percent of material retained between the No. 50 (300 $\mu$ m) and No. 100 (150 $\mu$ m) sieves.

c = Percent of material retained between the No. 100 (150 $\mu$ m) and No. 200 (75 $\mu$ m) sieves, plus C<sub>1</sub>.

d = Percent of fines determined by the average of the percent passing the No. 200 (75 $\mu$ m) sieve dry screened, and the percent passing the No. 200 (75 $\mu$ m) on wash test in separate determinations.

C<sub>1</sub> = The percent of material equal to the difference between the percent of material passing the No. 200 (75 $\mu$ m) sieve on wash test and "d".

S = 0.2, except for volcanic ash, in which case the "S" factor shall be 0.27.

**NOTE:** The quantity "d" shall be found by separate determinations on two similar samples of combined material; one sample shall be dry screened only, and the other sample shall be tested by the wash test plus dry screening after washing.

(2) Determination of Asphalt Content:

Example: Assume a predominantly sand-gravel BM-6 mixture containing some crushed stone and volcanic ash.

Gradation Percent Retained - Square Mesh Sieves									
19mm	9.5mm	4.75 mm	2.36 mm	1.18 mm	600µm	300µm	150µm	75µm	Dry Sieve 75µm
(3/4")	(3/8")	(#4)	(#8)	(#16)	(#30)	(#50)	(#100)	(#200)	(#200)
0	3	11	32	55	71	84	89	90	93

Water Absorption = 2.0% (Avg. of Combined Material)  
 Specific Gravity = 2.58 (Avg. of Combined Material)  
 S Factor = 0.27

a. Asphalt Content by New Mexico Formula:

$$P = (0.02 \times 84) + (0.07 \times 5) + (0.15 \times 1) + (0.20 \times 10)$$

$$P = 1.68 + 0.35 + 0.15 + 2.0 = 4.18\%$$

Increase the amount of bituminous material by 2/3 the amount of water absorption of the aggregate.

$$P = 4.18 + (0.67 \times 2.0) = 5.52\%$$

b. Asphalt Content by the Nebraska Formula:

$$A = 1 + (0.67 \times 2.0) = 2.34 = \text{Absorption Factor}$$

$$\frac{1}{G} = \frac{2.58}{2.61}$$

$$G = \frac{2.61}{2.58} = 1.0116 = \text{Gravity Correction Factor}$$

$$A_g = 2.34 \times 1.0116 = 2.37$$

$$d = \frac{10 + 7}{2} = 8.5$$

$$C_1 = 10 - 8.8 = 1.5$$

$$C = 1 + 1.5 = 2.5$$

$$P = 2.37 (0.02 \times 84) + (0.06 \times 5) + (0.10 \times 2.5) + (0.27 \times 8.5)$$

$$P = 3.98 + 0.30 + 0.25 + 2.30 = 6.83\%$$

The results of the above calculations using the New Mexico and Nebraska formulas show a calculated asphalt range (after aeration) of between 5.52% and 6.83% based on dry weight of aggregate. Since a cutback asphalt is to be used, the percent of total bituminous material must be increased an amount equal to the amount of diluent which will be lost during aeration and curing.

Thus if it is estimated that 50% of the volatiles will be removed and if the cutback contains 14% volatiles, then 7% volatiles by weight of asphalt will be removed. Then the above percentages should be increased as follows:

$$\frac{5.52}{(1-0.07)} = 5.94\% \quad \frac{6.83}{(1-0.07)} = 7.34\%$$

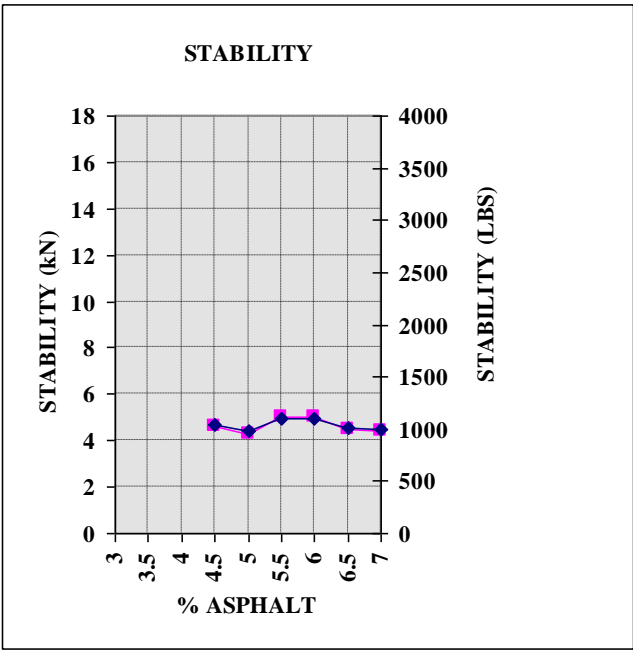
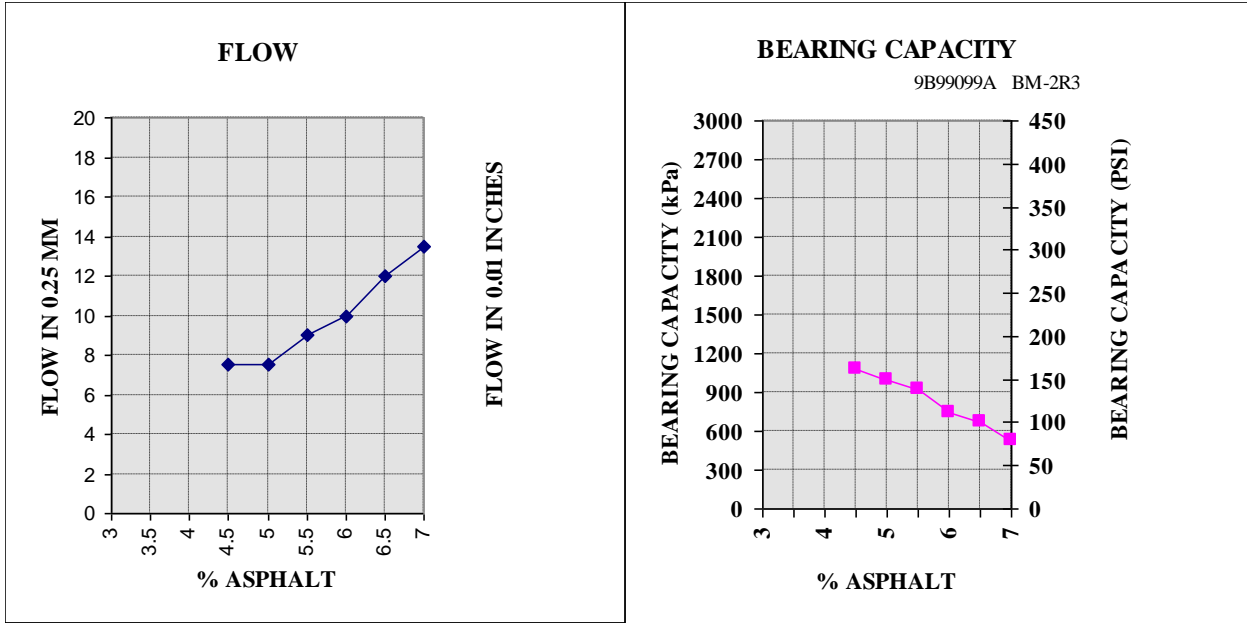
The results of the above calculations furnish the basis for establishing a starting asphalt content (on the basis of residue after aeration and curing).

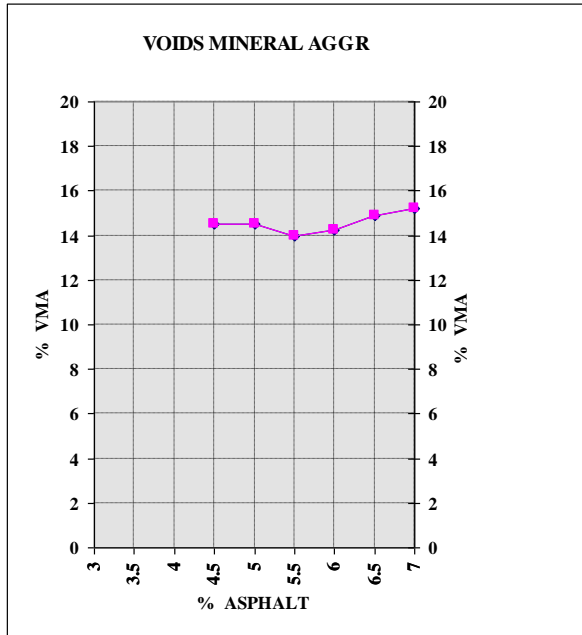
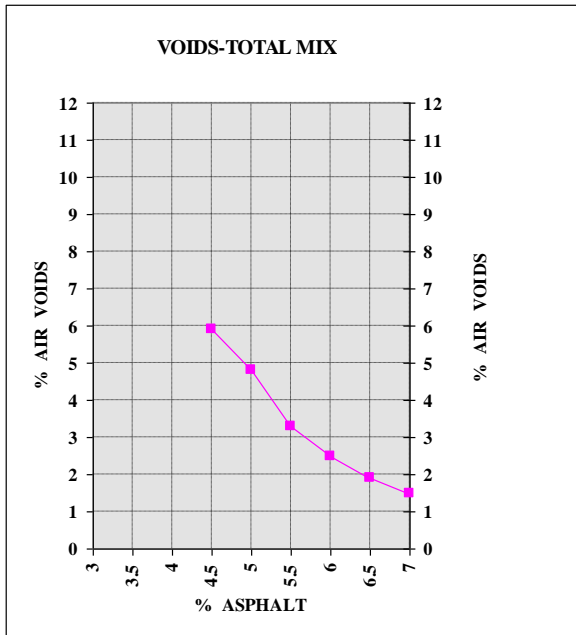
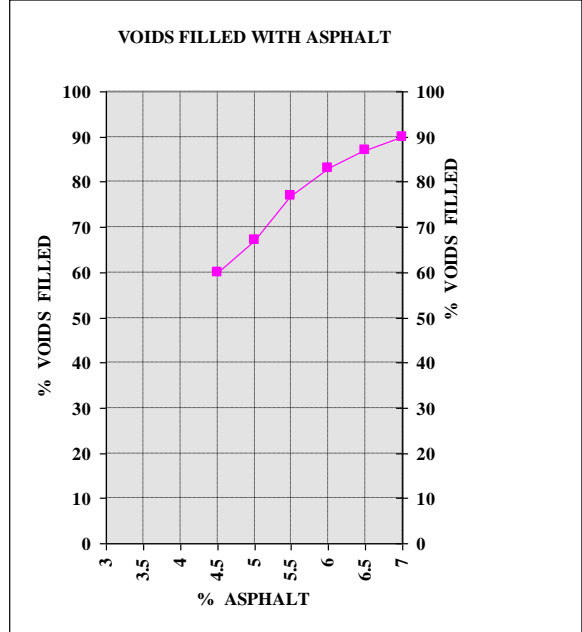
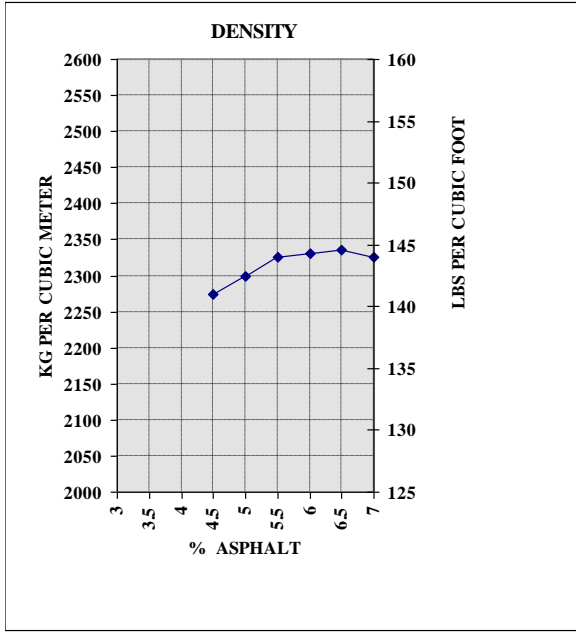
As previously mentioned, after mixing is started, judgment and experience may dictate adjustments in the percentage of asphalt actually used.

(c) Mixtures Containing Emulsified Asphalt.

A standard method of calculating the proper amount of emulsified asphalt to be used in bituminous mixtures has not been developed at this time. Consequently, the amount of emulsified asphalt to be added at the start of the work is currently being determined from the results of District Laboratory test and observations made on the aggregates and emulsions which will be used on each project.









KANSAS DEPARTMENT OF TRANSPORTATION

Lab No.: 9B99099A

DESIGN JOB-MIX COMPUTATION SHEETS

Contract #: 594066008

Mix Desig.: BM-2

Material Code : 002030500

Project: 99-115 K 4615-01

County: ZOLAN

Specifications: 1990 STD. & 90P-88R3

1. AGGREGATES

AGGR. TYPE	%	PRODUCER NAME		
MAT'L CODE	IN MIX	PRODUCER CODE #	LEGAL DESCRIPTION	COUNTY
CS-1	20.00	HAMM QUARRY	NE 1/4 S10,T072,R10E	POTTAWATOMIE
002010117		00800933		
CS-2	30.00	MARTIN-MARIETTE	SE 1/4 S33,T10S,R09E	RILEY
002010217		00802414		
SSG	50.00	BLUE RIVER	NE 1/4 S25,T05S, R07E	MARSHALL

AC-10	TOTAL
021110000	00002801

2. INDIVIDUAL AGGREGATE SINGLE POINTS

	%	1½	1	¾	½	⅜	4	8	16	30	50	100	200
		37.5	25	19	12.5	9.5	4.75	2.36	1.18	600	300	150	75
TYPE	IN MIX	mm	mm	mm	mm	mm	mm	mm	mm	µm	µm	µm	µm
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0

DESIGN													
SINGLE POINT		0	0	0	9	17	31	48	63	77	89	94	94.0

2A. INDIVIDUAL AGGREGATE GRADATIONS (AS SUBMITTED)

	%	1½	1	¾	½	⅜	4	8	16	30	50	100	200
		37.5	25	19	12.5	9.5	4.75	2.36	1.18	600	300	150	75
TYPE	IN MIX	mm	mm	mm	mm	mm	mm	mm	mm	µm	µm	µm	µm
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0

THEO COMB GRAD		0	0	0	9	17	31	48	63	77	89	94	94.1
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DOT FORM 703

## 3. DESIGN JOB MIX GRADING

	1½	1	¾	½	⅜	4	8	16	30	50	100	200
	37.5	25	19	12.5	9.5	4.75	2.36	1.18	600	300	150	75
	mm	mm	mm	mm	mm	mm	mm	mm	µm	µm	µm	µm
	0.00	0.00										
SINGLE POINT TOLERANCE			0	9	17	31	48	63	77	89	94	94.0
					6	6	6	5	5	4	4	2
	No											
BM-2R3 LOWER					11	25	42	58	72	85	90	92.0
BM-2R3 UPPER			0		23	37	54	68	82	93	98	96.0

## 4. MASTER GRADING LIMITS

	37.5	25	19	12.5	9.5	4.75	2.36	1.18	600	300	150	75
	mm	mm	mm	mm	mm	mm	mm	mm	µm	µm	µm	µm
BM-2R3 LOWER					8		42		64			90
BM-2R3 UPPER			0		30		72		88			97

## 5. INDIVIDUAL AGGREGATE LIMITS

	%	37.5	25	19	12.5	9.5	4.75	2.36	1.18	600	300	150	75
TYPE	IN MIX	mm	mm	mm	mm	mm	mm	mm	mm	µm	µm	µm	µm
CS-1	20.00	0	0	0	10	60	96	96	97	97	97	97	97
		0	0	0	28	77	99	99	99	99	99	99	100
CS-2	30.00		0	0	0	0	22	45	60	70	77	80	81
		0	0	0	0	5	34	55	69	78	84	88	88
CS-3	50.00		0	0	0	0	5	22	45	68	87	97	98
		0	0	0	0	5	15	32	55	77	95	100	100

## 6. INDIVIDUAL AGGREGATE COMBINED LIMITS

LOWER		0	0	2	12	28	44	60	74	86	92	93
UPPER		0	0	0	6	19	38	52	68	82	93	96

## 7. CHECK OF MIX SPECIFICATIONS

	SPECS	DESIGN
% CRUSHED AGGREGATE IN MIX	50 MIN.	50.00
% UNCRUSHED -75µm NATURAL SAND	30 MAX.	8.47
% -2.36mm +75µm NATURAL SAND	15 MIN.	35.50
SAND EQUIVALENT	45 MIN.	53

Design Job Mix Single Point Meets  
the Screen Spread Limits Specification.

DOT Form 704

Calculations for Items 7 Form 704

8.A. Natural Sand: Passing No. 2.38 mm and Retained on No. 75µm

Single Point Gradation (From Item 2)  
 $(0.50) (99.00 - 28.00) = \underline{35.5\%}$  Sand

Lower & Upper Limits (Lowest Calculated Value) (From Item 5)  
 $(0.50) (98.00 - 32.00) = \underline{33.0\%}$  Sand

8.B. Uncrushed Minus 75µm

Single Point Gradation (From Item 2A)

$$\frac{(100.00 - 99.00) (0.50) (100)}{(100 - 94.1)} = 8.47\% \text{ Uncrushed}$$

Lower & Upper Limits (Highest Calculated Value) (From Item 5)

SSG	50%	(100-98)	= 1.00	Uncrushed
CS-1	20%	(100-100)	= 0.00	Crushed
CS-2	30%	(100-88)	= <u>3.60</u>	Crushed
Total Minus 75µm			= 4.60	

Uncrushed Minus 75µm

$$\frac{1.00 (100)}{4.60} = 21.8 = 22\% \text{ Uncrushed}$$

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE

Contract #: 594066008  
 Project Number: 99-115 K 4615-01  
 Mix Designation: BM-2

Date: March 21, 1995  
 Lab No.: 9B99099A

% AC by Wt. Aggr.	4.50	5.00	5.50	6.00	6.50	7.00	Pb'
% AC by Wt. Mix	4.306	4.762	5.213	5.660	6.103	6.542	Pb=A
% Aggr. by Wt. Mix	95.694	95.238	94.787	94.340	93.897	93.458	Ps=B
S. G. of Asphalt	1.0180	1.0180	1.0180	1.0180	1.0180	1.0180	Gb=c
S. G. of Aggr. (bulk)	2.566	2.566	2.566	2.566	2.566	2.566	Gsb=D
Max. S. G. Mix (KT-39)	2.434	2.417	2.405				Gmm
(computed)	2.434	2.418	2.403	2.387	2.372	2.358	E
Theo. Max. Kg/m <sup>3</sup>	2434	2418	2403	2387	2372	2358	F(SI)=F
Eff. S. G. of Aggr.	2.597	2.597	2.597	2.597	2.597	2.597	Gse=G
% Abs. Asphalt	0.474	0.474	0.474	0.474	0.474	0.474	Pba=H
Eff. Asph. Content	3.852	4.311	4.764	5.213	5.658	6.099	Pbe=I
% V. M. A.	14.49	14.45	14.15	14.41	14.78	15.43	VMA=J
S. G. of plugs (KT-15)	2.293	2.305	2.323	2.328	2.329	2.322	Gmb=K
Lab Plugs Kg/m <sup>3</sup>	2293	2305	2323	2328	2329	2322	L(SI)=L
% Air Voids	5.79	4.67	3.29	2.47	1.81	1.53	Pa=M
% Voids Filled	59.88	67.55	76.86	82.73	87.58	90.16	VFA=N
P'b Max	5.51	5.49	5.36	5.47	5.63	5.90	O
Eff. Film Thickness	6.54	7.36	8.17	8.98	9.79	10.61	P
Filler/Binder Ratio	1.33	1.20	1.09	1.00	0.92	0.86	Q

$$PB = A = \frac{P'B * 100}{100 + P'B}$$

$$PS = B = 100 - A$$

$$F = 1000 E$$

$$GSE = G = \frac{B}{\frac{100}{E} - \frac{A}{C}}$$

$$PBA = H = 100 * \frac{G - D}{D * G} * C$$

$$PBE = I = A - \frac{H}{100} * B$$

$$VMA = J = 100 - \frac{K * B}{D}$$

COMBINED AGGREGATE SP. GR.

	APPARENT	BULK	%
+4.75 mm	2.652	2.484	31
-4.75 mm	2.669	2.754	69
Theo. Comb.	2.664		

$$L = 1000 K$$

$$PA = M = 100 * \frac{E - K}{E}$$

$$VFA = N = \frac{100 * \frac{I}{C}}{\frac{J}{K}}$$

KANSAS DEPARTMENT OF TRANSPORTATION  
HOT MIX DESIGN DATA (MARSHALL METHOD)

Contract: 594066008  
Project: 99-115 K 4615-01

County: Zolan Date: March 21, 1995

Lab No. 9B99099A

Mix Designation: BM-2

Asphalt Grade: AC-10

Sp. Gr. AC: 1.0180

Compaction, Blows/Side: 50

Deg.C	Compa ct Temp. (C)	Specimen Height (MM)	Weight, Grams				Water Absorbed %	SP. GR. Compact Mix	KG/ Cubic Meter	Water Bath (C)	Stability			Flow (0.25) (MM)	Bearing Capacity (kPa)
			Dry In Air	In Water	S.S.D In Air	S.S.D In Water					Dial. Reading	Corr.	Adjust (N)		
148	A	137	63.900	1175.1	661.7			2.289		59	117	1.00	4589	7.5 7.5 7.5	Error
	B	136	63.700	1183.8	669.2			2.300		59	143	1.00	5679		
	C	134	63.600	1174.2	661.5			2.290		61	122	1.00	4799		
4.50	Average							2.293	2293				4694	7.5	1091
148	A	137	63.800	1185.0	671.3			2.307		60	105	1.00	4087	7.5 7.5 7.5	
	B	137	63.500	1187.7	674.0			2.312		60	117	1.00	4589		
	C	136	63.200	1179.4	665.8			2.296		60	112	1.00	4380		
5.00	Average							2.305	2305				4352	7.5	1012
148	A	133	63.300	1187.1	675.7			2.307		60	117	1.00	4589	8.0 9.0 9.5	
	B	133	63.200	1186.6	676.2			2.325		60	127	1.00	5009		
	C	134	62.900	1187.1	676.7			2.326		60	131	1.00	5176		
5.50	Average							2.324	2324				4925	8.8	965
148	A	134	63.300	1193.6	680.6			2.327		59	131	1.00	5176	10.5 9.5 9.5	
	B	136	62.700	1183.9	675.6			2.329		59	122	1.04	4991		
	C	136	63.300	1190.0	679.1			2.329		60	116	1.00	4548		
6.00	Average							2.328	2328				4905	9.8	855
148	A	137	62.700	1190.5	679.2			2.328		60	114	1.04	4642	12.5 11.5 11.5	
	B	136	62.900	1184.8	675.6			2.327		60	122	1.00	4799		
	C	137	63.100	1186.1	677.6			2.333		60	112	1.00	4380		
6.50	Average							2.329	2329				4607	11.8	655
148	A	137	62.900	1184.5	674.7			2.323		59	119	1.00	4673	14.0 13.5 13.5	
	B	136	63.100	1184.3	672.9			2.316		60	105	1.00	4087		
	C	134	63.600	1189.2	677.8			2.325		60	118	1.00	4631		
7.00	Average							2.322	2322				4464	13.7	537

Specific Gravity Method: I

ERROR = PLUG OUT OF ALLOWED RANGE

D.O.T. FORM 705

KANSAS DEPARTMENT OF TRANSPORTATION

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF PAVING MIXTURES

References: ASTM D 2041 (Rice's Method) and Kansas Test Method KT-39

Date: March 21, 1995

Contract Number: 594066008

Project Number: 99-115 K 4615-01 County: Zolan

Lab No: 9B99099A

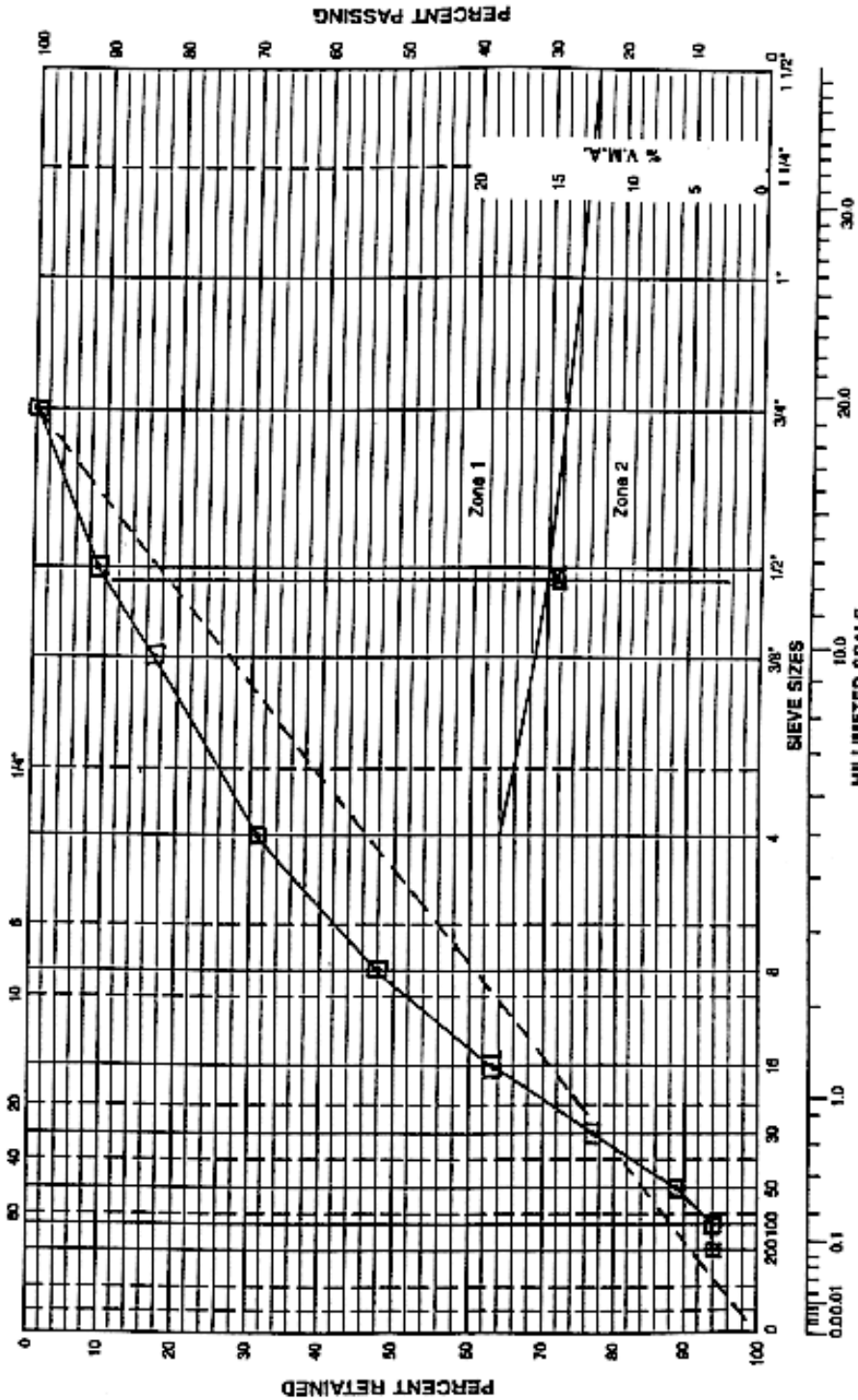
Bowl # Sample #	4.50 A	4.50 B	5.00 A	5.00 B	5.50 A	5.50 B
Mass of Sample & Bowl in Air, Grams	3646.5	3698.3	3720.3	3709.2	3681.9	3673.7
Mass of Bowl in Air, Grams	2144.0	2141.9	2173.7	2149.5	2114.6	2112.2
Mass of Sample in Air, Grams (A)	1502.5	1556.4	1546.6	1559.7	1567.3	1561.5
Temp. of Bath, Sample and Bowl after 10 Minutes	78.8	78.6	77.9	78.0	77.5	77.6
Mass of Sample and Bowl in Water, Grams	2240.4	2258.9	2270.3	2260.2	2251.9	2246.7
Mass of Bowl in Water, Grams	1368.2	1365.1	1386.9	1362.7	1337.8	1335.4
Mass of Sample in Water, Grams (C)	872.2	893.8	883.4	897.5	914.1	911.3
Maximum Sp. Gr. of Mix (Rice's) A/(A-C)	2.3838	2.3489	2.3320	2.3553	2.3994	2.4015
Average Max. Sp. Gr. of Mix	2.366		2.344		2.400	

D.O.T Form 706

KANSAS DEPARTMENT OF TRANSPORTATION

0.45 POWER GRADATION CHART

Contract 094066008 Project 99-115 K 4615-01 County Zolan Lab. No. 9899098A



INSTRUCTIONS FOR DETERMINING ZONE 1 or 2:  
 1. Plot design gradation.  
 2. Locate 10% retained point on gradation line.  
 3. Draw vertical line downward from 10% retained point.  
 4. Indicate V.M.A. value at tentative A.C. content on vertical line using scale labelled "% V.M.A." by drawing a symbol (X) at that point.  
 This point determines if this is a Zone 1 or Zone 2 mix.

Legend

- Single Point Grading
- - - Theoretical Maximum Density Line

Checked By Dec

BY ABC

DOT Form 616 201

KANSAS DEPARTMENT OF TRANSPORTATION  
MARSHALL TEST RESULTS

No. of Blows: 50  
Single Point to the tenth (Y/N)?: No

Contract #: <u>094066008</u>	County: <u>ZOLAN</u>	Lab. No.: <u>9B99099A</u>
Project: <u>99-115 K 4615-01</u>	Mix Material Code: <u>002030500</u>	
Mix Designation: <u>BM-2</u>	Contractor: <u>XYZ CONST. CO., INC.</u>	
Specification <u>1990, Sec. 1103 &amp; 90P-88R3</u>	Producer: <u>XYZ CONST. CO., INC.</u>	
Asphalt Source: <u>TOTAL</u>		
Asphalt Grade: <u>AC-10</u>	Date Rec./Rep.: _____ / <u>March 21, 1995</u>	

Percent Retained Square Mesh Sieves

	1½"	1"	¾"	½"	⅜"	4	8	16	30	50	100	200
	37.5	25	19	12.5	9.5	4.75	2.36	1.18	600	300	150	75
	mm	mm	mm	mm	mm	mm	mm	mm	µm	µm	µm	µm
Job Mix					11	25	42	58	72	85	90	92.0
Spec. Band			0		23	37	54	68	82	93	98	96.0
Job Mix Single Pt.			0	9	17	31	48	63	77	89	94	94.0
Marshall Gradation			0	9	18	31	48	65	76	88	94	95.0

Test Data

Range Tested (% AC)	Increment (% AC)	Marshall Mixing Temperature Range (°F)	Marshall Compaction Temperature Range (°F)
4.50 to 7.00	0.50	spec. 289 to 298	270 to 279

Operating Range for Hot Mix Plant: 270 to 298 °F

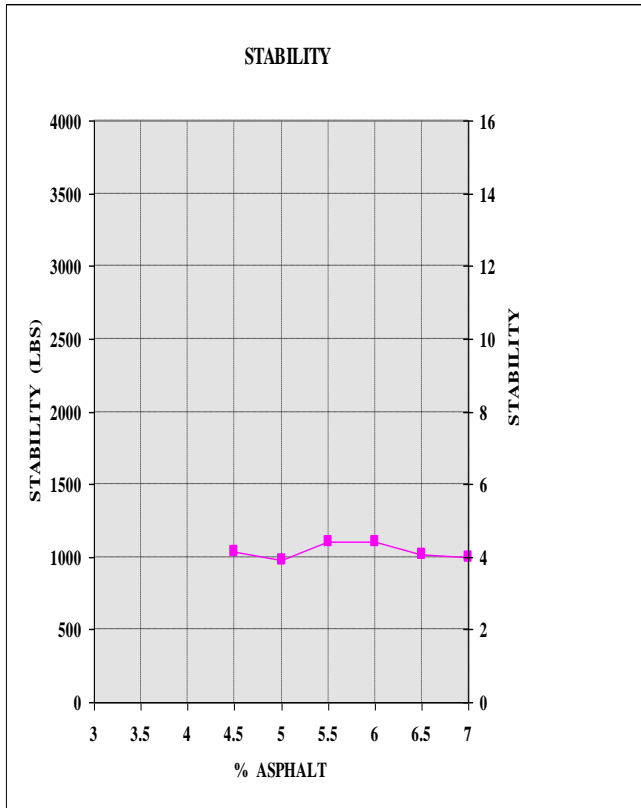
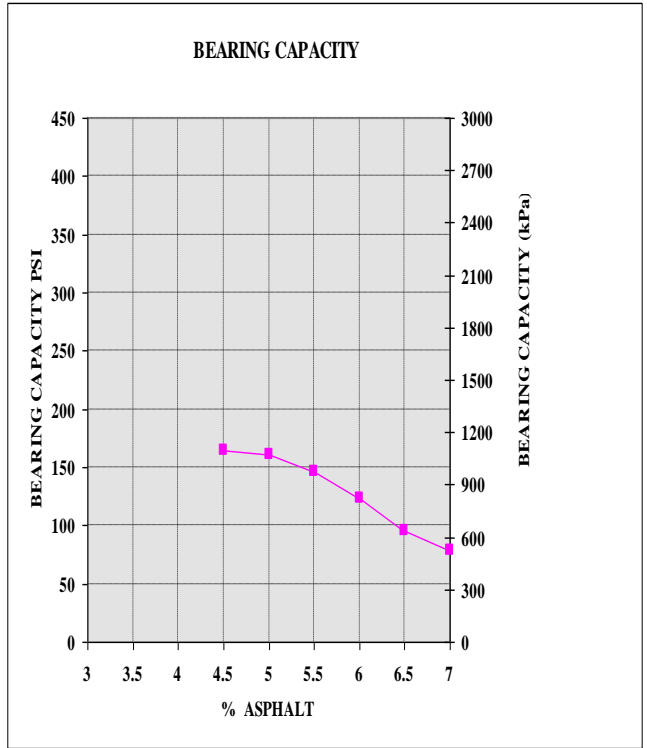
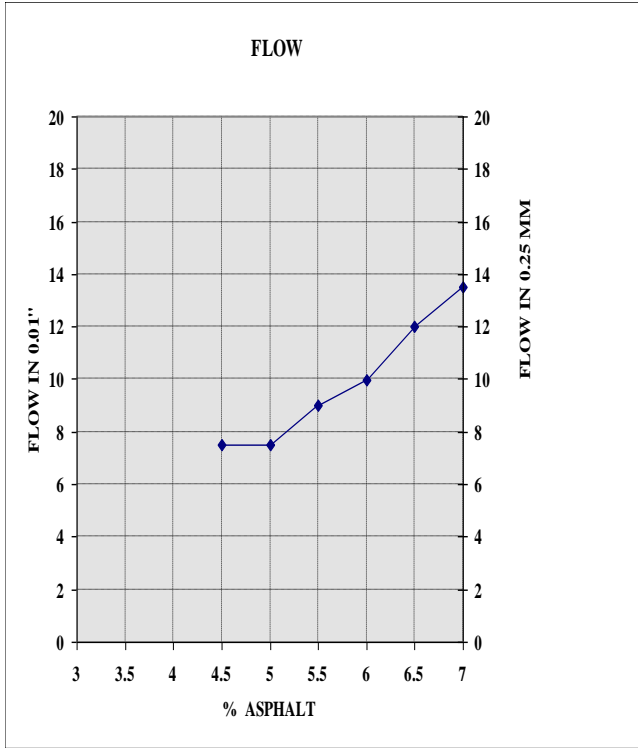
	← P <sub>b</sub> Max.						#Recommend
Asphalt Content%	4.50	5.00	5.50	6.00	6.50	7.00	5.25
Air Voids(3 to 5%)	[Bar from 4.50 to 5.50]						3.98
VFA (.=70% 80%)	[Bar from 5.00 to 6.00]						72.70
Bearing Capacity (690-1725 PSI)	[Bar from 4.50 to 6.00]						143
Density (lbs/ft <sup>3</sup> ) (Peak +/-0.5%)	[Bar from 5.50 to 6.50]						144.42
Stability Minimum 750 lbs.	[Bar from 4.50 to 7.00]						1043

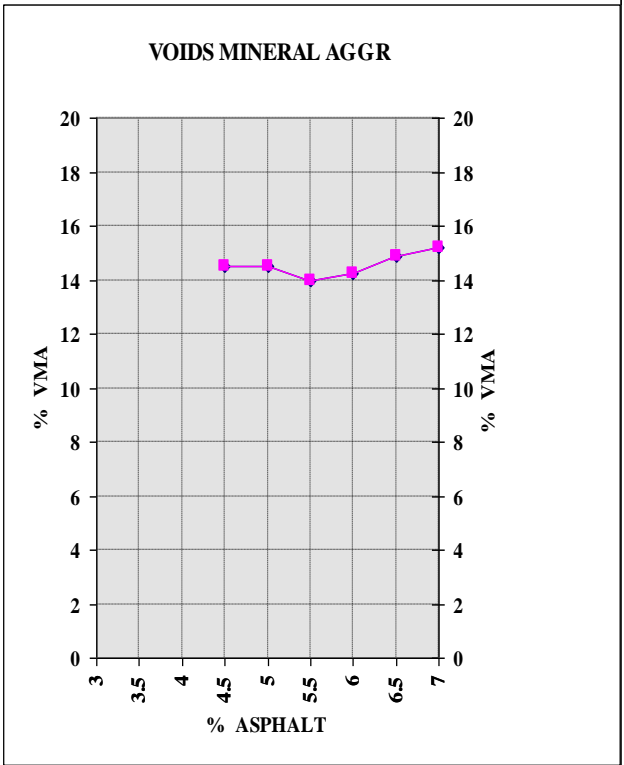
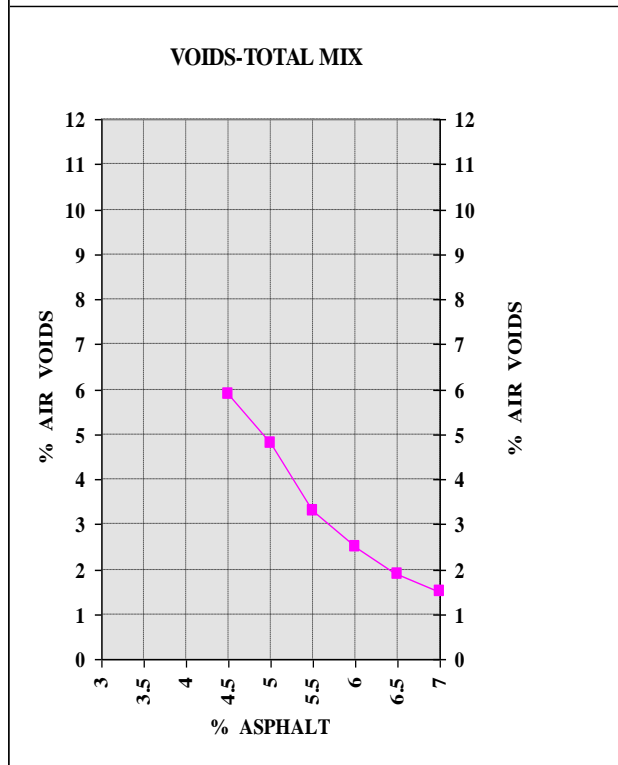
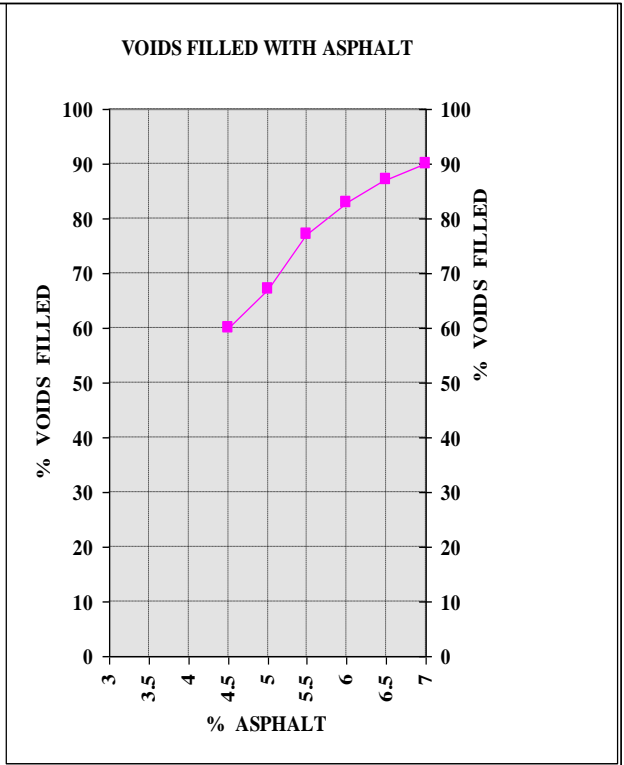
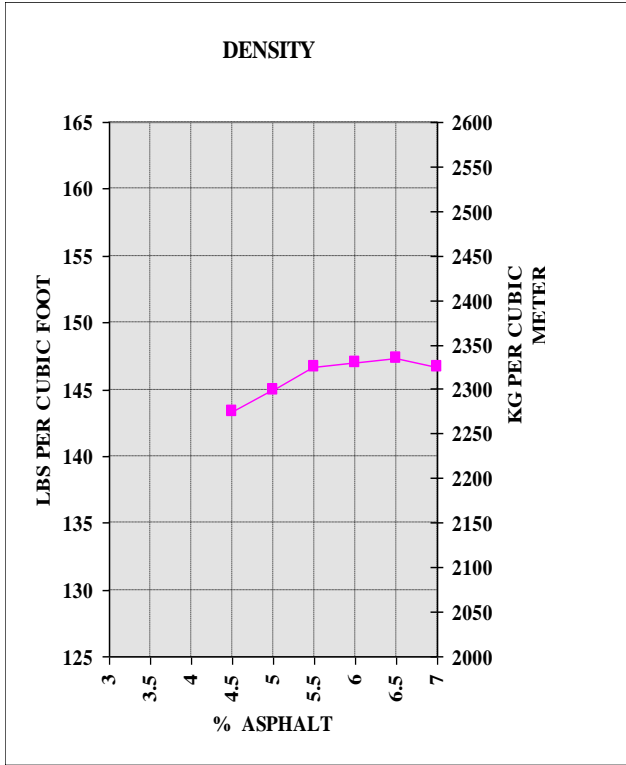
# Values at Recommended Asphalt Content

Filler/Binder Ratio: 1.14	Eff. Film Thick.: 7.76	P <sub>b</sub> Max: 5.42
V.M.A.: 14.30/Zone <u>2</u>	Max. Sp. Gr.: 2.410	Theo. Max Density: 150.38 lbs/ft <sup>3</sup>

\_\_\_\_\_  
District Materials Engineer







KANSAS DEPARTMENT OF TRANSPORTATION

Lab No. : 9B99098A

DESIGN JOB-MIX COMPUTATION SHEETS

Contract #: 904066008

Mix Design : BM-2  
Material Code : 002030500

Project: 99-115 K 4615-01

County: Zolan  
Specifications: 1990 STD. & 90P-88 R 3

1. AGGREGATES

AGGR. TYPE MAT'L CODE	% IN MIX	PRODUCER NAME PRODUCER CODE	LEGAL DESCRIPTION	COUNTY
CS-1 002010117	20.00	Hamm Quarry 00800933	NE 1/4 S10,T07S,R10E	Pottawatomie
CS-2 002010217	30.00	Martin-Marietta 00802414	SE 1/4 S33,T10S,R09E	Riley
SSG	50.00	Blue River	NE 1/4 S25,T05S,R07E	Marshall

AC-10 TOTAL  
021110000 00002801

2. INDIVIDUAL AGGREGATE SINGLE POINTS

TYPE	%	IN MIX											
		1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0

DESIGN SINGLE POINT 0 0 0 9 17 31 48 63 77 89 94 94.0

2A. INDIVIDUAL AGGREGATE GRADATIONS (AS SUBMITTED)

TYPE	%	IN MIX											
		1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0

THEO COMB GRAD 0 0 0 9 17 31 48 63 77 89 94 94.1

D.O.T FORM 703

3. DESIGN JOB MIX GRADING

	1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
SINGLE POINT TOLERANCE	0	0	0	9	17	31	48	63	77	89	94	94.0
					6	6	6	5	5	4	4	2
BM-2R3 LOWER					11	25	42	58	72	85	90	92.0
BM-2R3 UPPER			0		23	37	54	68	82	93	98	96.0

4. MASTER GRADING LIMITS

	1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
BM-2R3 LOWER					0		42		64			90
BM-2R3 UPPER			0		30		72		88			97

5. INDIVIDUAL AGGREGATE LIMITS

TYPE	% IN MIX	% IN MIX											
		1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
CS-1	20.00	0	0	0	10	60	96	96	97	97	97	97	97
		0	0	0	28	77	99	99	99	99	99	99	100
CS-2	30.00	0	0	0	0	0	22	45	60	70	77	80	81
		0	0	0	0	5	34	55	69	78	84	88	88
SSG	50.00	0	0	0	0	5	22	45	68	87	97	98	
		0	0	0	0	5	15	32	55	77	95	100	100

6. INDIVIDUAL AGGREGATE COMBINED LIMITS

LOWER		0	0	2	12	28	44	60	74	86	92	93
UPPER		0	0	0	6	19	38	52	68	82	93	96

7. CHECK OF MIX SPECIFICATIONS

	SPECS	DESIGN
% CRUSHED AGGREGATE IN MIX	50 MIN.	50.00
% UNCRUSHED -200	30 MIN.	8.47
% -8 +200 NATURAL SAND	15 MIN.	35.50
SAND EQUIVALENT	45 MIN.	53

DESIGN JOB MIX SINGLE POINT MEETS THE SCREEN SPREAD LIMITS SPECIFICATION.

Calculations for Items 7 Form 704

8.A. Natural Sand: Passing No. 8 and Retained on #200

Single Point Gradation (From Item 2)  
50% (99.00 - 28.00) = 35.5% Sand

Lower & Upper Limits (Lowest Calculated Value) (From Item 5)  
50% (98.00 - 32.00) = 33.0% Sand

8.B. Uncrushed Minus #200

Single Point Gradation (From Item 2A)

$$\frac{(100.00 - 99.00) (0.50) (100)}{(100 - 94.1)} = 8.47\% \text{ Uncrushed}$$

Lower & Upper Limits (Highest Calculated Value)(From Item 5)

SSG	50% (100-98)	= 1.00	Uncrushed
CS-1	20% (100-100)	= 0.00	Crushed
CS-2	30% (100-88)	= <u>3.60</u>	Crushed
Total Minus #200		= 4.60	

Uncrushed Minus #200

$$\frac{1.00 (100)}{4.60} = 21.8 = 22\% \text{ Uncrushed}$$

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE

Contract #: 594066008  
 Project Number: 99-115 K 4615-01  
 Mix Designation: BM-2

Date: March 21, 1995  
 Lab No.: 9B99099A

% AC by Wt. Aggr.	4.50	5.00	5.50	6.00	6.50	7.00	Pb'
% AC by Wt. Mix	4.306	4.762	5.213	5.660	6.103	6.542	Pb=A
% Aggr. by Wt. Mix	95.694	95.238	94.787	94.340	93.897	93.458	Ps=B
S. G. of Asphalt	1.0180	1.0180	1.0180	1.0180	1.0180	1.0180	Gb=c
S. G. of Aggr. (bulk)	2.566	2.566	2.566	2.566	2.566	2.566	Gsb=D
Max. S. G. Mix (KT-39)	2.434	2.417	2.405				Gmm
(computed)	2.434	2.418	2.403	2.387	2.372	2.358	E
Theo. Max. PCF	151.88	150.88	149.95	148.95	148.01	147.14	F
Eff. S. G. of Aggr.	2.597	2.597	2.597	2.597	2.597	2.597	Gse=G
% Abs. Asphalt	0.474	0.474	0.474	0.474	0.474	0.474	Pba=H
Eff. Asph. Content	3.852	4.311	4.764	5.213	5.658	6.099	Pbe=I
% V. M. A.	14.49	14.45	14.15	14.41	14.78	15.43	VMA=J
S. G. of plugs (KT-15)	2.293	2.305	2.323	2.328	2.329	2.322	Gmb=K
Lab Plugs PCF	143.08	143.83	145.02	145.27	145.33	144.89	L
% Air Voids	5.79	4.67	3.29	2.47	1.81	1.53	Pa=M
% Voids Filled	59.88	67.55	76.86	82.73	87.58	90.16	VFA=N
P'b Max	5.51	5.49	5.36	5.47	5.63	5.90	O
Eff. Film Thickness	6.54	7.36	8.17	8.98	9.79	10.61	P
Filler/Binder Ratio	1.33	1.20	1.09	1.00	0.92	0.86	Q

$$PB = A = \frac{P'B * 100}{100 + P'B}$$

$$PS = B = 100 - A$$

$$F = E * 62.4$$

$$GSE = G = \frac{B}{\frac{100}{E} - \frac{A}{C}}$$

$$PBA = H = 100 * \frac{G - D}{D * G} * C$$

$$PBE = I = A - \frac{H}{100} * B$$

$$VMA = J = 100 - \frac{K * B}{D}$$

COMBINED AGGREGATE SP. GR.

	APPARENT	BULK	%
+4	2.652	2.484	31
-4	2.669	2.578	69
Theo. Comb.	2.664	2.566	

$$L = K * 62.4$$

$$PA = M = 100 * \frac{E - K}{E}$$

$$VFA = N = \frac{100 * \frac{I}{C}}{\frac{J}{K}}$$

KANSAS DEPARTMENT OF TRANSPORTATION  
HOT MIX DESIGN DATA (MARSHALL METHOD)

Contract: 594066008  
Project: 99-115 K 4615-01

County: Zolan Date: March 21, 1995

Lab No. 9B99099A

Mix Designation: BM-2

Asphalt Grade: AC-10

Sp. Gr. AC: 1.0180

Compaction, Blows/Side: 50

Deg.C	% AC	Comapat Temp. (C)	Specimen Height (MM)	Weight, Grams				Water Absorbed %	SP. GR. Compact Mix	KG/ Cubic Meter	Water Bath (C)	Stability			Flow (0.25) (MM)	Bearing Capacity (kPa)
				Dry In Air	In Water	S.S.D In Air	S.S.D In Water					Dial. Reading	Corr.	Adjust (N)		
298	A	279	2.516	1175.1	661.7				2.289		139	117	1.00	1032	7.5	Error
	B	277	2.506	1183.8	669.2				2.300		139	143	1.00	1277	7.5	
	C	274	2.497	1174.2	661.5				2.290		141	122	1.00	1079	7.5	
4.50	Average								2.293	143.08				1056	7.5	158
298	A	279	2.512	1185.0	671.3				2.307		140	105	1.00	919	7.5	
	B	278	2.500	1187.7	674.0				2.312		140	117	1.00	1032	7.5	
	C	276	2.487	1179.4	665.8				2.296		140	112	1.00	985	7.5	
5.00	Average								2.305	143.83				979	7.5	147
298	A	272	2.493	1187.1	675.7				2.307		140	117	1.00	1032	8.0	
	B	272	2.487	1186.6	676.2				2.325		140	127	1.00	1126	9.0	
	C	274	2.476	1187.1	676.7				2.326		140	131	1.00	1164	9.5	
5.50	Average								2.324	145.02				1107	8.8	140
298	A	276	2.492	1193.6	680.6				2.327		139	131	1.00	1164	10.5	
	B	276	2.468	1183.9	675.6				2.329		139	122	1.04	1122	9.5	
	C	276	2.492	1190.0	679.1				2.329		140	116	1.00	1022	9.5	
6.00	Average								2.328	145.27				1103	9.8	124
298	A	279	2.469	1190.5	679.2				2.328		140	114	1.04	1044	12.5	
	B	277	2.478	1184.8	675.6				2.327		140	122	1.00	1079	11.5	
	C	278	2.486	1186.1	677.6				2.333		140	112	1.00	985	11.5	
6.50	Average								2.329	145.33				1036	11.8	95
298	A	279	2.478	1184.5	674.7				2.323		139	119	1.00	1051	14.0	
	B	276	2.485	1184.3	672.9				2.316		140	105	1.00	919	13.5	
	C	274	2.503	1189.2	677.8				2.325		140	118	1.00	1041	13.5	
7.00	Average								2.322	144.89				1004	13.7	78

Specific Gravity Method: I

ERROR = PLUG OUT OF ALLOWED RANGE

D.O.T. FORM 705

KANSAS DEPARTMENT OF TRANSPORTATION

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF PAVING MIXTURES

References: ASTM D 2041 (Rice's Method) and Kansas Test Method KT-39  
 Contract Number: 594066008  
 Project Number: 99-115 K 4615-01

Date: March 21, 1995  
 County: Zolan  
 Lab No: 9B99099A

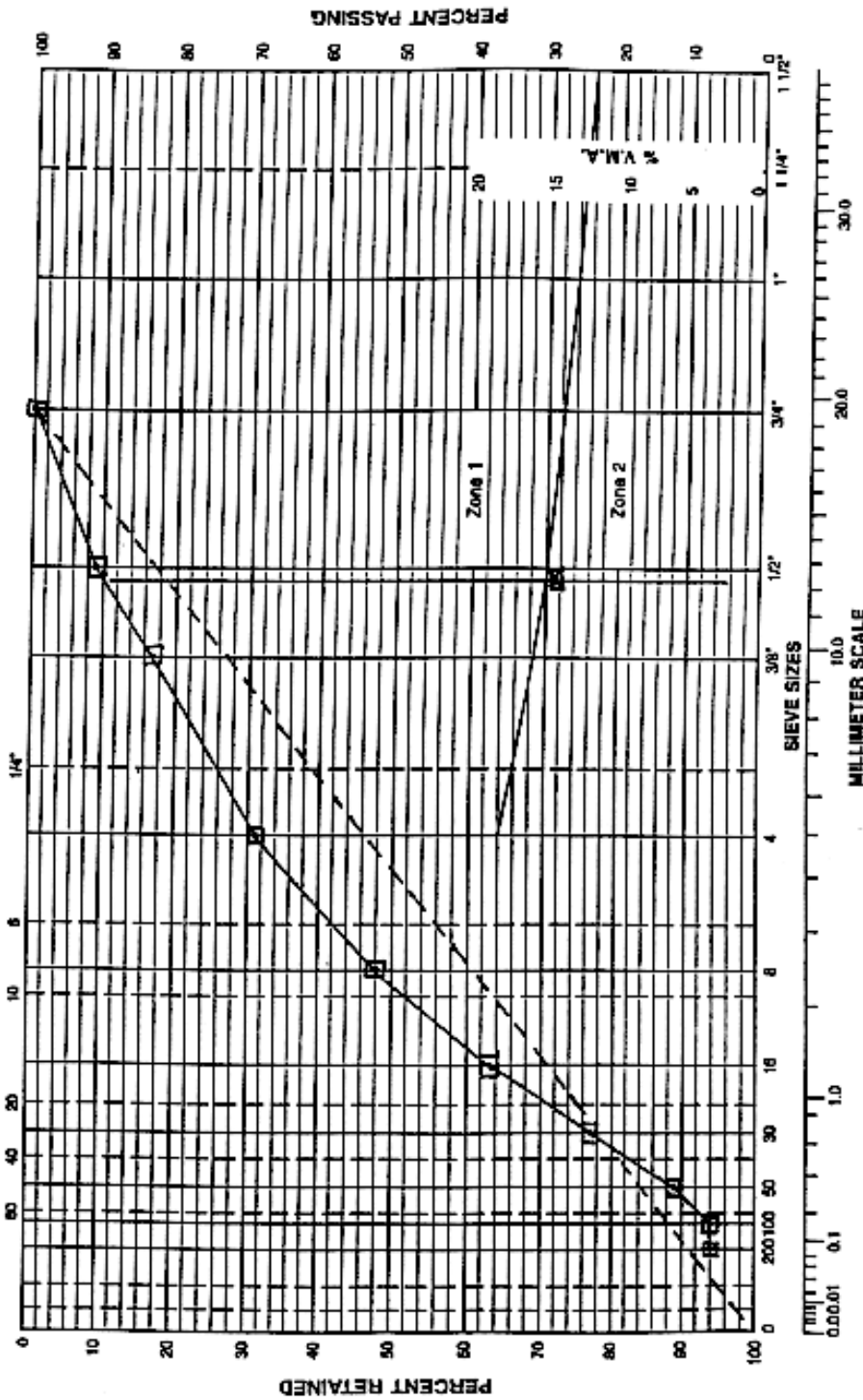
Bowl # Sample #	4.50 A	4.50 B	5.00 A	5.00 B	5.50 A	5.50 B
Mass of Sample & Bowl in Air, Grams	3646.5	3698.3	3720.3	3709.2	3681.9	3673.7
Mass of Bowl in Air, Grams	2144.0	2141.9	2173.7	2149.5	2114.6	2112.2
Mass of Sample in Air, Grams (A)	1502.5	1556.4	1546.6	1559.7	1567.3	1561.5
Temp. of Bath, Sample and Bowl after 10 Minutes	78.8	78.6	77.9	78.0	77.5	77.6
Mass of Sample and Bowl in Water, Grams	2240.4	2258.9	2270.3	2260.2	2251.9	2246.7
Mass of Bowl in Water, Grams	1368.2	1365.1	1386.9	1362.7	1337.8	1335.4
Mass of Sample in Water, Grams (C)	872.2	893.8	883.4	897.5	914.1	911.3
Maximum Sp. Gr. of Mix (Rice's) A/(A-C)	2.3838	2.3489	2.3320	2.3553	2.3994	2.4015
Average Max. Sp. Gr. of Mix	2.366		2.344		2.400	

D.O.T Form 706



KANSAS DEPARTMENT OF TRANSPORTATION  
 0.45 POWER GRADATION CHART

Contract 094066008 Project 99-115 K 4615-01 County Zolan Lab. No. 9899098A



INSTRUCTIONS FOR DETERMINING ZONE 1 or 2:  
 1. Plot design gradation.  
 2. Locate 10% retained point on gradation line.  
 3. Draw vertical line downward from 10% retained point.  
 4. Indicate V.M.A. value at tentative A.C. content on vertical line using scale labelled "% V.M.A." by drawing a symbol (X) at that point.  
 This point determines if this is a Zone 1 or Zone 2 mix.

Legend

- Single Point Grading
- - - Theoretical Maximum Density Line

BY ABC Checked By DES

### **5.3.3 Superpave Mix Design**

This information is currently located in the Superpave Training Manual, taught at Kansas State University. Field Laboratory Technician (SF) Certification



### 5.3.4. MIX DESIGN PROCEDURES FOR CIR (COLD-IN-PLACE RECYCLING) MATERIAL

#### 1. Mixtures Containing an Emulsion.

##### 1.1. Scope.

This method covers the procedure for obtaining materials and the preparation, either by the Contractor or the emulsion supplier, of a mix design as specified in the following manner.

##### 1.2. Sampling and Processing

Obtain cores from the areas to be recycled. If cores show significant differences in various areas, such as different type or thickness of layers between cores, then separate mix designs shall be performed for each of these pavement segments. It is recommended to take, at a minimum, one core for every 1.2 miles (2 kilometers) of lane and where visual differences in the pavement are noticed. Cores shall be cut in the laboratory to the depth specified for the CIR project. Cores shall be crushed in the laboratory. Perform a mix design using the medium gradation and a minimum of one of the fine or coarse gradations using the following recycled asphalt pavement millings criteria.

	Fine	Medium	Coarse
1¼ in (31.5 mm)	0	0	0
1 in (25 mm)	0	0	0-15
¾ in (19 mm)	0-5	4-15	8-25
#4 (4.75 mm)	25-45	45-60	55-70
#30 (600 µm)	65-85	86-96	93-99
#200 (75 µm)	93-99	97-99.4	97-99.9

The mix design shall be performed on these crushed millings. Gradation of the millings after crushing shall be determined by **KT-01**, **KT-02**, and **KT-03** (dried at 104°F (40°C) or less). An alternative method is to dry, screen, and recombine millings in the laboratory to target gradation. Suggested screens are ½ in (12.5 mm), ⅜ in (9.5 mm), #4 (4.75 mm), #8 (2.36 mm), #30 (600 µm), and pan. Scalp oversize material with a 1 in (25 mm) screen when using 4 in (100 mm) diameter compaction molds.

##### 1.3. Asphalt Emulsion (CSS)(SPECIAL)

The contractor shall purchase and use asphalt emulsion that meets the following requirements.

Test		Minimum	Maximum
Residue from distillation, %	AASHTO T 59 <sup>1</sup>	64.0	66.0
Oil distillate by distillation, %	AASHTO T 59 <sup>1</sup>		0.5
Sieve Test, %	AASHTO T 59 <sup>1</sup>		0.1
Penetration, 25°C, dmm	AASHTO T 49 <sup>2</sup>	-25%	+25%

<sup>1</sup> Modified **AASHTO T 59** procedure – Slowly bring the temperature of the lower thermometer to 350 ± 9°F and maintain for 20 minutes. Complete the distillation in 60 ± 15 minutes from the first application of heat.

<sup>2</sup> Penetration will be determined by the producer and submitted to the Chief Chemist at the time of prequalification.

#### 1.4. Mixing

Specimen size: the amount that will produce a 2.40 to 2.60 in (61.0 mm to 66.0 mm) tall specimen; use **KT-39** to determine the size for Rice specific gravity.

Number of specimens: 4 plugs per emulsion content for a total of 6 sets for long-term stability, and 6 plugs for moisture testing at 3 emulsion contents. Two specimens are required for Rice specific gravity; test at the highest emulsion content in the design and back calculate for the lower emulsion contents. Recommended emulsion contents: 1.5%, 2.0%, 2.5%, 3.0%, 3.5%, and 4.0%. Choose three emulsion contents that bracket the estimated recommended emulsion content.

Add moisture that is expected to be added at the milling head, typically 1.5 to 2.5 %.

If any lime is in the mixture, introduce the lime in a similar manner as during field production.

Mixing of test specimens shall be performed with a mechanical bucket mixer. Mix the CIR RAP millings thoroughly with water first, then mix with emulsion. Mixing shall occur at ambient temperature. One specimen shall be mixed at a time. Mixing time with emulsion should not exceed 60 seconds.

#### 1.5. Compaction

Specimens shall be compacted immediately after mixing. Place paper disks on the top and bottom of the specimen before compacting.

Specimens shall be compacted with a Superpave gyratory compactor (SGC) in a 4 in (100 mm) mold as specified in **KT-58** for 30 gyrations. The mold shall not be heated.

#### 1.6. Curing after compaction

Extrude specimens from molds immediately after compaction. Carefully remove paper disks.

Place specimens in 140°F (60°C) forced draft oven with ventilation on sides and top. Place each specimen in a small container to account for material loss from specimens.

Specimens for Rice specific gravity should be dried to constant mass (less than 0.05% mass loss in 2 hours). Care should be taken not to over-dry the specimens.

Cure compacted specimens to constant mass but no more than 48 hours and no less than 16 hours. Constant mass is defined as no more than 0.05% change in mass in 2 hours. After curing, cool specimens at ambient temperature for  $18 \pm 6$  hours.

#### 1.7. Measurements

Determine bulk specific gravity (density) of each compacted (cured and cooled) specimen according to **KT-15**, procedure III; however, the mass of the specimen in water (measurement C) can be recorded after one minute submersion.

Determine specimen heights according to **KT-14** or equivalent. Alternatively, the height can be obtained from the SGC printed copy, at 30 gyrations.

Determine Rice (maximum theoretical) specific gravity, **KT-39**, except as noted in Item 6 of this procedure, and do not break any agglomerates which will not easily reduce with a flexible spatula. It is normally necessary to perform the supplemental dry-back procedure outlined in **AASHTO T 209** to adjust for uncoated particles.

Determine air voids at each emulsion content.

Determine corrected Marshall stability by **KT-14** at 104° F (40° C) after 2 hour temperature conditioning in a forced draft oven. This testing shall be performed at the same time that the moisture conditioned specimens are tested.

### **1.8. Moisture Susceptibility**

Perform same conditioning and volumetric measurements on moisture-conditioned specimens as on other specimens. Vacuum saturate to 55 to 75 percent, soak in a 77°F (25°C) water bath for 23 hours, followed by a one hour soak at 104°F (40°C). Determine corrected Marshall stability. The average moisture conditioned specimen strength divided by the average dry specimen strength is referred to as retained stability.

### **1.9. Thermal Cracking**

See **KT-60**.

### **1.10. Raveling**

See **KT-61**.

### **1.11. Emulsion Content Selection**

The properties of the specimens at design emulsion content shall meet the properties in Table A1.

### **1.12. Report**

The report shall contain the following information: Gradation of RAP; percent lime, recommended water content range as a percentage of dry RAP; optimum emulsion content as a percentage of dry RAP and corresponding density, air void level, and absorbed water; Marshall stability and retained stability at recommended moisture and emulsion contents, Raveling %, and Thermal Cracking initiation temperature. Include the emulsion designation, company name, plant location, and residue content.

### **1.13. Mixture Design Criteria**

**1.13.1.** A preconstruction mix design shall be submitted by the Cold In-Place contractor tested in accordance with this section using materials obtained directly from the project site. Based on cores taken before the project, more than one mix may be required. The job mix formula shall meet the criteria of Table A1 and be approved by the District Materials Engineer.

1.13.2. Table A1

<b>Mix Design Criteria</b>	
4 in (100 mm) specimens shall be prepared in a Superpave Gyratory compactor. The mixture should meet the following criteria at the selected design asphalt emulsion content:	
<b>Property</b>	<b>Criteria</b>
Compaction effort, Superpave Gyratory Compactor	Refer to <b>KT-58</b>
Density, <b>KT-15</b>	Report
Gradation for Design Millings, <b>KT-03</b>	Report
Marshall stability *, <b>KT-14</b> , 104°F (40°C)	5.56 kN, min.
Retained stability based on cured stability **	70 % min.
Indirect Tensile Test, <b>AASHTO T 322</b> , Modified in <b>KT-60</b>	See note in <b>KT-60</b>
Raveling Test, Ambient, <b>KT-61</b>	2 % max.

\* Cured stability tested on compacted specimens after 140°F (60°C) curing to constant mass.

\*\* Vacuum sat. of 55 to 75 percent, water bath 77°F (25°C) @ 23 hours, last hour at 104°F (40°C) water bath.

## 5.4. LABORATORY AND SAMPLE IDENTIFICATION

### 5.4.1. LABORATORY IDENTIFICATION

#### 1. General.

Identifying symbols for each "in-state" laboratory and some "out-of-state" laboratories that sample, inspect or test material for the Department of Transportation have been established. Knowledge of these symbols is often beneficial in determining the general source of material and the laboratory that performed the initial sampling, inspection and testing operations.

#### 2. Identification Symbols.

**2.1. General:** The symbols listed below are to be used and identification numbers are to be assigned in accordance with the following instructions for all materials inspected, tested or submitted for test

**2.2. Materials and Research Center:** All samples received at the Materials and Research Center are assigned laboratory numbers bearing a prefix to denote the calendar year during which the samples were received. The first sample received in 2020 bears the laboratory number 20-0001. When tests are completed, the test report will also bear this number if the sample was submitted outside of AWP or the test report will bear the Sample ID number with the Materials and Research assigned laboratory number shown in the remarks for samples submitted in AWP.

**2.3. Branch Laboratories:** Branch laboratories are identified by letter prefix followed by the calendar year, then by the laboratory number.

<u>Laboratory Location</u>	<u>Identification</u>
Topeka	A-03-XXXX
Kansas City	B-03-XXXX
Wichita	D-03-XXXX

#### 2.4. "Out-of-State" Laboratories:

A. W. Williams Inspection Co., Mobile, AL (Timber Products)	AWW (Identifying mark placed on inspected and/or tested material)
--	--

Missouri Highway Dept. Kirkwood, MO (St. Louis Area) Miscellaneous Materials	OAK-91
--	--------



## 5.4.2. SAMPLE IDENTIFICATION

Samples, tests and inspections entered into the AWP will be assigned a unique system generated sample ID number. If a district assigns additional numbers to samples, tests and inspections to aid in tracking and/or filing then the numbering procedures outlined below should be used. Multiple split or replicate samples can be assessed during a single witness by the KDOT Independent Assurance (IA) representative. The first recorded sample (A) in AWP is to be the IA results.

**1. District Laboratory Numbers:** Unless Sample Id Nos. are used, all samples, tests or inspections by district laboratories are to be assigned laboratory numbers in the following manner: District Number--Year--Laboratory number. A separate series of laboratory numbers shall be assigned to each of the designated types of samples.

### 1.1. Laboratory Number Designations

0001 - 2999	For Acceptance Samples
3000 - 3999	For Verification Samples
4000 - 4999	For Assurance Samples reported by the District Materials Engineer or by the Materials and Research Center.
5000 - 5999	For samples designated in this Instruction as "Other"
6000 - 6999	For Production Samples

**1.2. Additional information** is to be shown which will identify the type or purpose of the sample and test. Examples:

**1.2.1.** Sample 3-86-4783 is a replicate or split assurance sample. In this case, a direct comparison of results is intended. This information should show as:

<u>Non-AWP</u>	<u>AWP</u>
Lab. No.: 3-86-4783	ID No.: Preassigned A, B, C, D, etc.
Type: Split Sample	Type: ASR
or	
Replicate Sample	

**1.2.2.** Sample 1-86-4231 represents an actual witnessing of an assurance testing or sampling procedure. This information should show as:

<u>Non-AWP</u>	<u>AWP</u>
Lab. No.: 1-86-4231	ID No.: Preassigned
Type: Witness	Type: ASW

**1.2.3.** Sample 2-86-3014 represents a sample of asphalt cement taken as a part of the monitoring process conducted for manufactured and certified materials. This information should show as:

<u>Non-AWP</u>	<u>AWP</u>
Lab. No.: 2-86-3014	ID No.: Preassigned
Type: Verification-Certified Materials	Type: VER

**1.3.** The identification numbers assigned by district personnel for "other" Samples and Tests should be for sample and test types not listed in the Sampling and Testing Frequency Chart. "Other" tests and samples are designated as "OTH" in AWP.

**2.** Assurance Tests reported by the Materials and Research Center must show the Sample ID number under which the sample was tested, and in addition, will show the district laboratory number and identification number under which the sample was taken or submitted, if not entered into AWP. The district laboratory number or Sample ID number should appear in the upper right hand corner of the report.

### **5.4.3. SAMPLE IDENTIFICATION FORMS**

#### **1. DOT Form No. 624**

This form is used when submitting samples to the Materials & Research Center.

**1.1.** (Sample of \_\_\_\_\_). The precise name of the material as set forth in the specifications is to be used. For example, use the term "Emulsified Asphalt (SS-1H)" instead of "Emulsion."

Do not use one information sheet for two or more nonrelated items. For example, do not put cement and reinforcing steel on the same sheet.

**1.2.** (Specification Number). Use correct, applicable and complete specification number including the subarticle, if necessary. When the material submitted is covered by special provision or project special provision, these references to the applicable document should be listed.

**1.3.** (Quantity \_\_\_\_\_). Except in the case of Assurance Samples, show the quantity of material represented by the sample. If the sample consists of several different items, write "See Below" and show the number of units represented by each sample under the "Remarks" column in the main body of the form. An approximate figure may be shown for deposits and stockpiles of aggregates.

**1.4.** (Property of or Mfg. by). Include name of company manufacturing the material as well as the supplier. It may be one and the same, however, it may be two different companies, i.e., hot pour joint compound manufactured by W.R.M. Co., Ginel, Illinois supplied by C-W Co. at Kansas City, Missouri.

**1.5.** (Location \_\_\_\_\_). It is very important that this item be completed accurately and in full detail. For aggregate samples, the full legal description including the 1/4 section, section number, township, range and county should be included. If characteristics of location or nature of production are such that it is required for proper control or identification of a material, the 1/16 corner of the section should be shown. Stockpile samples should show the stockpile location, i.e., Jones Ready-Mix Plant at Smithville, as well as the legal description of the deposit and the county from which the aggregate was produced.

**1.6.** (Identification Marks \_\_\_\_\_). It is very important that this item be completed accurately and in full detail.

**1.7.** (Submitted by \_\_\_\_\_). It is very important that this item be completed accurately and in full detail.

**1.8.** (Field Lab No. \_\_\_\_\_). This number is assigned by the individual who submits the sample or samples and is based on an established system. It is necessary that all individual samples listed on a single sheet be submitted under a single field laboratory number.

**1.9.** (Address). The mailing address of the manufacturer or the supplier should be shown for manufactured products.

**1.10.** (Date). The date the sample was taken or taken possession of.

**1.11.** (Project or POV). The project number that the sample was taken from or is intended for.

**1.12.** (County). The county that the sample was taken from or is intended for.

**1.13.** (Dist). The District that the sample was taken from or is intended for.

**1.14.** (Type Construction). The type of project construction that the sample was taken from or is intended for, (ie: paving, bridge pier, etc.)

**1.15.** (Act, Prelim, Res).

**1.16.** (Contractor). The Contractor that the sample was taken from or is intended for.

**1.17.** (Sample). Provide a simple definition of what the sample is and at what it is representing.

**1.18.** (Description). Provide a description of what the sample is and at what it is representing.

**1.19.** (Tests Required). If complete quality tests of aggregates are required, it is only necessary to indicate "Complete Quality." If only certain specific tests are required, it is necessary to list these.

Tests specified for items other than aggregates are listed in somewhat general terms. For example, the tests listed for structural steel are "physical and chemical," or for galvanized items the listing would show "weight of zinc coating." The term "Complete Tests" should be entered only when all tests listed in the Specifications are to be conducted.

**1.20.** (Remarks). Applicable information not previously listed elsewhere related directly to the sample is entered here. The quantity of miscellaneous items such as fasteners, fencing items, etc. may be shown in this column.

**1.21.** (Date Received). The date the sample was received at the Materials and Research Laboratory or other Regional or District Laboratory.

**1.22.** (Laboratory No.). The number of the laboratory the sample is being received at.

**1.23.** (Remarks #2). Applicable information not previously listed elsewhere is entered here. State any specific information that may be pertinent to the sample but related to the project, or other specific items not listed previously.

**1.24.** Scheduling - Unless otherwise indicated on the information sheet, samples submitted to the Laboratory will be placed in line for test in the order received and following similar samples already in the laboratory. Reports will be issued electronically when tests are complete.

**1.25.** Assurance Samples are indicated by entering the proper notation with capital letters at the extreme upper right hand corner of the sheet.

**1.26.** When samples are delivered to the Laboratory by Department personnel, the copy of the sample identification sheet will be handed to laboratory receiving personnel along with the sample.

**2. DOT Form No. 667.**

This form is to be used only when submitting samples of soil.







## 5.5 REQUIRED SAMPLE SIZES

### 1. SCOPE

This section covers the size of samples to be submitted to the Materials and Research Center for testing. The sample sizes listed are minimums and in special cases the Engineer of Tests may request that larger samples are submitted.

Each sample or group of samples must be accompanied by an information sheet containing all data necessary for issuing a complete report of the test results. Additional details are set forth in **Section 5.4** of this manual.

### 2. REQUIREMENTS

#### 2.1. AGGREGATES

##### 2.1.1. Aggregates for Quality Testing

**2.1.1.1.** Official Quality (OFQ) requirements for soundness do not apply for aggregates having less than 10% material retained on the No. 4 (4.75 mm) sieve.

**2.1.1.2.** OFQ requirements for wear do not apply to aggregate having less than 10% materials retained on the No. 8 (2.36 mm) sieve.

**2.1.1.3.** Crushed aggregates with less than 10% material retained on the No. 4 (4.75 mm) sieve (excluding mineral filler supplements) must be produced from a source complying with the official quality requirements prior to final processing.

Material	Sample Size
Crushed Stone	Two 50 lb (23 kg) bags of -1" (-25.0 mm), + #8 (+2.36 mm) material. Select a grading from <b>Table 1</b> based on the predominant particle size of the sample material, and make certain the minimum size fraction amounts outlined in <b>Table 1</b> are included in the 100 lb (45 kg) sample. Additional bags of individual sized material may be submitted to assure these minimums.  A sample graded in accordance with the requirements of <b>Table 2</b> shall also be submitted.
Fine Aggregate for Concrete	50 lbs (23 kg) of pile run material.
Chat or Sand-Gravel	50 lbs (23 kg) of + #8 (+2.36 mm) material plus 50 lbs (23 kg) of pile run material.  A sample graded in accordance with the requirements of <b>Table 2</b> shall also be submitted.
Aggregate for Wetting & Drying Test	Six 50 lbs (6-23 kg) bags of Sand-Gravel graded to meet the middle 1/3 of the MA-1 grading.



**Table 1 - Minimum Mass Requirements for Crushed Aggregate Soundness Tests**

Sieve Size		Grading and Mass, lbs (kg)		
Passing	Retained On	I	II	III
1" (25.0 mm)	3/4" (19.0 mm)	20 (9)		
3/4" (19.0 mm)	3/8" (9.5 mm)	15 (7)	30 (14)	
3/8" (9.5 mm)	No. 4 (4.75 mm)	6 (3)	10 (5)	35 (16)
No. 4 (4.75 mm)	No. 8 (2.36 mm)	6 (3)	6 (3)	10 (5)

**Table 2 - Grading of Wear Test Samples**

Sieve Size		Grading and Mass, lbs (kg)			
Passing	Retained On	A	B	C	D
1-1/2" (37.5 mm)	1" (25.0 mm)	10 (5)			
1" (25.0 mm)	3/4" (19.0 mm)	10 (5)			
3/4" (19.0 mm)	1/2" (12.5 mm)	10 (5)	20 (9)		
1/2" (12.5 mm)	3/8" (9.5 mm)	10 (5)	20 (9)		
3/8" (9.5 mm)	1/4" (6.3 mm)			20 (9)	
1/4" (6.3 mm)	No. 4 (4.75 mm)			20 (9)	
No. 4 (4.75 mm)	No. 8 (2.36 mm)				40 (18)

**2.1.2 Lightweight Aggregates for Prequalification**

Material	Sample Size
Lightweight Aggregate for Concrete	<p>Eight 50 lbs (8-23 kg) bags pile run material. Select a grading from <b>Table 1</b> based on the predominant particle size of the sample material, and make certain the minimum size fraction amounts outlined in <b>Table 1</b> are included in the total 400 lb (180 kg) sample. Additional bags of individual sized material may be submitted to assure these minimums.</p> <p>A sample graded in accordance with the requirements of <b>Table 2</b> shall also be submitted.</p>
Lightweight Aggregate for Cover Material	<p>Two 50 lbs (2-23 kg) bags of pile run material. Make certain the minimum amounts for III Grading from <b>Table 1</b> are included in the 100 lb (45 kg) sample. Additional bags of individual sized material may be submitted to assure these minimums.</p> <p>A sample graded in accordance with the C Grading of <b>Table 2</b> shall also be submitted.</p>

### 2.1.3. Aggregates for Verification Samples

Material	Sample Size
Crushed Stone	<p>Two 50 lbs (2-23 kg) bags of pile run material. If the #4 (4.75 mm) and #8 (2.36 mm) retained material is not available in the amounts outlined in <b>Table 1</b>, it may be obtained from finer material delivered to the project if the finer material is from the same source as the coarser material. If finer material from the same source is not delivered to the project, then a Modified Soundness test will be conducted.</p> <p>A sample graded in accordance with the requirements of <b>Table 2</b> shall also be submitted.</p>
Fine Aggregate for Concrete	50 lbs (23 kg) of pile run material.
Chat or Sand-Gravel	<p>Two 50 lbs (2-23 kg) bags of pile run material.</p> <p>A sample graded in accordance with the requirements of <b>Table 2</b> shall also be submitted.</p>
Lightweight Aggregates	<p>Two 50 lbs (2-23 kg) bags of pile run material. Sample size may be increased to ensure the minimum amounts from <b>Table 1</b> are included in the sample.</p> <p>A sample graded in accordance with the requirements of <b>Table 2</b> shall also be submitted. For Cover Material, provide a C Graded sample.</p>

### 2.1.4. On Grade Concrete Aggregates

Material	Sample Size
Ledge Sample	400 lbs (180 kg) per 8' bed, maximum 50 lbs (23 kg) per bag, hand-picked from the ledge. Samples to be selected by Geologist.
Production Samples	<p>Two 40 lbs (2-18 kg) bags of material passing the 3/4" (19.0 mm) sieve and retained on the 1/2" (12.5 mm) sieve.</p> <p>Two 40 lbs (2-18 kg) bags of material passing the 1/2" (12.5 mm) sieve and retained on the 3/8" (9.5 mm) sieve.</p>

## 2.2. ASPHALT MATERIAL

Material	Sample Size
Performance Graded Asphalt Binder	Two 1 qt (1 L) cans.
Cutback Asphalt	Two 1 qt (1 L) cans.
Emulsion and Rejuvenating Agent	1 gal (4 L) – Plastic Containers ONLY!

## 2.3. BRICK AND CONCRETE MASONRY UNITS

Material	Sample Size
Masonry Brick, Common	5 per lot ( <b>see note</b> ).
Masonry Brick, ADA Compliant	Call the Materials Certification Technician at the Materials & Research Center.
Facing	10 per lot.
Concrete Building Brick	5 per lot.
Concrete Masonry Units (solid)	5 per lot.
Concrete Masonry Units (hollow load-bearing)	10 per lot per size.

Note: For the purposes of **Section 2.3** (above), a lot shall be any well defined quantity of material produced by essentially the same process.

## 2.4. CONCRETE CURING MATERIALS

Material	Sample Size
Liquid Membrane – Forming Compounds	Two 1 qt (1 L) samples per each lot of 2000 gal (7500 L) or less.

## 2.5. JOINT SEALERS AND JOINT FILLERS

Material	Sample Size
Hot Joint Sealing Compound	Information or Verification: 5 lbs. (2.3 kg) Prequalification: 30 lbs. (14 kg)
Cold Applied Chemically Cured Joint Sealant	Two 1 qt (1L) cans per lot.
Preformed Elastomeric Compression Joint Seal	For prequalification – one 6' (1.80 m) long piece. For identification – one 2.5' (0.75 m) long piece.
Plastic Joint Compound for Concrete	5 lbs (2.5 kg) per lot.

## 2.6. MISCELLANEOUS MATERIALS

Material	Sample Size
Air Entraining Admixtures	1 qt (1 L).
Admixtures for Water Reduction and Set Retardation	1 qt (1 L).
Calcium Chloride	Solution – 1 qt (1 L). Dry – 1 gal (4 L).

## 2.7. NON-FERROUS METALS

Material	Sample Size
Aluminum Alloys – Bridge Rail Posts Bolts Nuts Sheet	1 post per 100. 2 bolts per lot. 4 nuts per lot. One 12" (300 mm) square piece per lot.
Bronze – Bridge Number Markers Castings	20 g of drillings. 50 g of drillings.

## 2.8. PAINT MATERIALS AND MIXED PAINTS

Material	Sample Size
Bridge Paint – Dry Pigment Mixed Paint Vehicle, Thinner, Etc. Aluminum Paste	1 pt. (0.5 L) per lot of each component
Pavement Marking Paint	Two 1 quart (1 L) cans per lot of each color

**2.9. REFLECTIVE MATERIALS**

**2.9.1.**

	Sample Size
Reflective sheeting	Prequalification: 3 pieces, 24" x 24" per color. Verification: 1 piece, 12" x 12" minimum per lot per color
Center Mount Reflectors	5000 or less – 18 each. Each additional 5000 (or fraction thereof) of each color – 4 each.

**2.9.2. Pavement Marking**

Material	Sample Size
Cold Plastic Patterned Cold Plastic High Durability	One 36" (900 mm) piece for materials less than 12" (300 mm) in width. One 24" (600 mm) piece for materials of 12" (300 mm) and greater in width.
Epoxy Resin and/or Epoxy Hardener	Two ½ pint (0.25 L) cans per lot per color.
Multi-Component Resin/Hardener	Two ½ pint (0.25 L) cans per lot per color.
Glass Beads ( <i>only needed if having issues on project, beads should be already prequalified by MRC prior to use</i> )	Two 1 quart cans per lot per color.
Thermoplastic	One gallon can lid per lot per color.

**2.10 CULVERT, SEWER AND UNDERDRAIN PIPE**

Material	Sample Size
Clay Pipe (except drain tile)	0.5% of total lot, 2 tiles minimum.
Clay Drain Tile	5 per lot.
Cast-Iron Culvert Pipe	5% of total lot, 1 pipe minimum.
Cast-Iron Soil Pipe	5% of total lot, 1 pipe minimum.
Corrugated Steel Underdrain Pipe	0.5% of total lot, 2 pipes minimum.
Corrugated Aluminum Underdrain Pipe	0.5% of total lot, 2 pipes minimum.

Bituminous Coated Corrugated Metal Pipe, Pipe Arches, Coupling Bands, and Structural Plate	1 qt (1 L) of the bituminous coating and approximately 1 ft <sup>2</sup> (3000 mm <sup>2</sup> ) of coated corrugated steel.
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**2.11. PORTLAND CEMENT, SCM’s, AND LIME**

Material	Sample Size
Portland Cement, Fly Ash, Slag, Silica Fume	1 gal (4 L) sample.
Blended Cements	2 gal (8 L) sample.
Hydrated Lime, Quicklime,	1 qt (1 L)

**2.12. MATERIALS FOR ROADSIDE IMPROVEMENT**

Material	Sample Size
Herbicides	1 qt (1 L) sample.

**2.13. STEEL AND IRON**

**2.13.1 Bar, Strand, and Plate**

Material	Sample Size
Steel Bars for Concrete Reinforcement	<p>Prequalification –            #3 (10) thru #6 (19) – Three 8 ft (2.5 m) samples per heat.            #7 (22) thru #11 (36) – Three 9 ft (2.75 m) samples per heat.            #14 (43) and #18 (57) – Three 10 ft (3 m) samples per heat.</p> <p>Verification (Preferable Single Bar Option) –            #3 (10) thru #6 (19) – One 8 ft (2.5 m) sample.            #7 (22) thru #18 (57) – One 10 ft (3 m) sample.</p> <p>Verification (Alternative Two Bar Option) –            #3 (10) thru #5 (16) – Two 4 ft (1.25 m) samples.            #6 (19) thru #10 (32) – Two 5 ft (1.5 m) samples.            #11 (36) and #14 (43) – Two 6 ft (2 m) samples.            #18 (57) – Two 7 ft (2.2 m) samples.</p>
Reinforcing Bar Splices	<p>Prequalification -            3 samples each for bar sizes #4 (13), #6 (19), and #8 (25).            Each splice shall have reinforcing bar extending 24” (610 mm) from both ends of the splice.</p> <p>Verification –            2 samples for each bar size used. Each splice shall have reinforcing bar extending 24” (610 mm) from both ends of the splice.</p>

Welded Steel Wire Fabric for Concrete Reinforcement	1 piece, 48” (1.2 m) long and full width.
Fabricated Steel Bar or Rod Mats	See verification of Steel Bars for Concrete Reinforcement for length(s). 1 or 2 pieces sample per size per heat.
Prestressing or Post-Tensioning Strand	One 8 ft (3 m) sample for each 20 ton (18 Mg) lot (or heat). Cut into two 4 ft (1.5m) pieces for shipment.
Structural Steel	1 piece, 24” (610 mm) x 4” (100 mm) minimum.  Note: If plate width is 24” (610 mm) or less, cut long dimension of sample parallel with the direction of rolling. If plate width is greater than 24” (610 mm), cut long dimension of sample perpendicular to the direction of rolling.

### 2.13.2 Fasteners

Material	Sample Size
High Strength Steel Fasteners for Structural Connections (i.e. Bridges, Overhead Sign Supports, etc.):  Uncoated ≤ 8000 > 8000 but ≤ 22,000 > 22,000  Coated ≤ 8000 > 8000 but ≤ 22,000 > 22,000	6 each of bolt, nut, and washer. * 9 each of bolt, nut, and washer. 12 each of bolt, nut, and washer.  6 each of bolt, nut, and washer. * 10 each of bolt, nut, and washer. 15 each of bolt, nut, and washer. * 3 ea. of bolt, nut and washer if greater than 1”.
Rivets ≤ 8000 > 8000 but ≤ 22,000 > 22,000	3 5 7

Note: For the fasteners of **Section 2.13.2** (above), the number of specimens listed are per each individual lot and identified by the individual bolt length, diameter, and head marking (strength and type); or nut marking.

### 2.13.3 Miscellaneous Steel and Iron Products

Material	Sample Size
Materials for Guardrail:	Note: Sample only if a Type A certification cannot be provided.
Bolts, Nuts, and Washers	3 each per lot.
Guardrail Fittings	3 each per lot.

Sheet Metal for Signs	One 12" (300 mm) square piece for each 4000 lbs (2000 kg).
Anchor Bolts for Bridges, Signing, Lighting, and Traffic Signals Coated or Uncoated	1 per lot (sample only if a Type A certification cannot be provided).
Pipe (A 53) Black or Galvanized	One 36" (1 m) per lot or heat.
Structural Steel Tubing (A 500 or A 501)	One 36" (1 m) per lot or heat. Only if needed for verification testing
Tire Chains:  Sets Cross Chains, Repair Links, etc. Side Chains	1/2 set per size per order. 1% of pieces. Minimum 5 pieces per order. 1% of length. Minimum 5 ft (1.5 m) per order.

## 2.14. WATER

Material	Sample Size
Water for Use with Portland Cement	1 gal (4 L).

## 2.15. MATERIALS FOR ASPHALT AND AGGREGATE MIXTURES, AND SOILS

### 2.15.1 Asphalt Mixtures

Material	Sample Size
Marshall Analysis:	
Sample of Combined Aggregate	125 lbs (57 kg).
Individual Aggregates – Each Aggregate Except Mineral Filler Mineral Filler	50 lbs (23 kg). 25 lbs (12 kg).
Asphalt Cement	2 gal (8 L).
Bituminous Stabilization of Soils:	
Soils Sample	200 lbs (91 kg).
Cutback Asphalt or Emulsion	3 gal (12 L).



Marshall Density, Stability, and Extraction/Gradation:	50 lbs (23 kg).
Reflux Extraction or Absorb Recovery	30 lbs (14 kg) for PG grading, 20 lbs (9 kg) for all others.
Moisture and Volatile Determination	5 lbs (2.5 kg).

### 2.15.2 Aggregate Mixtures

Material	Sample Size
Cement Stabilized Bases	500 lbs (225 kg).
Lime Stabilized Bases	500 lbs (225 kg).
Aggregate Binder Bases:	
Gradation and P.I.	40 lbs (18 kg).
Standard Compaction	150 lbs (68 kg).

### 2.15.3 Soils

Material	Sample Size
Routine Analysis Only	5 lbs (2.5 kg).
Routine Analysis and Compaction	Two 50 lb (23 kg) bags
Routine analysis, Compaction, and Resilient Modulus	Two 50 lb (23 kg) bags.
Soil Cement Tests	300 lbs (135 kg). In 50 lb (23 kg) bags.
Soil Lime Tests	300 lbs (135 kg). In 50 lb (23 kg) bags.
Moisture Determination	6 oz (170 g) sealed ointment can.
Resistivity and pH	10 lbs (5 kg).
Permeability	Two 50 lb (23 kg) bags.
Comparison P.I.	
Prepared: (- #40 [-425 μm])	0.5 lb (227 g).
Unprepared:	Sufficient material to yield 0.5 lb (227 g) of prepared material.
Soil Fertility	5 lbs (2.5 kg).

## **5.6 AGGREGATES**

### **1. GENERAL**

This section covers the inspection, sampling, testing and acceptance of aggregates. Nothing in Section 5.6, including without limitation, prequalification or preapproval of a given aggregate/source of aggregate, guarantees a contractor, producer, or supplier that the given aggregate/source of aggregate will be approved by or remain approved by KDOT, be accepted by KDOT for use on projects, or be purchased by others for use on projects.

### **2. TYPES OF PRODUCTION**

Aggregate production is classified into two groups according to the methods of operation. Commercial production is defined as production from a permanently established location that supplies aggregate to both commercial consumers and contractors performing KDOT work. Some producers may operate in some locations intermittently, depending on the market in that particular area, utilizing mobile plants; however, these locations remain established as a production sites and are still considered commercial producers.

Non-commercial or roadside production is defined as aggregate production using portable plants that is incidental to other work being performed; for example, a highway cut section where rock is excavated and used by the contractor or sub-contractor for one or more materials that are needed on that particular project.

### **3. INSPECTION RESPONSIBILITIES**

#### **3.1. Contractor Inspection**

The Contractor performs or causes to be performed all inspections and tests necessary to provide and maintain an adequate process control system. An adequate process control system is one that provides that all aggregates or aggregate combinations submitted for acceptance will conform to contract requirements whether manufactured or processed by the Contractor, or procured from subcontractors, vendors, or producers.

The Contractor is responsible for performing all process control activities for all aggregate and aggregate combinations during production, handling, stockpiling, blending, mixing, and placing operations.

#### **3.2. Department Inspection**

All aggregate acceptance tests will be conducted by the Department at the point of usage, unless designated otherwise by the Engineer. The Department reserves the right to run any test at any time or place to determine contract compliance. When test results on aggregates indicate non-compliance with contract requirements, the Engineer may reject the material and cause it to be removed at the Contractor's expense. If the aggregate is on a prequalified list or otherwise approved for use on the project, the Engineer still has the right to reject the material when test results indicate non-compliance with contract requirements. However, the Department will pay the price difference between the previously approved aggregate and the replacement aggregate if the Contractor can demonstrate that no action of the Contractor, subcontractor, vendor, or producer caused the failing test result.

Department inspection is for the Department's benefit and not to ensure Contractor quality control; therefore, Department inspection does not replace the need for Contractor inspection or otherwise relieve the Contractor of responsibility to furnish acceptable aggregates.

## 4. APPROVAL OF DEPOSITS

### 4.1. General.

Aggregate shall not be used for KDOT work until the deposit from which it is being produced and the production process has been approved. The aggregate producer shall notify the District Materials Engineer (DME) and request that an Official Quality sample be obtained during the production of the aggregate. The aggregate producer shall determine and record the GPS coordinates where excavation is occurring. An aggregate source will be approved only after tests on "Official Quality" (OFQ) samples taken by a KDOT representative, or by the producer while under the direct supervision of a KDOT representative, have been completed and the test results show that aggregate produced from a specific deposit using a specific production process meets the quality requirements of the contract documents. If the current OFQ fails, then the source will no longer be approved for projects not yet under contract until production is again approved.

Tests on "Official Quality" samples taken to determine aggregate source approval are conducted in the Materials and Research Center at Topeka. The tests are as follows:

#### ALL AGGREGATES

- ◆ Specific Gravity and Absorption (KT-06)
- ◆ Acid Insoluble Residue (KTMR-28) (as requested)

#### COARSE AND MIXED AGGREGATE

- ◆ Soundness (KTMR-21)
- ◆ Wear (AASHTO T96)
- ◆ Micro Deval (AASHTO T327)

#### FINE AGGREGATE (as requested)

- ◆ Mortar Strength (KTMR-26)
- ◆ Organic Impurities (AASHTO T21)

#### ADDITIONAL TESTING REQUIRED FOR CONCRETE AGGREGATES

- ◆ Durable Aggregate Test (KTMR-22) (for coarse aggregates for on-grade concrete)
- ◆ Wetting and Drying Test (KTMR-23) (for siliceous coarse aggregates for all concrete)

Refer to the Standard Specifications for more detailed information on specific applications.

It is the responsibility of the District Materials Engineer (DME) to see that aggregate deposits and processed aggregates are sampled and tested.

It is the responsibility of the Field Engineer to confirm that aggregates comply with all applicable specifications prior to use. The delivery of aggregate to KDOT projects before OFQ tests show compliance with specifications is prohibited.

### 4.2. Basis of Approval.

#### 4.2.1. Active production sources

Deposits approved on the basis of OFQ tests conducted on either processed (crushed, screened, washed, etc.) or "pit-run" production samples remain approved if there are no significant changes in production or deposit characteristics or no other reasons to doubt the quality of the material. Significant changes in

production include, but are not limited to: how ledge is quarried, equipment changes or modifications to include crushers, screens and wash plants, and changes in the production sequence. In addition, it should not be considered a “significant change” if a crusher is replaced with a nearly identical crusher of the type of crushing mechanism that would have minimal to no effect in quality. The local District Materials Engineer with consultation of the Chief Geologist will determine if a change in quality is expected due to the replacement. Significant changes in deposit characteristics include, but are not limited to: color change, bed thickness change, shale seam thickness change, and mineral changes. KDOT quarry and project inspection personnel, the contractor, and the aggregate producer shall be alert for any of these significant changes in production or deposit characteristics and any other events or conditions that may lead them to doubt the quality of the material. When changes or events occur, they should immediately notify the other involved parties and arrange for submission of new OFQ samples that reflect such changes. After the change, until the new OFQ results are determined, separate all material that could be affected by the change.

The DME reserves the right to deny or withdraw approval of aggregate sources which have a history of inconsistent test results or test results that fall below the specification limits even if the current OFQ passes.

Once approval of aggregate from a specific source has been given to a contractor for use in a specific project, that approval will be maintained for the duration of that project; in the event that the project sample indicates deterioration of the product and if subsequent testing indicates the product no longer meets specification requirements, if inspection reveals deterioration of the product due to significant change in production or deposit characteristics, due to some unknown reason, or if field condition surveys demonstrate aggregate failure or aggregate deterioration that may lead to aggregate failure, material from that source will be discontinued immediately.

Should any sample taken from the project and submitted for quality testing fail, a new OFQ sample will be collected and submitted forthwith. The results of the new OFQ sample will be used to determine whether further use of the material will be permitted on the project or whether the contractor will be required to obtain acceptable material from another source. The new OFQ sample test results will also be considered in determining approval of the material for use on future projects.

In the event that field condition survey indicates deterioration of the product, the product from that source will be discontinued immediately and the DME will determine the role of that material for use on the project and use on future projects. Field condition surveys include, but not limited to: surveys performed by maintenance personnel, pavement management surveys, surveys conducted by Research, inspections by Headquarters, District, Area, and Subarea personnel, and any other field survey conducted under KDOT’s authority.

#### **4.2.2. Stockpiles**

Stockpiles produced under contract will remain approved for use on that contract, regardless of age, as long as the quality remains acceptable. Aggregate produced and stockpiled at the quarry under an approved OFQ will be good for 2 years in the stockpile. Aggregate that has been stockpiled at the quarry for more than 2 years must pass verification testing before use on KDOT projects. Do not add new production to existing stockpiles more than 2 years old before verification of the stockpile and an OFQ of the current production have been completed.

**4.2.3. Inactive Production Sources:** Samples taken from non-producing deposits will be tested for information only.

#### **4.3. Appeal of Official Quality Test Results.**

Aggregate producers must notify the DME if they wish to appeal OFQ test results. Two additional samples will be taken. Both samples must comply with the applicable specification(s) before approval is given. The first resample will be taken immediately after the results of the initial sample are made available and the producer has appealed. The second resample will be taken after a minimum of 2500 tons have been produced. If either of the two resamples fail, no further OFQ testing will be conducted on the location until the DME has determined the operations have moved a significant distance or there is a significant change in production or deposit characteristics as defined in section **5.6.4.2.1**.

#### **4.4. Department Discretion in Approving/Rejecting Aggregates and Adopting Standards.**

KDOT has discretion to create, implement, and modify its standards, specifications, and testing procedures for aggregates as needed for the safety of the traveling public and proper expenditure of taxpayer funds. In its discretion, KDOT may find the standards, specifications, or testing procedures applicable to aggregates are not accomplishing the desired results. Nothing in this Section 5.6 shall be construed as limiting KDOT's ability to reject aggregates based upon changes in standards, specifications, testing procedures, field performance or for other reasons determined by the Deputy Secretary and State Transportation Engineer.

### **5. INSPECTION, SAMPLING AND TESTING**

#### **5.1. General.**

This section of the manual pertains to general policy covering aggregate source inspection and the frequency of and procedures for sampling aggregates for quality, production, and acceptance testing. The detailed methods to be followed when sampling are set forth in Section **5.9** of this manual.

#### **5.2. Sampling for Quality Determination.**

##### **5.2.1. General Sampling Procedures**

When obtaining OFQ samples, the Department representative must thoroughly examine the exposed portions of the deposit, record the GPS coordinates per 5.2.1.1, at the ledge face or location in the pit where production is occurring, and observe and document production and processing operations.

Samples for OFQ will be obtained from locations or from production points that will provide a representative sample of the aggregates that will be used for State work.

OFQ samples will be collected from current production. Quality samples obtained from stockpiles other than current production will only determine the acceptability of the aggregate in the individual pile.

Tests for quality conducted on Verification Samples are not to be considered OFQ tests. Verification Samples are obtained only as a check on the quality of material being delivered to the project. KDOT will attempt to notify aggregate producers when aggregate Verification Samples are collected.

Aggregate producers may use the sampling methods outlined in this section to obtain preliminary quality information from prospective aggregate deposits. Samples so obtained under the supervision of a representative of the Department may be submitted to the Materials and Research Center for information only testing. No charges will be made for such tests.

When exploring for new locations or deposits, each producer will be permitted to submit a maximum of 10 samples for quality tests during each calendar year. No limit will be imposed on the number of samples a producer may submit from deposits explored for use on a specific project which has been advertised for letting on KDOT's bidding and letting website. Exploration submittal requirements do not apply to currently producing locations.

The District Materials Engineer will make "Official Quality" test results available to the producer.

#### **5.2.1.1. Recording GPS Coordinates**

Take GPS coordinates and enter into AWP in the decimal format (XX:XX:XX.XX). Many GPS receivers use a default setting of degrees and decimal minutes (xxx° xx.xxx') or degrees, minutes and seconds (xxx° xx' xx.xx"). Note that many receivers will display two digits when reporting degrees latitude and three digits when displaying degrees longitude. Latitude may additionally be indicated with an "N", "north", "lat", or positive sign on the display and longitude may be indicated by a "W", "west", "lon" or a negative sign. Enter ONLY numerals into AWP fields; do not enter any proceeding text or positive/negative signs. Refer to the AWP manual and the manual for the receiver for more information.

The GPS receiver may revert to a default setting or inadvertently be changed to an incorrect format. Correct operation of the receiver and correct format will be checked each time the receiver is used. This can be accomplished by establishing coordinates for a reference point such as the corner of a sidewalk or a survey monument that can be checked each time the receiver is used. The reference point will be established in an area not likely to be disturbed and clear of overhead obstructions such as trees and nearby buildings. Verify that the receiver is set correctly to the decimal degree format and record the coordinates of the reference point for future use. Wait several minutes to get an accurate reading on the reference point. Two or more readings may be taken at different times to get an average. Due to the inherent nature of GPS receivers, when checking the receiver against the reference coordinates, the reading may vary on the order of 00.00010° (about 29 feet East/West or about 36 feet North/South) or possibly more. This is acceptable and not cause for concern. A variation of more than .00015° when checking the reference coordinates may indicate a problem with the setting or operation of the GPS receiver and will be investigated further

#### **5.2.2. Stone Deposits:**

##### **5.2.2.1. Opened Deposits.**

Commercial quarries and non-commercial quarries that are operational are sampled for OFQ from normal production.

Commercial stone from active production locations is sampled yearly. Intermittently producing locations are sampled each calendar year that aggregate is being produced or, for locations with mobile production equipment, each time the equipment is remobilized. A contractor may still consider sources with a lapsed OFQ for contract bidding purposes provided the OFQ sample was taken within the last 1000 tons of production or the last week of production and the Quarry Inspector has evidence that no production has taken place since the mobile production equipment that produced the material for the OFQ had moved out. However, a current OFQ is required before the material is used on a project.

##### **5.2.2.2. Unopened Deposits.**

Unopened quarries are sampled by opening the quarry face the full depth of the usable ledge or ledges far enough back from exposure to reach unweathered stone. From this opening, the full depth of the finish face is shot down and a representative portion of the material is crushed at an operating quarry site by regular

production crushing methods. The sample is obtained from this crushed product. Tests conducted on samples following this procedure will be for information only unless the end product is to be large sized aggregate greater than +2". Uncrushed samples are acceptable for quality samples when the stone is intended for use of +2" sized aggregate products or other miscellaneous uses. The AWP inspection type for these samples is OQA. OFQ samples will be obtained from the processing plant (crusher, gradation unit) only after production at the site has commenced.

Uncrushed ledge samples and drilled cores are prepared in the Materials and Research Center to produce samples of proper size and gradation for testing. These samples are generally tested for information only and are not a basis for approval or disapproval of aggregate that will be used after crushing.

### **5.2.3. Sand and Gravel Deposits:**

#### **5.2.3.1. Definitions (Sand and Gravel)**

"Pit Run" material shall be defined as sand or sand-gravel which, upon excavation, has been subjected to minimal processing or no processing at all. Such processing shall be limited to the removal of excess soil and/or oversize material. OFQ samples of sand or sand-gravel shall be "Pit Run" material if feasible.

In the event that the quality characteristics exhibited by the "Pit Run" material do not meet the specification requirements for the intended product, the producer may utilize methods which will improve the aggregate quality by selective removal of some of the lower quality aggregate. OFQ samples may then be taken from the altered material.

#### **5.2.3.2. Operating or Opened Deposits.**

Commercial deposits and those under intermittent production are sampled for OFQ from normal production. Samples are to include all size fractions retained by the producer. Commercially operated deposits are to be resampled for OFQ when results from verification samples show significant variation from past results, and at least every five years. Non-commercially operated deposits are to be sampled at the direction of the DME.

#### **5.2.3.3. Unopened Deposits.**

Unopened deposits may be sampled prior to production by thoroughly drilling or otherwise sounding out the deposit. Samples taken for quality tests from unopened deposits will be for information only. OFQ samples will be taken from actual production.

#### **5.2.4. Chat Deposits**

Chat deposits are sampled by the most appropriate method. Chat piles or the products of screening plants from which material is being produced are sampled yearly for OFQ.

#### **5.2.5. Lightweight Aggregate**

Lightweight aggregate produced by expansion of clay, shale, or slate deposits, is sampled from the production site for initial prequalification. The Engineer of Tests will maintain prequalified listings of sources for Lightweight Aggregate for Concrete (PQL 3.2) and Lightweight Aggregate for Cover Material (PQL 3.3). Once prequalified, lightweight aggregate is sampled for verification directly from the project site. Lightweight aggregate sources will retain prequalified status unless a significant change in the deposit characteristics or production occurs, verification test results indicate the material no longer meets

specification requirements, there is a change in the specifications or testing procedures which the source cannot meet, the material otherwise fails in field performance, or other reasons cause the Department to doubt the quality of the material. Whether a change in production or deposit characteristics is significant is determined by the DME, in the DME's discretion.

### **5.3. Coarse Aggregate for All Concrete**

Although other classifications exist, generally, aggregates available for use in Kansas will be assigned one of two classifications: siliceous or calcareous. An aggregate's classification is typically only important when its use is intended for concrete.

Siliceous aggregates contain the compound silicon dioxide. Some common examples of siliceous rock are natural sands and gravels, quartzite, and almost all igneous rock. Calcareous rock contains some form of calcium carbonate; the most common being limestone and dolomite.

Siliceous coarse aggregates for use in concrete may require either additional testing to determine their potential for causing deterioration related to alkali-silica reaction (ASR) or mitigation of their ASR potential through use of a supplementary cementitious material (SCM).

Any siliceous aggregate source wishing to supply coarse, intermediate, or mixed aggregate for concrete shall be tested according to KDOT's Wetting and Drying Test of Sand and Sand-Gravel Aggregate for Concrete (KTMR-23). This testing determines a source's ASR potential and is performed on concrete produced with a total gradation of aggregate from the source being evaluated; therefore, sources must be able to supply a gradation that meets the middle 1/3<sup>rd</sup> of the MA-1 grading. The Engineer of Tests will maintain a complete record of each source tested and the test results. The Engineer of Tests will prepare and distribute the prequalified List of Non-Reactive Siliceous Aggregate Sources for Concrete (PQL 3.1), also known as the "Wetting and Drying List".

Siliceous aggregate sources that are not singly able to provide one of the MA gradations or do not pass the wetting and drying test are not necessarily precluded from use in concrete. However, approval of concrete mix designs that utilize such aggregates will be contingent upon the contractor incorporating a coarse aggregate sweetener or using an SCM to mitigate the ASR, as described in Section 1102 of the Standard Specifications.

### **5.4. Coarse Aggregate for On-Grade Concrete**

#### **5.4.1. General**

On-Grade Concrete Aggregates (OGCA) are subject to additional testing that is performed on concrete produced with OGCA to determine if acceptable levels of freeze/thaw resistance are provided in order to reduce the risk of the occurrence of premature deterioration. OGCA are intended for use in "on-grade" concrete such as Portland cement concrete pavement, sidewalk, curb, gutter, etc. Prequalification of OGCA material is granted on a geologic unit basis for each geologic unit in a quarry face and to individual pits for sand-gravel sources. OFQ sampling and testing is also required. The acceptance of OGCA is contingent upon production being from approved geologic units and in compliance with OFQ requirements.

The Engineer of Tests will maintain a complete record of each source tested and the test results. The Engineer of Tests will prepare and distribute the prequalified List of Freeze/Thaw Resistant Coarse Aggregate Sources for On-Grade Concrete (PQL 3.4). This listing will be included with the prequalified materials list and will be updated monthly. The PQL will list the following information for each approved source: state (if outside of KS), county, quarry number, producer's name, producer's AWP identification



number, legal description, geological unit name or type (if applicable), bed number(s) (if applicable), the date of completion for the most recent production sample, and the date of the last geologic inspection (if applicable).

#### 5.4.2. Initial Prequalification of Sources

##### 5.4.2.1. Initial Request Procedure

The District Materials Engineer (DME) is responsible to initiate KDOT's prequalification activities for sources in their respective District. Upon receipt of a written request from a producer, the DME will forward a copy of the written request to the Chief Geologist and the Engineer of Tests. The Chief Geologist will determine whether an initial geologic inspection is appropriate.

##### 5.4.2.2. Initial Geologic Inspection Procedure

**Some geologic units can be separated into beds. The KDOT Chief Geologist will do this whenever possible. Other geologic units, sand, and sand and gravel deposits cannot be separated into beds. These locations will be defined by the geologic units whenever possible. The term “unit” will be used to describe these scenarios. When extraordinary circumstances arise (IE: non-horizontal bedding, beds that cannot be separated, etc.), the Chief Geologist will determine when that scenario will be described as a “unit”.**

##### Crushed Stone Quarry

The Chief Geologist will arrange for a geologist to meet with District inspection personnel at the quarry. The Chief Geologist is responsible for preparing a KDOT Quarry Report (including GPS coordinates and color photographs) for the quarry. The quarry report will include identification and detailed description of each geologic unit(s) and bed(s) present in the quarry face. Producers have the option of submitting ledge samples or production samples for initial testing for prequalification determination. Producer's must submit a production plan if production samples are being submitted for testing.

Ledge samples are hand-picked samples collected by the geologist directly from the quarry face. Ledge samples will be taken from each bed(s) within the geologic unit(s) in the quarry face, unless the producer wishes to specifically preclude any bed(s) from the geologic unit(s) from initial prequalification determination. If the producer opts to forego ledge sampling, an initial production sample must be obtained from the production of each individual bed, or geologic unit. It is the producer's responsibility to maintain adequate separation of the bed(s) within the geologic units through all phases of production and sampling.

A plan view of the quarry indicating the location(s) in the quarry that are intended to be mined for OGCA must be provided by the quarry operator prior to sampling. The plan view must show appropriate landmarks for future reference.

##### Sand-Gravel Pit

Typically, gravel pits will not require a full geologic inspection prior to initial sampling. However, the DME should become familiar with the production site, process, general depositional characteristics, and other items that could potentially influence the quality of the material being produced prior to production sampling.

### **5.4.2.3. Prequalification Testing Procedures**

All samples will be tested at KDOT's Materials and Research Center (MRC) to determine which sources and/or individual bed(s) within the geologic unit(s) meet the additional requirements for OGCA. If the crushed stone producer opted to submit ledge samples, two production samples from complying bed(s) within a geologic unit(s), singly or in combination, must meet the additional requirements for OGCA before prequalification status is granted. If the producer opted to forego ledge sampling for initial prequalification determination, the initial production sample will be considered the first of the two required production samples. Sand-gravel sources must submit production samples for prequalification testing, therefore only one additional sample must meet the requirements for OGCA. All sources must have the last two passing production samples to meet the requirements for OGCA. For both crushed stone and sand-gravel, the two production samples must be separated by a minimum of 2500 tons of production.

Due to the timing differences between inspection, production, and testing activities, it is possible for a producer to have its production sample(s) submitted before the initial sample testing is complete. KDOT reserves the right to delay the testing of subsequent samples until the initial samples indicate compliance with the specification or to terminate testing on subsequent samples if at any point it is determined that a bed(s) within a geologic unit(s) or source will fail to meet the specification requirements for OGCA.

Once a source has two passing production tests on file with KDOT, the source will be added to PQL 3.4. Should a source fail to pass prequalification testing, resampling will not be permitted until significant changes occur or until the producer can provide reasonable explanation of why the testing failed and a plan for addressing the issue in the future. Requests for resampling should be made in accordance with the guidelines for initial prequalification. Exceptions to this process will require approval of the Chief of Construction and Materials.

### **5.4.3. Inspection of OGCA Production**

#### **5.4.3.1. Approved Production Plan**

The DME will obtain a written production plan for OGCA from the producer prior to providing inspection. The production plan shall include but not be limited to the following information (as applicable): the location(s) that will be mined; the approved bed(s) and geologic unit(s) that will be mined; and the procedures that will be used to prevent any non-approved material from mixing with the OGCA throughout the entire mining, hauling, crushing, stockpiling, and shipping processes. Producers shall provide updated production plans to the DME at the beginning of each production season, or as otherwise determined by the DME, and any time significant changes occur in production or deposit characteristics as defined in section 5.6.4.2.1.

#### **5.4.3.2. Aggregate Source Inspection Requirements**

The DME is assigned the responsibility to provide periodic inspection of aggregate production operations to verify that OGCA produced for Department work is produced from only the approved locations and/or bed(s) and geologic unit(s). In addition, the DME is responsible for verifying that the production process is essentially the same as that used to produce the aggregates selected for the OGCA production tests. The proper level of inspection is to be determined by the DME based on the unique circumstances encountered at each source.

KDOT quarry inspectors must familiarize themselves with the plan view of the production facility, the OGCA production plan, and the KDOT Quarry Report (if applicable). These three documents should provide the inspector with sufficient information to verify that only approved material is being produced

from approved locations and that the aggregates are processed in the appropriate manner. Inspectors are required to document their inspection activities during each visit to the site. The documentation is to be kept in a diary or other hard copy form approved by the DME.

#### **5.4.3.3. Notification of shipment**

Producers shall notify the DME responsible for inspection of OGCA production prior to producing and shipping such aggregates to concrete production sites for use on KDOT projects. The DME will then provide proper inspection during OGCA production and notify the appropriate Construction Office of the pending delivery of OGCA.

#### **5.4.4 Production Sampling**

It is the responsibility of the DME to collect aggregate samples for production testing. Reassignment of such responsibility between DME's may be made when mutually agreeable to the DMEs. Documentation of such reassignments should be disseminated to the affected quarry inspectors and the producer.

It is the responsibility of the contractor to notify the DME of all potential sources of on-grade concrete for a project under contract. The DME will arrange for production sampling of aggregate at each concrete production facility utilized for on-grade concrete as required by the frequency given in Section **5.6.5.4.4.1**.

When practical, the quarry inspectors should visit concrete production sites to assist project personnel with identification of OGCA produced and hauled from sites they inspect and to assist in the collection of production samples. KDOT will attempt to notify the aggregate producer at least 24 hours in advance of when OGCA production samples are collected from a concrete production plant.

##### **5.4.4.1. Sampling Frequency and Location**

###### Sampling from Aggregate Production Site

A minimum of one production sample must be collected annually from the aggregate production site when OGCA is being provided to KDOT projects. Samples of non-calcareous aggregate produced from sources outside Kansas may be collected annually from the point in which they are shipped into Kansas.

###### Sampling from Contractor Concrete Production Plant

A minimum of one production sample representing each 20,000 tons of OGCA must be obtained for each producer from the plant where on-grade concrete is being produced.

###### Sampling from Ready-Mix Concrete Production Plant

A minimum of one production sample representing each 5000 tons of OGCA must be collected from any concrete ready-mix plant that is producing on-grade concrete for KDOT.

The DME has discretion for adjusting sampling frequencies at any site to provide adequate assurance of material quality. The DME will inform the producer when the frequency will be adjusted and provide the reason for doing so.

##### **5.4.4.2. Testing**

Collected samples are to be delivered to the Engineer of Tests. The Engineer of Tests is responsible for testing the samples and for comparing the test results with the historical test data for that source. The Engineer of Tests will issue test result reports and notify the DME and the producer of test results in a timely manner.

#### 5.4.5. Continuation of Prequalified Status

When any person feels that any change in the prequalified status of an aggregate/source of aggregate is warranted, that person should notify the DME responsible for quarry inspection who in turn will advise the Chief of Construction and Materials. The Chief of Construction and Materials will review all available information and render a decision on any such changes. Official notification of any change in OGCA prequalification status for a quarry will be provided by the Engineer of Tests to the quarry owner/operator and the appropriate contractors.

In addition to a significant change in production as defined in section 5.6.4.2.1 or other reasons that cause the Department to doubt the quality of the aggregate, any of the following occurrences may warrant a resample and/or immediate change in the prequalification status of a source:

##### 5.4.5.1. Geologic Changes

When geologic changes are identified, the DME, the Chief Geologist, and the Chief of Construction and Materials should be immediately notified. The Chief Geologist will determine whether a new geologic inspection and re-testing of bed(s) and/or geologic unit(s) is required. The Chief of Construction and Materials will determine whether the source is allowed to remain on PQL 3.4 or allowed to be used for OGCA to projects under contract with or without restrictions or conditions.

The following are considered geologic changes:

##### Changes in the Deposit

All personnel responsible for QC at the production site or concrete plant (Contractor, Producer, KDOT quarry monitors and inspectors, etc.) have the right and responsibility to monitor for significant changes in the deposit characteristics. Typical examples of such changes would be a significant color change in any of the bed(s) and/or geologic unit(s) being produced, a significant change in thickness of any bed(s) or geologic unit(s) in the quarry face, the addition or complete disappearance of any bed(s) and/or geologic unit(s) in the quarry face, a significant change in the type or amount of fossils observed in any bed(s) and/or geologic unit(s), or an increase of the deleterious materials in the aggregate.

##### Significant Change in Production Location

Generally, mining operations are considered to have made a significant change in production location when they have moved 1/4 mile or more from the most recent inspection site.

##### Geologic Inspection Expiration

Geologic site inspections are good for two years from the date the inspection was completed. It is the producer's responsibility to contact the DME and request a new geologic inspection prior to the current inspection's expiration.

##### 5.4.5.2. Failed Material

When failing material is identified, the DME and the Chief of Construction and Materials should be notified and the source will be immediately removed from PQL 3.4. The Chief of Construction and Materials will determine whether the source is allowed to be used for OGCA to projects under contract with or without restrictions or conditions.

Failing material can be identified either through OFQ testing, production sample testing, or through field condition surveys as defined in section 5.6.4.2.1 of existing pavements. A source will be evaluated for

failing field performance if its product is used for OGCA on a state highway project and the completed on-grade concrete shows evidence of aggregate caused deterioration prior to 20 years of life.

#### **5.4.5.3. Lapse of Prequalification Requirements**

If a source's OFQ or geologic inspection expires, or if 18 months have elapsed since the source's last production sample was completed, the source may remain on the PQL at the discretion of the Chief of Construction and Materials. A contractor may still consider sources with lapsed status for contract bidding purposes; however, the source must renew its geologic inspection, submit a production sample with a passing test result, and/or have a current OFQ, whichever are applicable, before any material from the lapsed source will be accepted on a KDOT project.

It is the contractor's responsibility to communicate with potential OGCA producers to determine if any of these conditions exist prior to bidding work and to verify all specification requirements have been met prior to delivering the aggregate to the project.

#### **5.4.5.4. Procedure for On-Grade Concrete Aggregate Removal**

Prior to KDOT removing an aggregate source from its "List of Prequalified Aggregates Sources for On-Grade Concrete" (the "PQL") due to a failing test, the Engineer of Tests will average the three most recent KTMR-22 Relative Dynamic Modulus of Elasticity (RDME) test results for the aggregate. If the RDME 3-point rolling average is 96 or greater, then the aggregate will remain on the "List of Prequalified Aggregates Sources for On-Grade Concrete" (the "PQL") provided the expansion is below 0.025%.

In the event KDOT removes an aggregate source from its "List of Prequalified Aggregates Sources for On-Grade Concrete" (the "PQL") for failure to meet KDOT requirements the following applies

##### **5.4.5.4.1. Removal Procedure**

**5.4.5.4.1.1.** Following the removal, the owner of the quarry from which the aggregate is produced will be notified in writing of the removal action, and the notification will set forth the reason or reasons for the removal ("Removal Letter").

**5.4.5.4.1.2.** Copies of all test results or other relevant documentation, if any, upon which the removal is based, together with test results for the last two years, shall be delivered to the quarry owner/supplier along with the Removal Letter by the KDOT Engineer of Tests. Producers may request data from test results older than two years by contacting the Engineer of Tests.

##### **5.4.5.4.2. Levels of Review**

- (1) Bureau Chief of Construction and Materials. Upon receipt and within 30 days following receipt of the Removal Letter, the owner may notify the Chief of KDOT's Bureau of Construction and Materials ("Bureau Chief") in writing that it wishes to contest the removal. Upon receipt of such request, KDOT's Engineer of Tests and/or Bureau Chief will schedule a meeting with the owner to be held within 30 days of KDOT's receipt of the owner's written notification. During such meeting, the owner may present to KDOT officials whatever relevant information, evidence, arguments or requests it has concerning the validity of the removal. Such information, evidence, arguments or requests may address the testing process, test results, aggregate performance history, applicable specifications, or other item(s) relevant to the removal decision. The owner's request to meet with KDOT does not stay or suspend the removal of the affected aggregate from

the PQL. If the owner fails to seek consideration of the removal by the Engineer of Tests or Bureau Chief within the 30 days permitted, the Removal Letter will be deemed final agency action for purposes of judicial review.

- (2) State Transportation Engineer. Within 15 days following the meeting held pursuant to **5.6.5.4.5.4.2(1)**, the Engineer of Tests or Bureau Chief will notify the quarry owner in writing of the results or outcome of KDOT's decision. Within 7 days following the receipt of KDOT's written notice of its decision, the quarry owner may request reconsideration by the Deputy Secretary and State Transportation Engineer ("Deputy Secretary"). Within 90 days following receipt of the owner's request for the Deputy Secretary's reconsideration, the Deputy Secretary will schedule and complete a hearing regarding removal from the PQL. Either party may request a record be made of the hearing for purposes of judicial review of the Agency's action under the Kansas Judicial Review Act. Within 30 days following the hearing, the Deputy Secretary will notify the quarry owner in writing of the results or outcome of his or her reconsideration and this written notice shall be considered final agency action for purposes of judicial review. If the quarry owner fails to seek reconsideration by the Deputy Secretary within the seven days permitted, the results or outcome of KDOT's consideration by the Engineer of Tests or Bureau Chief, whichever applies, will be considered final agency action for purposes of judicial review.

#### **5.4.5.4.3. Time**

Nothing in **5.6.5.4.5.4** prevents KDOT and a quarry owner from entering into a written agreement to modify the time limits specified herein upon mutual consent.

#### **5.4.5.4.4. Department Discretion**

For purposes of OGCA, whether a change in production or deposit characteristics is significant and whether an event or condition is significant is determined by the Bureau Chief of Construction and Materials.

Nothing in **5.6.5.4.5.4** is intended to restrict or preclude KDOT from modifying its procedures for removal of aggregates for on-grade concrete pavement if KDOT determines the specified procedure(s) is/are not in the best interest of KDOT, the State of Kansas, or the traveling public.

#### **5.4.6. Process of Returning to PQL Following Removal.**

In the event an on-grade concrete aggregate source on PQL 3.4 is removed by KDOT, the process for the quarry owner to seek re-inclusion of the aggregate on the PQL is that set forth in in section **5.6.5.4.2**. Before KDOT will begin re-inspection, the owner or producer shall provide evidence of changes in geology or production process that warrant re-inspection. The request should be submitted to the Chief of Construction and Materials who will review the owner's/producer's justification for re-inspection, testing history, field performance history, and any other pertinent data to determine whether to allow or deny re-inspection. The procedure for re-inspection will follow the initial prequalification procedure described in Section **5.6.5.4.2**.

### **5.4.7. Stockpiles**

Stockpiles produced under contract will remain approved for use on that contract, regardless of age, as long as the quality remains acceptable during production.

A producer wishing to stockpile OGCA must provide a production plan detailing such activities as described in Section 5.6.5.4.3.2. Production sampling for stockpiles will be at the same interval given in Section 5.6.5.4.4.1. Stockpiles constructed under approved OFQ and approved production testing will remain approved for two years from the date of the last production sample that represents the stockpile.

## **5.5. Aggregate for Riprap and Ditch Lining and Other Miscellaneous Uses**

### **5.5.1. Initial Request Procedure**

The District Materials Engineer (DME) is responsible to initiate KDOT's prequalification activities for aggregates/sources of aggregate in their respective District. Upon receipt of a written request from a producer, the DME will forward a copy of the written request to the Chief Geologist and the Engineer of Tests. The Chief Geologist will determine whether an initial geologic inspection is appropriate.

### **5.5.2. Prequalification Testing Procedures**

All samples will be tested at KDOT's Materials and Research Center (MRC) to determine which sources and/or individual bed(s) and/or geologic unit(s) meet the additional requirements for Riprap, Ditch Lining and other miscellaneous uses. The Chief Geologist will make this determination for riprap. Either the Quarry Monitor or the Chief Geologist will make this determination for ditch lining and other miscellaneous uses.

Once a source has been inspected and approved by the KDOT Chief Geologist along with meeting the quality requirements, the source will be added to PQL 3.5. Exceptions to this process will require approval of the Chief of Construction and Materials.

### **5.5.3. Continuation of Prequalified Status**

A riprap source may be rejected as detailed in the standard specifications for product control. When any person feels that any change in the prequalified status of a source is warranted, that person should notify the DME responsible for quarry inspection who in turn will advise the Chief of Construction and Materials. The Chief of Construction and Materials will review all available information and render a decision on any such changes. Official notification of any change in prequalification status for a quarry will be provided by the Engineer of Tests to the quarry owner/operator and the appropriate contractors.

In addition to a significant change in production, any of the following occurrences may warrant a resample and/or immediate change in the prequalification status of a source:

#### **5.5.3.1. Geologic Changes**

When geologic changes are identified, the DME, the Chief Geologist, and the Chief of Construction and Materials should be immediately notified. The Chief Geologist will determine whether a new geologic inspection and re-testing of bed(s) or geologic unit(s) is required. The Chief of Construction and Materials will determine whether the source is allowed to remain on PQL 3.5 or allowed to be used for Rip Rap, Ditch Lining, or other miscellaneous use to projects under contract.

The following are considered geologic changes:

### Changes in the Deposit

All personnel responsible for QC at the production site or concrete plant (Contractor, Producer, KDOT Quarry Monitors and inspectors, etc.) have the right and responsibility to monitor for significant changes in the deposit characteristics. Typical examples of such changes would be a significant color change in any of the bed(s) and/or geologic unit(s) being produced, a significant change in thickness of any bed(s) and/or geologic unit(s) in the quarry face, the addition or complete disappearance of any bed(s) and/or geologic unit(s) in the quarry face, a significant change in the type or amount of fossils observed in any bed(s) and/or geologic unit(s), or an increase of the deleterious materials in the aggregate.

### Significant Change in Production Location

Generally, mining operations are considered to have made a significant change in production location when they have moved 1/4 mile or more from the most recent inspection site.

### Geologic Inspection Expiration

Geologic site inspections are good for five years from the date the inspection was completed. It is the producer's responsibility to contact the DME and request a new geologic inspection prior to the current inspection's expiration.

#### **5.5.3.2. Failed Material**

When failing material is identified, the DME and the Chief of Construction and Materials should be notified and the source will be immediately removed from PQL 3.5. The Chief of Construction and Materials will determine whether the source is allowed to continue supplying aggregate for Riprap, Ditch Lining and other miscellaneous uses to projects under contract with or without restrictions or conditions.

Failing material can be identified either through OFQ testing, production sample testing, or through field condition surveys as defined in section **5.6.4.2.1** of existing material.

#### **5.6. Inspection and Testing of Project Aggregates.**

##### **5.6.1. Project Control:**

The Field Engineer in charge of the project is responsible for monitoring inspection and testing procedures to offer reasonable assurance to the Department that all aggregate used meets specification requirements. Minimum sampling and testing frequencies for KDOT and the contractor are set forth in Appendix A and Appendix B of this manual. The frequencies should be increased if there is evidence that aggregate is consistently near or slightly outside specification limits. Adjustment of frequencies is not appropriate under statistical sampling plans as currently specified for hot mix acceptance.

The sampling and testing of aggregates is an important operation since the results are part of the basis for payment to the contractor by the Department. On Federal-aid projects, certain test results are part of the basis for reimbursement to the State for the Federal Government's share of the expenditure. Therefore, it is imperative that all sampling and testing be performed in the prescribed manner. The volume of aggregate tested and accepted for State use each year represents a considerable sum of money and the inspection of such aggregate should always be considered a most important part of project administration. The various types of tests are defined in section **5.2.5** of this manual.



## 5.6.2. Inspection, Sampling and Testing.

### 5.6.2.1. Inspection.

**5.6.2.1.1.** The Contractor is responsible for proper inspection during the production of aggregates and the processing of aggregates for use on state contracts. Proper control requires the services of a quality control technician with adequate experience and training who is capable of exercising good judgment and common sense. The technicians should never devote their entire time to mechanically sampling and testing aggregates. Technicians shall follow prescribed sampling and testing procedures and observe production or processing methods on a regular basis, so the technician is thoroughly familiar with all phases of these operations.

If the finished product is stockpiled prior to delivery to the project site or prior to delivery to the roadway, stockpiling operations should be observed and any specifications pertaining to stockpiling and removal of material from stockpiles shall be followed by the contractor and will be enforced by the Department.

**5.6.2.1.2.** Department personnel will inspect aggregate production sites in order to verify that the source of the aggregate was from the correct bed(s) and/or geologic unit(s) which meet specified quality requirements.

Inspection requirements for Department personnel at processing plants vary with the type of material being produced. A thorough knowledge of applicable specifications is necessary to perform the proper inspections. Department personnel will follow all posted safety and security rules required by producers of all visitors and contractors to production sites.

Department personnel should question (warn) the Contractor or Producer regarding any operation or sequence of operations which will likely result in unsatisfactory compliance with specification requirements; however, Department personnel shall not instruct the Contractor or Producer how to manufacture material as this is the contractor's responsibility under the contract documents.

### 5.6.2.2. Sampling.

Since it is physically impractical to test the entire production of aggregate, the proper taking of samples to represent the material is as important as correctly following the proper test procedure.

Follow the sampling methods outlined in **KT-01** of this manual. If modifications in sampling methods are needed, agreement between the Engineer and the Contractor shall be obtained and documented in the project records per Standard Specifications Subsection **105.8**.

### 5.6.2.3. Testing.

All tests must be conducted in accordance with prescribed procedures and equipment. The test equipment must be in good condition. Written instructions covering test procedures should be reviewed frequently to keep the operator from "drifting away" from prescribed procedures. Equipment should be checked regularly to verify that it is in adjustment and performing satisfactorily. Specific test methods are set forth in Section **5.9** of this manual.

## 5.7. Specific Gravities for the Hot Mix Asphalt (HMA) Specific Gravity List

### 5.7.1. Establishing a Location and Specific Gravity Value

#### 5.7.1.1. General

Specific Gravity values, verification date, and GPS coordinates for HMA aggregate sources shall be posted on the Specific Gravity List published by the Bureau of Construction and Materials. The list will be published monthly when changes occur. These specific gravity values may be used by hot mix contractors for that month's letting or a more current agreed upon value as established within this section. If no changes occur during a month, the previous month's values **may be used**. The Specific Gravity List will contain two sections. KDOT will allow the values in the upper section to be used for each month's letting. The lower section of the list will contain "deleted" values. The deleted values are for reference only and shall be verified by KDOT before they are allowed to be used on HMA projects. There is generally no need to determine a Procedure I specific gravity value for a material that has less than 10% material retained on the #4 (4.75 mm) sieve. There is generally no need to determine a Procedure II specific gravity value for a material that has less than 10% material passing the #4 (4.75 mm) sieve.

When a contractor or aggregate producer wishes to have an aggregate source placed on the HMA Specific Gravity List, a sample of the aggregate shall be split between the contractor and/or producer, the District Lab and the Materials and Research Center. This sample shall be taken at the source when possible and in the presence of District personnel, aggregate producer and contractor (when applicable). Samples for imported aggregates may be taken from stockpiles, truck beds or railcars. The processing at the time the sample is obtained should be noted in AWP. GPS coordinates for the location of the sample source or mining operations, not the stockpile or crusher location, will be recorded by District personnel at the time the sample is taken. Refer to Section 5.6.5.2.1.1 for instructions on recording GPS coordinates for point of aggregate production.

For each product the average Bulk Dry, Saturated Surface Dry, Apparent Specific Gravities and Absorption submitted by the Aggregate Producer and/or the Contractor, the District Laboratory, and the Materials and Research Center will be computed. The products being produced and the Geologic Class of the beds must be considered when determining an aggregate's specific gravity.

KDOT reserves the right to withhold or remove an aggregate source from the specific gravity list due to a lack of cooperation from the aggregate producer, variations in specific gravity values within the location, or a significant change in production or deposit characteristics.

#### 5.7.1.2. Procedure I Specific Gravities.

If the range of Bulk Dry Specific Gravity values is less than or equal to 0.040, then all values for that individual aggregate will be used to calculate the combined Average Bulk Dry Specific Gravity of the product.

If the range of Bulk Dry Specific Gravity values is greater than 0.040, then "Outliers" must be eliminated using the following procedure. Eliminate the value that is furthest from the average, and recalculate the average with the remaining values. Continue to eliminate outliers until the range of remaining values is less than or equal to 0.040 or until there are only 2 sets of data remaining. If the last 2 sets of remaining data have a range greater than 0.040, then an additional split sample will be obtained and tested. If the second sample fails the criteria then the Aggregate Producer's production must be reviewed and a possible cause for the wide range of values must be identified. No additional sampling will be permitted until the producer identifies and corrects the problem.

KDOT will average individual specific gravity values when several products from a source are tested. If no individual specific gravity value is more the 0.020 from the average, then the combined average will be placed on the HMA Specific Gravities List used for Bid Letting Estimates for each product. Otherwise, the products will be listed individually on the HMA Specific Gravities List.

#### **5.7.1.3. Procedure II Specific Gravities.**

If the range of Bulk Dry Specific Gravity values is less than or equal to 0.060, all values for that individual aggregate will be used to calculate the combined Average Bulk Dry Specific Gravity of the product.

If the range of Bulk Dry Specific Gravity values is greater than 0.060, then "Outliers" must be eliminated using the following procedure. Eliminate the value that is furthest from the average, and recalculate the average with the remaining values. Continue to eliminate outliers until the range of remaining values is less than or equal to 0.060 or until there are only 2 sets of data remaining. If the last 2 sets of remaining data have a range greater than 0.060, then an additional split sample will be obtained and tested. If the second sample fails the criteria then the Aggregate Producer's production must be reviewed and a possible cause for the wide range of values must be identified. No additional sampling will be permitted until the producer identifies and corrects the problem.

KDOT will average individual specific gravity values when several products from a source are tested. If no individual specific gravity value is more the 0.030 from the average, then the combined average will be placed on the HMA Specific Gravities List used for Bid Letting Estimates for each product. Otherwise, the products will be listed individually on the HMA Specific Gravities List.

#### **5.7.2. Verification of Location,**

Aggregate Producers must notify the DME when operations move more than  $\frac{1}{4}$  mile (within the same geological classifications for quarries) from the location on the list, or crosses a quarter section line.

If a crushed aggregate source has not been verified within two years or if a sand/sand gravel aggregate source has not been verified within five years, it will be the responsibility of the aggregate producer to notify the DME that the location where that material is being quarried needs to be checked. If the DME determines that operations have not moved more than  $\frac{1}{4}$  mile (within the same geological classification for quarries) from the location noted on the HMA Specific Gravity list, the DME shall notify the Engineer of Tests and the verification date on the list shall be changed. Otherwise, the location will be placed on the deleted values list until the location of operations is verified.

If the DME determines that operations have moved more than  $\frac{1}{4}$  mile from the location noted on the HMA Specific Gravity list, a new split sample shall be tested.

The DME may check the location of quarry operations at any time.

#### **5.7.3. Verification or Modification of Specific Gravity Values**

The use of an aggregate on a HMA project does not necessarily mean that the specific gravity value of that aggregate will be verified.

Specific gravity values for Chat must be verified every 2 years, regardless of GPS coordinates. Verification samples of HMA aggregates submitted to the Materials and Research Center may be used to verify specific gravity values on the list. Official Quality test results for sand/sand and gravel locations may

also be used to verify the specific gravity. Districts may also verify the specific gravities of an aggregate when they check the contractors mix design. Districts shall notify the Engineer of Tests when these values are verified.

A contractor or producer may ask that an existing value be verified or modified by the procedure used to establish values on the list. **The requesting producer or contractor must participate in the split sample testing and reporting.**

KDOT may ask that an existing value be verified or modified by the procedure used to establish values on the list. The producer or a contractor will be invited to participate in the 3-way split. If the producer or contractor declines to participate or does not provide test results in a timely manner, then only values from the District Lab and the Materials and Research Center will be used to calculate average values.

A Procedure I specific gravity value will be considered verified if the single test result (District or MRC) does not vary from the value on the list by more than 0.040. If the verification test result does vary from the value on the list by more than 0.040, then the Engineer of Tests may request a 3-way split to modify the list value. The Procedure I value will be considered verified if the average of a 3-way split does not vary from the current value on the list by more than 0.020. The Procedure I value will be modified if the average of a 3-way split does vary from the current value on the list by more than 0.020.

A Procedure II specific gravity value will be considered verified if the single test result (District or MRC) does not vary from the value on the list by more than 0.060. If the verification test result does vary from the value on the list by more than 0.060, then the Engineer of Tests may request a 3-way split to modify the list value. The Procedure II value will be considered verified if the average of a 3-way split does not vary from the current value on the list by more than 0.030. The Procedure II value will be modified if the average of a 3-way split does vary from the current value on the list by more than 0.030.

Aggregate Sources not kept current as outlined in these procedures will be removed from the HMA Specific Gravity Values list. It is not necessary for a source to be on the list for the Contractor to use the aggregate on a Project. Specific Gravities for any single Project can still be established by any method agreeable to the DME. Regardless of the method used, the DME may require the contractor to perform Specific Gravity verification tests on aggregates used from these sources during production on the project.

## 5.8. Documentation and Reporting

### 5.8.1. Documentation

Observed data from each test shall be clearly recorded, the inspector's initials and the date affixed and the data permanently filed as a part of the project "source document" files. Such data is **not** to be recorded on scraps and odd bits of paper with such paper being discarded after the data has been copied into note books or onto specified forms. Observed data must be recorded in permanent document form **at the time the observation is being made**. The pertinent data is then transferred to the proper report form or AWP Screen and distributed to the required offices. Reports should be issued covering all tests conducted by each inspection agency.

The Contractor is to maintain records of all inspection and tests performed by its representatives, and the documentation procedures shall be approved by the Engineer prior to starting the work.

### 5.8.2. Reporting

The Contractor is to provide the Engineer access to all process control test results. Upon completion of work, copies of all charts, forms and records documenting the Contractor's process control tests and inspection are to be provided to the Engineer upon the Engineer's request.

When test results fall outside of the specification limits, underline or circle in red the points of noncompliance. Results reported in AWP should reference the points of noncompliance in the remarks or elsewhere on the data screen.

# KANSAS DEPARTMENT OF TRANSPORTATION

CERTIFICATION OF AGGREGATES USED BY \_\_\_\_\_  
(Producer or Contractor name)

KDOT CONTRACT NUMBER \_\_\_\_\_

KDOT PROJECT NUMBER \_\_\_\_\_

Aggregate Description	Quantities Tons or Cu Yards	Location of Deposit				Ledge, Beds, or Thicknesses	KDOT Quality No.
		Sec.	Twp.	Range	County		
1.							
2.							
3.							
4.							
5.							

This is to certify (check applicable box)

All the aggregates described above:

(A) That will be provided to the project are in compliance with all applicable specifications.

(B) That were provided to the project were in compliance with all applicable specifications.

\_\_\_\_\_  
**Producer Code**

\_\_\_\_\_  
**Name of Producer**

\_\_\_\_\_  
**Date**

\_\_\_\_\_  
**Signature** **Title**



## 5.7. INSPECTION AND SAMPLING OF MATERIALS

### 1. ASPHALT MATERIALS

#### 1.1. GENERAL

These instructions cover the inspection and sampling of asphalt materials.

##### 1.1.1. Performance Graded Asphalt Binders and Cutback Asphalt.

Asphalt is a natural constituent of most crude petroleum oils. The crude petroleum is refined to separate the various components including naphtha, gasoline, kerosene, diesel fuel, lubricating oils, etc., and to recover the asphalt.

Asphalt binder is the basic result of this recovery and it is produced in a variety of grades. For highway uses, these are Performance Graded (PG) Binders ranging from PG52-22 to PG82-22. At normal temperatures asphalt binder is semi-solid and is brought to and maintained in a liquid state by the application of heat.

Rapid curing (RC) and medium curing (MC) cutback asphalts consist of an asphalt base fluxed with suitable petroleum distillates or diluents. Blending of the asphalt binder and diluents is done either in tanks or by automatic blending devices which draw the individual ingredients from storage tanks, mix them in pre-determined proportions and discharge the mixture into railroad tank cars or trucks.

##### 1.1.2. Emulsified Asphalt.

Emulsified asphalt is a homogeneous liquid mixture consisting of asphalt binder, water and a small amount of emulsifying chemicals. Some emulsified asphalt grades also contain added petroleum distillate to improve mixing conditions and give long term stockpile life. Asphalt emulsions are of the anionic or cationic types. In general, the anionic type deposits the asphalt binder by evaporation of the water while in the case of the cationic type the asphalt binder is deposited because of an electro-chemical attraction to the aggregate.

##### 1.1.3. Asphalt Rejuvenating Agent.

Asphalt Rejuvenating Agent (ARA) is composed of a polymer modified asphalt emulsion. It is used to increase the ductility and penetration of the asphalt binder in an existing pavement.

#### 1.2. Storage Facility

Special storage facilities (terminals) may be established on approval of the Chief, Bureau of Construction and Materials at a location other than a refinery. A producer's certification must accompany each shipment.

#### 1.3. Sampling Procedure.

Asphalt materials must be sampled in accordance with Department of Transportation Test Methods as set forth in subsection **KT-26**.



#### 1.4. Asphalt Sampling Frequency.

The following Sampling Frequency can be used for Performance Graded Asphalt Binders, Cutback Asphalt, and Emulsified Asphalt.

**SAMPLING FREQUENCY LEVEL I** - one out of every three trucks is sampled and tested. When 5 more consecutive samples from all sources statewide have been tested, by the Central Laboratory, and all comply with specification requirements, the producer will be upgraded to Level II.

**SAMPLING FREQUENCY LEVEL II** - one out of every six trucks is sampled and tested. When 5 more consecutive samples from all sources statewide have been tested, by the Central Laboratory, and all comply with specification requirements, the producer will be upgraded to Level III.

**SAMPLING FREQUENCY LEVEL III** - When 5 more consecutive from all sources statewide have been tested, and all comply with specification requirements, one out of every 12 trucks is sampled and tested.

All newly prequalified asphalts begin at Level I. District Materials Engineers and Lab Chiefs will be notified of changes of frequency by e-mail as soon as the change is made. Indicate the sampling frequency level used on the sample container or information sheet.

Some samples may be disposed of in the Materials and Research Center Lab queue as soon as the sampling frequency changes. The disposal will not be entirely random, as all projects will be represented, but will be random within projects. The sample ID will be cleared with the explanation, "Not tested due to change in sample frequency requirements." Samples over 14 days old when received will be disposed.

#### 1.5. Testing performed for each sampling frequency level.

##### 1.5.1. Performance graded asphalt binder.

**SAMPLING FREQUENCY LEVEL I** - of the 5 samples, all will get a complete analysis.

**SAMPLING FREQUENCY LEVEL II** - of the 5 samples, all will get a complete analysis.

**SAMPLING FREQUENCY LEVEL III** - once this level is reached all samples will get a partial analysis. Each month, a complete analysis will be performed on at least one sample per grade per producer.

##### 1.5.2. Asphalt rejuvenating agent, cutback asphalt, and emulsified asphalt.

All samples, regardless of Sampling Frequency Level will get a complete analysis.

## 1.6. Analysis of Performance graded (PG) asphalt binder

### COMPLETE ANALYSIS

#### Original Binder:

Flash Point, COC  
Brookfield Viscosity, 135°C  
Dynamic Shear  
Separation Test, 163°C (modified only)

#### Rolling Thin Film Oven Residue:

Mass Loss  
Dynamic Shear  
Elastic Recovery, 77°F (modified only)

#### Pressure Aging Vessel Residue:

Dynamic Shear  
Creep Stiffness, 60 seconds  
Slope  
40 hr. Delta Tc

### PARTIAL ANALYSIS

#### Original Binder:

Dynamic Shear

#### Rolling Thin Film Oven Residue:

Dynamic Shear

## 2. BRICK AND CONCRETE MASONRY UNITS

### 2.1. Methods of inspection

#### 2.1.1. At the Source.

Inspection of brick and concrete masonry units will, if possible, be made at the manufacturer's storage yard and will be made by an authorized representative of the Chief, Bureau of Construction and Materials. Inspection at the source will consist of subjecting each lot to a careful visual inspection and obtaining a representative sample of the lot to be submitted to the Materials and Research Center, Topeka, Kansas for test.

The number of samples required is shown in **section 5.5** of this manual. Each size of unit will constitute a separate lot. Specimens selected for sampling shall be representative of the lot of units from which they are selected. After sampling, the lot represented shall be marked for identification.

#### 2.1.2. At Destination.

Inspection of masonry units delivered to the project will be the responsibility of the Field Engineer or the District Materials Engineer.

If the units have been tested and accepted before delivery, a visual inspection should be made to check the condition of the units and their identification. Slight imperfections, minor indentations or surface cracks incidental to the usual method of manufacture, or the chipping resulting from the customary methods of handling in shipment, should not be deemed grounds for rejection.

Units which have not been sampled before delivery must be sampled and inspected on the project. Sampling and inspection will be in accordance as above.

### **3. CONCRETE CURING MATERIALS**

#### **3.1. Burlap**

All burlap is visually inspected prior to use to determine compliance with applicable portions of the specifications. Normally, burlap will only be sampled to check the weight. However, if the inspector suspects the material is contaminated with a water soluble ingredient which retards setting of the concrete, the materials should be sampled in accordance with **section 5.5** of this manual. Such samples are submitted to the Materials and Research Center.

#### **3.2. Liquid Membrane Forming Compounds**

Acceptance by certification will be discontinued if tests show poor quality control during production.

Samples are taken from the containers in which the material is shipped. Prior to sampling, the material must be thoroughly mixed so that a representative sample is obtained.

Sample size shall be in accordance with the requirements of **section 5.5** of this manual.

### **4. JOINT SEALING AND JOINT FILLER MATERIALS**

#### **4.1. Hot Type Joint Sealing Compound**

Inspection and sampling of hot type joint compound is limited to securing samples from filled shipping containers and submitting them to the Materials and Research Center for testing. Samples will be taken by a representative of the Department, and must be available for testing in the Materials and Research Center a minimum of 10 working days prior to the date the material is required for installation.

Samples shall be taken as set forth in **KT-27**.

#### **4.2. Cold Applied, Chemically Cured Joint Sealing Compound**

Inspect the material visually before it is used. The Engineer should be satisfied that the shipment can be identified with the certification.

#### **4.3. Preformed Elastomeric Compression Joint Seals for Concrete**

The Type C certification shall be reviewed and the material will be inspected by the Engineer before it is used. The Engineer should be satisfied that the shipment is identified and that the proper material has been received.

#### **4.4. Materials for Filling and Sealing Joints in Pipe**

##### **4.4.1. Compound Type Joint Filler**

Inspection and sampling is limited to securing samples from filled shipping containers and submitting them to the Materials and Research Center for testing. If the material has been sampled, tested and accepted prior to shipment, the Engineer should inspect the material before it is used to satisfy that each package is identified with the test report and that no damage has occurred during handling, shipping and storage. If the material has not been sampled, the District Materials Engineer should be advised so arrangements can be made for sampling. Samples shall be taken as set forth in **KT-27**.

#### 4.4.2. Flexible Gasket Type Joint Filler

The Engineer should inspect each piece of pipe at destination before it is placed so that it is identified with the test report and that the pipe and joint materials have not been damaged during shipping, handling, and storage.

#### 4.4.3. Factory Molded Joints

Since these types of materials are not inspected prior to shipment, they must be inspected by the Engineer. The joint should be inspected for cross-sectional uniformity and freedom from defects that would allow the entrance of the melted lead into the pipe.

#### 4.4.4. Materials for Sealing Joints in Cast Iron Pipe

The seals should be inspected at destination and prior to installation to determine the presence of imperfections that could cause leakage of the joint.

#### 4.4.5. Expanded Closed-Cellular Rubber Gaskets for Reinforced Concrete Pipe and Precast Boxes

Visual Inspection by the Engineer for workmanship, fit, and final installation practices.

### 5. MISCELLANEOUS MATERIALS

#### 5.1. ADMIXTURES FOR PORTLAND CEMENT CONCRETE

The inspection of admixtures is the responsibility of the Engineer. Since admixtures are delivered to the project without inspection, the Engineer must ensure that the product is on the prequalified list and that certifications as specified are available for each lot of material. If the Engineer has doubt as to the condition of the product or if the material fails to perform as expected, the material should be sampled immediately and submitted to the Materials and Research Center for testing. Samples should be accompanied by a letter stating the deviation from expected performance.

#### 5.2. CALCIUM CHLORIDE

This material will be inspected at destination and a verification sample is to be obtained from the first unit delivered.

Solid calcium chloride will be sampled by selecting at random not less than three containers. Each container so chosen is to be sampled by scraping aside the top layer to a depth of approximately 1 inch (25 mm) and taking samples by means of a sampling thief or other method which will ensure obtaining a representative cross section in the container to a depth of at least 6 inches (150 mm). Precautions must be taken during the sampling to avoid unduly exposure of the sample to atmospheric moisture. The individual samples are immediately and thoroughly mixed to form a representative composite sample which is placed in a moisture tight container for shipment to the laboratory.

Liquid calcium chloride will be sampled using the thief method as describe in **KT-26** to obtain a 1 qt (1 liter) sample.

### 5.3. REFLECTIVE SHEETING

All reflective sheeting will be sampled according to **ASTM D 4956**. A full width X 1 yd (1 m) long specimen is selected at random to represent the entire sheet, roll or lot.

### 5.4. ELECTRIC LIGHTING AND TRAFFIC SIGNAL EQUIPMENT

When miscellaneous hardware and span and guy wire is shipped from a warehouse located within or near State borders, arrangements will be made to have the various items sampled and tested prior to shipment. When these items arrive on the project without previous sampling and testing, they will be inspected and sampled by the Engineer. The Engineer should review test reports and certifications to ensure that all items on the project are covered by the necessary documents, and should be satisfied that the entire shipment meets the required specifications.

A report covering items accepted by certification and visual inspection is issued by the Engineer. Items sampled and tested by the Materials and Research Center are covered by a copy of the laboratory report.

### 5.5. CENTER MOUNT REFLECTORS

Center Mount reflectors will be sampled by the Engineer and submitted to Materials and Research Center according to **section 5.5** of this manual.

When only 1 reflector per sample fails testing the entire sample will be accepted for use on KDOT projects. A failure of 2 reflectors per sample will require resampling and testing. A failure of 3 or more will cause the entire sample to be rejected without resampling.

### 5.6. BEARING PADS OR MATS FOR STRUCTURES

Inspection and the issuance of acceptance reports is the responsibility of the Engineer. The Engineer is responsible for visual inspection on all Elastomeric and Preformed fabric pads.

## 6. MISCELLANEOUS METALS

### 6.1. ALUMINUM ALLOYS AND CAST ALUMINUM

Cast products that will be subjected to appreciable stress are the exception to this policy. The aluminum from which the castings are made is shipped to the foundry in ingots where it is remelted, cast and heat treated to a prescribed temper. Since there is a possibility that the alloy might lose its identity, or that heat treatment might not be adequate, it is the Department's policy to test such items prior to acceptance. This policy is especially applicable to stress designed bridge handrail posts cast from Aluminum Association Alloy A444-T4.

Since all aluminum products except castings are shipped to the project without inspection, the Engineer must visually inspect the items for compliance with dimensional requirements, identification with certifications, workmanship, damage during handling, shipment, storage, erection, etc.

While cast items have usually been inspected at the point of production, they should be subjected to visual inspections by the Engineer to determine manufacturing flaws, dimensional defects and possible handling and shipping damage. If castings have not been inspected and sampled at the point of production, sampling in the field will be necessary. If field sampling is required, take one or more castings to represent each lot as defined in the specifications. Forward the samples to the Materials and Research Center for testing. If

radiographs accompanied the shipment, forward these to the Materials and Research Center with the samples. If radiographs have not been furnished, the castings will be subjected to radiographic examination. In either case specimens will be removed for physical and chemical test, which will destroy the sample. Therefore, the Contractor must furnish additional castings at no charge to replace those taken for samples.

## **6.2. SHEET METAL FOR SIGNS**

Sheet thickness should be measured with a micrometer.

## **7. BRIDGE PAINTS AND PAVEMENT MARKING MATERIALS**

### **7.1. BRIDGE PAINT**

#### **7.1.1. Inspection at the Source**

Inspection of paint or paint materials at the factory or at a distributor's or dealer's storage area will be made by the Engineer and will be limited to the taking of a representative sample and submitting it to the Materials and Research Center for testing. Except for mixed paints that may have settled badly, this is readily accomplished by following the methods in **KT-28**. If the inspector is asked to sample paint that has settled badly, with pigment caked on the bottom of the container to such an extent that it is impossible to properly mix, the Engineer should reject it on visual inspection and refuse to sample. Make sure all paints have been thoroughly mixed prior to sampling.

#### **7.1.2. Inspection at the Destination**

Inspection of paint delivered to a job site will normally be the responsibility of the Engineer. Since the paint should have been tested and accepted prior to delivery, the inspection will usually consist only of visual inspection for identification marks and for the condition of the paint in the container. The Engineer shall see that all paint is properly mixed before application. Paint that has been tested and accepted by the laboratory may be unfit for use if held in storage for extended periods of time. If the contractor is unable to mix the paint so that the pigment is completely and uniformly incorporated with the vehicle, the Engineer should reject it and require the contractor to obtain new material. Attention is called to the fact that it is extremely difficult to properly mix a five gallon can of paint by stirring with a paddle. If any hard pigment settlement is present it is impossible to do so. If necessary, the Engineer should insist that the paint be mixed according to **KT-28**. Make sure all paints have been thoroughly mixed prior to sampling.

#### **7.1.3. Types of Packaging**

Paint will usually be offered for sampling in the ready mixed form and may be either in a bulk storage tank or sealed packages such as one gallon and five gallon cans. Aluminum Paint, Inorganic Zinc Primer, Aluminum Epoxy Mastic Primer, and Polyurethane Field Coat will be offered in two or more containers with the paste or pigment in one container and the vehicle in the other container.

The source of the material will usually be the paint factory where the product will be in storage tanks or sealed packages, but it may be a distributor's warehouse or dealer's storage area where the material will be in sealed packages only. Occasionally materials such as linseed oil or thinners will be at a manufacturer's plant other than a paint factory where the manufacturer will be compounding other products used in maintenance or construction.

#### **7.1.4. Thinning**

If thinning is permitted, the Engineer should inspect the thinner and see it is the type allowed by the Specifications. If a thinner is used, it must be one specified by the paint manufacturer.

#### 7.1.5. Shop Coat

The shop coat primer on structural steel delivered to the job should be inspected by the Engineer. If the shop coat has been damaged by moving the steel before complete drying, or if the surface is contaminated by dirt, cinders, etc., it should be cleaned and repainted. In extreme cases the Engineer should require the damaged shop coat to be completely removed and the steel repainted with the shop primer. After erection of the steel, the Engineer should check the condition of the shop coat. Any skips, small areas left unpainted because of erection marks, rivets, bolt heads, and welded areas should be properly cleaned and touched up with an appropriate primer. The cleaning of field welded areas should be given careful attention. All slag, spatter, and excess reinforcing should be ground off and the weld area sand blasted before painting.

#### 7.1.6. Methods of Sampling

Unless otherwise specified, all bridge paints will be sampled according to **KT-28**.

### 7.2 TRAFFIC LINE PAINT

#### 7.2.1. Inspection at the Destination

Inspection of paint delivered to a job site will normally be the responsibility of the Engineer. Inspection will usually consist only of visual inspection for identification marks and for the condition of the paint in the container. The Engineer shall see that all paint is properly mixed before application. Paint may be unfit for use if held in storage for extended periods of time. If the contractor is unable to mix the paint so that the pigment is completely and uniformly incorporated with the vehicle, the Engineer should reject it and require the contractor to obtain new material. Attention is called to the fact that it is extremely difficult to properly mix a five gallon can of paint by stirring with a paddle. If any hard pigment settlement is present it is impossible to do so. If necessary, the Engineer should insist that the paint be mixed according to **KT-28**. Make sure all paints have been thoroughly mixed prior to sampling.

#### 7.2.2. Types of Packaging

Paint will usually be offered for sampling in single component form and may be either in a bulk storage tank or sealed packages such as 55, 5 or 1 gallon containers.

#### 7.2.3. Method of Sampling

Unless otherwise specified, all pavement marking paints will be sampled according to **KT-68**.

### 7.3. EPOXY PAVEMENT MARKING MATERIAL

#### 7.3.1. Inspection at the Destination

Inspection of Epoxy Pavement Marking Material delivered to a job site will normally be the responsibility of the Engineer.

#### 7.3.2. Types of Packaging

Epoxy Pavement Marking Material will usually be offered for sampling in a ready form and be in a heated bulk tanks. The source of the material will usually be the contractor.

### **7.3.3. Method of Sampling**

Unless otherwise specified, all pavement marking paints will be sampled according to **KT-66**.

## **7.4. THERMOPLASTIC PAVEMENT MARKING MATERIAL**

### **7.4.1. Inspection at the Destination**

Inspection of Thermoplastic Pavement Marking Material delivered to a job site will normally be the responsibility of the Engineer.

### **7.4.2. Types of Packaging**

Thermoplastic Pavement Marking Material will usually be offered for sampling in the melted form in heated bulk tanks or in powder form in sealed sacks. The source of the material will usually be the contractor.

### **7.4.3. Method of Sampling**

Unless otherwise specified, all pavement marking paints will be sampled according to **KT-30**.

## **7.5. PREFORMED THERMOPLASTIC PAVEMENT MARKING MATERIAL**

### **7.5.1. Inspection at the Destination**

Inspection of Preformed Thermoplastic Pavement Marking Material delivered to a job site will normally be the responsibility of the Engineer.

### **7.5.2. Types of Packaging**

Preformed Thermoplastic Pavement Marking Material will usually be offered for sampling in performed markings that are heat fused to the pavement. The source of the material will usually be the contractor.

## **7.6. SPRAYED THERMOPLASTIC PAVEMENT MARKING MATERIAL**

### **7.6.1. Inspection at the Destination**

Inspection of Sprayed Thermoplastic Pavement Marking Material delivered to a job site will normally be the responsibility of the Engineer.

### **7.6.2. Types of Packaging**

Sprayed Thermoplastic Pavement Marking Material will usually be offered for sampling in the molten form that is applied to the pavement by spray means. The source of the material will usually be the contractor.

## **8. CULVERT, SEWER AND UNDER-DRAIN PIPE**

### **8.1. CAST IRON PIPE**



If pipe with a push-on or a mechanical joint is furnished, the joint elements should be examined carefully to determine whether or not they will produce a pressure tight seal. Each length should be carefully examined for all manufacturing defects or damage during handling that will impair its usefulness.

## **8.2. CORRUGATED METAL PIPE, PIPE ARCHES AND END SECTIONS**

As a minimum, the Engineer should inspect the pipe at destination for possible damage during handling and shipping. A tag with the project number and station number should be attached to each section of pipe by the manufacturer. Defective pipe or pipe of questionable quality should be reported to the District Materials Engineer. If the pipe has not been inspected at the fabricator's plant or some other location, a more stringent inspection will be required at the job site, consult the District Materials Engineer for guidance.

## **8.3. ASPHALT COATED CORRUGATED METAL PIPE, PIPE ARCHES, COUPLING BANDS AND STRUCTURAL PLATE**

The pipe is identified by tags attached to each piece. The tags bear the laboratory number under which the pipe was inspected and the date of inspection.

## **9. CEMENTITIOUS MATERIAL**

### **9.1. PORTLAND CEMENT**

Many types of cement are manufactured. and utilized by These types are covered by **Kansas Department of Transportation Specifications Section 2001**. Portland cement may be delivered to the project in bags or in bulk. Most shipments to projects and to ready-mix plants are in bulk.

#### **9.1.1. Responsibility**

It is the responsibility of the Engineer to assure that cement manufacturers, concrete producers, and contractors comply with the Standard Specifications and Special Provisions. Complete and sincere cooperation of all persons involved is essential for successful and efficient cement inspection. The current list of prequalified cement plants is available from Kansas Department of Transportation's website.

**9.1.1.1.** The operator of a prequalified cement plant or terminal furnishes all necessary information and facilities for adequate sampling by the Engineer to maintain prequalified status.

**9.1.1.1.1.** The plant operator exercises good quality control of the products and submits a monthly report of the test results and a statistical analysis (including standard deviations and means) of all the plant's quality control tests for the month to the Chief, Bureau of Construction and Materials for all products for which the plant is prequalified.

**9.1.1.1.2.** A representative of the cement company must issue a certification to accompany each shipment consigned to State work. The certifications shall show compliance with the specification and is to be attached to or made a part of the scale ticket, weigh bill, or other shipping document accompanying the shipment.

**9.1.1.2.** Terminals are described as storage facilities established by cement companies in urban or large market areas some distance from a cement plant. The terminal is considered approved to supply cement to the Department of Transportation projects if the cement plant which produced it is prequalified. Cement shipped from terminals established by a prequalified cement company is to be handled the same as if shipped direct from the cement plant. A certification indicating compliance with the specifications, signed by a representative of the cement company, must accompany each shipment.

**9.1.1.3.** The Contractor, when purchasing cement from a prequalified cement plant advises the plant of the type of cement required and that a certification must accompany each shipment. The contractor must submit a copy of each certification to the Engineer. When purchasing concrete from a ready-mix operator, the contractor advises the operator of the need for certification of the cement by a representative of the cement company, and furnishes the ready-mix operator information relative to project number, type of cement, and class concrete.

**9.1.1.4.** The Ready-Mix Plant Operator, when furnishing concrete for State work requires certifications from the cement company for all cement delivered during the progress of work. In the case of cement in storage at the ready-mix plant at the beginning of a project which cannot be certified to be the producing cement company, or which has been in storage for more than three months, the Engineer must be notified so that appropriate sampling and testing may be done prior to the beginning of the work. The Ready-Mix operator certifies each week to the Engineer that all cement used to produce concrete for State work during that week was State approved, and lists certified cement received during the week.

**9.1.1.5.** The Engineer determines if the project is to be constructed of job mix or ready-mix concrete and reminds the Contractor that cement company certifications or State tests are required for all cement in storage at the beginning of the work and that all shipments received during the progress of the work must be accompanied by certifications. The Engineer verifies that the plant furnishing the cement is prequalified for the type being furnished. The Engineer determines during the construction of the project that certifications are available for all cement being used. The cement is acceptable for immediate use provided each shipment is accompanied by a certification showing compliance with specifications. The Engineer is to review the certifications from the contractor or ready-mix plant operator and at the completion of the project issues an acceptance report covering all cement used on each State project.

**9.1.1.6.** Regional and District Laboratories perform sampling, record keeping and reporting necessary for monitoring compliance with specifications at cement plants and terminals in their area. Information Samples are obtained at the frequency of one per type prequalified every other month throughout the year. Offices sampling more than one plant should stagger their plants on opposing months to level out their sampling and MRC testing workloads. Samples of cement are to be obtained from one or more of the following sources.

Production Streams (only when agreed to by the producer)  
Loading streams  
Loaded containers  
Transfer streams (from storage silo to shipping silo)

Verification samples are taken by each District at the rate of one sample per each one-half calendar year from each producer's cement plant that is being supplied within the District during this period.

Additional verification samples and tests may be required if any of the producer submitted data, or KDOT Verification or Information Sampling indicate a problem with quality control or compliance with Kansas specification limits. The increased sample frequency will be established in writing by the Chief of Construction and Materials, and will remain in effect until the problem is resolved.

Test reports are issued to the Bureau of Construction and Materials and to the appropriate cement plants on special request.

#### **9.1.2. Basis of Acceptance.**

See Standard Specifications Manual Subsection 2001.

#### **9.1.3. Reporting.**

Acceptance reports covering shipments of cement from unqualified plants are issued by the Materials and Research Center.

An acceptance report covering cement received from each qualified plant or approved terminal storage unit is issued by the Engineer. The report is issued after all concrete work is completed and covers the quantity of each brand and type of cement used on the project.

#### **9.1.4. Sample Forms and Reports.**

The following report forms and suggested certification statements illustrate references in the preceding sections.

##### **9.1.4.1. Certification from the Prequalified Cement Plant or Terminal.**

A certification similar to this suggested statement must accompany each shipment destined for State Projects. (See **Figure 1**)

##### **9.1.4.2. DOT Form 697 (697A) - Certification of Cement used by Ready-Mix Company.**

**9.1.4.2.1.** One copy of this form is sent to the Engineer by the Ready-Mix producer for the cement received and/or used during each week. If cement is neither received nor used during a weekly period, this form need not be submitted. (See **Figure 2**)

**9.1.4.2.2.** A certification is supplied to the Engineer covering cement in storage at the beginning of a project. (See **Figure 3**)

**9.1.4.3.** DOT Form 623 - Miscellaneous Report Form for projects. It is used by the Engineer to report cement produced by prequalified companies and used on State Projects. (See **Figure 4**)

SUGGESTED CERTIFICATION FROM A PREQUALIFIED  
CEMENT PLANT OR TERMINAL

Date: \_\_\_\_\_

Truck or Car No. \_\_\_\_\_

Shipped to: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

This certifies that the Type \_\_\_\_\_ Portland Cement in this shipment was loaded from silo Number \_\_\_\_\_, and that it complies with Kansas Department of Transportation specifications.

CEMENT COMPANY: \_\_\_\_\_

PLANT LOCATION: \_\_\_\_\_

TERMINAL (IF DIFFERENT): \_\_\_\_\_

SIGNED: \_\_\_\_\_

Figure 1



KANSAS DEPARTMENT OF TRANSPORTATION  
 CERTIFICATION OF MATERIALS USED BY READY MIX COMPANY

Project No.: \_\_\_\_\_

Date: \_\_\_\_\_

MEMORANDUM TO: \_\_\_\_\_, CONSTRUCTION ENGINEER

Re: Certification of Cement

This is to certify that all of the cement used in the production of concrete for the above project during the week of \_\_\_\_\_ to \_\_\_\_\_ was Type \_\_\_\_\_ cement and \_\_\_\_\_ (Sunday) \_\_\_\_\_ (Sat., Include.) that the company from which this cement was received has certified that the cement meets the specifications of the Kansas Department of Transportation. Certifications covering this cement are on file in this office.

Re: Certification of Aggregates

Type of Aggregate	Location of Deposit				Total Approx. Tons/Yds. This Week	
	Sec.	Twp.	Range	County	Received	Incorporated in Mix

This is to certify (Check applicable box or boxes)

1. All of the aggregates described above were:
  - (A) Produced at the deposit location described.
  - (B) Loaded from State tested and approved stockpile at the production site or from the plant while it was producing aggregate meeting applicable specifications.
2. Only State tested and approved aggregates were used to produce ready-mixed concrete delivered to State work.

\_\_\_\_\_  
 Name of Ready Mix Co

\_\_\_\_\_  
 (Signature)

\_\_\_\_\_  
 (Title)

Figure 3

KANSAS DEPARTMENT OF TRANSPORTATION

REPORT OF SAMPLE OF \_\_\_\_\_

Laboratory No. \_\_\_\_\_

20

Received \_\_\_\_\_ 20

Specification No. \_\_\_\_\_ Quantity Represented \_\_\_\_\_

Source of Material \_\_\_\_\_

Sample From \_\_\_\_\_

Submitted By \_\_\_\_\_

Identification Marks \_\_\_\_\_

Project or POV \_\_\_\_\_

Type of Construction \_\_\_\_\_

Contractor \_\_\_\_\_

TEST RESULTS

Reported By \_\_\_\_\_

Title \_\_\_\_\_

D.O.T. Form No. 623

**Figure 4**

## 9.2. HYDRATED LIME AND QUICKLIME

### 9.2.1. Inspection and Sampling

Lime shipped from plants having a satisfactory record of quality control is not inspected by the Engineer prior to its arrival at destination. Therefore, the Engineer is responsible for the identification of the shipment with the accompanying certifications and the taking of verification samples from shipments selected at random. Samples are to be taken in accordance with the requirements of **KT-29**.

The Engineer obtains samples from shipping containers selected at random to verify the certifications issued by the producer. Should these samples indicate inadequate internal quality control by the producer, acceptance on certification is halted and each shipment is sampled and tested prior to use.

### 9.2.2. Reporting

The Engineer issues reports for lime covered by producer's certifications.

## 9.3. FLY ASH, SLAG, SILICA FUME

Fly ash is finely divided residue that results from the combination of ground or powdered coal. Slag is a glass-like by-product left over after a desired metal has been separated from its raw ore. Silica fume, also known as microsilica, is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. See **KDOT Standard Specification section 2004, 2005, 2006, and 2007**. Samples are to be taken in accordance with the requirements of **KT-29**.

## 10. MATERIALS FOR ROADSIDE IMPROVEMENTS

**10.1.** This section covers the inspection, sampling and testing of materials used for roadside improvements, including safety rest areas.

Where reference is made to regular sampling and testing procedures or regular inspection procedures, the intent is that the material receives such testing or inspection as is prescribed in the Standard Specifications or in this manual. Reports should be issued for these materials.

Individual material items that do not require regular testing should be judged on the basis of visual inspection and, where indicated, approved catalog cuts. Reports of these inspections are not generally required.

Visual inspection reports of completed bid items should be based on the use of accepted materials in the construction of such items as indicated by tests, approved catalog cuts or visual inspection of the materials as indicated above. Specific reference to the individual tests or inspections need not be made. On visual inspection reports of completed bid items, only a general statement need be made to the effect that all materials used were acceptable.

### 10.2. PLANTS

Plants used in roadside improvements are either nursery grown or collected from their natural growing site. For acceptance criteria see **Standard Specifications Manual Subsection 2102**. Preliminary inspection may be made at the nursery or collecting field when deemed desirable by the Engineer. Final inspection and acceptance or rejection is made at the planting site in accordance with the Standard Specifications.





### 10.3. SEEDS

Seed used for highway projects is field grown, usually in Kansas or neighboring states. Contractors may procure seed from the grower or from individuals or companies engaged in buying and selling seed. Seed intended or offered for sale for planting must be processed and handled in accordance with the Kansas Seed Law and applicable rules and regulations of the Kansas State Board of Agriculture. For acceptance criteria see **Standard Specifications Manual Subsection 2103**. The appearance of the seed must not indicate improper storage or handling resulting in damage by rodents, excess humidity, free moisture, overheating or other cause.

**10.3.1. Labels - Untreated Seed:** The labels must be in the English language and must contain the following information:

**10.3.1.1.** The commonly accepted name of the kind and the variety, of each agricultural seed component in excess of five percent (5%) of the whole, and the percentage by weight of each in the order of its predominance. Where more than one component is required to be named, the word "mixture" or the word "mixed" shall be shown conspicuously on the label.

**10.3.1.2.** The percentage by weight of pure seed.

**10.3.1.3.** The percentage by weight of all weed seeds.

**10.3.1.4.** The percentage by weight of inert matter.

**10.3.1.5.** For each named agricultural seed:

**10.3.1.5.1.** The percentage of germination, exclusive of hard seed.

**10.3.1.5.2.** The percentage of hard seeds, if present.

**10.3.1.5.3.** Total germination percentage including hard seed may be shown.

**10.3.1.5.4.** The calendar month and year the test was completed to determine such percentages. (Seeds shipped within Kansas which have not been planted within 9 months after testing shall be resampled and retested. Seeds shipped across state lines which have not been planted within 5 months after testing shall be resampled and retested.)

**10.3.1.6.** The percentage by weight of agricultural seeds (which may be designated as "crop seeds") other than those required to be named on the label.

**10.3.1.7.** The lot number or other lot identification.

**10.3.1.8.** The origin: i.e., the state where grown, except for lawn grass seeds in quantities of less than 10 pounds.

**10.3.1.9.** The name and rate of occurrence per unit weight of each kind of "restricted noxious weed seeds" present, which shall not exceed the limit stated in the Kansas Seed Law.

**10.3.1.10.** The name and address of the person responsible for such statement.

**10.3.2. Labels - Treated Seed:** Agricultural seed which has been treated with chemicals for insect or disease control, shall be labeled to show the following:

**10.3.2.1.** A word or statement indicating that the seed has been treated.

**10.3.2.2.** The commonly accepted, coined, chemical or abbreviated chemical (generic) name of the applied substance.

**10.3.2.3.** If the substance in the amount applied is harmful to human or other vertebrate animals, a caution statement, such as: "Do not use for food, feed or oil purposes." The caution for mercurials and similarly toxic substances must include in a contrasting color the word "poison" along with a skull and crossbones.

**10.3.2.4.** A separate label may be used to show this information, or it may be a component part of the main label.

**10.3.3. Sampling.**

Sampling of seed by Department personnel will seldom be required; however, should such sampling become necessary, it should be accomplished in a manner which will produce a representative sample in accordance with the Rules and Regulations of the Kansas State Board of Agriculture.

#### **10.4. NITROGEN FIXING BACTERIA**

Media for the inoculation of legume (bean) seed with nitrogen fixing bacteria are produced by only a few specialists in this field. Legume (bean) plants, when properly inoculated, form nodules on the root systems which contain millions of bacteria, called Rhizobia, that are fed by the host plant and in turn produce nitrogen. This nitrogen is then available to the legume plant to aid growth and making it independent of the supply of nitrogen in the soil. These bacteria are very sensitive to high temperatures and to drying. For acceptance criteria see **Standard Specifications Manual Subsection 2106.**

Observe the contractor's handling and storage of the inoculating material. Heat and drying must be avoided as either will cause extremely rapid death of the nitrogen fixing bacteria. The treating of the seed must be done in strict accordance with the supplier's directions and must result in heavy coating of the seed. Leguminous seed must be planted as soon as possible after inoculation. The maximum number of live bacteria will be on the seed at the time of inoculation after which the live bacteria decrease at a rate dependent on storage conditions. Exposure of the inoculated seeds to sunlight, high temperatures or drying conditions will increase the death rate of the bacteria.

No sampling of Nitrogen Fixing Bacteria is required, but perform a visual inspection of the container label to verify that the bacteria is of the proper culture, supplied in the proper quantity and properly dated.

#### **10.5. AGRICULTURAL LIMESTONE**

Ground limestone for agricultural purposes is almost always produced as a by-product of commercial quarrying and crushing limestone for other purposes such as highway and building construction. For acceptance criteria see **Standard Specifications Manual Subsection 2107.**

Sources supplying this material shall have been qualified by the State Board of Agriculture.

## **10.6. FERTILIZERS**

Commercial mixed fertilizers are blended or formulated of ingredients which will furnish the desired amounts of nitrogen (N), phosphorus (P) and potassium (K) together with an inert material.

Usually this item will be listed in the contract proposal as "Fertilizer (xx-xx-xx)." The first number in parenthesis denotes the minimum percentage of nitrogen (N) required, the second number indicates the minimum percentage of available phosphorus (P) required and the third number indicates the minimum percentage of water soluble potassium (K) required. The particular fertilizer required for a contract is chosen by the Landscape Architect to best supply the needs of the crop being planted and the soil conditions on the project. For acceptance criteria see **Standard Specifications Manual Subsection 2108**.

## **10.7. SUMMARY OF INSPECTION, TESTING AND REPORTING REQUIREMENTS**

Many roadside improvement projects contain a number of items not directly related to seeds or plants. These occur in rather variable quantities or numbers and often the Inspector is uncertain of the required inspection. The following gives the requirements for a number of such items.

**10.7.1. AGRICULTURAL LIMESTONE** - By receipt of proper certification.

**10.7.2. AUTOMATIC WATERING SYSTEM** - Use regular sampling and testing or inspection procedures on concrete, concrete reinforcing bars, cast iron pipe, steel pipe and corrugated metal pipe used for casing under roadways. Use regular procedure for plastic pipe if plans or specifications require conformance with an ASTM or other specifications. Other items are to be visually inspected. Issue a visual inspection report on the entire completed system.

**10.7.3. BERMUDA GRASS SOD RETARDS** - Issue visual inspection report.

**10.7.4. BURLAP BAG SOD RETARDS** - Issue visual inspection report.

**10.7.5. CHARCOAL GRILL** - Issue visual inspection report.

**10.7.6. CHARCOAL GRILL BASE** - Use regular sampling and testing or inspection procedures for concrete and reinforcing steel. Issue a visual inspection report for completed base.

**10.7.7. COMBINATION TOOL SHED AND COMFORT STATION** - Use regular sampling and testing or inspection procedures for concrete, concrete masonry units and reinforcing steel. Issue a visual inspection report for completed shelter.

**10.7.8. CONCRETE SHELTER WITH WINDBREAK** - Use regular sampling and testing or inspection procedures for concrete, curing material and concrete reinforcing steel. Issue a visual inspection report for completed shelter and windbreak.

**10.7.9. ELECTRIC LIGHTING SYSTEM** - Use regular sampling and testing or inspection procedures for anchor bolts, concrete, conduit and conduit fittings. Issue a visual inspection report on completed system.

**10.7.10. FERTILIZER** - Use regular inspection system.

**10.7.11. FIREPLACE** - Use regular sampling and testing or inspection procedures for concrete and reinforcing steel. Issue a visual inspection report for completed fireplace.

**10.7.12. GLASS FIBER MAT (DITCH LINING, RIPRAP, WEED CONTROL)** - Use regular procedures for glass fiber mat and subsidiary items such as seed, fertilizer, cover material, etc. Issue a visual inspection report for completed work.

**10.7.13. GRILL** - Use regular sampling and testing or inspection procedures for concrete and reinforcing steel. Issue a visual inspection report for completed grill.

**10.7.14. JUTE MESH EROSION CONTROL MATERIALS** - Use regular sampling and testing procedure. Issue a visual inspection report for completed erosion control.

**10.7.15. MANURE** - Issue visual inspection report.

**10.7.16. MULCHING** - Issue visual inspection report.

**10.7.17. PEAT MOSS** - Use regular sampling and testing procedure.

**10.7.18. PIPE UNDERDRAIN** - Use regular sampling and testing procedures for clay tile and underdrain aggregate.

**10.7.19. SANITARY SEWER** - Use regular sampling and testing or inspection procedures for pipe and materials for sealing and filing pipe joints.

**10.7.20. SEEDS AND REQUIRED NITROGEN FIXING BACTERIA** - Use regular inspection procedures.

**10.7.21. SOD** – Issue a visual inspection report for completed item.

**10.7.22. TABLE (WOOD WITH OR WITHOUT BASE: CONCRETE WITH BASE)** - Use regular sampling and testing or inspection procedures for concrete and reinforcing steel. Issue a visual inspection report for completed table.

**10.7.23. TABLE SHADE** - Issue a visual inspection report for completed shade.

**10.7.24. TOPSOIL** - Issue a visual inspection report.

**10.7.25. TREES, SHRUBS, ETC.** - Issue a visual inspection report.

**10.7.26. WATERING SYSTEM** - Use regular sampling and testing or inspection procedures for concrete, reinforcing steel and pipe. Issue a visual inspection report for completed system.

**10.7.27. WATER WELL PUMP** - Use regular sampling and testing or inspection procedures for concrete and reinforcing steel. Issue a visual inspection report for complete pump.

## **11. STEEL AND IRON**

### **11.1. STRUCTURAL STEEL**

#### **11.1.1. Shapes and Plates.**

For acceptance criteria see **Standard Specifications Manual Subsection 1605**. Acceptance reports issued by engineers who inspect items fabricated from structural steel also include the acceptance of the steel used in the fabrication of such units.

#### **11.1.2. Structural Steel Fasteners.**

Acceptance reports covering fasteners for bridge connections, splices and sign supports are issued by the Materials and Research Center. Acceptance reports for uncoated fasteners for other uses will be issued by the Field Engineer.

### **11.2. DEEP BEAM GUARDRAIL AND FITTINGS**

Guardrail terminal sections, rail elements and hardware including bolts, nuts and washers must be visually inspected by the Field Engineer for conformance with dimensional requirements, including gage of metal, width, configuration of corrugations, condition of galvanized coating and identification of the shipment with the manufacturer's certification.

## **12. TIMBER, LUMBER, PILING AND POSTS**

**12.1.** These instructions cover the inspection of timber products used for construction and maintenance purposes. The majority of timber products are produced in the southern states or the west coast region. The treating of most timber products is performed in the general region where the products are produced.

#### **12.2. Basis of Acceptance.**

For acceptance criteria see **Standard Specifications Manual Subsections 2303, and 2304**.

##### **12.2.1. Pre-qualification required for wood posts and blocks**

##### **12.2.2. Appropriate certification packets required for all wood products**

#### **12.3. Methods of Inspection, Sampling and Testing.**

##### **12.3.1. Inspection.**

Timber products from treatment plants will be pre-qualified and monitored by Department employees working out of the Wichita Regional Laboratory.

##### **12.3.2. Inspection Methods.**

**12.3.2.1.** All wood products will meet the requirements as specified in the Standard Specification Manual subsections, as listed above.

**12.3.2.2. Identification:** Each piece of inspected timber product is identified by supplier, or their representative, for the required material grade. Following treatment, a lot number is stamped on each piece,

or it may be stamped on a small piece of thin metal which is tacked to one end of the piece. As a minimum, the supplier identification, the treatment lot number, and minimum treatment requirement will be identifiable.

**12.3.2.3. Inspection at Destination:** Timber products should be inspected by the Field Engineer for identification marks, possible damage during handling and shipment, and serious defects that will impair the utility or durability of the piece. Defects that may have escaped the notice of the inspector include oversize knots, shakes, splits, checks, rot or decay, and straightness. Damage incurred during handling and shipment includes damaged ends and broken surfaces which expose untreated wood.

**12.3.2.4.** Notify the District Materials Engineer of any timber products that arrive on the project without proper documentation.

#### **12.4. Reporting.**

Acceptance reports will be written by field personnel, based on correct and complete documentation, covering all wood products received for use on Kansas Department of Transportation projects.

### **13. WATER FOR USE WITH PORTLAND CEMENT**

#### **13.1. Water from Domestic or City Supplies.**

Water from domestic or city supplies and from other sources approved by health authorities for domestic use may be accepted without testing for all concrete except that to be used in the production of prestressed concrete units. All water must be tested before it is used in concrete for the production of prestressed units.

#### **13.2. Untreated Water from Lakes, Ponds, Wells and Streams.**

Water from these sources must be sampled and tested in the Materials and Research Center and accepted before it is used in the production of all classes of concrete.

#### **13.3. Sampling.**

Care should be exercised to ensure that the sample of water is representative of the source of supply. Equipment used to take the sample and containers for shipping it to the laboratory should be clean. Samples are to be shipped in plastic or glass containers. If glass containers are used they must be carefully packed for shipment. Metal containers are not acceptable for shipping samples of water.

#### **13.4. Reporting.**

**13.4.1. Water from Domestic or City Supplies.** A visual inspection report is issued by the Engineer to cover the water used for regular concrete work. AWP projects do not require this report, because it is handled within the mix design.

**13.4.2. Untreated Water and Water for Prestressed Concrete.** The Materials and Research Center will issue a report showing the results of tests conducted on samples submitted by the Engineer.





# Kansas Department of Transportation Standard Operating Manual

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 1 of 7
	EFFECTIVE DATE: 07/01/2013	
INFORMATION CONTACT: Bureau of Construction and Materials		
APPROVED: _____, Secretary of Transportation		

## **POLICY STATEMENT:**

Kansas Department of Transportation (KDOT) employees involved with nuclear gauges shall be trained in their operation. They shall be knowledgeable of safety guidelines and shall follow the guidelines when handling or transporting a nuclear gauge.

## **DEFINITIONS:**

Nuclear Gauge. A portable device utilizing radioactive material to determine the density and/or hydrogen content of a material is a nuclear gauge.

Film Badge. A small device that is carried by an individual to measure radiation exposure for a stated period of time is a film badge.

Survey Meter. A device capable of monitoring the level of radiation emitted by nuclear sources is a survey meter.

## **PROCEDURAL GUIDELINES:**

### **General Operation**

Construction Office Supervisors shall have a minimum of two KDOT employees on the project who are trained to use nuclear gauges on projects requiring nuclear gauges and know the procedures to follow in case of an accident, theft, or fire. One of these employees shall be the operator.

Operators shall observe safety procedures while using nuclear gauges to perform a test.

Operators shall keep their hands clear of the underside of the nuclear gauge except when removing extraneous material.

Operators shall be familiar with and follow the operating procedures detailed in the operating manual for the nuclear gauge and/or instructions provided by the Bureau of Construction and Materials.

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 2 of 7
	EFFECTIVE DATE: 07/01/2013	

Operators shall correct only nuclear gauge malfunctions or perform other maintenance which is specifically covered in the manual for that gauge. If malfunctions are not covered by the manufacturer's manual, operators should contact the District Materials Office.

### **Pregnant Employees**

Any pregnant employee whose working assignment requires the use of the nuclear gauge may voluntarily declare the pregnancy. This declaration can be implemented or removed at any time by the employee. If the pregnant employee wants to declare the pregnancy, then the employee is to provide written notification of the pregnancy to the Construction Office Supervisor and District Materials Engineer. Removing a declaration also requires written notification to the same parties. The pregnant employee shall provide an anticipated due date in the written notification. The due date is necessary to determine exposure limits in accordance with Kansas Department of Health and Environment's (KDHE) requirements. KDOT strongly encourages pregnant employees to declare their pregnancy.

The pregnant employee's District Materials Engineer will inform the employee of quarterly/monthly exposure rates. This will continue throughout the pregnancy.

Radiation exposures are to be monitored by the District Materials Engineer for compliance with KDHE's limits during the course of the pregnancy.

When resources and personnel allow, an attempt should be made to minimize the use of nuclear gauges by the pregnant employee who has declared her pregnancy.

### **Film Badges**

All operators and other authorized personnel, when using the nuclear gauge, shall wear a film badge. Badges are furnished by KDOT and shall be worn waist high. When not in use, badges shall be stored away from radioactive areas, heat sources, and video display devices. Badges shall not be stored in vehicles. The individual to whom the film badge is assigned is the only person whose history shall be represented by the badge.

District records and communications regarding radiation exposure readings will be controlled by and filed in the District office. A copy of the records shall be sent to the Radiation Safety Officer at the Materials and Research Center. Badges for the Headquarters personnel will be controlled by the Bureau of Construction and Materials.

### **Daily Log and Survey of Nuclear Gauge with Survey Meter Check**

A survey meter shall accompany the nuclear gauge and shall be available for immediate use.

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 3 of 7
	EFFECTIVE DATE: 07/01/2013	

## Log Books

Two Log Books shall be established for each nuclear gauge and shall remain with the gauge. The log book shall contain all of the following:

### 1. Log Book One:

- Telephone numbers of the Bureau of Construction and Materials, Materials and Research Center, after-hours radiation emergency number, and office number of the company manufacturing the nuclear gauge.
- Serial number of nuclear gauge.
- Names of operators, dates of transfer to other operators.
- All survey meter readings and observations concerning the nuclear gauge.
- Equipment that came with the nuclear gauge when purchased.
- Any operating problems experienced while using the gauge.
- Any reporting forms required.

### 2. Log Book Two:

- Daily results of standardization check.
- Time of day gauge is removed from storage area / time of day gauge is returned to storage area.

## Survey of Nuclear Gauge with the Survey Meter

Nuclear gauges are to be scanned with a survey meter and the readings are to be recorded in the field Log Book. For density gauges, readings are to be taken with the survey meter probe/sensor held at a distance of approximately 12 inches from the four sides, top and bottom of the gauge with source of ionizing radiation closed and also at approximately 12 inches from the bottom with the source open. Readings shall be taken upon initial receipt of the nuclear gauge, upon transferring the gauge, once per week (minimum) when used in the field, and in case of an accident.

When a nuclear gauge is transferred between operators, the gauge shall be scanned for radioactivity as set forth in this directive and the readings shall be recorded in the field Log Book. The names of persons making the survey and the date of the survey will also be recorded.

Any significant change in survey readings shall be noted and called to the attention of the District Materials Engineer. **Readings greater than or equal to twice the normal radiation level (the reading of the most recent survey) are considered a significant change.**

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 4 of 7
	EFFECTIVE DATE: 07/01/2013	

## Handling and Storage of Nuclear Gauge

Operators of nuclear gauges shall observe the following precautions:

1. Never leave the gauge unattended unless properly stored. **Whenever the gauge is being transported or stored, the case in which it is kept shall be locked.**
2. If a gauge is left in an unattended vehicle, the vehicle should always be locked.
3. The gauge and carrying case shall be protected from moisture.
4. Probes shall always be in the locked or safe position (source of ionizing radiation closed) unless actually performing a test.
5. When transporting the gauge by vehicle, the gauge shall be in a locked storage area in the pickup bed or van or locked trunk of car, at least 4 feet from any occupant.
6. A copy of this SOM shall accompany the nuclear gauge at all times. This document and the survey meter must be in the transport vehicle and immediately accessible to the driver during transport on a public highway.
7. The “Bill of Lading” must accompany the driver of the vehicle during the transportation of the gauge upon a public highway. This document must have the following information:
  - name of shipper (KDOT)
  - description of the shipment (proper shipping name, material identification number, hazard class, type of package, name and activity of each nuclide, category of labeling, transport index)
  - emergency response telephone number
  - signature of the shipper
8. A portable gauge licensee is required to use a minimum of two independent physical controls i.e. locks, that form tangible barriers to secure portable gauges from unauthorized removal.
9. Gauges shall be stored as follows:
  - **Gauges shall not be stored overnight in vehicles or field laboratories.**
  - At night, gauges shall be stored in a locked room or building which is posted with a “Caution Radioactive Material” sign furnished for that purpose. Signs should be on all building entrances and interior doors of the storage room.
  - Gauges shall be stored in an area which is at least 4 feet from the general working

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 5 of 7
	EFFECTIVE DATE: 07/01/2013	

area of any personnel. A general working area is a place where an employee would spend over 75% of their work time.

10. The following gauge precautions should be observed:

- Project personnel employed by the State and the contractor shall be informed that a nuclear gauge is in use on the project.
- For roadway paving operations, an extended red flag mounted on the vehicle or otherwise prominently displayed to mark the general location of the nuclear gauge when performing tests is recommended. A flashing light on the vehicle is also recommended.

### Accident Procedures

The operator of nuclear gauges and others as directed by the Construction Office Supervisor should familiarize themselves with KDHE Radiation Emergency Handout, 9th edition. In case of an accident involving a nuclear gauge the following steps, as a minimum, shall be taken. (See Attachment A for flowchart.) **The needs of an individual with a life-threatening injury take precedence.**

1. If the operator is injured, another person with knowledge of these procedures will assume responsibility for any emergency procedure that may be required.
2. All road equipment or vehicles involved in the accident shall be stopped immediately and not allowed to be moved until the Construction Office Supervisor authorizes its removal.
3. The area where the accident occurred shall be isolated for a distance of at least 20 feet. Adjacent lanes carrying through traffic, even if within 20 feet of the accident area, need not be closed to through traffic if the damaged gauge or accident area does not include that surface.
4. The nuclear gauge, accident area, and any equipment involved shall be scanned with the survey meter to determine radiation levels. **Readings greater than or equal to twice the normal radiation level (the reading of the most recent survey) are considered a significant change.** As an alternative, a damp rag on a stick may be wiped in a small region around the sources of the gauge. Move the damp rag at least 30 feet from all nuclear gauges and take a reading with the survey meter. The meter will clearly indicate if there is any radioactive material on the rag.
  - a. If readings demonstrate no significant change from normal readings for the nuclear gauge, then attend to those with non-life threatening injuries. The nuclear gauge shall be placed in its transporting case unless damages prevent proper fit. If the gauge will not fit in its transporting case, the gauge will then be wrapped in heavy plastic and moved to a safe location. A second survey will be performed after the gauge is removed to verify there was no significant change from the normal readings, then the area restrictions can be lifted.

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 6 of 7
	EFFECTIVE DATE: 07/01/2013	

- b. If any readings demonstrate significant change from normal readings, the gauge shall not be moved and the area shall remain restricted until authorities from the KDHE authorize its removal. Attend to the injured people, then complete a survey of the injured people to determine if they have been contaminated (the survey will need to be completed away from the contaminated area). If the injured person is not contaminated, then send the person to the hospital.
  - c. If the injured is contaminated, send the person(s) to the hospital and inform EMS and hospital personnel that the injured was involved in a "Radiation Accident."
5. Upon completing the examination of the extent of radiation hazard, i.e., damage to container only, leakage involving risk to personnel, probable extent of contamination, the operator or person with knowledge of policies and procedures in charge shall proceed as follows:

**Call:**

- a) (785) 296-2231 during normal weekday hours: 8:00am - 5:00pm: KDOT Materials and Research Center, Topeka. Ask for the Radiation Safety Officer. If unavailable, provide information to the person answering the phone.
  - b) (785) 827-4437 after hours: Kansas Highway Patrol. State:
    - "This is a KDOT Radiation Emergency."
    - Whether any injuries have occurred.
    - Your name.
    - Accident location and District where occurred.
    - The city or nearest city and the telephone number from where you are placing the call.
6. **Remain at your telephone until you receive a call from the Radiation Safety Officer, District Materials Engineer, or KDHE.**
7. After discussing the situation with an authority listed in #6, return to the location of the accident.
8. KDOT personnel involved in an accident shall prepare a report of the accident as soon as possible. In addition, the Construction Office Supervisor or Area Engineer shall assemble facts pertinent to the accident. This report shall be sent to the Radiation Safety Officer and the District Materials Engineer.

**Theft**

If a nuclear gauge appears to have been stolen, the operator or supervisor shall notify the District Materials Engineer as soon as possible. The District Materials Engineer is to notify the Radiation Safety Officer. The Radiation Safety Officer is to notify KDHE and the manufacturer of the

		SOM: 1.13.2
SUBJECT: <b>Radiological Safety Guidelines</b>	VERSION: 7	PAGE: 7 of 7
	EFFECTIVE DATE: 07/01/2013	

gauge.

### **Fire**

If requested by a fire department, the Construction Office Supervisor will furnish a list of locations within the fire department’s jurisdiction where KDOT keeps radioactive materials. The information supplied to the fire department will include the name of KDOT’s Radiation Safety Officer. In the event of a fire at a location where radioactive materials are stored, the District Materials Engineer will notify the Radiation Safety Officer. The Radiation Safety Officer is to notify KDHE and the manufacturer of the gauge.

### **Responsibilities**

The Chief of the Bureau of Construction and Materials and the District Materials Engineers shall be responsible for seeing that nuclear gauge safety procedures are followed.

### **AUTHORITATIVE REFERENCES:**

Note: The following references are for additional information only. Clarification of this policy may be obtained from the information contact listed.

- KSA 48-1601
- KSA 48-1624
- Radiation Emergency Handbook, 9th edition, Kansas Department of Health and Environment





## 5.8.2. INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES

The following establishes a method for verifying whether a nuclear density gauge is properly operating as established in **Appendix C**. It can also be a check to determine if the operator understands proper procedures for running the nuclear gauge.

### 1. GENERAL OVERVIEW

Nuclear gauge operators are to demonstrate proficiency in operating the gauge *at the project*. This will represent the Independent Assurance Witness (ASW) portion of the program. The focus of this section is to determine if the nuclear gauge can function properly. If more than one type of nuclear gauge (different series or manufacture) might be used during the course of the project, then each gauge is to be checked by this procedure. Properly warm up the gauge and establish the standard count as outlined under **Section 2. NUCLEAR GAUGE**. Turn off all offsets and correction factors (see **Section 3. OPERATOR**). Verify the nuclear gauge by placing it on the KDOT District's Validator™ (or Validator II™ when checking the 3450 or 4640 gauge) and establish the density of the block by taking 1 four-minute count.

If the gauge value is within the quantity established in **Appendix C**, when on the KDOT District's Validator™ or Validator II™, then the gauge can be used on the project. If not, then run a stability and drift test. If the gauge passes the stability and drift test, as outlined in **Section 2. NUCLEAR GAUGE**, then the gauge can be used on the project. If not, the gauge cannot be used on a KDOT project until the above requirements are met. Provide proof to the district representative that the problem has been corrected (i.e. new calibration with appropriate papers).

### 2. NUCLEAR GAUGE

#### 2.1. GENERAL.

The nuclear gauge is to receive a multi-block calibration and a verification annually. Present copies of the previous two calibration papers to the district representative at the time of the Independent Assurance Replicate (ASR) check. Calibration papers are to be checked at the start of a project. Include yearly Calibration Papers in the QC/QA project's Quality Manual when applicable.

#### 2.2. CALIBRATION OF NUCLEAR GAUGE.

As a minimum, the nuclear gauge must be calibrated by a Qualified Service Center for a full multi-block calibration on an annual basis. The technician performing the gauge calibration must have a current certificate in moisture density gauge calibration from a gauge manufacturer. The gauge must be disassembled, cleaned and lubricated prior to the calibration. Provide a copy of the gauge calibration documents to the district representative at the time of the ASR check.

#### 2.3. VERIFICATION OF NUCLEAR GAUGE.

At least once a year, the nuclear gauge must be verified by KDOT. Verify the nuclear gauge by placing it on the KDOT District's Validator™ (or Validator II™ when checking the 3450 or 4640 gauge). Follow the procedures outlined in **Section 1. GENERAL OVERVIEW**. The Validator™ and Validator II™ blocks shall be calibrated at least once every five years. Maintain copies of the current Validator™ and Validator II™ calibrations at the District Office.

## 2.4. PROPER WARM-UP.

The gauge should be properly warmed up before starting any check. For the Troxler units, this means a minimum of 10 minutes. This permits the electronics to warm up to operating temperatures. If this step is not permitted the counts given can be significantly altered.

## 2.5. STABILITY AND DRIFT TEST.

Perform a stability and drift test on the gauge when the gauge fails the IA check. Any time the nuclear gauge readings are “suspect”, perform the STAT TEST (or stability test) to validate the normal operation of the gauge. The stability test requires the gauge to take 20 one-minute counts.

Perform the drift test 2 to 3 hours after the stability test to determine if the gauge reading “drifts” between tests. The drift test consists of 5 four-minute counts. It is highly recommended that the gauge not be moved from the block after taking the stability test and prior to taking the drift test.

Check the manufacturer’s manual for specifics on the results to be obtained. Contact the Materials Quality Control Engineer at the Materials and Research Center for assistance. For Troxler gauges, use the following table for acceptable limit results:

TROXLER GAUGE SERIES	Stability (STAT) Test*	Drift Test
3411-B and 3440	0.17 to 0.33 – acceptable <0.12 or >0.40 - unacceptable	Density: <0.5% Moisture: < 1.0%
4640-B	0.25 to 0.45	System 1 (Drift A): 0.50% System 2 (Drift B): 0.80%

\* For the 3411-B and 3440, the numbers falling between acceptable and unacceptable should be considered carefully prior to acceptance/unacceptance. The 4640-B is considered to be unstable if the ratios are outside these limits for two out of three stat tests.

## 2.6. STANDARD COUNTS.

Take a standard count on a surface with 100 lb/ft<sup>3</sup> (1600 kg/m<sup>3</sup>) or better. **DO NOT perform the standard count on the Validator.** Perform the stability and drift test prior to taking the standard count.

## 2.7. PASS/FAIL OF STABILITY AND DRIFT.

If the gauge fails the stability and drift test as defined in the manufacturer’s manual, then see **Section 1. GENERAL OVERVIEW** and consult the manufacturer (if KDOT gauge, call Materials Quality Control Engineer). If the gauge passes the stability but fails the drift, one alternative is to have the operator take new standard counts twice each day. Once when the operator begins in the morning and another in the early afternoon. All standard counts are to be recorded and monitored. As always, pay attention to your immediate surroundings when operating a nuclear gauge.

### 3. OPERATOR

The operator is to demonstrate understanding of the gauge's fundamental operations, which include the following:

1. Gauge turned on and permitted proper warm up time? \_\_\_\_\_
2. Set up, establish, and record a standard count? \_\_\_\_\_
3. Maintained a minimum of 3 ft (1 m) distance from gauge when in operation? \_\_\_\_\_
4. Verified all offsets and correction factors were turned off? \_\_\_\_\_
5. Properly seated gauge on concrete block? \_\_\_\_\_
6. Probe securely placed in the backscatter mode?  
(verified the latch is properly seated in the notch) \_\_\_\_\_
7. Gauge permitted to determine density and results recorded? \_\_\_\_\_
8. Were there any vehicles within 10 ft (3 m)? YES / NO
9. Were there any nuclear gauges within 30 ft (10 m) YES / NO
10. What was the density determined? \_\_\_\_\_ lb/ft<sup>3</sup> or kg/m<sup>3</sup>

DISTRICT    1    2    3    4    5    6

COMMENTS: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

OPERATOR'S NAME: \_\_\_\_\_  
WORKS FOR: \_\_\_\_\_  
DATE: \_\_\_\_\_

The checklist represents the minimum an operator should know. A knowledgeable operator should provide new operators guidance. New operators are encouraged to take the gauge out and record a multitude of numbers in a single location with slight variations to the positioning of the base. This will give the operator a better understanding of the gauges' precision and how to optimize seating the gauge to the surface when such conditions apply.



### 5.8.3. SEGREGATION CHECK USING THE NUCLEAR DENSITY GAUGE

#### 1. OBJECTIVE

The objective of these instructions is to give guidance on establishing a density profile behind the laydown machine. This is accomplished by taking multiple readings within a 50 foot (15 m) section. Use the nuclear density gauge results to plot a density profile. Check the profile for a drop in density caused by segregation. Check the roadway profile location for visible segregation. It is important to record the profile location to permit possible future evaluation of the segregated section. It is intended that English projects use English values and that metric projects use metric values.

#### 2. PROJECT STARTUP

**NOTE:** Check gauge to verify it is in asphalt mode.

At the start of the project, allow the paving unit 1000 ft (300 m) progress with each mix designation before implementing a profile analysis.

#### 3. SELECTION OF PROFILE LOCATIONS

It is intended that visibility identifiable segregated areas be profiled. Two basic types of segregation are encountered on the roadway. They are truck load segregation and longitudinal segregation.

- Truck load segregation (spot, chevron, or gull wing type segregation) has a visible pattern repeated with each truck load. These segregated areas are about the same longitudinal distance apart. This type of segregation will normally occur 10 to 25 ft (3 to 7.5 m) from the screed stop point when trucks dump directly into the paver. The use of a material transfer vehicle (MTV) has been known to extend this further down the paving section.
- Longitudinal segregation (streaking) is normally caused by the paver. This streaking is parallel to the centerline of the project, and may occur continually, or may periodically start and stop.

If the laydown machine continues to progress without stops, then the engineer will establish profile starting points.

If the laydown machine periodically stops, then use the location where the screed stops as the “zero” point for the profile starting point. The Engineer should use caution on whether to run a profile if the laydown machine has been stopped for more than 10 minutes, due to cooling of the mix.

#### 4. LOCATION OF DENSITY READINGS

Take readings approximately every 5 ft (1.5 m) along the longitudinal direction. The first reading should be located approximately 10 ft (3 m) behind the screed (zero point). If a segregated location is visible between two locations, then take an additional reading at that location.

- When checking for truck load segregation, the longitudinal distance from centerline may vary, but not the transverse distance (see **Figure 1**).
- When checking for longitudinal streaking, the longitudinal distance from centerline will vary.

This is done so the profile will cross over the longitudinal streaks. Determine the transverse distance from centerline to the longitudinal segregation. Start the profile approximately 2 ft (0.6 m) farther

transversely than the center of the longitudinal streak. End the profile approximately 2 ft (0.6 m) less transversely than the center of the longitudinal streak. The approximate distance (2 ft or 0.6 m) from the center of the streak to start and end the profile will be determined by the Engineer (see **Figure 1**). Pick a distance from either edge of which you believe will be most likely to detect segregation. That distance shall be more than 2 ft (0.6 m) from either edge of placement. Only one distance is to be used throughout the length of a single profile section for truck load segregation. When testing for longitudinal segregation, each end of the profile will be more than 1 ft (0.3 m) from the edge of paving. If there is no visible segregation, then randomly select the location for the profile section.

## 5. NUCLEAR GAUGE READINGS

Minus No. 30 (600  $\mu\text{m}$ ) aggregate from the mix will be used to fill any voids in the surface. Smooth and level the minus No. 30 (600  $\mu\text{m}$ ) material with a metal plate or straight edge. The aggregate is not to be used as a thin film between the hot mix and the gauge. Use only enough aggregate to fill the voids. (For this procedure, the aggregate shall be minus No. 30 (600  $\mu\text{m}$ ) material from the mix with no more than 20% passing the No. 100 (150  $\mu\text{m}$ ) sieve.

**NOTE:** For uniformity, position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

In backscatter mode, take 3 one-minute readings and average. If one of the readings varies by more than 1  $\text{lb/ft}^3$  (16  $\text{kg/m}^3$ ) of the average, then discard and take an additional reading to replace it. It is not necessary for the gauge to be calibrated to the mix.

Take a minimum of ten locations along the profile section. It is not necessary to maintain a rigid longitudinal spacing of 5 ft (1.5 m) as stated above. Remember to take additional readings if a segregated location is encountered along the profile.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

## 6. PROFILE EVALUATION

Initially perform four segregation checks for each mix. When four consecutive profile evaluations meet the acceptable criteria established in the Contract Documents, the District Materials Engineer may reduce the segregation checks to a frequency deemed appropriate.

The contractor field representative will be provided results of the segregation checks as they are completed. When one of the segregation checks fails the acceptable criteria established in the Contract Documents, the contractor will be allowed to make changes to the mix, plant, or roadway operations before the next profile evaluation is made. If any changes are to be made by the contractor, these changes are to be made within the first hour of production following notification of a failing evaluation. Production of the hot mix is to cease whenever two consecutive checks fail. The contractor will make changes to the mix or process before production is restarted. The contractor may produce enough mix to place approximately 2000 ft (600 m) of pavement one paver width wide. Two segregation checks will be taken within this 2000 ft (600 m) of production. If both segregation checks meet acceptable criteria, the contractor may resume normal production. If one or both of the segregation checks fail, the contractor will make changes before production is restarted. The contractor may then produce enough mix for an additional 2000 ft (600 m) of pavement and this production will be evaluated as was the previous 2000 ft (600 m) of production. This procedure of placing and evaluating 2000 ft (600 m) sections will be continued until both segregation checks pass. Normal production and segregation checks will resume when both evaluations pass.

The drop in density caused by segregation will be calculated by subtracting the lowest density obtained from the average profile density. The average profile density shall be calculated using all density determinations in the profile section. The density range will be calculated by subtracting the lowest from the highest profile density.

## **7. SEGREGATION CHECK FORM**

The **SEGREGATION CHECK USING THE NUCLEAR GAUGE** form provides the user a means of recording key information to pinpoint the location of the profile section. It also provides a chart for graphing the average recorded nuclear density readings.

**Note:** the screed location is referred to as the zero point. When the paver is stopped, rollers are prevented from compacting all of the asphalt material that has been laid down. A portion of material has the chance to cool before being compacted. Recording the densities behind the screed provides the gauge operator a complete profile of possible low density locations.

On the right side of the chart is a location to place a different scale in case the left side does not fall in the density region of the material being profiled. If this side is used, cross out values on the left side to help eliminate any confusion.

## **8. DENSITY GAUGES AND TEMPERATURE**

It is recommended to allow the compacted surface to cool for as long as possible prior to using the density gauge. Remove the gauge from the surface immediately after the readings have been taken.

Although the density gauge is designed for high surface temperatures [350°F (175°C)], the ambient temperature inside the gauge is not to exceed 160°F (70°C). If the gauge remains on the surface for any length of time, the surface temperature becomes the ambient temperature inside the gauge. This occurs when the surface temperature penetrates up into the electronics. The electronics can experience temporary malfunction or permanent damage due to excessive heat.



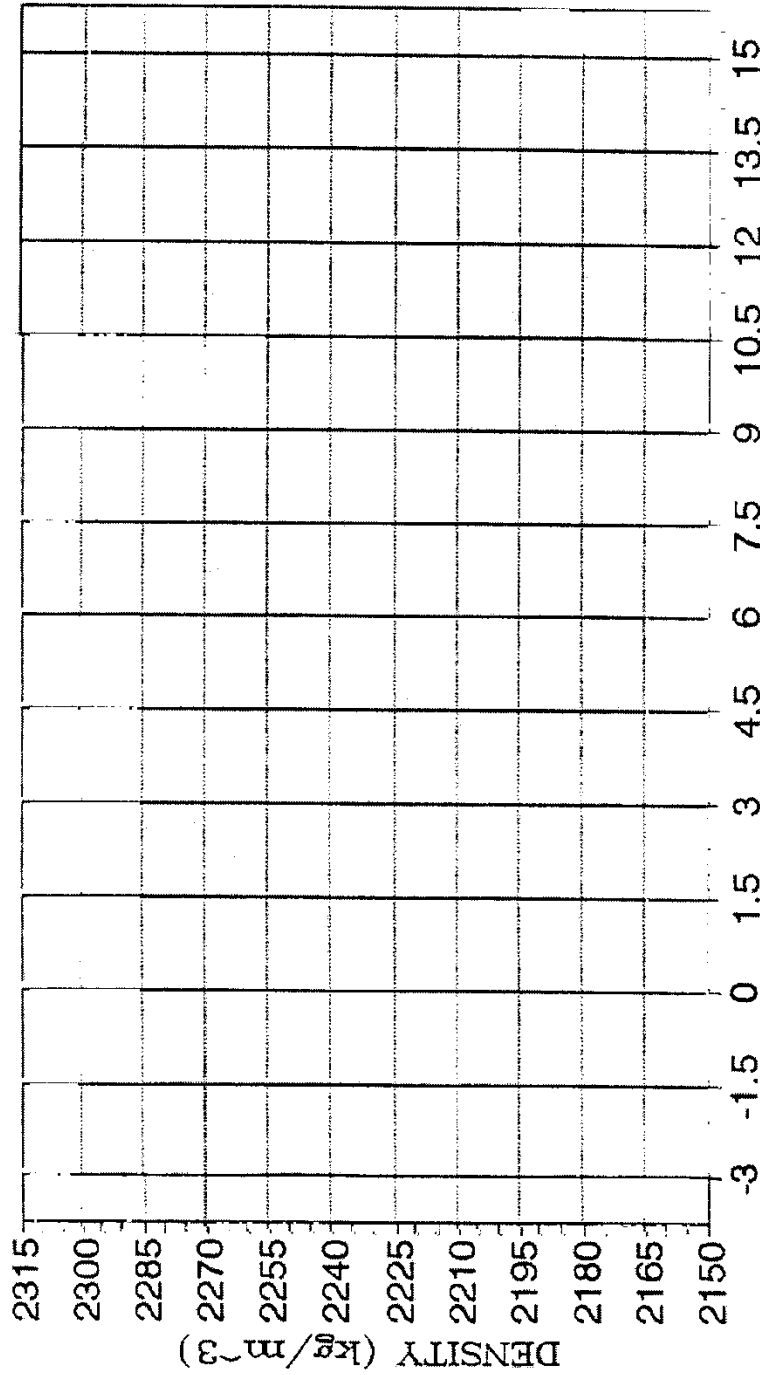


# SEGREGATION CHECK USING THE NUCLEAR DENSITY GAUGE

Rev 09/12/98

Project No.	Mix Type	O/L Thickness	Profile No.	Dist.
Profile Station No.	Profile Lift No.	Visible Segregation (Yes/No)		
Date	Gauge Serial No.	Profile Distance From CL		
Operator	Contractor	Brand and Model of Paver		

Remix Equipment (In or Ahead of Paver): None, Auger Paver, Shuttle Buggy, Pick Up Device, Material Transfer Device, Other

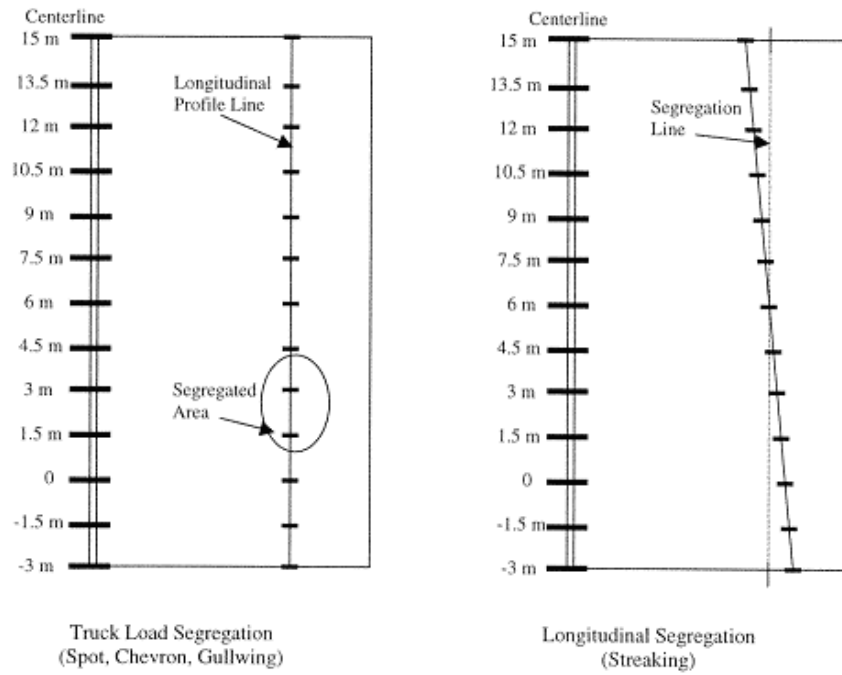


Revised  
Density  
Scale

SCREED LOCATION

Send Copy To Bureau of Materials and Research

FIGURE 1: SEGREGATION PROFILE LOCATION



## 5.8.4. JOINT DENSITY EVALUATION USING THE NUCLEAR DENSITY GAUGE

(For English projects use English units)

(For metric projects use SI units)

### 1. OBJECTIVE

The objective of these instructions is to give procedures for evaluating traveled way joint density. This is accomplished by taking two or three readings in the transverse direction one paver width wide. The traveled way joint density, either one or two locations, is subtracted from the interior density and the difference in density compared to the allowable limits. It is important to record the profile location to permit possible future evaluation of this location.

### 2. PROJECT STARTUP

**NOTE:** Check gauge to verify it is in asphalt mode.

At the start of the project, allow the paving unit 1000 ft (300 m) progress with each mix designation before implementing the joint density evaluation. During this initial 1000 ft (300 m) the contractor should be establishing laydown and compaction procedures and training personnel. The contractor should make preliminary nuclear gauge evaluations of their procedures.

### 3. SELECTION OF JOINT DENSITY EVALUATION LOCATIONS

A lot is defined as the distance paved with each mix designation per day. Determine the number of sublots from **Table 1**. Make each subplot approximately the same length. Randomly select one longitudinal location within each subplot.

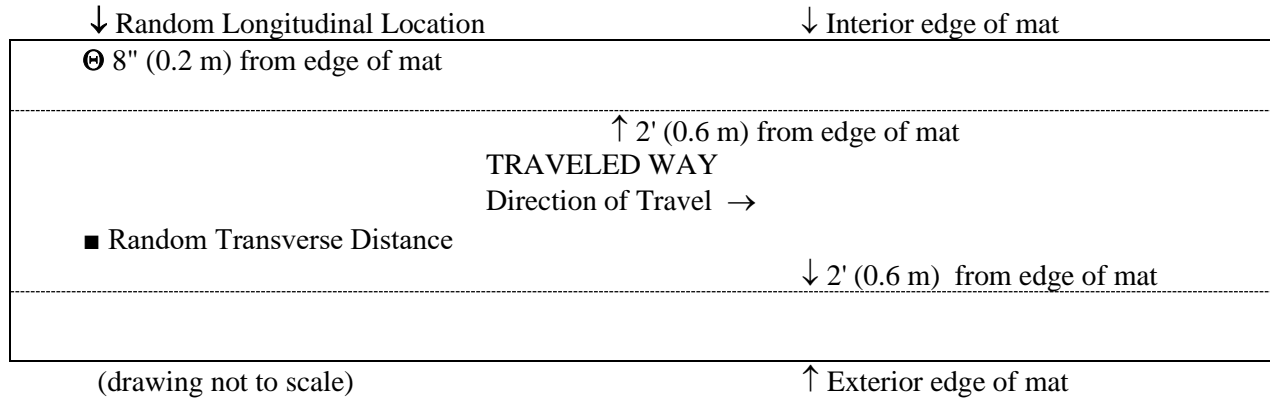
**Table 1. Determination of Number of Sublots Per Day**

Distance Paved		Number of Sublot
English (ft)	Metric (m)	
0 - 500	0 - 150	0
501 - 1000	151 - 300	1
1001 - 2000	301 - 600	2
2001 - 3000	601 - 900	3
3001 - 4000	901 - 1200	4
4001 and greater	1201 - and greater	5

At each subplot longitudinal test location, determine the nuclear density on the traveled way at two or three transverse locations. (See **Figures 1 and 2**) Sublot joint density evaluation will be completed before compaction is completed in the third subplot. (Second subplot evaluated before fourth subplot compaction completed. Third subplot evaluated before fifth subplot completed.)

**Figure 1**

- Traveled way without hot mix shoulders or shoulders placed at the same time as the traveled way. Test two transverse locations. Test each lane as placed.



Test two or three locations as follows: (For three locations, see **Figure 2**)

1. Locate the random longitudinal location as described above in selection of Joint Density Evaluation Locations.

2. ⊕ Determine "joint density" with the source rod of the gauge 8" (0.2 m) off the mat edge that will become a longitudinal joint. Position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

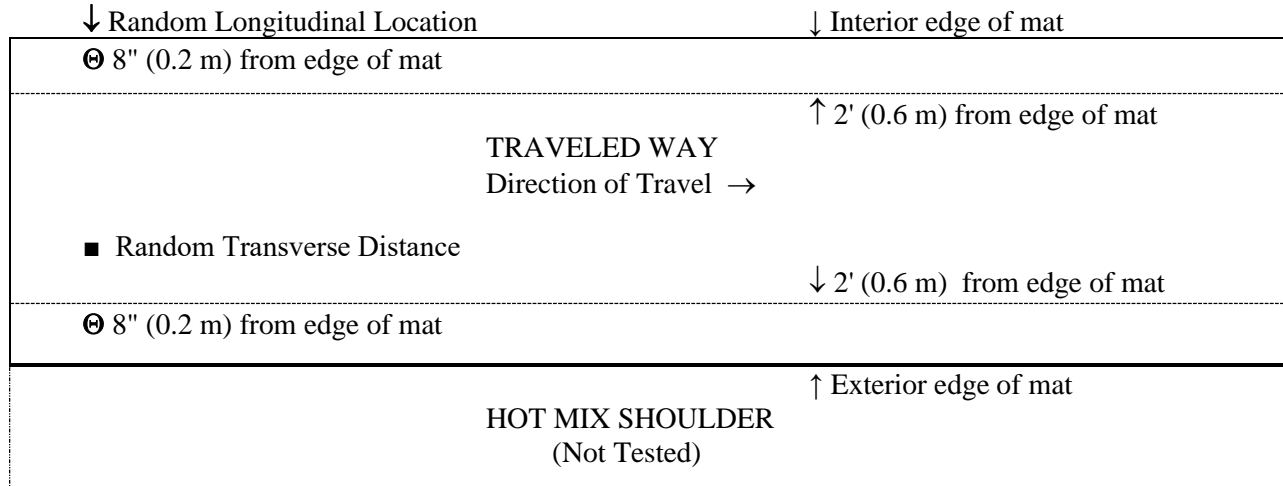
**Note:** Check tip of source rod to assure it is free of any foreign substance, (i.e. grease, asphalt, concrete, etc.).

3. ■ Randomly select a transverse location between 2' (0.6 m) for each edge of the mat. Determine "interior density." Position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**Note:** Check tip of source rod to assure it is free of any foreign substance, (i.e. grease, asphalt, concrete, etc.).

**Figure 2**

Traveled way with hot mix shoulder or shoulders not placed at the same time as the traveled way. Test three transverse locations as described above. Test each lane as placed.



(drawing not to scale)

#### 4. NUCLEAR GAUGE READINGS

In backscatter mode, take 5 one- minute readings, record wet density values, discard the single highest and lowest values, average the three remaining values, and record the average value. It is necessary for the gauge to be calibrated to the mix.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance, (i.e. grease, asphalt, concrete, etc.).

#### 5. PROFILE EVALUATION

The contractor field representative will provide the Engineer results of the joint density evaluation as they are completed. Whenever the Engineer makes independent joint density verifications, the contractor will be supplied joint density evaluation results as they are completed. Whenever one of the evaluations fails the acceptable criteria established in **Division 600, Section 602 of the 2015 Standard Specifications for State Road and Bridge Construction**, the contractor will make changes to the mix, plant or roadway operations. Production of the hot mix is to cease whenever two consecutive checks by the contractor or by the Engineer fail. The contractor will make changes to the mix or process before production is restarted. The contractor may produce enough mix to place approximately 2000 ft (600 m) of pavement one paver width wide. Two joint density evaluations will be taken within this 2000 ft (600 m) of production. If both joint density evaluations meet acceptable criteria, the contractor may resume normal production. If one or both of the joint density evaluations fail, the contractor will make changes before production is restarted. The contractor may then produce enough mix for an additional 2000 ft (600 m) of pavement and this production will be evaluated as was the previous 2000 ft (600 m) of production. This procedure of placing and evaluating 2000 ft (600 m) sections will be continued until both joint density evaluations pass. Once the evaluation passes, normal production and joint density evaluations will resume.

Calculate the "drop in density" by subtracting the "joint density" from the "interior density." Compare drop in density to specification limits. (Note: whenever three tests are taken at one transverse location, each joint density evaluation must pass the specified limits to be considered a passing location.)

## 5.9. SAMPLING AND TEST METHODS FOREWORD

### 1. SAFETY

The responsibility for safety rests with each and every employee in the laboratory or field. You must use common sense and work carefully to avoid the hazards your job may expose you to like hazardous chemicals, flying particles and heavy or awkward lifting are a few of the hazards you will be exposed to.

You are responsible to know the hazards that each test may expose you to so that you can work with the right level of protection while completing certain test procedures. Through OSHA 1910 and 1926 and KDOT SOM 2.6.2 your employer is required to tell you what hazards you will be exposed to and how to protect yourself from those hazards.

OSHA 1910 and 1926 also makes it the employee's responsibility to understand and follow the safety programs provided by their employers to protect them. SOM 2.6.2 refers to the KDOT safety Manual which requires employees to follow the guidelines of KDOT Hazardous Communications Program and the KDOT Personal Protection Program. These two programs will assist you with how to read an MSDS and provide information on the type of personal protection required to protect you from the physical, chemical, biological and ergonomic hazards you will be exposed to while performing the tests in this manual.

### 2. SCOPE

The purpose of this section is to standardize the testing procedures used throughout the State by all laboratories. A hierarchy for test methods exists in order to establish a specific test procedure for a given circumstance.

Test method hierarchy corresponds to the following publications unless otherwise stated in the Standard Specifications, plans or project specifications:

- First - Kansas Department of Transportation Construction Manual, Part V.
- Second - Standards published by the American Association of State Highway and Transportation Officials (AASHTO).
- Third - Standards published by the American Society for Testing and Materials (ASTM).

Each test method is an independent document, page numbered and printed individually. The primary number linking it to this manual is the sub-paragraph number. Any future corrections, additions or revisions will be printed and forwarded to the manual holders at the time they occur, to reflect current testing procedures.

Footnotes at the bottom of the page of a test procedure are a quick check for contractors or consultants to determine differences between KT methods and AASHTO/ASTM standards. **ALL PROCEDURES ARE TO BE PERFORMED AS STATED WITHIN KT METHODS, EXCLUDING THE INFORMATION FOUND IN THE KT FOOTNOTES.**

Unless noted in the test method, the use of potable water is required.

Unless otherwise stated in the test method, drying to a constant mass means less than 0.1% mass decrease from the previous measurement after 1 hour following the temperature requirements in the test method.

Consult the Bureau of Construction and Materials and in case of ambiguity or difficulty in the interpretation of testing procedures.

### 3. ACCURACY

As a general guideline use the following for an accuracy requirement when not stated within the test procedure:

**Thermometers:** Temp  $\leq$  140°F (60°C), accuracy of 0.2°F (0.1°C); Temp  $>$  140°F (60°C), accuracy of 2°F (1°C).

**Balances/Scales:** Accuracy is equal to the mass stated or 0.1 percent of the test load, whichever is greater, throughout the range of use. The following table shows the various classes as established in AASHTO M 231:

Class	Readability and Sensitivity	Accuracy*
G1	0.01 g	0.02 g or 0.1 percent
G2	0.1 g	0.2 g or 0.1 percent
G5	1 g	2 g or 0.1 percent
G20	5 g	5 g or 0.1 percent
G100	20 g	20 g or 0.1 percent

\* Accuracy equal to the mass stated or 0.1 percent of the test load, whichever is greater, throughout the range of use.

### 4. SI UNITS

The following information provides the user of these test procedures with specific comparisons between metric (SI) and English units and nomenclature.

Where possible, "Hard Conversion" practices are used converting the testing procedures from English to SI units. This system establishes an approximate measurement in SI units compared to the English units. An example of this is to convert one inch to SI units. One inch is equal to 25.4 millimeters (1 in = 25.4 mm). Using Hard Conversion, 25 mm is the new measurement, and compared to the 25.4 mm, is easier to verify. However, where test methods requires rigidly specified equipment or procedures measured in English units, a soft conversion will be shown. These cases should be obvious due to the outrageous metric number presented.

The nomenclature used to represent SI units are as follows (conversions originated or derived from ASTM E 380):

$$\underline{\text{SI (full name)}} = \underline{\text{ENGLISH (full name)}} \times \underline{\text{Conversion}}$$

#### AREA

mm <sup>2</sup> (millimeter <sup>2</sup> )	in <sup>2</sup> (inches <sup>2</sup> )	645.16
m <sup>2</sup> (meters <sup>2</sup> )	ft <sup>2</sup> (feet <sup>2</sup> )	0.092903
m <sup>2</sup>	yd <sup>2</sup> (yard <sup>2</sup> )	0.8361274

#### DENSITY (MASS PER UNIT VOLUME)

<u>kg</u> <u>kilogram</u>	<u>lb</u> or <u>pound</u>	16.01846
---------------------------	---------------------------	----------



m<sup>3</sup> meter<sup>3</sup> ft<sup>3</sup> feet<sup>3</sup>  
 (also known as PCF)

**FORCE**

N (Newton) lbf (pound-force) 4.448222

**LENGTH**

mm (millimeters) in (inches) 25.4

m (meters) ft (feet) 0.3048

km (kilometer) (mile) 1.609347

SI (full name) = ENGLISH (full name) X Conversion

**MASS**

g (gram) lb (pound) 453.5924

kg (kilogram) lb (pound) 0.4535924

Mg (megagram) TONS 0.9071847

**PRESSURE (FORCE PER UNIT AREA)**

kPa (kilopascal) psi or  $\frac{\text{pound-force}}{\text{inches}^2}$  6.894757

**TEMPERATURE**

°C (Celsius) °F (Fahrenheit)  $t_C = (t_F - 32)/1.8$

**VOLUME**

mm<sup>3</sup> (millimeters<sup>3</sup>) in<sup>3</sup> (inches<sup>3</sup>) 16,387.06

m<sup>3</sup> (meters<sup>3</sup>) ft<sup>3</sup> (feet<sup>3</sup>) 0.02831685

m<sup>3</sup> yd<sup>3</sup> (yards<sup>3</sup>) 0.7645549

mL (milliliter) in<sup>3</sup> 16.38706

L (Liter) qt (quart) 0.9463529

L gal (gallon) 3.785412

L ft<sup>3</sup> 28.31685

NOTE:  $1 \text{ m}^3 = 1,000 \text{ L}$   
 $1 \text{ L} = 1,000 \text{ mL}$

## 5.9.01 SAMPLING AND SPLITTING OF AGGREGATES (Kansas Test Method KT-01)

### **1. SCOPE**

These methods apply to the sampling of coarse and fine aggregates for quality tests and for inspection and testing of aggregates being produced for State construction and maintenance work. **KT-01** reflects testing procedures found in **AASHTO R 90** and **R 76**.

Where practicable, samples to be tested for quality shall be obtained from the finished product. Conditions may require sampling from hauling units or from stockpiles located at the production plant site or a specified location.

General policy regulations covering the frequency of and procedures for sampling aggregates are set forth in **Part V, Section 5.6** of this manual.

### **2. REFERENCED DOCUMENTS**

**2.1.** KDOT Construction Manual, Part V, Section 5.6; Aggregates

**2.2.** AASHTO R 90; Sampling Aggregate Products

**2.3.** AASHTO R 76; Reducing Samples of Aggregate to Testing Size

### **3. SAMPLING METHODS**

#### **3.1.** Sampling from Discharge or Flowing Streams:

Obtain at least three approximately equal sample increments, selected at random from the stream and combine to form a field sample that equals or exceeds the minimum required mass. Take each increment from the entire cross section of the material as it is being discharged. It is usually necessary to have a special device constructed for a particular plant. This device consists of a pan of sufficient size to intercept the entire cross section of the discharge stream and hold the required quantity of material without overflowing. A set of rails may be necessary to support the pan as it is passed under the discharge stream. The use of heavy equipment, such as a loader, may also be enlisted for this purpose. Sampling the initial discharge or the final few tons from a bin or conveyor belt increases the chance of obtaining segregated material and should be avoided. To the extent possible, keep bins continuously full to reduce segregation.

#### **3.2** Sampling from a Stationary Conveyor Belt:

Only when the belt is completely stopped and easily within reach, should belt samples be obtained. Never walk on a stopped conveyor belt. Elevated conveyors must be equipped with a suitable walkway and necessary fall protection must be utilized. An individual obtaining a conveyor belt sample must have their own lock out/tag out device(s) in place during sampling.

Insert two templates, the shape of which conform to the shape of the belt, in the aggregate stream on the belt. Carefully scoop all material between the templates into a suitable container and collect the fines from the belt with a brush and dustpan and add to the container. Obtain at least three approximately equal increments, selected at random, and combine to form a field sample with a mass that equals or exceeds the minimum.

### 3.3. Sampling from Stockpiles:

When possible, avoid sampling from stockpiles. It is very difficult to ensure unbiased samples due to the segregation which often occurs when material is stockpiled with coarse particles rolling to the outside base of the pile.

Loaders must be used to scoop material from the main stockpile and create a separate smaller stockpile. This should be done by loading out a minimum of three buckets from various heights and locations around the main pile and dumping each load on top of the previous in a separate location. When feasible, stockpiles under production can be sampled by moving the stacking or conveyor equipment in order to create the smaller pile for sampling.

For coarse aggregate, the loader should flatten one side of the pile by inserting the bucket vertically at or near the apex of the pile, and backing the material out away from the pile. The flattened material should then be sampled by inserting a shovel vertically in at least 5 different locations. Combine the individual increments to produce a field sample weighing not less than 75 lb (35 kg), mix thoroughly and reduce to the specified size for testing.

For fine aggregate, collect the sample using a sampling tube or shovel. Sample fine aggregate with a sampling tube having a diameter at least three times the size of the maximum size aggregate being sampled. Scalp away the outer layer of fine aggregate to assure the sample has not become segregated. Obtain a minimum of five increments at several locations in the pile with samples taken from each 1/3 volume of the pile by inserting the tube or digging a hole 1 to 2 ft (0.3 to 0.6 m) deep. Combine the individual increments to form a field sample, mix and reduce to proper size for testing.

**3.4. Plant Mixed Aggregate:** There are several acceptable methods of taking samples from each type of plant. Every situation should be studied and evaluated to determine whether or not the method to be used will provide a representative sample of the material being produced. Plant mixed aggregate samples are generally obtained by one of the following procedures. If these procedures, due to unforeseen circumstances, prove to be unworkable, other procedures may be used if approved in writing by the District Materials Engineer.

#### 3.4.1. Apparatus.

##### 3.4.1.1. For Asphalt Plant Sampling.

**3.4.1.1.1. For Batch Plants:** A vertical receptacle having a closed bottom and an open top with no dimension in the opening of less than 5 in (125 mm). Appropriate handles for lifting and handling and a wide flat base for vertical stability are recommended. The height of the container must be sufficient that it will not overflow during the discharge of material from the pugmill.

Some containers have been designed to automatically split the material that enters the opening into two or more portions and discard one-half or more of all material received.

**3.4.1.1.2. Continuous Flow Plants:** A horizontal trough having a minimum width of 5 in (125 mm), a minimum depth of 12 in (300 mm), and a length equal to or greater than the width of the pugmill discharge stream., so constructed that it can be passed through the pugmill stream in a horizontal plane. Appropriate handles for lifting and handling are required. The apparatus shall meet the requirements in **Section 3.1.**, of this test method and be approved by the District Materials Engineer.

**3.4.1.2.** For Screenless Operation Sampling: The apparatus shall meet the requirements in **Section 3.1.** of this test method and be approved by the District Materials Engineer.

**3.4.2.** Procedure.

**3.4.2.1.** For Asphalt Plant Sampling.

**3.4.2.1.1.** Batch Plant: Center the container under the pugmill discharge, open the gate and empty the pugmill before removing the container.

**3.4.2.1.2.** Continuous Flow Plants: Pass the container horizontally through the drum discharge stream in such a manner that a representative sample will be obtained, and the container will not be filled to overflowing.

**3.4.2.2.** For Screenless Operation Sampling: The contractor shall provide a system for sampling the combined material ahead of the mixing chamber. Such a system must be approved by the District Materials Engineer.

**3.5.** Windrows: Windrows are not to be sampled until all blending and mixing is completed. They must be sampled by methods that will ensure that the sample will be representative of the material within the windrow cross section at the point of sampling. Power equipment is helpful in cutting through a windrow prior to sampling and should be used whenever available. Samples should be ample size to be representative of the windrow at the point of sampling and reduced to proper size for testing.

It has been determined that windrows containing aggregate with not more than 10% of material retained on the 3/8 in (9.5 mm) sieve and not more than 25% crushed material may be effectively sampled with a standard sampling tube.

To provide an acceptable sample, the following conditions are required:

**3.5.1.** A properly mixed and well “peaked” windrow.

**3.5.2.** Force the tube into the windrow and equal number of times, well-spaced, on each side of the windrow, and in a direction normal to the slope of the windrow face.

**3.5.3.** Sample size is sufficient for reduction by splitting using the standard procedure. Not less than 75 lb (35 kg) sample is recommended.

**3.6.** Unopened Sand-gravel Deposits: Unopened deposits of sand-gravel are usually explored by drilling test holes spaced at regular intervals over the area underlaid by the deposit. The holes are extended through the soil and other non-usable over-burden and through the workable depth of the deposit. Remove the sand-gravel from each test hole and examine for major changes in the quality and gradation characteristics, then record such changes. Place all usable material removed from each test hole on a quartering canvas, sheet of plywood, or other material to prevent contamination from grass, topsoil, etc. Thoroughly mix a 15 lb (7 kg) sample for gradation tests.

If the quality of the material removed from all test holes appears to be reasonably uniform, a sufficient amount of material from each test hole should be obtained to produce a 200 lb (90 kg) composite sample for quality testing. This sample will be tested for information only.

## 4. SAMPLE REDUCTION

**4.1. Quartering Canvas Procedure:** Samples that weigh 75 lb (35 kg) or more may be reduced to one-half size by using a quartering canvas. The canvas is not to be used as the first step in the reduction of samples smaller than approximately 75 lb (35 kg).

**4.1.1.** Spread the canvas on a smooth level surface. Dump the sample in a pile near the center and mix by alternately lifting each corner and rolling the aggregate toward the opposite corner. This should be performed in a vigorous manner.

**4.1.2.** Center the material on the canvas in a uniform pile. Flatten the pile to a uniform thickness and diameter by pressing down the apex with a straight-edge scoop, shovel, or trowel (depending on the size of sample). Press down so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness.

**4.1.3.** Insert a rod, shovel handle, or similar object under the canvas and under the center of the pile and lift both ends of the rod to divide the pile into two equal parts. Remove the stick leaving a fold of the blanket between the divided portions. Insert the rod under the canvas and under the center of the resulting two piles at right angles to the first division and again lift the rod to divide the sample into four equal parts.

**4.1.4.** Discard two opposite quarters, combine the two remaining quarters, mix and reduce to proper size with a riffle splitter or by repeating the quartering procedure.

When a quartering canvas is used, the Field Engineer and District Materials Engineer should be certain that proper procedures are being followed at all times.

**4.2. Riffle Splitter:** The initial sample size shall be at least four times the size of the required test portion. If use of this method is desired and the sample has free moisture on the particle surfaces, the entire sample must be dried to at least the saturated-surface-dry condition (SSD) using temperatures that do not exceed those specified for any tests contemplated. If the moist sample is very large, a preliminary split may be made using a mechanical splitter having wide chute openings 1 1/2 in (37.5 mm) or more to reduce the sample to not less than 5000 g.

**4.2.1. Apparatus:** The splitter shall have an even number of equal width chutes, not less than a total of eight for coarse aggregate, or twelve for fine-aggregate, which discharge alternatively to each side of the splitter. For coarse and mixed aggregate the minimum width of the individual chutes shall be approximately 50% larger than the largest particles in the sample to be split. For dry fine aggregate, finer than the 3/8 inch (9.5 mm) sieve, a splitter having chutes 1/2 to 3/4 inches (12.5 to 19 mm) wide shall be used. The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. A hopper or straight-edged pan, with a width equal to or slightly less than the overall width of the assembly of chutes, shall be used to feed the sample at a controlled rate to the chutes. The splitter and accessory equipment shall be designed so the sample will flow smoothly without restriction or loss of material.

**NOTE:** Any disputed samples shall be split using the appropriate splitter meeting the above specifications.

**4.2.2.** Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. The rate at which the sample is introduced shall allow free flowing through the chutes into the receptacles

below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test.

**4.3. Miniature Stockpile Sample Reduction Procedure:** This method of sample reduction may be used only on wet fine aggregate. For this quartering procedure, wet is defined as free moisture on the surface as approximated by the fine aggregate retaining its shape when molded by hand.

Place the sample on a clean, hard, level surface where there will be neither loss of material nor the accidental addition of foreign material. The initial sample size shall be at least four times the size of the required test portion. Mix the sample thoroughly with a shovel by turning it over completely three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down on the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened pile into four equal quarters with a straight edge (trowel or similar metal blade) and remove two pre-selected diagonally opposite quarters, using a brush or broom to clean the cleared space. Repeat the process until the sample is reduced to the proper size.

**Quartering on a Hard, Clean, Level Surface**



COCO

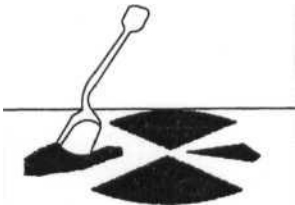
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Cone Sample on  
Hard Clean Surface

Mix by  
Forming New  
Cone

Quarter after  
Flattening Cone

---



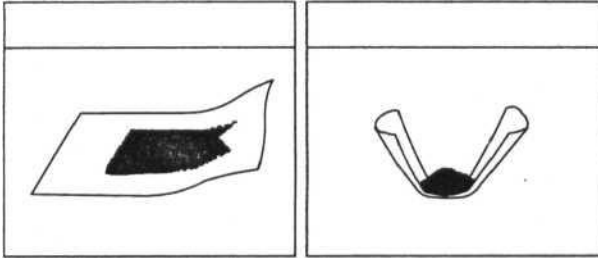
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Sample divided into  
Quarters

Retain opposite  
Quarters, Reject the  
other Two Quarters



## Quartering on a Canvas Blanket



Mix by Rolling on  
Blanket

Form Cone After  
Mixing

Quarter after flattening Cone.



Stick Placed under flattened  
cone

Sample divided in half

Sample divided into quarters

Retain Opposite Quarters. Reject the Other Two Quarters.



## 5.9.02 SIEVE ANALYSIS OF AGGREGATES (Kansas Test Method KT-02)

### 1. SCOPE

This method of test covers procedures for the determination of the particle size distribution of aggregates using standard sieves. **KT-02** reflects testing procedures found in **AASHTO T 27**.

### 2. REFERENCED DOCUMENTS

- 2.1. Part V, 5.9; Sampling and Test Methods Foreword
- 2.2. KT-01; Sampling and Splitting of Aggregates
- 2.3. KT-03; Material Passing No. 200 (75 $\mu$ m) Sieve by the Wash Method
- 2.4. ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves
- 2.5. AASHTO T 27; Sieve Analysis of Fine and Coarse Aggregates

### 3. APPARATUS

3.1. The balance shall be readable to 0.1% of the sample mass and conform to the requirements of **Part V, Section 5.9; Sampling and Test Methods Foreword** of this manual for the class of general purpose balance required for the principal sample mass of the sample being tested.

3.2. Sieves meeting **ASTM E11**. As a minimum, set of sieves will include the 3/8 in (9.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600  $\mu$ m), No. 50 (300  $\mu$ m), No. 100 (150  $\mu$ m) and No. 200 (75  $\mu$ m) for all aggregates. Gradations with larger sized aggregate will require addition of appropriate larger sieves to the set.

3.3. A mechanical sieve shaker shall impart a vertical, or lateral and vertical motion to the sieve, causing the particles to bounce and turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving is met in a timely manner as described in **Section 9**. of this test method.

3.4. An oven of appropriate size capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

3.5. Drying pans.

### 4. SAMPLES

4.1. Composition: Obtain samples for sieve analysis by the use of a sample splitter or by the method of quartering. Fine aggregate sampled by the quartering method shall be thoroughly mixed and in a moist condition. The sample for test shall be approximately the mass desired and shall be the end result of proper reduction methods. Do not attempt the selection of samples of an exact predetermined mass.

4.2. Fine Aggregates: Sample of fine aggregate for sieve analysis shall have a mass, after drying, not less than 300 g.

4.3. Coarse Aggregate: Samples of coarse aggregate and mixtures of coarse and fine aggregate for sieve analysis shall have a mass, after drying, not less than the amounts indicated in **Table 1**.

**Table 1**  
**Sample Size for Determination of**  
**Coarse Aggregate Gradation Tests**

Sieve Size	Minimum Mass of Samples (g)
2 1/2 in (63 mm) or more	35,000
2 in (50 mm)	20,000
1 1/2 in (37.5 mm)	15,000
1 in (25.0 mm)	10,000
3/4 in (19.0 mm)	5,000
1/2 in (12.5 mm)	2,000
3/8 in (9.5 mm) or less	1,000

**NOTE:** To select the sample size, use the largest sieve on which 5% or more of the material is specified to be retained.

**NOTE:** 12.00 in (300 mm) diameter sieves should be used for testing coarse aggregates and in testing samples with a mass of 5,000 g or more. If 12.00 in (300 mm) diameter sieves are not available, the split sample procedure in **Section 7.2** of this test method shall be used.

## 5. PREPARATION OF SAMPLES

**NOTE:** Remove deleterious material prior to determining the total original dry mass of sample if required by relevant specifications.

**5.1.** Dry all samples to a constant mass at a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ). Determine the mass of the sample to the nearest 0.1% of the sample mass. Record this as the total original dry mass of sample.

**5.1.1.** In the case of Cold in Place Recycle, air drying is acceptable.

**5.2.** Wash the sample over the No. 200 (75 $\mu\text{m}$ ) sieve as specified in **KT-03**. Then redry the sample to constant mass. Determine the mass of the sample to the nearest 0.1% of the total original dry mass of sample. Record this as the dry mass of sample after washing.

**NOTE:** For lightweight aggregate cover material: Dry-screen lightweight aggregate cover material according to **KT-04** instead of washing. Remove and discard all deleterious material from the sample including clay lumps retained on the No.4 (4.75 mm) sieve before the mass of the sample after dry-screening is determined.

**5.3.** For convenience, mixtures of coarse and fine aggregates may be separated into two portions by screening the dried sample over a No. 4 (4.75 mm) sieve.

**5.3.1** Reduce the material passing the No. 4 (4.75 mm) sieve by means of a sample splitter to a mass of approximately 1,000 g. Wash both the coarse and reduced fine portions of the total sample in accordance with **KT-03** and conduct a sieve analysis on each portion. Calculate the total combined grading in accordance with subsection **Section 7.2** of this test method.

## 6. TEST PROCEDURES

**6.1.** Nest the sieves in order of decreasing size of opening from top to bottom and place the sample, or portion of the sample, if it is to be sieved in more than one increment, on the top sieve. Agitate the sieves by mechanical sieve shaker for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in **Section 10.** of this test method.

**6.1.1.** If a mechanical sieve shaker is not used, follow the procedures for hand sieving in **Section 11.**

**6.2.** Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than No. 4 (4.75 mm) the mass retained on any sieve at the completion of the sieving operation shall not exceed 4 g/in<sup>2</sup> (7 kg/m<sup>2</sup>) of sieving surface. For sieves with openings No. 4 (4.75 mm) and larger, the mass in kg/m<sup>2</sup> of sieving surface shall not exceed the product of 2.5 times the sieve opening in mm. In no case shall the mass be so great as to cause permanent deformation of the sieve cloth.

**NOTE:** The 4 g/in<sup>2</sup> (7 kg/m<sup>2</sup>) amounts to 200 g for the usual 8 in (203 mm) diameter sieve and 450 g for a 12 in (305 mm) diameter sieve. The amount of material retained on a sieve may be regulated by (1) the introduction of a sieve with larger openings immediately above the given sieve or (2) testing the sample in a number of increments.

**6.3.** In the case of coarse and fine aggregate mixtures, the portion of the sample finer than the No. 4 (4.75 mm) sieve may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

**6.3.1.** Alternatively, the portion finer than the No. 4 (4.75 mm) sieve may be reduced in size using a mechanical splitter according to **KT-01, Section 4.2.** If this procedure is followed, compute the mass of each size increment of the original sample as outlined in **Section 7.2.** of this test method.

**6.4.** Determine the mass of each sieve size increment to the nearest 0.1% of the total original dry mass of sample (as defined in **Section 5.1.** of this test method) by weighing on a scale or balance conforming to the requirements specified in **Section 3.1.** of this test method. The total mass of the material after sieving should check closely with the original mass of sample placed on the sieves. If the amounts differ by more than 0.3%, based on the original mass of sample placed on the sieves, the results should not be used for acceptance purposes.

**6.5.** If the sample has previously been tested by **KT-03,** add the mass finer than the No. 200 (75 μm) sieve determined by that method to the mass passing the No. 200 (75 μm) sieve by sieving of the same sample in this method.

## 7. CALCULATIONS

**7.1** Calculate the total percent of material retained on each sieve as follows:

Percent Retained=

$$\frac{100 (\text{Mass Retained})}{\text{Total Original Dry Mass of Sample}}$$

Percent Passing No. 200 (75 μm)=

$$\frac{100 (\text{Sum of material Passing No. 200 (75 } \mu\text{m) by Sieve and Wash )}}{\text{Total Original Dry Mass of Sample}}$$

**7.2. Instructions for using split sample procedure (KDOT Form #645):**

**7.2.1.** Record the total dry mass of sample before separation as A.

**7.2.2.** Record the total dry mass of material retained on No. 4 (4.75 mm) sieve following separation as B.

**7.2.3.** Record the total dry mass of material passing the No. 4 (4.75 mm) sieve following separation as C.

$$C = A - B$$

**7.2.4.** Record reduced mass of material passing the No. 4 (4.75 mm) sieve as D.

**7.2.5.** Compute percent of material passing the No. 4 (4.75 mm) sieve as follows:

$$E = \frac{100(C)}{A}$$

Where: E = percent of material passing the No. 4 (4.75 mm) sieve in the total sample.

**7.2.6.** Wash the plus No. 4 (4.75 mm) portion of the sample over the No. 200 (75  $\mu\text{m}$ ) sieve as specified in **KT-03**, dry to a constant mass. Weigh and record the mass. Conduct sieve analysis using all regular sieves including the No. 200 (75  $\mu\text{m}$ ). Compute the percent of material retained on each sieve as follows:

$$G = \frac{100(F)}{A}$$

Where: G = Total percent of the entire sample that is retained on each sieve.  
F = Total mass of the plus No. 4 (4.75mm) material retained on each sieve size.

Calculate the total percent of material finer than the No. 200 (75  $\mu\text{m}$ ) sieve for the plus No. 4 fraction of the original sample by adding the mass determined by **KT-03** to the mass passing the No. 200 (75  $\mu\text{m}$ ) sieve by dry sieving, multiplying by 100 and divide by total dry mass of the sample before separation:

$$Q = \frac{100(\text{Sum of material Passing No. 200 (75 } \mu\text{m) by Sieve and Wash)}}{A}$$

Where: Q = Total percent of the plus No. 4 (4.75 mm) sieve passing the No. 200 (75  $\mu\text{m}$ ) sieve.

**7.2.7.** Wash the reduced sample of minus No. 4 (4.75 mm) material over a No. 200 (75  $\mu\text{m}$ ) sieve as specified in **KT-03**, dry to a constant mass. Weigh and record the mass. Conduct sieve analysis using all regular sieves including the No. 200 (75  $\mu\text{m}$ ). Compute the total percent of the reduced minus No. 4 (4.75 mm) sample retained on each sieve as follows:

$$J = \frac{100(H)}{D}$$

Where: J = Total percent of the reduced minus No. 4 (4.75 mm) sample retained on each sieve.

H = Total mass of the reduced minus No. 4 (4.75 mm) material retained on each sieve.  
D = Total dry mass of reduced minus No. 4 (4.75 mm).

Calculate the total percent of material finer than the No. 200 (75 µm) sieve for the plus No. 4 (4.75 mm) fraction of the original sample by adding the mass determined by **KT-03** to the mass passing the No. 200 (75 µm) sieve by dry sieving, multiplying by 100 and divide by total dry mass of reduced minus No. 4 (4.75 mm):

$$S = \frac{100(\text{Sum of material Passing No. 200 (75 } \mu\text{m) by Sieve and Wash)}}{D}$$

Where: S = Total percent of reduced minus No. 4 (4.75 mm) material passing the No. 200 (75 µm) sieve

**7.2.8.** Calculate the adjusted percent retained on each size sieve for the minus No. 4 (4.75 mm) material as follows:

$$K = \frac{(J)(E)}{100}$$

Where: K = Adjusted percent of minus No. 4 (4.75 mm) material.  
J = Total percent of reduced minus No. 4 (4.75 mm) sample retained on each sieve.  
E = Percent of minus No. 4 (4.75 mm) material in total sample.

**7.2.9.** Calculate the combined percentage of material retained on each sieve in the series as follows:

$$R = K + G$$

**7.2.10** Calculate the total material finer than the No. 200 (75 µm) sieve for the original sample as follows:

$$\text{Total \% Passing No. 200 (75 } \mu\text{m) Sieve} = Q + \frac{(S)(E)}{100}$$

**7.2.11.** Record the sieve analysis on the proper KDOT form.

**NOTE:** The use of the “Work Sheet for Split Sample Gradation and Plastic Index Tests”, **KDOT Form No. 645**, is provided for the above calculations.

## 8. REPORTING

The results of the sieve analysis and, when required, the percent passing the No. 200 (75 µm) sieve by the Wash Method (KT-03) are reported on appropriate KDOT forms. Report gradation test results to the nearest whole percent, except when the percentage passing the No. 200 (75 µm) sieve is less than 10%. In this case, both the percentage passing the No. 200 (75 µm) sieve and the material retained on the No. 200 (75 µm) sieve shall be reported to the nearest 0.1%. Note that some specifications require these values be reported to the 0.01% such as asphalt mix gradations. The project number, name of producer, location of deposit, and all other pertinent data are shown on each report.

The first aggregate report issued for each project shall list the laboratory number under which the latest Official Quality Sample was tested and the results of such tests with the exception that specific gravities will be reported only if required by the specification. Subsequent reports may list only the laboratory number which the quality tests were conducted.

## 9. PRECISION

Precision for sieving aggregates are established in **TABLE 2**. The estimates for precision are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program.

**TABLE 2**

	Total percentage of Material Passing	Standard Deviation (1S), %	Acceptable Range of Two Results (D2S), %
<b>Coarse Aggregates:</b>			
Single-Operator Precision			
	<100 ≥95	0.32	0.9
	<95 ≥85	0.81	2.3
	<85 ≥80	1.34	3.8
	<80 ≥60	2.25	6.4
	<60 ≥20	1.32	3.7
	<20 ≥15	0.95	2.7
	<15 ≥10	1.00	2.8
	<10 ≥5	0.75	2.1
	<5 ≥2	0.53	1.5
	<2 ≥0	0.27	0.8
Multilaboratory Precision			
	<100 ≥95	0.35	1.0
	<95 ≥85	1.37	3.9
	<85 ≥80	1.92	5.4
	<80 ≥60	2.82	8.0
	<60 ≥20	1.97	5.6
	<20 ≥15	1.60	4.5
	<15 ≥10	1.48	4.2
	<10 ≥5	1.22	3.4
	<5 ≥2	1.04	3.0
	<2 ≥0	0.45	1.3
<b>Fine Aggregates:</b>			
Single-Operator Precision			
	<100 ≥95	0.26	0.7
	<95 ≥60	0.55	1.6



	<60 ≥20	0.83	2.4
	<20 ≥15	0.54	1.5
	<15 ≥10	0.36	1.0
	<10 ≥2	0.37	1.1
	<2 ≥0	0.14	0.4
Multilaboratory Precision			
	<100 ≥95	0.23	0.6
	<95 ≥60	0.77	2.2
	<60 ≥20	1.41	4.0
	<20 ≥15	1.10	3.1
	<15 ≥10	0.73	2.1
	<10 ≥2	0.65	1.8
	<2 ≥0	0.31	0.9

**NOTE:** These numbers represent, respectively, the (1S and D2S) as describe in **ASTM C670**. The precision estimates are based on coarse aggregates with nominal maximum size of 3/4 in (19.0 mm).

## 10. VERIFICATION OF MECHANICAL SIEVE SHAKER EFFICIENCY

**10.1.** The following procedure defines a methodology to verify the efficiency of mechanical sieve shaker equipment. This procedure should be applicable to any manufacturers mechanical sieve shaker but has not been verified internally at KDOT.

**10.1.1.** Shaker efficiency is a requirement for all acceptance testing of fine and coarse aggregate and should be determined based on each product type. As aggregate production and mining operations can cause a change to aggregate properties (soundness, durability, angularity and specific gravity), re-evaluation of shaker efficiency shall be required.

**10.1.2.** Measurement of shaker efficiency is required for all sieves 12-in. diameter or smaller.

**NOTE** – Screens larger than 12-in. diameter, i.e. 14 x14 in. or 16 x 24 in., are typically used for aggregate separation and accurate measurement of sieving efficiency may be difficult to determine.

**10.1.3.** Nest the sieves, No. 4 and smaller, according to product being evaluated. Fit the sieve nest with a lid and a pan.

**10.1.4.** Determine the initial mass of the sample and shake for 6 minutes or by the time established by product history.

**10.1.5.** Determine and record the percent retained of each sieve size. Verify the material on each sieve does not exceed the maximum allowable mass per **6.2**. If overloaded, repeat using an adjusted sample mass.

**10.1.6.** Collect and recombine all of the material.

**10.1.7.** Re-shake the collected material using the same shaker and settings and increase the time by 1 minute.

**10.1.8.** Determine and record the percent retained of each sieve size.

**10.1.9.** Compare the percent retained to the percent retained in 10.1.5. The difference between two percent retained values on any sieve shall not exceed 0.5 percent by mass. If the difference between the two percent

retained values on any screen exceeds 0.5 percent by mass, then increase the shaker time another minute and repeat the process until the requirement can be met.

**10.1.10.** Record the minimum shaker time in which the requirement outlined in 10.1.9 is met as the established shaker time for the aggregate product being evaluated. This established shake time shall be used for testing this product in accordance with the procedure established in **Section 6**. For example, if the requirement was met when placed in the shaker for 6 and then 7 minutes, then the 6 minute time on the shaker provides adequate sieving.

## **11. HAND SIEVING (OPTIONAL)**

**11.1.** Sieving for a sufficient period and in such a manner that, after completion, not more than 0.5% by mass of the total sample passes any sieve during one minute of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one-sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the No. 4 (4.75 mm) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 8 in (203 mm) diameter sieves to verify the sufficiency of sieving.

**11.2.<sup>1</sup>** An alternative to maintain a snug fitting pan and cover is to sieve the material over an oversized pan. The pan must be large enough to ensure all material is retained during the hand sieving process. Any material leaving the sieve over the top of the rim must be returned to the sieve.

**11.3.** Once hand sieving is complete return to **Section 6.4** to complete the test procedure.

<sup>1</sup> **11.2.** is not found in **AASHTO T 27** but provides a realistic approach to monitoring material falling thru the sieve.

## KANSAS DEPARTMENT OF TRANSPORTATION WORK SHEET FOR SPLIT SAMPLE GRADATION AND PLASTIC INDEX TEST

Date \_\_\_\_\_ Inspector \_\_\_\_\_ Proj. No. \_\_\_\_\_

Sample No. \_\_\_\_\_ Material \_\_\_\_\_ Spec. No. \_\_\_\_\_

A	Dry Wt. of Total Sample	g.	D	Dry Wt. of -4.75 (-4) Reduced	g.			
B	Dry Wt. of +4.75 (-4) Matl.	g.	E	% of -4.75 (-4) in Total Sample				
C	Dry Wt. of -4.75 (-4) Matl.	g.						
Sieve Size	+4 Material		-4 Material		Combined Gradation			Spec.
	Grams Ret. (F)	$\frac{F \times 100}{A}$ (G)	Grams Ret. (H)	$\frac{H \times 100}{D}$ (J)	$\frac{J \times E}{100}$ (K)	% of +4.75 (G)	K + G (R)	
37.5 (1 1/2")								
25 (1")								
19 (3/4")								
12.5 (1/2")								
9.5 (3/8")								
4.75 (4)								
2.36 (8)								
1.18 (16)								
600 (30)								
425 (40)								
300 (50)								
150 (100)								
75 (200)								
75 (200) Dry								

	Dish No.	Dish + Wet Soil (a)	Dish + Dry Soil (b)	Wt. of Dish (c)	Wt. of Dry Soil (d)	Wt. of Water (e)	% Moist. (f)	P.I. (g)
Liquid Limit								
Plastic Limit								

$$d = b - c$$

$$e = a - b$$

$$f = \frac{e}{d} \times 100$$

$$g = \text{Liquid Limit} - \text{Plastic Limit}$$

Rev. 9-95

D.O.T. Form No. 645

5.9.03 MATERIAL PASSING NO. 200 (75µm) SIEVE BY THE WASH METHOD  
(Kansas Test Method KT-03)

## 1. SCOPE

This method of test covers the procedure for determining the quantity of material finer than the No. 200 (75µm) sieve in aggregate by the wash method. It should be recognized that this procedure will not determine the total amount of material finer than the No. 200 (75µm) sieve and that the total amount must be determined by a combination of washing, drying and re-screening as outlined in **KT-02** of this manual. **KT-03** reflects testing procedures found in **AASHTO T 11**.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-02; Sieve Analysis of Aggregates

2.3. KT-07; Clay Lumps and Friable Particles in Aggregate

2.4. ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

2.5. AASHTO T 11; Materials Finer Than No. 200 (75µm) Sieve in Mineral Aggregates by Washing

## 3. APPARATUS

3.1. A nest of two sieves, the lower being a No. 200 (75µm) sieve and the upper being a sieve with openings in the range of No. 8 (2.36 mm) to No. 16 (1.18 mm), both conforming to the requirements of **ASTM E11**.

3.2. A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

**NOTE:** Pans or vessels shall be solid construction and not contain a screen through which the sample or wash water can pass through.

3.3. Drying pans.

3.4. The balance shall conform to the requirements of **Part V, 5.9, Sampling and Testing Methods Foreword** for the class of general purpose balance required for the principal sample mass of the sample being tested.

3.5. Oven capable of maintain uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

3.6. *Wetting Agent*—Any dispersing agent, such as liquid dishwashing detergents, that will promote separation of the fine materials.

**NOTE:** The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

#### 4. TEST SAMPLE

Select the test sample from material that has been thoroughly mixed. Except for plant dried aggregate, the material from which the sample is selected should contain sufficient moisture to prevent segregation. Select a representative sample of sufficient size to yield not less than the mass of dried material shown in **Table 1**.

**Table 1**  
**Sample Size for Determination of Percent of Material**  
**Passing No. 200 (75 µm) Sieve by Washing**

Sieve Size	Minimum Mass of Samples (g)
1 1/2 in (37.5 mm) or more	5,000
3/4 in (19.0 mm)	2,500
3/8 in (9.5 mm)	1,000
No. 4 (4.75 mm) or less	300

**NOTE:** To select the sample size, use the largest sieve on which 5% or more of material is specified to be retained.

**NOTE:** Monitor test samples for clay lumps. The percent of clay lumps permitted in these aggregates is covered by a separate specification for the following materials and the method of determination is covered by **KT-07**:

- Concrete (except lightweight aggregate).
- Underdrain.
- Cover Material.
- Subgrade Modification or Reconstruction.
- Surfacing or Resurfacing.
- Surfacing or Subgrade Modification for Secondary Roads.
- Crushed Stone for Backfill.

#### 5. TEST PROCEDURE

**5.1.** Dry the sample to constant mass at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ). Determine the mass of the sample to the nearest 0.1%. Record this as the total original dry mass of sample.

**5.2.** Place the test sample in the container. Add sufficient water to cover the sample, and add wetting agent to the water. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the No. 200 (75-µm) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, as described in **Section 3.1** of this test method, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

**NOTE:** There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

**5.3.** Add a second charge of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

**NOTE:** A spray nozzle or a piece of rubber tubing attached to a water faucet may be used to rinse any of the material that may have fallen onto the sieves. The velocity of water, which may be increased by pinching the tubing or by use of a nozzle, should not be sufficient to cause any splashing of the sample over the sides of the sieve.

Return all material retained on the nested sieves by flushing to the washed sample.

Following the washing of the sample and flushing any materials retained on the No. 200 (75 µm) sieve back into the container, no water should be decanted from the container except through the No. 200 (75 µm) sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.

If mechanical wash equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

**5.4.** Dry all material retained to constant mass at a temperature of approximately 230 ± 9°F (110 ± 5°C). Weigh the sample to the nearest 0.1% of the total original dry mass of sample. Record this as the final dry mass. Note that the final dry mass is the same as the original mass of the sample placed on the sieves in KT-02.

## 6. CALCULATIONS

Calculate the results by use of the following formula:

$$P = \frac{100(\text{ODM} - \text{FDM})}{\text{ODM}}$$

Where: P = Percent of material finer than No. 200 (75 µm).  
ODM= Original Dry Mass.  
FDM= Final Dry Mass (after washing).

## 7. CHECK DETERMINATIONS

When check determinations are desired either evaporate the wash water to dryness or filter it through tared filter paper which shall subsequently be dried and the residue weighed. Calculate the percentage by use of the following formula:

$$P = \frac{100(\text{MR})}{\text{ODM}}$$

Where: P = Percent of material finer than No. 200 (75 µm).  
MR= Mass of Residue.  
ODM= Original Dry Mass.

## 8. REPORT

Record the material passing the No. 200 (75  $\mu\text{m}$ ) sieve by the wash method to 0.1% of the total original dry mass of sample.

Report the percentage of material finer than the No. 200 (75  $\mu\text{m}$ ) sieve by washing to the nearest 0.1%, except if the result is 10% or more, report the percentage to the nearest whole number.

## 9. PRECISION

The estimates for precision of this test method are based on the results from the **AASHTO Materials Reference Laboratory Proficiency Sample Program** and are presented in **Table 2**.

**Table 2**

	Standard Deviation (1S), Percent	Acceptable Range of two Results (D2S), Percent
Coarse aggregate:		
Single operator precision	0.10	0.28
Multilaboratory precision	0.22	0.62
Fine aggregate:		
Single operator precision	0.15	0.43
Multilaboratory precision	0.29	0.82

5.9.04 PERCENT RETAINED ON THE NO. 200 (75 μm) SIEVE BY DRY SCREENING  
(Kansas Test Method KT-04)

**1. SCOPE**

This method of test covers the procedure for determining the amount of material retained on the No. 200 (75 μm) sieve by dry screening only.

**NOTE:** When the percent retained on the No. 200 (75 μm) sieve by dry screening is part of the project specifications, it is common practice to conduct **KT-04** followed by **KT-02** on the sample.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-02; Sieve Analysis of Aggregates

**2.3** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Sieves meeting **ASTM E11** of specified sizes for the aggregate being tested.

**3.3.** Oven capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**3.4.** Drying pans.

**4. TEST SAMPLES**

**4.1.** Obtain samples of plant-mixed aggregate from the dried, pugmill mixed material and road mixed material from the combined windrow. The original sample before splitting shall weigh approximately 75 lb (35 kg).

**4.2.** Reduce sample by quartering or splitting before further drying to a mass of not less than the amount shown in **Table 1**. Exercise extreme care to prevent segregation and/or degradation during the splitting operation.



**TABLE 1**  
**Sample Size for Determination of Percent of**  
**Material Passing No. 200 (75 µm) Sieve of Dry Screening**

*Sieve Size	Samples (g)
1 1/2 in (37.5 mm) or more	15,000
1 in (25.0 mm)	10,000
3/4 in (19.0 mm)	5,000
1/2 in (12.5 mm)	2,500
3/8 in (9.5 mm) or less	1,000

\*To select the sample size, use the largest sieve on which 5% or more of the material is specified to be retained.

## 5. DRYING OF SAMPLES

**5.1.** After reducing the Road Mixed Project samples to the size indicated, dry it to constant mass at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ). Measure the temperature, do not allow the tip of the thermometer to come in contact with the pan bottom. Do not manipulate or stir the material during the drying phase. Upon reaching a constant mass condition allow the sample to cool to room temperature before proceeding with the test.

## 6. TEST PROCEDURE

**6.1.** The sample prepared as above shall be accurately weighed and sieved through the sieve series in the applicable specification. Conduct the sieving operation by means of a lateral and vertical motion accompanied by a jarring action to keep the sample moving continuously over the surface of the sieve. (In no case shall fragments in the sample be turned or manipulated through the sieve by hand nor shall a coin or other foreign object be placed in the sieve along with the sample to aid in sieving operation). Continue sieving until no more than 0.5% by mass of the residue passes any sieve (except the No. 100 and No. 200 (150 and 75 µm) during one minute. Continue sieving operation for the No. 100 and No. 200 (150 and 75 µm) sieves until not more than 0.5% by mass of the residue passes each individual sieve during a two minute period. When mechanical sieving is used, the thoroughness of sieving shall be tested by using the hand method of sieving as described above. Before using a mechanical shaker, in addition to hand shaking, for production control, comparison test should be run to check the results against hand shaking only. The time on the mechanical shaker should be adjusted so that the same results are obtained as by the hand method.

**6.2.** In no case shall the fraction retained on any sieve at the completion of the sieving operation weigh more than  $4 \text{ g/in}^2$  ( $7 \text{ kg/m}^2$ ) of sieving surface. (This amounts to 200 grams on the 8 in (200 mm) diameter sieve). This may be accomplished by removing excess material from the screen, placing it in a suitable container, sieving the material remaining on the screen, then sieving the material retained in the container.

## 7. CALCULATIONS

7.1. The percent retained on the No. 200 (75 µm) by dry screening is calculated as follows:

$$\frac{100 (A)}{B}$$

Where:           A= Mass of the retained fraction of the original sample as determined by dry screening only, over a No. 200 (75 µm) sieve.  
                  B= Original dry mass of sample.

## 8. REPORTING

Report test results to the nearest whole percent, except for when the percentage retained on the No. 200 (75 µm) sieve is less than 10%, it shall be reported to the nearest 0.1% , unless otherwise directed (most asphalt mix gradations are rounded to the nearest 0.01%). The project number, name of producer, location of deposit and all other pertinent data are shown on each report.

The first aggregate report issued for each project shall list the laboratory number under which the latest Official Quality Sample was tested and the results of such tests with the exception that specific gravities will be reported only if required by the specification. Subsequent reports may list only the laboratory number under which the quality tests were conducted.



5.9.05 UNIT WEIGHT OF AGGREGATE (Kansas Test Method KT-05)

**1. SCOPE**

This method of test covers the procedures for determining the unit weight of fine, coarse, or mixed aggregates. The method is applicable to aggregates not exceeding 1 1/2 in (37.5 mm) in nominal maximum size<sup>1</sup>. **KT-05** reflects testing procedures found in **AASHTO T 19**.

**NOTE:** Unit weight is the traditional terminology used to describe the property determined by this test method. Some believe the proper term is unit mass or density or bulk density, but consensus on this alternate terminology has not been obtained.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-06; Specific Gravity and Absorption of Aggregates

**2.3.** KT-15; Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)

**2.4.** KT-20; Mass per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete

**2.5.** AASHTO T 19; Bulk Density ( "Unit Weight") and Voids in Aggregate

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, Section 5.9; Sampling and Test Methods Foreword** for the class of general purpose required for the principal sample mass of the sample being tested.

**3.2.** Tamping Rod: A straight steel rod, 5/8 in (16 mm) in diameter and approximately 24 in (600 mm) in length, having the tamping end rounded to a hemispherical tip.

**3.3.** Cylindrical measure shall be provided with a handle and be watertight. The top rim shall be smooth and plane within 0.01 in (0.25 mm) and shall be parallel to the bottom within 0.5 degrees (0.1592 rads). The 0.5ft<sup>3</sup> (0.014m<sup>3</sup>) measure shall be reinforced around the top with a band or rim and shall conform to the following dimensional requirements:

**TABLE 1**  
**Cylindrical Measure Requirements for Unit Weight**

	Overall Measurements	Wall Thickness of Measure	
Capacity	0.5 ft <sup>3</sup> (0.014 m <sup>3</sup> )	Bottom	0.20 in (5.0 mm)
Inside Diameter	10.0 in (254 mm)	Side	0.12 in (3.0 mm)
Inside Height	11.0 in (280 mm)	Top Rim	0.20 in (5.0 mm)

<sup>1</sup> **AASHTO T 19** provides for aggregates up to 6 in (150 mm) in Table 1. Under KDOT aggregate specifications, 1 1/2 in (37.5 mm) represents the maximum size aggregate permitted.

**NOTE:** The top rim is satisfactorily planed if a 0.01 in (0.25 mm) feeler gage cannot be inserted between the rim and a piece 1/4 in (6 mm) or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87% in any direction.

#### **4. CALIBRATION OF MEASURE**

Calibrate the measure as set forth in **KT-20, Section 4**. Obtain the factor for any unit by dividing the unit weight of water (as defined in **Table 1 in KT-15, Section 5.4.**) by the mass of water required to fill the measure.

#### **5. SAMPLE**

The size of the sample shall be approximately 125 to 200% of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the sample of aggregate to essentially constant mass, preferably in an oven  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

#### **6. TEST PROCEDURE (RODDED WEIGHT)<sup>2</sup>**

**6.1.** Weigh the measure empty, fill the measure one-third full and level the top of the sample with the fingers. Rod the layer with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure to two-thirds full, level and rod with 25 strokes. Fill the measure to overflowing, rod 25 times, and strike off the surplus aggregate using the tamping rod as a straight edge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure. In rodding the first layer, do not permit the rod to forcibly strike the bottom of the measure. In rodding the second and final layers use only enough force to cause the tamping rod to just penetrate the previous layer of the aggregate placed in the measure.

**6.2.** Determine the net mass of the aggregate in the measure to the nearest 0.1 lb (50 g).

**6.3.** Calculate the unit weight of the aggregate by multiplying the net mass of the aggregate by the factor found as described in **Section 4** of this test method.

#### **7. TEST PROCEDURE (LOOSE MASS FOR LIGHT WEIGHT AGGREGATE)**

**7.1.** Fill the calibrated measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 2 in (50 mm) above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

**7.2.** Determine the mass of the measure and its content and record the net mass of the aggregate to the nearest 0.1%. Using the calibration factor of the measure, determine the loose unit mass of the aggregate.

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<sup>2</sup> **AASHTO T 19** also has jiggling and shoveling procedures to determine the unit weight of the aggregate. These procedures are not permitted under **KT-05**.

## 8. BULK DENSITY AND AIR VOIDS CALCULATIONS

8.1. Bulk Density-Calculate the bulk density as follows:

$$M = (G - T)/V$$

Or

$$M = (G - T) \times F$$

Where: M=bulk density of aggregate, lb/ft<sup>3</sup> (kg/m<sup>3</sup>).  
G=mass of aggregate plus the measure, lb (kg).  
T=mass of the measure, lb (kg).  
V=volume of measure, ft<sup>3</sup> (m<sup>3</sup>).  
F=factor for measure, ft<sup>-3</sup> (m<sup>-3</sup>).

8.2. The bulk density determined by this method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated-surface dry (SSD) condition is desired, use the exact procedure in this method, and then calculate the SSD bulk density by the following formula:

$$M_{SSD}=M[1+(A/100)]$$

Where: M<sub>SSD</sub>=bulk density in SSD condition, lb/ft<sup>3</sup> (kg/m<sup>3</sup>); and  
A=absorption, percent, determined in accordance with **KT-06, Section 3.3.4 and 4.3.5.**

8.3. Void Content- Calculate the void content in the aggregate using the bulk density as follows:

$$\text{Voids \%} = \frac{100[(S \times W) - M]}{S \times W}$$

Where: M=bulk density aggregate, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
S=bulk specific gravity (dry basis) as determined in accordance with **KT-06**; and  
W=density of water as established in **Table 1 in KT-15, Section 5.4.**

## 9. REPORT

Record to the nearest 50 g, 0.1 lb. or 0.1% of mass and the bulk density to the nearest 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>). Report the results for bulk density (unit weight) to the nearest 1 lb/ft<sup>3</sup> (10 kg/m<sup>3</sup>).

## 10. PRECISION

The following estimates of precision for this method are based on results from the **AASHTO re:source Proficiency Sample Program (AASHTO T 19, Section 15. Precision and Bias):**

**TABLE 2**  
**Precision for Unit Weight Test Procedure**

Coarse Aggregate	1S lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	D2S lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	Fine Aggregate	1S lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	D2S lb/ft <sup>3</sup> (kg/m <sup>3</sup> )
Single Operator Precision	0.88 (14)	2.5 (40)	Single Operator Precision	0.88 (14)	2.5 (40)
Multilaboratory Precision	1.87 (30)	5.3 (85)	Multilaboratory Precision	2.76 (44)	7.8 (125)

## 5.9.06 SPECIFIC GRAVITY AND ABSORPTION OF AGGREGATES (Kansas Test Method KT-06)

### **1. SCOPE**

This method of test covers the procedures for determining the specific gravity and absorption of aggregates. Coarse aggregate (Procedure I) represents aggregate retained on the No. 4 (4.75 mm) sieve. Fine aggregate (Procedure II) is all aggregate passing the No. 4 (4.75 mm) and retained on the No.100 (150  $\mu$ m) sieve. **KT-06** reflects testing procedures found in **AASHTO T 84** and **T 85**.

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2** KT-01; Sampling and Splitting of Aggregates

**2.3.** KT-11; Moisture Tests

**2.4.** KT-24; Determination of Free Moisture or Absorption of Aggregate for Use in Concrete

**2.5.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

**2.6.** AASHTO T 84; Specific Gravity and Absorption of Fine Aggregate

**2.7.** AASHTO T 85; Specific Gravity and Absorption of Coarse Aggregate

**2.8.** ASTM C128; Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

**2.9.** ASTM C670; Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

### **3. PROCEDURE I: COARSE AGGREGATE**

#### **3.1. Apparatus**

**3.1.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, Class G5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of weighing platform or pan of the balance.

**3.1.2.** Bucket approximately 8 in (200 mm) in diameter and 8 in (200 mm) in height.

**3.1.3.** Container with overflow for immersing the bucket in water.

**3.1.4.** Drying oven capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**3.1.5.** Drying pans.

**3.1.6.** Absorbent cloth.

**3.1.7.** Standard No. 4 (4.75 mm) sieve meeting the requirements of **ASTM E11**.



## 3.2. Test Method

**3.2.1. Sample Preparation:** This test is normally conducted on the portion of the aggregate that passes the 2 in (50 mm) sieve and is retained on the No. 4 (4.75 mm) sieve. If the test is conducted on larger size particles, it shall be so noted on the test report.

**3.2.1.1.** Select a portion of the aggregate by splitting or quartering as specified in **KT-01, Section 4**. The minimum mass of the sample, all of which passes the 2 in (50 mm) sieve and is retained on the No. 4 (4.75 mm) sieve, shall be as set out in the following **Table 1**:

**Table 1**  
**Minimum Sample Size for Coarse Aggregate**

Sieve Size	Minimum Mass of Samples (g)
1 1/2 in (37.5 mm) or more	5,000
1 in (25.0 mm)	4,000
3/4 in (19.0 mm)	3,000
1/2 in (12.5 mm) or less	2,000

**NOTE:** To select the sample size, use the largest sieve on which 5% or more of the material is specified to be retained.

**3.2.1.2.** Thoroughly wash<sup>1</sup> the sample over the No. 4 (4.75 mm) sieve to remove dust and other adherent coatings.

**3.2.1.3.** Dry the sample to a constant mass in the oven at a constant temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**NOTE:** If the absorption and specific gravity values will be used as a basis for the design of concrete mixes where aggregates are used in a moist condition, this drying procedure may be eliminated. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by **KT-11 Section 5.1**. Free moisture can also be calculated as described in **KT-24 Section 6**.

## 3.2.2. Procedure

**3.2.2.1.** Immerse the sample in water<sup>2</sup> and stir vigorously. Soak for a period of  $24 \pm 4$  hours.

**3.2.2.2.** Remove the sample from the water and bring to a saturated surface-dry condition by rolling the sample in a dampened, absorbent cloth. (For the purpose of this test, a saturated surface-dry condition of the aggregate has been reached when the particle surface appears to be moist but not shiny.)

**3.2.2.3.** Weigh the sample immediately after obtaining the saturated surface-dry condition. Record this value as "B". All masses determined in this test shall be to the nearest 1 g or 0.1% of the sample mass, whichever is greater.

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<sup>1</sup> **AASHTO T 85** requires dry sieving and then thoroughly wash to remove dust or other coatings from the surface.

<sup>2</sup> **AASHTO T 85** requires the sample to be dried to constant mass prior to immersing in water for a period of 15 to 19 hours.

**3.2.2.4.** Immediately after obtaining the saturated surface-dry mass, immerse the sample in water, stir to remove any entrapped air and weigh. Record this value as “C”. The water temperature shall be  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ )<sup>3</sup>.

**3.2.2.5.** Dry the sample to a constant mass at a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**3.2.2.6.** Cool the sample at room temperature, until aggregate has cooled to a temperature that is comfortable to handle and determine the mass. Record this value as “A”.

### 3.3. Calculations

Where:           A= Mass of oven-dry sample in air, g  
                      B= Mass of surface-dry sample in air, g  
                      C= Mass of saturated sample in water, g

**3.3.1.** Bulk Specific Gravity:

$$\frac{A}{B - C}$$

**3.3.2.** Bulk Specific Gravity Saturated Surface-Dry Basis:

$$\frac{B}{B - C}$$

**3.3.3.** Apparent Specific Gravity:

$$\frac{A}{A - C}$$

**3.3.4.** Absorption (%):

$$\frac{100 (B - A)}{A}$$

## 4. PROCEDURE II: FINE AGGREGATE

### 4.1. Apparatus

**4.1.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, Class G2.

**4.1.2.** Volumetric flask of known mass having a minimum capacity of 500mL and calibrated by the manufacturer to within:

- 0.20mL at 68°F (20°C) for a 500mL flask.
- 0.30mL at 68°F (20°C) for a 1000mL flask.

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<sup>3</sup> **AASHTO T 85** requires the water temperature to be  $23 \pm 1.7^\circ\text{C}$  ( $73.4 \pm 3^\circ\text{F}$ ). Changing the temperature to  $25 \pm 1^\circ\text{C}$  ( $77 \pm 2^\circ\text{F}$ ) establishes a uniform temperature requirement on all water bath test-related procedures.

**4.1.3.** Not less than two drying pans with a bottom surface of the pan that will have no effect on the material and results but should allow for the presence of free moisture to be observed. A worn oxidized surface has been known to work well in showing the presence of free moisture. Other surfaces such as a worn aluminum pan or galvanized pan may also work. The pan should be flat, dry, clean and have a dull, non-absorbent surface.

**4.1.4.** Drying oven capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**4.1.5.** Water bath having a capacity of at least 2 gal (8 L) maintained at a temperature of  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ) and a depth approximately equal to or above the height of the bowl of the volumetric flask.

**4.1.6.** Standard No. 4 (4.75 mm) sieve meeting requirements of **ASTM E11**.

**4.1.7.** Standard No.100 (150  $\mu\text{m}$ ) sieve meeting requirements of **ASTM E11**.

## **4.2. Test Method**

**4.2.1.** Sample Preparation: This test is conducted on that portion of aggregate passing the No. 4 (4.75 mm) and retained on the No.100 (150  $\mu\text{m}$ ) sieve.

**4.2.1.1.** Select a portion of the aggregate by splitting or quartering as established in **KT-01, Section 4**. The portion selected should be of sufficient size to yield a sample weighing approximately 1,000 g all of which passes the No. 4 (4.75 mm) sieve and retained on the No. 100 (150  $\mu\text{m}$ ) sieve.

**4.2.1.2.** Screen the portion selected over the No. 4 (4.75 mm) sieve and discard all material retained on that sieve.

**4.2.1.3.** Wash the minus No. 4 (4.75 mm) material [material passing the No. 4 (4.75mm) sieve] over the No. 100 (150  $\mu\text{m}$ ) sieve to remove dust.

**4.2.1.4.** Dry the plus No. 100 (150  $\mu\text{m}$ ) material [material retained on the No. 100 (150  $\mu\text{m}$ ) sieve] to a constant mass in the oven.

**NOTE:** If the absorption and specific gravity values will be used as a basis for the design of concrete mixes where aggregates are used in a moist condition, this drying procedure may be eliminated. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture can be determined by deducting the absorption from the total moisture content determined by **KT-11 Section 5.1**. Free moisture can also be calculated as described in **KT-24 Section 6**.

## **4.2.2. Procedure**

**4.2.2.1.** Immerse the sample in water and stir vigorously. Soak for a period of  $24 \pm 4$  hours.

**4.2.2.2.** Remove the sample from the water and bring it to a saturated surface-dry condition<sup>4</sup>. The procedure to be used to obtain the surface-dry condition is as follows:

**4.2.2.2.1.** Place the saturated sample in a drying pan and allow to dry in air for a short time. Stir the sample regularly to ensure uniform drying.

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<sup>4</sup> **AASHTO T 84 Section 7.2.1** uses the cone test for determining SSD condition. Under **NOTE 4 (2) Provisional Surface Test**, the use of alternative surfaces are permitted and represents the method presented in **Section 4.2.2**.

**4.2.2.2.2.** Transfer the sample to another drying pan. The surface of the pan may be of any surface that will have no effect on the material and results but should allow for the presence of free moisture to be observed.

**4.2.2.2.3.** Stir the sample and check for the presence of free moisture as indicated by a presence of moisture on the bottom surface of the pan. This can typically be seen by a change in color or the presence of a sheen of moisture on the surface of the pan.

**NOTE:** The first check should be conducted when there is some free moisture on the surface of the aggregate particles to ensure that a saturated surface-dry condition has not been passed. If no moisture is present, it is likely the SSD condition is passed, and the test must be restarted.

**4.2.2.2.4.** Stir the sample regularly and transfer it frequently from pan to pan until a saturated surface-dry condition is reached as indicated by the absence of free moisture on the bottom of the pan.

**4.2.2.2.5.** Determine the mass of the empty flask. Record the value as “F”.

**4.2.2.3.** Immediately split out and weigh a sample of the saturated surface-dry material weighing not less than 500 g. Record this value as “B”. Place the sample in the flask.

**4.2.2.4.** Fill the flask to a level slightly below the calibration mark with water at a temperature of  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ).

**4.2.2.5.** Rotate the flask in an inclined position to eliminate all air bubbles. Do not shake. Allow the flask to sit for several minutes then roll flask again. Continue the process until there are no visible air bubbles present.

**NOTE:** Bubbles or foam may be dispelled by touching them carefully with a hot wire or the tip of a paper towel.

**4.2.2.6.** Place the flask in the water bath until the temperature of the material inside the flask is the same as that of the water bath.

**4.2.2.7.** Fill the flask to the calibrated mark, remove from the water bath and wipe all moisture from the outside surface.

**4.2.2.8.** Weigh the flask and its contents to the nearest 0.1 g. Record the value as “K”.

**4.2.2.9.** Remove the aggregate from the flask and dry to a constant mass in the oven at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**4.2.2.10.** Cool the sample to room temperature and weigh. Record the value as “A”.

**4.3.** Flask Verification – Perform minimum every 12 months - Determine the mass of flask filled to the calibration line with water at  $77^{\circ}\text{F}$  ( $25^{\circ}\text{C}$ ) and subtract the mass of the flask to determine the mass of water the flask will hold. Record this value as “C”. This step need not be performed for every test but must be done a minimum of once every 12 months.

#### **4.4. Calculations**

**4.4.1.**  $W = K - (F + B)$

#### 4.4.2. Bulk Specific Gravity:

$$\frac{A}{C - W}$$

#### 4.4.3. Bulk Specific Gravity (Saturated Surface-Dry Basis):

$$\frac{B}{C - W}$$

#### 4.4.4. Apparent Specific Gravity:

$$\frac{A}{(C - W) - (B - A)}$$

#### 4.4.5. Absorption (%):

$$\frac{100 (B - A)}{A}$$

Where: W= Mass of water added to the flask, g  
F= Mass of empty flask, g  
K= Mass of flask, plus sample, plus water (See step in **Section 4.2.2.8** above), g  
A= Mass of oven-dry sample in air, g  
B= Mass of saturated surface-dry sample in air, g  
C= Mass of water the flask will hold filled to the calibration line at 77°F (25°C)

## 5. REPORT

**5.1.** Record the specific gravities to the nearest 0.001. Record the absorption to the nearest 0.01%. Report all specific gravities to the nearest 0.001 and indicate the type of specific gravity. Report the absorption result to the nearest 0.1%.

## 6. PRECISION

**6.1.** The estimates of precision of this test method (listed in **Table 2**) are based on results from the **AASHTO Materials Reference Sample Program** with testing conducted by **AASHTO, T 84** and **T 85**, and **ASTM, C128** and **C670**. The significant difference between the methods is that ASTM requires a saturation period of  $24 \pm 4$  hours, and AASHTO requires a saturation period of 15 to 19 hours. This difference has been found to have an insignificant effect on the precision indices.

**Table 2  
Precision for Specific Gravities  
and Absorption of Aggregates**

Single Operator Precision	Coarse Aggregate		Single Operator Precision	Fine Aggregate	
	1S	D2S		1S	D2S
Bulk Specific Gravity (Dry)	0.009	0.025	Bulk Specific Gravity (Dry)	0.011	0.032
Bulk Specific Gravity (SSD)	0.007	0.020	Bulk Specific Gravity (SSD)	0.0095	0.027
App. Specific Gravity	0.007	0.020	App. Specific Gravity	0.0095	0.027
Absorption percent	0.088	0.25	Absorption percent	0.11	0.31
Multilaboratory Precision	1S	D2S	Multilaboratory Precision	1S	D2S
Bulk Specific Gravity (Dry)	0.013	0.038	Bulk Specific Gravity (Dry)	0.023	0.066
Bulk Specific Gravity (SSD)	0.011	0.032	Bulk Specific Gravity (SSD)	0.020	0.056
App. Specific Gravity	0.011	0.032	App. Specific Gravity	0.020	0.056
Absorption percent	0.145	0.41	Absorption percent	0.23	0.66

## 7. ADDENDUM – SUPPLEMENTAL CALCULATION TO COMBINE AGGREGATE ABSORPTION

7.1. In a few special cases the specifications have an absorption requirement on each individual source. Procedures I and II are both used and the combined aggregate absorption must be calculated. (This calculation is not to be used when the specifications have an absorption requirement by Procedure I and/or Procedure II.

7.2. Absorption of the individual source equals:

Combined Absorption,  $A_{co}(\%)$ :

$$\frac{(AbS_c)(\%C) + (AbS_f)(\%I)}{100}$$

Where:

- $A_{co}$  = Combined Absorption, %
- $AbS_c$  = Absorption, Proc. I, %
- $AbS_f$  = Absorption, Proc. II, %
- $\%C$  = Percent plus No. 4 (4.75 mm) in each individual source
- $\%I$  = Percent minus No. 4 (4.75 mm) in each individual source

## 5.9.07 CLAY LUMPS AND FRIABLE PARTICLES IN AGGREGATE (Kansas Test Method KT-07)

### **1. SCOPE**

This method of test covers the procedure of determining the percentage of clay lumps and friable particles in aggregate. Whenever mud balls and clay balls are referred to in specifications, they shall be considered as clay lumps. Clay lumps in aggregate shall be defined as any particles or aggregate of particles which when thoroughly wet, can be distorted when squeezed between the thumb and forefinger, or will disintegrate into individual grain sizes when immersed for a short period in water.

Friable particles are defined as particles which vary from the basic aggregate particles in that they may either readily disintegrate under normal handling and mixing pressures imposed upon them by construction procedures, or break down after being incorporated into the work. **KT-07** reflects testing procedures found in **AASHTO T 112**.

### **2. REFERENCED DOCUMENTS**

- 2.1.** Part V, 5.9; Sampling and Test Methods Foreword
- 2.2** KT-03; Material Passing No. 200 (75  $\mu$ m) Sieve by the Wash Method
- 2.3.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves
- 2.4.** AASHTO T 112; Clay Lumps and Friable Particles in Aggregate

### **3. APPARATUS**

- 3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.
- 3.2.** Drying pans.
- 3.3** Sieves conforming to **ASTM E11** requirements.
- 3.4.** Oven providing free circulation of air and capable of maintaining a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

### **4. SAMPLE PREPARATION**

- 4.1.** Aggregate for this test shall consist of the material remaining after completion of **KT-03**. To provide the quantities designated in **Section 4.3** and **Section 4.4** of this test method, it may be necessary to combine material from more than one test by **KT-03**.
- 4.2.** The aggregate shall be dried to substantially constant mass at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).
- 4.3.** Test samples of fine aggregate shall consist of the particles coarser than a No. 16 (1.18 mm) sieve and shall weigh not less than 100 g.



**4.4.** Test samples of coarse aggregate shall be separated into different sizes using the following sieves: No. 16 (1.18 mm), No. 4 (4.75 mm), 3/8 in (9.5 mm), 3/4 in (19.0 mm), and 1 1/2 in (37.5 mm). The test samples shall have a mass not less than indicated in **Table 1**:

**Table 1**  
**Sample Sizes for Coarse aggregate**  
**When testing for Clay Lumps and Friable Particles**

Sizes of Particles Making Up Test Sample	Minimum Mass of Test Sample, g
No. 4 to 3/8 in (4.75 to 9.5 mm)	1,000
3/8 to 3/4 in (9.5 to 19.0 mm)	2,000
3/4 to 1 1/2 in (19.0 to 37.5 mm)	3,000
Over 1 1/2 in (37.5 mm)	5,000

**4.5.** If the grading of the original sample provides less than 5% of any of the sizes indicated in **Section 4.4** of this test method, do not test that size.

**4.6.** In the case of aggregate which is composed of substantial amounts of both fine and coarse aggregate sizes, the material shall be separated into two sizes at the No. 4 (4.75 mm) sieve, and the samples of fine and coarse aggregate shall be prepared in accordance with **Section 4.3** and **Section 4.4** of this test method. Any aggregate containing 50% or more material retained on the No. 4 (4.75 mm) sieve is considered to be coarse aggregate.

**NOTE:** In most cases, only the plus No. 4 (4.75 mm) fraction of coarse aggregate needs to be evaluated by this test method regardless of the amount of minus No. 4 (4.75 mm) material present. However, the amount of No. 16 (1.18 mm) to No. 4 (4.75 mm) material present shall be included in the mass of the test sample in **Section 6** of this test method, when calculating the percent of clay lumps and friable particles.

## **5. TEST PROCEDURE**

**5.1.** Weigh the test sample and spread it in a thin layer on the bottom of the container, cover it with water and allow it to soak for a period of  $24 \pm 4$  hours. Roll and squeeze particles individually between the thumb and forefinger to attempt to break the particle into smaller sizes. Do not use fingernails to break up particles or press particles against a hard surface or each other. Any particles that can be broken with the fingers into fines removable by wet sieving shall be classified as clay lumps and friable particles. After all discernible clay lumps and friable particles have been broken; separate the undersized material from the remainder of the sample by wet sieving over the sieve prescribed in **Table 2**.

Perform the wet sieving by passing water over the sample through the sieve while manually agitating the sieve, until all undersize materials has been removed.

**5.2.** Remove the retained particles carefully from the sieve, dry to substantially constant mass at a temperature  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ), allow to cool, and weigh to the accuracy specified for the balance in **Part V, 5.9; Sampling and Test Methods Foreword**.

**Table 2**  
**Size of Sieve for Removing**  
**Residue of Clay Lumps and Friable Particles**

Sizes of Particles Making Up Test Sample	Sieve Size for Removing Clay Lumps and Friable Particles
Fine Aggregate [retained on No. 16 (1.18 mm)]	No. 20 (850 μm)
No. 4 to 3/8 in (4.75 to 9.5 mm)	No. 8 (2.36 mm)
3/8 to 3/4 in (9.5 to 19.0 mm)	No. 4 (4.75 mm)
3/4 to 1 1/2 in (19.0 to 37.5 mm)	No. 4 (4.75 mm)
Over 1 1/2 in (37.5 mm)	No. 4 (4.75 mm)

## 6. CALCULATIONS

**6.1** Compute the percentage of clay lumps and friable particles by the following formula:

$$P = \frac{100 (W-R)}{W}$$

Where:

P = percent of clay lump and friable particles

W = mass of test sample (for fine aggregate the mass of the portion coarser than the No. 16 (1.18 mm) sieve as described in **Section 4.3** of this test method), and

R = mass of particles retained on designated sieve, as determined in accordance to **Section 5.2** of this test method.

**6.2.** For coarse aggregate, the percent of clay lumps and friable particles shall be an average based on the percent of clay lumps and friable particles in each sieve size fraction weighted in accordance with the grading of the original sample before separation or, preferably, the average grading of the supply represented by the sample. For the purpose of calculating the weighted average when the sample contains less than 5% of the material in a given size, that size shall be considered to contain the same percent of clay lumps and friable particles as the next larger or next smaller size, or use the average of the next smaller and larger sizes, if both are present.

## 7. REPORT

**7.1.** Record the mass of clay lumps and friable particles in aggregate to the nearest 0.1 g or 0.01% of the sample mass. Record the calculated percentages of clay lumps and friable particles in aggregate to the nearest 0.01%. Report the clay lumps and friable particles in aggregate to the nearest 0.1%.



## 5.9.08 SHALE OR “SHALELIKE” MATERIALS IN AGGREGATE (Kansas Test Method KT-08)

### **1. SCOPE**

This test method shall be used to determine the percentage of shale, mudstone, clay stone or other materials which would exhibit the properties of shale upon weathering.

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

### **3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Oven capable of maintaining uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**3.3.** Standard 3/8 in (9.5 mm) sieve conforming to **ASTM E11**.

**3.4.** Drying pans

### **4. SAMPLE PREPARATION**

**4.1.** A sample having a minimum mass of 10,000 g shall be used for this test. The sample shall first be dried to a constant mass at a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ). After the sample has cooled so that it may be readily handled, it shall be weighed to the nearest 1.0 g and the mass recorded. The sample shall then be screened over a 3/8 in (9.5 mm) sieve and the material passing the 3/8 in (9.5 mm) sieve shall be discarded. The material retained on the 3/8 in (9.5 mm) sieve shall be moistened sufficiently to facilitate identification of the deleterious material. Moistening of the material shall be within the range of lightly spraying to completely immersing for a ten minute period. The amount of moistening shall be that amount which will best assist in identifying the deleterious material but will not result in disintegration and subsequent loss of the material.

### **5. TEST PROCEDURE**

**5.1.** While the sample is still moist, it shall be examined carefully and all pieces of shale or shale-like material shall be removed for weighing. The shale and shale-like material may be identified by any of the following:

**5.2.** A soapy, slick surface when wet.

**5.3.** Laminations or bedding planes along which it will split with comparative ease.

**NOTE:** Mineralized or organic seams can be common in specimens but should not be mistaken for or considered as laminations unless they are coincident with individual laminations or bedding planes.

**5.4.** Mudstone appearing particles in which very crude and indistinct laminations can be observed but will not easily separate along the laminations.

**5.5.** Mudstone appearing particles in which no laminations appear but which are composed of finely divided mineral matter of clay grade and composition.

**5.6.** The shale or shale-like material removed from the sample shall be dried to a constant mass at a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ). After the shale/ shale-like material has cooled so that it may be readily handled, it shall be weighed to the nearest 1.0 g and the mass recorded.

## 6. CALCULATIONS

**6.1.** Compute the percentage of shale by the following formula:

$$\text{Percent Shale} = \frac{100 (\text{Mass of Dry Shale Retained})}{\text{Original Dry Mass of Test Sample}}$$

**NOTE:** As an alternative to drying the whole sample, a representative sample of 2,500 g minimum for moisture may be split out of the whole sample. The moist sample is dried to constant mass at a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ). The percentage of moisture is calculated to two places to the right of the decimal point and is used to correct the mass of the remainder of the sample to dry mass. This dry mass of the remainder of the sample is used as the Original Dry Mass of Test Sample (10,000 g minimum in **section 4.1** of this test method).

Example:

$$\begin{aligned} \text{Wet mass of moisture sample} &= 2,645 \text{ g} \\ \text{Dry mass of moisture sample} &= 2,557 \text{ g} \\ \text{Wet mass of the remainder of sample} &= 10,976 \text{ g} \end{aligned}$$

Percentage of Moisture =

$$\frac{100(\text{Wet mass of sample} - \text{Dry mass of sample})}{\text{Dry mass of sample}}$$

$$\frac{100 (2,645 - 2,557)}{2,557} = 3.44\%$$

Dry mass of the remainder of the sample =

$$\frac{100(\text{Wet mass of the remainder of the sample})}{(100 + \text{Percentage of Moisture})}$$

$$\frac{100(10,976)}{100 + 3.44} = \frac{100(10,976)}{103.44} = 10,611 \text{ g}$$

## 5.9.10 PLASTICITY TESTS (Kansas Test Method KT-10)

### **1. SCOPE**

This method of test covers the procedures for determining the liquid limit, plastic limit and plastic index of soils and the minus No. 40 (425  $\mu$ m) portions of aggregates. For aggregates, use the wet preparation method described in **Section 9** of this test method. **KT-10** reflects testing procedures found in **AASHTO R-58, T 89** and **T 90**.

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2** KT-11; Moisture Tests

**2.3.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

**2.4.** AASHTO T 89; Determining the Liquid Limit of Soils

**2.5.** AASHTO T 90; Determining the Plastic Limit and Plasticity Index of Soils

### **3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, Section 5.9; Sampling and Test Methods Foreword** for the class of general purpose required for the principal sample mass of the sample being tested.

**3.2.** A suitable device capable of drying samples at a temperature not exceeding 140°F (60°C), for the preparation of the samples.

**3.3.** Oven thermostatically controlled capable of maintain a uniform temperature of 230  $\pm$  9°F (110  $\pm$  5°C), for drying of moisture samples.

**3.4.** A porcelain-evaporating dish, preferably unglazed about 4.5 in (115 mm) in diameter.

**3.5.** Spatula having a blade about 0.75 in (20 mm) wide and 3 in (75 mm) long.

**3.6.** A mechanically operated Liquid Limit Device consisting of a brass cup and carriage meeting the requirements of **AASHTO T 89, Figure 1** and **Sections 4.3.1 and 4.3.2** of this test method.

**3.7.** A manually operated device constructed in accordance with **AASHTO T 89, Section 3.3.1**.

**3.8.** Curved grooving tool meeting the requirements of **AASHTO T 89, Figure 1**.

**3.9.** A gage whether attached to the grooving tool or separate, conforming to the critical dimension “d” shown in **AASHTO T 89 Figure 1** and may be, if separate, a metal bar 0.394  $\pm$  0.008 in. (10.0  $\pm$  0.2 mm) thick and approximately 2 in (950 mm) long.

**NOTE:** All Liquid Limit Devices and curved grooving tools should be examined for conformance with the requirements of **AASHTO T 89** before they are used.

**3.10.** Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

**3.11.** Pulverizing apparatus: Either a mortar and rubber-covered pestle or a mechanical device consisting of a power driven rubber-covered muller suitable for breaking up the aggregation of soil particles without reducing the size of the individual grains.

**NOTE:** Other types of apparatus, such as a revolving drum into which the soil sample and rubber-covered rollers are placed and tumbled until soil aggregations are pulverized, are satisfactory if the aggregations of soil particles are broken up without reducing the size of the individual grains.

**3.12.** Series of sieves including No. 4 (4.75 mm), No. 10 (2.00 mm), and No. 40 (425  $\mu\text{m}$ ) conforming to **ASTM E11**.

**3.13.** Standard KDOT 16 by 10 by 5.5 in (400 by 250 by 140 mm) wash pan equipped with No. 40 (425  $\mu\text{m}$ ) screen (optional).

**3.14.** Ground glass plate. The finish on the ground glass plate is obtained using a medium to fine grade of abrasive dust. An emery dust essentially passing the No. 60 (250  $\mu\text{m}$ ) sieve and retained on the No. 100 (150  $\mu\text{m}$ ) sieve has been found to be satisfactory.

A small amount of water is sprinkled on a glass plate along with the abrasive dust. Another plate is laid on top and the plates are rubbed together until a uniform frosty finish is obtained.

**3.15.** Plastic Limit Device such as a Gilson SA-18. (See **Figure 2**) This is used for the alternate procedure using the Plastic Limit Device, see **Section 6.4** of this test method.

#### **4. LIQUID LIMIT TEST<sup>1</sup>**

**4.1.** Definition: The liquid limit of a material is the water content, when determined in accordance with this test method, at which the material passes from a plastic to a liquid state. This corresponds to a theoretical moisture content at which the material will flow in such a manner as to produce a 0.5 in (13 mm) closure of a groove when jarred by 25 drops of the cup on the Liquid Limit Device.

**4.2.** Preparation of Sample: Dry the material at a temperature not exceeding 140°F (60°C). See **Section 9**, aggregate material preparation.

**4.2.1.** The dried sample shall be separated into two fractions using a No. 10 (2.00 mm) sieve. The fraction retained on the sieve shall be ground with the pulverizing apparatus until the aggregations of soil particles are broken into separate grains. The ground soil shall then be separated into two fractions using the No. 10 (2.00 mm) sieve. Discarding the material retained on the sieve.

**4.2.2.** Dry-screen the material over a No. 40 (425  $\mu\text{m}$ ) sieve to remove as much of the portion passing the No. 40 (425  $\mu\text{m}$ ) sieve as possible.

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<sup>1</sup> **AASHTO T 89 and ASTM D4318** allow for both method “A” and method “B”. **KT-10** allows for method “A” only.

**4.2.3.** The fraction retained on the No. 40 (425  $\mu\text{m}$ ) sieve shall be ground with the pulverizing apparatus in such a manner as to break up the aggregations without fracturing the individual grains. If the sample contains brittle particles, such as flakes of mica, fragments of seashells, etc., the pulverizing operation shall be done carefully and with just enough pressure to free the finer material that adheres to the coarser particles. The ground soil shall then be separated into two fractions by means of the No. 40 (425  $\mu\text{m}$ ) sieve and the material shall be reground as before. When the repeated grinding produces only a small quantity of soil passing the No. 40 (425  $\mu\text{m}$ ) sieve, the material retained on the No. 40 (425  $\mu\text{m}$ ) sieve shall be discarded. The several fractions passing the No. 40 (425  $\mu\text{m}$ ) sieve obtained from the grinding and sieving operations just described shall be thoroughly mixed together and set aside for use in performing the physical tests.

### **4.3. Test Procedure**

**4.3.1.** Adjust the height of drop of the brass cup on the Liquid Limit Device by means of the adjustment plate. The height to which the cup is lifted by the cam is adjusted so that the point on the cup which comes in contact with the base is  $0.394 \pm 0.008$  in ( $10.0 \pm 0.2$  mm) above the base. Secure the adjustment plate by tightening the appropriate screws.

Place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot (**See Figure 3**). Place the tape between the wear spot and the pivot so that the edge of the tape away from the cup hanger bisects the spot on the cup that contacts the base. Slide the height gauge under the cup to the device and turn the crank until the cup is raised to its maximum height.

The adjustment is checked with the gauge in place by revolving the crank several times. If the adjustment is correct, a slight ringing sound will be heard when the cam strikes the cam follower. If the cup is raised off the gauge or no sound is heard, further adjustment is made.

Remove the tape after adjustment.

**4.3.2.** Inspect the Liquid Limit Device to be sure that it is in good working order and that there are no worn or “out of alignment” parts that will affect the test results.

**4.3.3.** Take a sample weighing approximately 100 g and place in the mixing dish. The sample shall be thoroughly mixed with 15 to 20 mL of distilled or demineralized water by alternately and repeatedly stirring, kneading and chopping with a spatula. Further additions of water shall be made in 1 to 3 mL increments. Each increment of water shall be thoroughly mixed with the soil, as previously described, before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit Device shall not be used for mixing soil and water. If too much moisture has been added to the sample, the sample shall either be discarded, or mixed and kneaded until the natural evaporation lowers the closure point into acceptable range.

**NOTE:** Some soils are slow to absorb water; therefore, it is possible to add increments of water so fast that a false liquid limit value is obtained. This can be avoided if more mixing and/or time is allowed. Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water. However, referee, or disputed tests shall be performed using distilled or demineralized water.

**4.3.4.** When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficient quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall be squeezed and spread with the spatula to level and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. As few strokes of the spatula as possible shall be



used, care being taken to prevent the entrapment of air bubbles within the mass. The excess soil shall be returned to the mixing dish. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean sharp groove of proper dimensions will be formed. To avoid tearing the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

**4.3.5.** The cup containing the sample prepared as described in **Section 4.3.4** of this test method, shall be lifted and dropped by turning the crank at the rate of approximately two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 0.5 in (13 mm). The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank is turned.

**NOTE:** Some soils tend to slide on the surface of the cup instead of flowing. If this occurs, more water should be added to the sample and remixed, then the soil-water mixture placed in the cup, a groove cut with grooving tool and **Section 4.3.5** repeated. If the soil continues to slide on the cup at a lesser number of blows than 25, the test is not applicable and a note should be made that the liquid limit could not be determined.

**4.3.6.** A slice of soil approximately the width of the spatula, extending from the edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in suitable container. Record the sample mass to the nearest 0.01 g. The soil in the container shall be dried in accordance with **KT-11** to determine the moisture content. The use of a lid for the container as stated in **KT-11** is required. Record the results.

**4.3.7.** The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall be washed and dried in preparation for the next trial.

**4.3.8.** The foregoing operations shall be repeated for at least two additional portions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that at least one determination will be made in each of the following ranges of shocks: 25-35, 20-30, 15-25. The range of the three determinations shall be at least 10 shocks.

## 5. CALCULATIONS

**5.1.** Calculate the moisture content of the sample as follows:

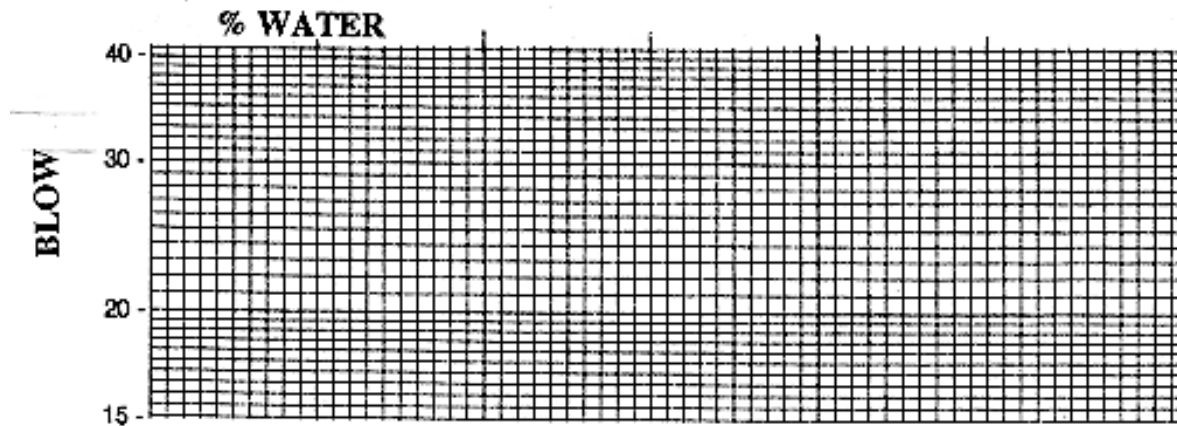
$$\text{Moisture Content} = \frac{100 \times (A-C)}{(C-B)}$$

Where:        A= Mass of wet soil and container, g  
                  B= Mass of container, g  
                  C= Mass of dry soil and container, g

**5.1.1.** Record the moisture content to the nearest 0.1%.

**5.2.** A “Flow Curve” representing relation between moisture content and corresponding number of shocks shall be plotted on a semi-logarithmic graph with the moisture contents as abscissa on the arithmetical

scale, and the number of shocks as ordinates on the logarithmic scale. The flow curve shall be a straight line drawn as nearly as possible through the three plotted points. (Figure 1)



**Figure 1**  
**Flow Curve Chart**  
**(KDOT Form No. 664)**

**5.3.** The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

## **6. PLASTIC LIMIT TEST**

**6.1. Definition:** The plastic limit of a material is the lowest water content, when determined in accordance with this test method, at which the material remains plastic.

**6.2. Preparation of Sample:** The test is conducted using material finer than the No. 40 ( 425  $\mu$ m) sieve. The minus No. 40 ( 425  $\mu$ m) material is prepared as outlined in **Section 4.2** of this test method.

### **6.3. Test Procedure**

**6.3.1.** Thoroughly mix the minus No. 40 ( 425  $\mu$ m) material and place approximately 20 g in an evaporation dish.

**6.3.2.** Thoroughly mix with distilled or demineralized water until the mass becomes plastic enough to be easily shaped into a ball. Take a portion of this ball with a mass of about 10 g for the test sample.

**NOTE:** Tap water may be used for routine testing if comparative tests indicate no differences between using tap water and distilled or demineralized water. However, referee or disputed tests shall be performed using distilled or demineralized water.

**6.3.3.** If both the liquid and plastic limits are required, take a test sample with a mass of about 10 g from the thoroughly wet and mixed portion of the soil prepared in accordance with **Section 4.3.3** of this test method. Take the sample at any stage of the mixing process at which the mass becomes plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed. If the sample is taken before completion of the liquid limit test, set it aside and allow it to season in air until the liquid limit test has been completed. If the sample taken during the liquid limit test is too dry to permit rolling to a 1/8 in (3.0 mm) thread, add more water and remix.

**6.3.4.** Select 1.5 to 2.0 g of soil taken in **Section 6.3.3** of this test method. Form into an ellipsoidal mass.

**6.3.5.** Roll this mass between the fingers and the palm of the hand and a ground glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again. Reduce the diameter of the thread to 1/8 in (3.0 mm), taking no more than 2 min. Quickly squeeze and reform the thread into an ellipsoidal shaped mass and re-roll. Continue this alternate reforming and re-rolling to a thread 1/8 in (3.0 mm) in diameter, gathering together, kneading and re-rolling, until the thread crumbles under the pressure required for rolling and the material can no longer be rolled into a thread. The crumbling may occur when the thread is greater than 1/8 in (3.0 mm) in diameter. This shall be considered a satisfactory end point, provided the material has been rolled to a thread of 1/8 in (3.0 mm) during the previous rolling. The crumbling will manifest itself differently with various types of material. Some materials fall apart in numerous small aggregations of particles; others may form an outside tubular layer that starts splitting at both ends. Splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. It is not practical to define crumbling to an exact degree since, as stated above, crumbling will manifest itself differently for different materials. At no time shall the operator attempt to produce failure at exactly 1/8 in (3.0 mm) diameter by allowing the thread to reach 1/8 in (3.0 mm), then reducing the rate of rolling or the hand pressure or both, and continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal shaped mass nearer to the required 1/8 in (3.0 mm) final diameter.

**6.3.6.** Place the crumbled thread in a watch glass or other suitable container of known mass and close to prevent evaporation loss. Repeat steps 6.3.4. to 6.3.6. until the entire 10 gram sample has been tested.

**6.3.7.** Gather the portions of the crumbled soil together and place in a suitable tared container. Record the sample mass to the nearest 0.01 g. The soil in the container shall be dried in accordance with **KT-11 Sections 3 through 5**, to determine the moisture content. The use of a lid for the container as stated in KT-11 is required. Record the results.

#### **6.4. Alternate procedure using the Plastic Limit Device**

**6.4.1.** Attach smooth unglazed paper to both the bottom fixed plate and the top of the Plastic Limit Device.

**6.4.2.** Split the 10 g. test sample taken in **Section 6.3.3 and 6.3.4** of this test method into four or five masses of 1.5 to 2.0 g each. Squeeze into an ellipsoidal-shape and place two to three masses on the bottom plate. Place the top plate in contact with the soil masses. Simultaneously with a slight downward force, apply a back-and-forth rolling motion with the top plate until the top plate comes into contact with the 3.2 mm side rails, within two minutes. Do not allow the soil thread to come into contact with the side rails.

**6.4.3.** Continue the test as outlined in **Sections 6.3.5, 6.3.6, and 6.3.7** of this test method.

### **7. CALCULATIONS**

**7.1.** Calculate the moisture content of the sample at its plastic limit as follows:

$$\text{Plastic Limit} = \frac{100 \times (A - C)}{(C - B)}$$

Where:        A= Mass of wet soil and container, g  
                  B= Mass of container, g  
                  C= Mass of dry soil and container, g

**7.2.** Record all masses to the nearest 0.01 g. Calculate and record the percentage of moisture to the 0.1%, report the percentage of moisture to the nearest whole percent.

## **8. PLASTIC INDEX**

**8.1.** Definition: The plastic index of a material is the numerical difference between the liquid limit and the plastic limit.

**8.2.** Calculations: Calculate the plastic index as follows, or calculate on **KDOT Form 663**.

Plastic Index = Liquid Limit (as recorded) – Plastic Limit (as recorded).

**8.3.** Reporting: Report the plastic index and liquid limit (when required) to the nearest whole number.

**NOTE:** When testing extremely sandy samples, it is permissible to conduct the plastic limit test first. If the plastic limit cannot be determined, report the plastic index as NP (i.e. nonplastic). If the plastic limit is equal to or greater than the liquid limit, report the plastic index as NP.

## **9. WET PREPARATION (FOR AGGREGATE MATERIAL ONLY)**

**9.1.** The following “wash” method of preparation shall be used for all types of aggregates, binder soil and mineral fillers. However, in the case of a mineral filler which all passes a No. 40 (425 µm) sieve, the washing process may be waived and the sample prepared for testing by reducing it to particle size using the pulverizing apparatus.

**9.2.1.** Dry the material to a moisture condition at which it can be pulverized and dry-screened without sticking or clogging the screens.

**9.2.2.** Dry-screen the material over a No. 40 (425 µm) sieve to remove as much of the portion passing the No. 40 (425 µm) sieve as possible before washing. Several larger sieves may be used in this process to keep part of the load off the No. 40 (425 µm) sieve. This initial dry-screening is very important as it helps to reduce the time and water required for the washing process which follows. Set aside the minus No. 40 (425 µm) material obtained in this manner for recombination with material obtained by later steps.

**9.2.3.** Place the material retained on the No. 40 (425 µm) sieve in a pan, cover with water and soak for a minimum of 30 minutes.

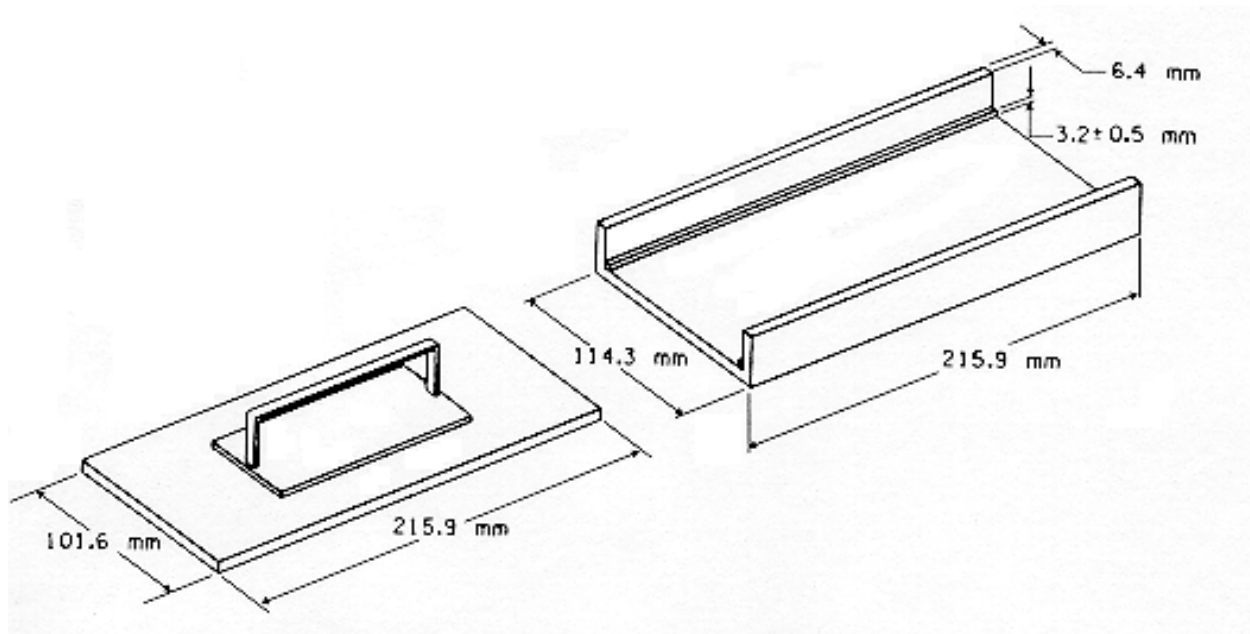
**9.2.4.** Following the soaking period, wash the material, using not less than four applications of wash water, including the soaking water. Each application of water must cover the entire sample. The washing for each application is accomplished by a “sloshing” action of the pan. Should an appreciable amount of plastic material remain with the sample after four applications of water, use additional applications accompanied by more vigorous agitation of the material. Decant each application of the wash water through a No. 40 (425 µm) sieve, saving all of the wash water and material.

**9.2.5.** Evaporate the water from the washed plus No. 40 (425  $\mu\text{m}$ ) material and from the material washed through the No. 40 (425  $\mu\text{m}$ ) sieve using an oven with temperature settings not to exceed 140°F (60°C). In most cases, after a short period of heating, the particles in suspension will settle out so that the clear water at the top of the pan may be siphoned off to reduce the drying time.

**9.2.6.** If the material in the retained wash water becomes caked during the drying process, break it down to pass the No. 40 (425  $\mu\text{m}$ ) sieve with the pulverizing apparatus. This pulverizing shall be done, insofar as possible, in a manner which will not change the characteristics of the material.

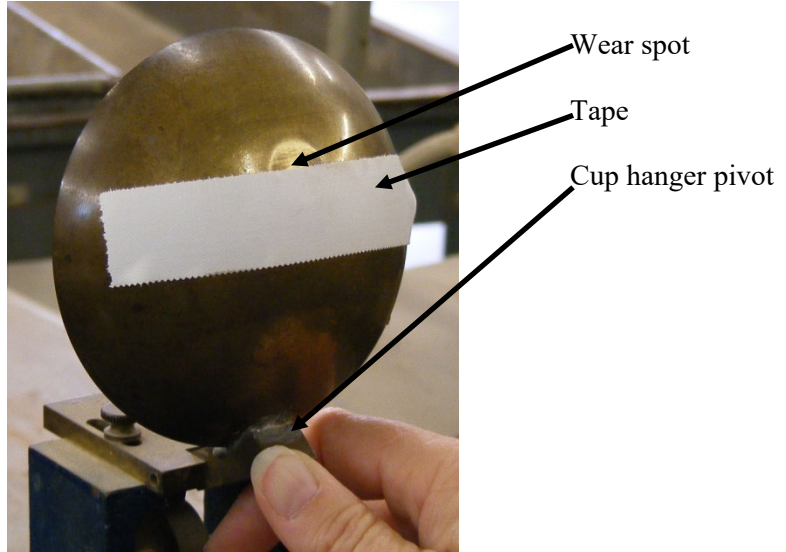
**9.2.7.** Dry-screen the dried material, retained on the No. 40 (425  $\mu\text{m}$ ) sieve during the washing process, over a No. 40 (425  $\mu\text{m}$ ) sieve after which the material retained on the sieve may be discarded.

**9.2.8.** Recombine and thoroughly mix the minus No. 40 (425  $\mu\text{m}$ ) material obtained by the initial dry-screening, that obtained by washing and that obtained by re-screening the coarse material after washing. The sample thus prepared is ready for testing.



**Figure 2**  
**Plastic Limit Device**

**Figure 3**  
**Brass Cup Calibration**





## 5.9.11 MOISTURE TESTS (Kansas Test Method KT-11)

### 1. SCOPE

This method of test covers the procedure for the determination of the moisture content of soil and aggregate. **KT-11** reflects testing procedures found in **AASHTO T 217** and **T 265**.

### 2. REFERENCED DOCUMENTS

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** AASHTO T 217; Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester

**2.3.** AASHTO T 265; Laboratory Determination of Moisture Content of Soils

### 3. CONSTANT MASS METHOD

#### 3.1. Apparatus:

**3.1.1.** The balance shall conform to the requirements of **Part V, 5.9, Sampling and Test Methods Foreword** for the class of general-purpose balance required for the principal sample mass of the sample being tested.

**3.1.2.** Drying oven should be thermostatically controlled, preferably of the forced-draft type. It shall be capable of being heated continuously at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**3.1.3.** Drying pans.

### 4. TEST PROCEDURE FOR CONSTANT MASS METHOD

**4.1.** Select a representative quantity of sample in the amount indicated in the method of test. If no amount is indicated, the minimum mass of the sample shall be in accordance with the following table:

Maximum Particle Size	Minimum Mass of Sample, g
No. 40 (425 $\mu\text{m}$ ) sieve	10
No. 4 (4.75 mm) sieve	100
1/2 in (12.5 mm) sieve	300
1 in (25.0 mm) sieve	500
2 in (50.0 mm) sieve	1000

**4.2.** Weigh a clean, dry container (with its lid if used for soils) and place the moisture content sample in the container. Replace the lid (if used) immediately, and weigh the container, including the lid (if used) and moist sample. Remove the lid (if used) and place the container with the moist sample in the drying oven maintained at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ) and dry to a constant mass. Immediately upon removal from the oven, replace the lid (if used) and allow the sample to cool to room temperature. Weigh the container including lid (if used) and dried sample.



**NOTE:** Checking every moisture content sample to determine that it is dried to a constant mass is impractical. In most cases, drying of a moisture sample over-night (15 to 16 hours) is sufficient. In cases where there is doubt concerning the adequacy of overnight drying, drying should be continued until the mass after two successive periods of drying indicate no change in mass. Samples of sand may often be dried to constant mass in a period of several hours. Since dry samples may absorb moisture from wet samples, dried samples should be removed before placing wet samples in the oven.

**NOTE: (for bulk soil samples):** A container without a lid may be used provided the moist sample is weighed immediately after being taken and providing the dried sample is weighed immediately after being removed from the oven or after cooling in a desiccators. This provision does not apply to samples used for plasticity index determination; lids must be used.

**NOTE:** Moisture content samples for soils should be discarded and should not be used in any other tests.

## 5. CALCULATIONS

5.1. Calculate the moisture content as follows:

$$w = \frac{(\text{mass of moisture})}{(\text{mass of oven-dried sample})} \times 100$$

$$w = \frac{(W_1 - W_2)}{(W_2 - W_c)} \times 100$$

Where:

- w = moisture content, percent
- $W_1$  = mass of container and moist sample, g
- $W_2$  = mass of container and oven-dried sample, g
- $W_c$  = mass of container, g

5.2. Calculate the percent of moisture content.

## 6. REPORT

6.1. Record the moisture content to the nearest 0.01% of mass of the oven dried sample. Report the percent of moisture content to the nearest 0.1%.

## 7. GAS PRESSURE (“SPEEDY”) METHOD

### 7.1 Significance and Use

This test method outlines procedures for determining the moisture content of soil by chemical reaction using calcium carbide as a reagent to react with the available water in the soil producing a gas. A measurement is made of the pressure produced when a specified mass of wet or moist soil is placed in a testing device with an appropriate volume of reagent and mixed.

This method is not intended as a replacement for Section 3, Constant Mass Method, but as a supplement when rapid results are required, for field use some distance from a lab or where an oven is not practical for use on the project.

This method is applicable for most soils, however, some soils that contain highly plastic clays that are not friable and do not break down may not produce representative results as the reagent may not react with all

the moisture contained in the sample. It is recommended to use Section 3 if highly accurate results are needed.

**NOTE:** This method shall not be used on granular materials having more than 5% particles large enough to be retained on a No. 4 (4.75 mm) sieve as determined by a visual estimate. The Super 200 D Tester is intended to be used when testing aggregate.

## 7.2. Apparatus

### 7.2.1. Calcium carbide pressure moisture tester. (Figure 1)

7.2.2. The balance shall conform to the requirements of **Part V, 5.9, Sampling and Test Methods Foreword.**

7.2.3. Two 1.25 in (31.75 mm) steel balls.

7.2.4. Cleaning brush and cloth.

7.2.5. Scoop for measuring calcium carbide reagent.

## 8. MATERIAL

### 8.1. Calcium carbide reagent.

**NOTE:** The calcium carbide must be finely pulverized and should be of a grade capable of producing acetylene gas in the amount of at least 2.25 ft<sup>3</sup>/lb (90.14 m<sup>3</sup>/kg) of carbide.

**NOTE:** The “shelf life” of the calcium carbide reagent is limited, so it should be used according to manufacturer recommendations.

**NOTE:** When combined with water, the calcium carbide reagent produces a highly flammable or explosive acetylene gas. Testing should not be carried out in confined spaces or in the vicinity of open flame or other source of heat that could cause combustion.

## 9. TEST PROCEDURE FOR SPEEDY METHOD

9.1. When using the 20 g or 26 g tester, place three scoops (approximately 24 g) of calcium carbide in the body of the moisture tester. When using the Super 200 D Tester to test aggregate, place 6 scoops (approximately 48 g) of calcium carbide in the body of the moisture tester.

**NOTE:** Care must be exercised to prevent the calcium carbide from coming into direct contact with water.

9.2. Weigh a sample of the exact mass specified by the manufacturer of the instrument in the balance provided and place the sample in the cap of the tester. When using the 20 g or 26 g size tester, place two 1.25 in (31.75 mm) steel balls in the body of the tester with the calcium carbide.

**NOTE:** If the moisture content of the sample exceeds the limit of the pressure gauge (12% moisture for aggregate tester or 20% moisture for soil tester), a one-half size sample must be used and the dial reading must be multiplied by 2. This proportional method is not directly applicable to the dry mass percent scale on the Super 200 D Tester.

**9.3.** With the pressure vessel in an approximately horizontal position, insert the cap in the pressure vessel and seal the unit by tightening the clamp, taking care that no carbide comes in contact with the soil until a complete seal is achieved.

**9.4.** Raise the moisture tester to a vertical position so that the soil in the cap will fall into the pressure vessel.

**9.5.** Shake the instrument vigorously so that all lumps will be broken up to permit the calcium carbide to react with all available free moisture. When steel balls are being used in the tester and when using the larger tester to test aggregate, the instrument should be shaken with a rotating motion so the steel balls or aggregate will not damage the instrument or cause soil particles to become embedded in the orifice leading to the pressure diaphragm.

**NOTE:** Shaking should continue for at least 60 seconds with granular soils and for up to 180 seconds for other soils so as to permit complete reaction between the calcium carbide and the free moisture. Time should be permitted to allow dissipation of the heat generated by the chemical reaction.

**9.6.** When the needle stops moving, read the dial while holding the instrument in a horizontal position at eye level.

**9.7.** Record the dial reading.<sup>1</sup>

**9.8.** With the cap of the instrument pointed away from the operator, slowly release the gas pressure. Empty the pressure vessel and examine the material for lumps. If the sample is not completely pulverized, the test should be repeated using a new sample. Clean the cap thoroughly of all carbide and soil before running another test.

**NOTE:** When removing the cap, care should be taken to point instrument away from the operator to avoid breathing the fumes and away from any potential source of ignition for the acetylene gas.

**9.9.** The dial reading is the percent of moisture by wet mass and must be converted to dry mass. With the Super 200 D Tester the dial reading is the percent of moisture by dry mass, and no further calculation is required.

## **10. CALCULATION**

**10.1** The percentage of moisture by dry mass of the soil may be determined from the conversion curve either provided with the device, a curve developed from local soils or the calculation provided with the device. Preference should be given to a curve developed from local soils that are to be used on a project.

**10.2** Calibration curves are produced by selecting several samples representing the range of soil materials to be tested and having a relatively wide range of moisture content. Utilize the method in Section 3 alongside the Speedy to develop the curve.

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<sup>1</sup> AASHTO T 217 requires recording sample mass and dial reading.

**NOTE:** A conversion curve, similar to **Figure 2**, is normally supplied with the moisture tester. However, check each moisture tester for accuracy of its gage, or the accuracy of the conversion curve annually<sup>2</sup>. Accuracy of the tester gage may be checked by using a calibration kit (obtainable from the tester manufacturer), equipped with the standard gage; in case of discrepancy, the gage tester should be adjusted to conform to the standard gage. For checking the accuracy of the conversion curve, a calibration should be made for meter readings using locally prepared soils at known moisture contents. Also, additional testing may be necessary to extend the conversion curve (**Figure 2**) beyond 44% moisture content.

**NOTE:** It may be convenient for field use of the apparatus to prepare a table of moisture tester readings versus oven-dry moisture content for the moisture tester.

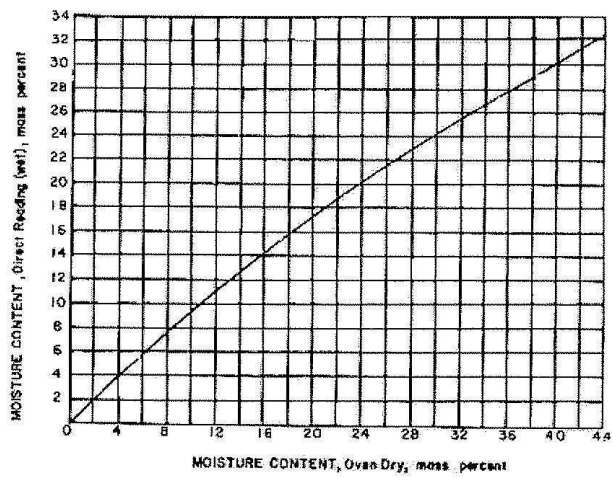
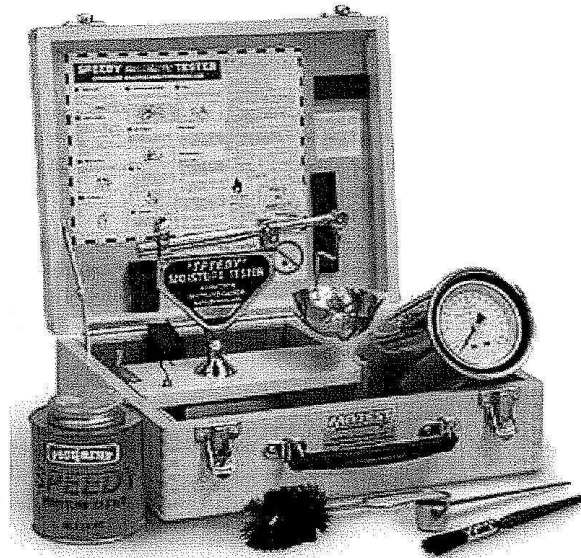
## **11. REPORT**

**11.1.** Record the dial reading to the nearest 0.1% and determine the percent moisture from the conversion chart. Report the percentage of moisture to the nearest whole percent.

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<sup>2</sup> KDOT requires that each Speedy Moisture tester be checked annually for accuracy of reading.

**Figure 1 Calcium Carbide Gas Pressure Moisture Meter**



**Figure 2 Conversion Curve for  
Moisture Tester Reading**

## 5.9.12 STANDARD COMPACTION TEST (Kansas Test Method KT-12)

### 1. SCOPE

**1.1. Fine Grained Materials (Section 4.):** This method of test is used to determine the relation between the moisture content and density of soils or other fine grained materials when subjected, at various moisture contents, to a standard compactive effort while confined in a rigid metal mold. **KT-12** reflects testing procedures found in **AASHTO T 99**.

The procedure for compaction of “fine grained materials” shall be followed whenever:

- (1) The material has less than 10% retained on the No. 4 (4.74 mm) sieve, or
- (2) The material has more than 10 % but less than 30% retained on the No. 4 (4.75 mm) sieve and the fraction passing the No. 40 (425  $\mu$ m) sieve has a plastic index greater than 8.

**1.2. Granular Materials (Section 5.):** This method of test is used to determine the relation between the moisture content and density of granular materials, when subjected, at various moisture contents, to a standard compactive effort while confined in a rigid mold. **KT-12** reflects testing procedures found in **AASHTO T 99**.

Granular materials are classified as materials passing the 3/4 in (19.0 mm) sieve.

### 2. REFERENCED DOCUMENTS

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2** KT-11; Moisture Tests

**2.3.** AASHTO T 19; Bulk Density (“Unit Weight”) and Voids in Aggregate

**2.4.** AASHTO T 99; Moisture-Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer and a 12 in (305 mm) Drop

**2.5.** AASHTO T 265; Laboratory Determination of Moisture Content of Soils

**2.6.** ASTM D2168; Test Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors

### 3. APPARATUS

**3.1.** Fine Grained Material:

**3.1.1.** The mold shall be solid wall, metal cylinders 4 in (101.6 mm) with a capacity of  $0.0333 \pm 0.0005 \text{ ft}^3$  ( $0.000943 \pm 0.000014 \text{ m}^3$ ) and an internal diameter of  $4.000 \pm 0.016 \text{ in}$  ( $101.60 \pm 0.40 \text{ mm}$ ) and a height of  $4.584 \pm 0.018 \text{ in}$  ( $116.40 \pm 0.50 \text{ mm}$ ). It shall have a detachable collar assembly approximately 2.375 in (60 mm) in height. The mold and collar assembly shall be constructed so that it can be fastened firmly to a detachable base plate made of the same material. The base plate shall be plane to 0.005 in.

**3.1.1.1.** A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50%; and the volume of the mold calibrated in accordance with **AASHTO T 19, Section 8**, for Unit Mass of Aggregate, is used in the calculations.

**3.1.1.2.** Any correction to the volume requires a new calculated multiplier ( $F$ ). The multiplier is an inverse function of the mold volume.

**NOTE:** The volume of the mold (without the collar) is measured by coating one end with cup grease or Vaseline to form a seal and then placing it on a glass plate which should be placed in a level position on a scale. The other end of the mold is coated with cup grease or Vaseline and then the mold and two glass plates are weighed. The mold may then be filled with  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ )<sup>1</sup> water after which the second glass plate should be placed on top of the mold in such a way as to eliminate air bubbles and excess water. Any excess water thus removed must be carefully wiped off after which the final weight of the mold, water and glass plates may be determined. The volume of the mold may then be calculated using  $62.243 \text{ lb/ft}^3$  ( $997 \text{ kg/m}^3$ ) as the density of water.

### **3.1.2. Rammer**

**3.1.2.1.** Manually operated. A metal rammer with a mass of  $5.5 \pm 0.02 \text{ lb}$  ( $2.495 \pm 0.009 \text{ kg}$ ) and having a flat circular face of  $2.000 \text{ in}$  ( $50.80 \text{ mm}$ ) diameter with a tolerance of  $\pm 0.01 \text{ in}$  ( $0.25 \text{ mm}$ ). The in-service diameter of the flat circular face shall be not less than  $1.985 \text{ in}$  ( $50.42 \text{ mm}$ ). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of  $12.00 \pm 0.06 \text{ in}$  ( $305 \pm 2 \text{ mm}$ ) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes, no smaller than  $3/8 \text{ in}$  ( $9.5 \text{ mm}$ ) diameter spaced at 90 degrees ( $1.57 \text{ rad}$ ) apart and  $3/4 \text{ in}$  ( $19 \text{ mm}$ ) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

**3.1.2.2.** Mechanically operated. A mechanically operated metal rammer is equipped to control the height of drop to  $12 \pm 0.06 \text{ in}$  ( $305 \pm 2.0 \text{ mm}$ ) above the elevation of the soil and to distribute the blows over the soil surface. The rammer has a  $2 \text{ in}$  ( $50.8 \text{ mm}$ ) diameter, flat circular face and has a mass of  $5.5 \pm 0.02 \text{ lb}$  ( $2.495 \pm 0.009 \text{ kg}$ ).

**NOTE:** The mechanically operated rammer must be calibrated as directed by **ASTM D 2168, Method A**.

**3.1.3.** Sample extruder (desirable) should consist of, a frame, jack and circular metal loading plate or other suitable device for removing specimens from the mold.

**3.1.4.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.1.5.** A thermostatically controlled drying oven capable of maintaining a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ) for drying moisture samples.

**3.1.6.** A hardened-steel straightedge at least  $10 \text{ in}$  ( $250 \text{ mm}$ ) in length. It shall have one beveled edge, and at least one longitudinal surface shall be plane within  $0.01 \text{ in per } 10 \text{ in}$  ( $0.250 \text{ mm per } 250 \text{ mm}$ ) ( $0.1\%$ ) of length within the portion used for trimming the soil.

**3.1.7.** No. 4 ( $4.75 \text{ mm}$ ) sieve.

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<sup>1</sup> **AASHTO T 99** references **AASHTO T 19** to calibrate the mold. **AASHTO T 19** permits the use of varying temperatures  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ) with correction factors to compensate for the water density. By using the fixed temperature requirement, KDOT uses a single value ( $62.243 \text{ lb/ft}^3$  [ $997 \text{ kg/m}^3$ ]) for the density of water during the calibration of such apparatuses.

### 3.1.8. Drying pans.

3.1.9. Trowels, spatulas and other mixing tools or a mechanical mixer that will thoroughly mix the material and water.

## 3.2. Granular Material:

3.2.1. The mold shall be solid wall, metal cylinders 6 in (152.4 mm) with a capacity of  $0.07500 \pm 0.0009$  ft<sup>3</sup> ( $0.002124 \pm 0.000025$  m<sup>3</sup>) and an internal diameter of  $6.000 \pm 0.026$  in ( $152.40 \pm 0.70$  mm) and a height of  $4.584 \pm 0.018$  in ( $116.40 \pm 0.50$  mm). It shall have a detachable collar assembly approximately 2.375 in (60 mm) in height. The mold and collar assembly shall be constructed so that it can be fastened firmly to a detachable base plate made of the same material. The base plate shall be plane to 0.005 in.

3.2.1.1. A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50%; and the volume of the mold calibrated in accordance with **AASHTO T 19, Section 7**, for Unit Mass of Aggregate, is used in the calculations.

3.2.2. A hardened-steel straightedge at least 10 in (250 mm) in length. It shall have one beveled edge, and at least one longitudinal surface shall be plane within 0.01 in per 10 in (0.250 mm per 250 mm) (0.1%) of length within the portion used for trimming the soil.

3.2.3. Other apparatus as listed under **Section 3.1** of this test method.

**NOTE:** When a mechanical compactor is used, the 2 in (50.8 mm) diameter circular face foot may be replaced with a rigid “pie-shaped” foot. The “pie-shaped” foot shall be a sector of a 6 in (152.4 mm) diameter circle and shall have an area equal to that of the circular face foot.

## 4. FINE GRAINED MATERIALS

### 4.1. Sample Preparation.

4.1.1. Obtain a 60 to 80 lbs (30 to 35 kg) sample, dry at 140°F (60°C) if necessary and break it down to pass the No. 4 (4.75 mm) sieve. Discard granular particles retained on the sieve.

4.1.2. Mix thoroughly and weigh out six portions, each weighing 5 lbs (2200 g).

### 4.2. Test Procedure.

4.2.1. Add a measured amount of water (approximately 12% by dry mass) to one 5 lb (2200 g) portion and thoroughly mix it into the sample.

4.2.2. The sample of soil-water mixture shall be placed in a closed container to minimize moisture loss. The sample shall then be allowed to stand for a minimum of 12 hours before compacting.

**NOTE:** When testing a mixture containing cementitious material such as cement or fly ash, skip section 4.2.2 to minimize the effects of hydration on the sample.

4.2.3. Obtain the mass of the mold to the nearest 0.0001 lb (0.0001 kg). It is suggested that the mold and collar be lightly coated with a light lubricant.



**4.2.4.** Place the assembled mold on the rigid base and fill the mold so that the compacted layer will equal 1/3 of the mold volume.

**4.2.5.** Compact the material with 25 blows of the rammer dropped from a height of 12 in (304.8 mm) above the surface of the material. Distribute the blows of the rammer evenly over the surface.

**4.2.6.** Place two more layers of the material in the mold and compact each layer as stipulated in **Section 4.2.3** above.

**4.2.7.** Remove the top collar and trim the excess material level with the top of the mold.

**4.2.8.** Remove the base and trim excess material level with the bottom of the mold.

**4.2.9.** Weigh the sample to the nearest 5 g while it is in the mold and multiply the mass of the sample and the mold, minus the mass of the mold, by 30 (1060), and record the result as the wet density,  $D_w$ , in pounds per cubic foot, (kilograms per cubic meter), of the compacted soil.

**4.2.10.** Repeat the compaction procedure using the other 5 lb (2200 g) increments of the sample to which different measured amounts of water have been added, thoroughly mixed and cured as in the note following **Section 4.2.1** of this test method. This procedure will be continued with varying moisture contents until at least three points are obtained on the dry side of “optimum moisture” and at least two points are obtained on the wet side of “optimum moisture.” This can usually be accomplished by compacting different specimens at moisture intervals of 2 to 3%, starting on the dry side of “optimum moisture” and ending on the wet side.

**4.2.11.** Remove the material from the mold and slice vertically through the center. Take a representative sample, weighing a minimum of 100 g of the material from one of the cut faces, determine the mass immediately and dry in accordance with **KT-11**, to determine the moisture content.

#### **4.3.** Calculations:

The calculations used are given in **Section 6.** of this test method.

#### **4.4.** Compaction Curve

**4.4.1** Plot a density/moisture curve on coordinate paper (**KDOT Form No. 638**) to determine the maximum density and optimum moisture. The dry density values are plotted as ordinates, the corresponding moisture contents are plotted as abscissa and a smooth curve is drawn to best fit the points.

**NOTE:** In drawing a curve by this method, all of the points will not necessarily be on the curve and the maximum density may be more or less than the highest test point. (See example at the end of this test method.)

The optimum moisture content is the moisture content at which the maximum density occurs on the curve.

## 5. GRANULAR MATERIALS

### 5.1. Sample Preparation.

**5.1.1.** Obtain approximately 100 lbs (45 kg) of the material to be tested, dry to maximum of 140°F if necessary and pulverize in such a manner as to avoid reducing the natural size of individual particles.

**5.1.1.1.** Sieve an adequate quantity of the pulverized soil over the 3/4 in (19.0 mm) sieve. Discard the coarse material, if any, retained on the 3/4 in (19.0 mm) sieve.

**5.1.2.** Thoroughly mix and weigh out six portions, each weighing 16 lbs (7 kg).

### 5.2. Test Procedure.

**5.2.1.** Add a measured amount (approximately 5%) of water and thoroughly mix one 16 lbs (7 kg) portion. After the addition of water and thorough mixing, the sample shall be placed in a covered container and allowed to stand for a minimum of 2 hours before conducting the moisture-density test.

**5.2.2.** Place the assembled mold on the rigid base and fill in three approximately equal layers. Compact each layer with 56 blows of the rammer with the blows being distributed uniformly over the surface of the layer.

**5.2.3.** After the third layer has been compacted, remove the collar and trim excess material level with the top of the mold.

**5.2.4.** Remove the base and trim excess material level with the bottom of the mold.

**5.2.5.** Weigh the sample while it is in the mold and multiply the mass of the sample and the mold, minus the mass of the mold, by 13.33 (471), and record the result as the wet density,  $D_w$ , in lb/ft<sup>3</sup> (kg/m<sup>3</sup>), of the compacted soil.

**5.2.6.** Repeat the compaction procedure using the other 16 lbs (7 kg) increments of the sample to which different measured amounts of water have been added, thoroughly mixed and cured as in the note following **Section 5.2.1** of this test method. This procedure will be continued with varying moisture contents until at least three points are obtained on the dry side of “optimum moisture” and at least two points are obtained on the wet side of “optimum moisture.” This can usually be accomplished by compacting different specimens at moisture intervals of 2 to 3%, starting on the dry side of “optimum moisture” and ending on the wet side.

**5.2.7.** Remove the material from the mold and slice vertically through the center. Take a representative sample, weighing a minimum of 300 g of the material from one of the cut faces, determine the mass immediately and dry in accordance with **KT-11**, to determine the moisture content.

### 5.3. Calculations.

The calculations used are given in **Section 6.** of this test method.

**5.4.** Plot a density/moisture curve on coordinate paper (**KDOT Form No. 638**) to determine the maximum density and optimum moisture. The dry density values are plotted as ordinates, the corresponding moisture contents are plotted as abscissa and a smooth curve is drawn to best fit the points.

**NOTE:** In drawing a curve by this method, all of the points will not necessarily be on the curve and the maximum density may be more or less than the highest test point. (See example at the end of this test method.)

The optimum moisture content is the moisture content at which the maximum density occurs on the curve.

The data for this test may be recorded on the “Work Sheet for Standard Compaction Tests” (**KDOT Form No, 676**) which is in bound book form.

## 6. CALCULATIONS

$$W = \frac{A - B}{B - C} \times 100$$

And

$$D = \frac{D_w}{W + 100} \times 100$$

Where:            W= percentage of moisture in the specimen, based on oven dry mass of soil  
                      A= mass of container and wet soil  
                      B= mass of container and dry soil  
                      C= mass of container  
                      D= dry density, in lb/ft<sup>3</sup> (kg/m<sup>3</sup>) of compacted soil  
                      D<sub>w</sub>= wet density, in lb/ft<sup>3</sup> (kg/m<sup>3</sup>) of compacted soil

Where:

$$D_w = (A - C)F$$

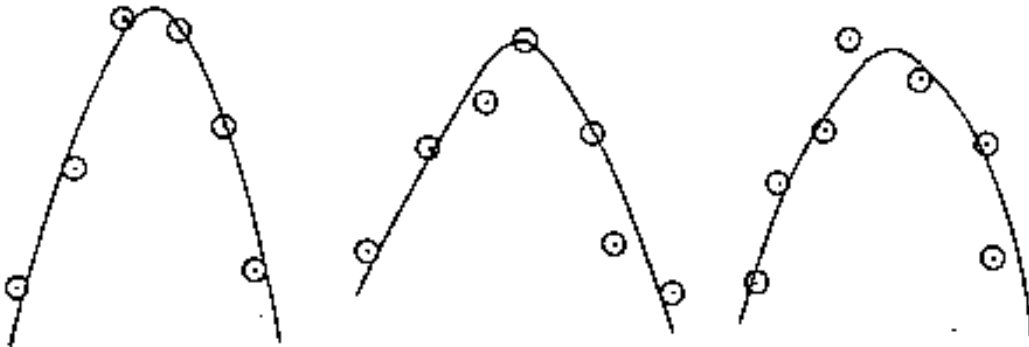
$F = 30$  for the 4 in mold and  $13.33$  for the 6 in mold (see **Section 5.2.5.**) (1060 for 101.6 mm mold and 471 for 152.4 mm mold)

## 7. RECORD AND REPORT

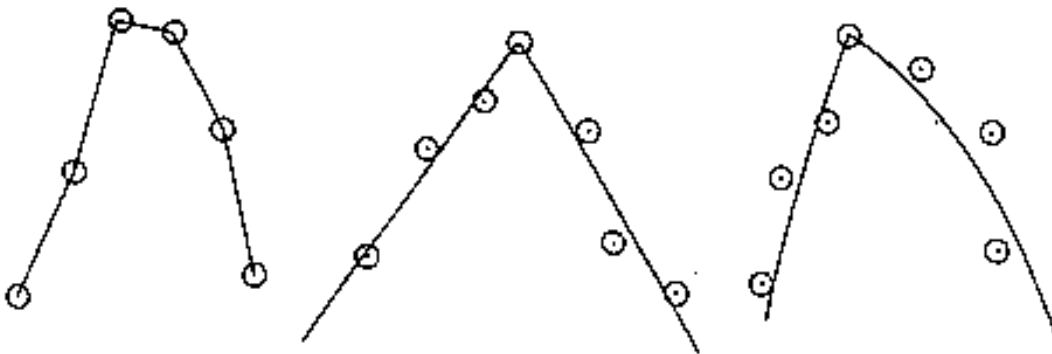
**7.1.** Record the density to the nearest 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>). Report the density to the nearest whole number. Record the moisture to the nearest 0.1%. Report the moisture to the nearest whole number.

# COMPACTION CURVE EXAMPLES

**CORRECT**



**INCORRECT**





5.9.13 FIELD DENSITY TESTS OF SOILS, TREATED BASE COURSES AND WATER BOUND  
BASE COURSES (Kansas Test Method KT-13)

**1. SCOPE**

This method of test covers the procedure for measuring the “in-place” density of soils and granular base courses. The density of a material is defined as the ratio of the mass of material to the volume of the same mass of material. The tests described consist of measuring the volume that a given mass of soil or base material occupies when it is in-place. **KT-13** reflects testing procedures found in **AASHTO T 191**.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2** KT-11; Moisture Tests

**2.3.** KT-15; Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt Mixtures (HMA)

**2.4.** KT-43; Moisture Content of Asphalt Mixtures or Mineral Aggregates - Microwave Oven Method

**2.5.** AASHTO T 99 Test for Moisture-Density Relations of Soils

**2.6.** AASHTO T 180; Moisture-Density Relations of Soils Using a 10 lb (4.54 kg) Rammer and an 18” (457 mm) Drop

**2.7.** AASHTO T 191; Density of Soil In-Place by the Sand-Cone Method

**3. APPARATUS**

**3.1.** General for all tests.

**3.1.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.1.2.** Oven capable of maintaining a uniform temperature of approximately 230°F (110°C) or a hot plate with a buffer consisting of a pan of sand or thick steel plate placed between the drying pan and the flame. If available, a microwave oven as described in **KT-43** may be used.

**3.1.3.** Equipment or shelter to protect balance from wind currents and the samples from exposure to the sun and wind.

**3.1.4.** Soil auger.

**3.1.5.** Speedy Moisture equipment as described in **KT-11**.

**3.1.6.** Miscellaneous equipment including standard drying pans, trowel, large spoon, hammer, chisels, heavy bladed knife, square point shovel and 12 in (300 mm) straight edge.

**3.2.** Sand Density Apparatus.

**3.2.1.** A cylindrical container of known volume usually between 0.05 and 0.10 ft<sup>3</sup>.

**3.2.2.** A pouring container with a volume larger than the volume of the test hole. A one pound coffee can with the rim bent into a “V” shape have previously been used as a pouring container, for shallow holes.

**3.2.3.** Any clean, dry, free-flowing, uncemented sand having few, if any, particles passing the No. 200 (75 µm) or retained on the No. 10 (2.00 mm) sieves. In selecting sand for use, several bulk density determinations should be made using the same representative sample for each determination. To be acceptable the sand shall not have a variation in bulk density greater than 1%.

### **3.3. Sand Cone Apparatus.**

**3.3.1.** The density apparatus shall consist of a 1 gal (4 L) jar and a detachable appliance consisting of a cylindrical valve with an orifice 1/2 in (12.7 mm) in diameter and having a small funnel continuing to standard G mason jar on one end and a large funnel on the other end. The valve shall have stops to prevent rotating the valve past the completely closed positions. (See **Figure 1** and **Figure 2**)

**NOTE:** The apparatus<sup>1</sup> describe here represents a design that has proven satisfactory. Other apparatus of similar proportions will perform equally well so long as the basic principles of the sand-volume determination are observed. This apparatus, when full, can be used with test holes having a volume of approximately 0.1 ft<sup>3</sup> (2.7 L). The base plate is optional; its use may make leveling more difficult but permits test holes of larger diameter and may reduce loss in transferring soil from test-hole to container as well as afford a more constant base for tests in soft soils. When the base plate is used it shall be considered a part of the funnel in the procedures of this test method.

**3.3.2.** Any clean, dry, free-flowing, uncemented sand having few, if any, particles passing the No. 200 (75 µm) or retained on the No. 10 (2.00 mm) sieves. In selecting sand for use, several bulk density determinations should be made using the same representative sample for each determination. To be acceptable the sand shall not have a variation in bulk density greater than 1%.

### **3.4. Alternate Test Method Apparatus.**

**3.4.1.** Small pipe about 3/4 in diameter.

**3.4.2.** 1/10 ft<sup>3</sup> bucket.

**3.4.3.** Funnel fitting small pipe in **Section 3.4.1.**

## **4. TEST PROCEDURE**

### **4.1. Sand Density Method<sup>2</sup>.**

**4.1.1.** Determine the loose unit weight of sand in lb/ft<sup>3</sup> (kg/m<sup>3</sup>) as follows:

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<sup>1</sup> See **AASHTO T 191 Figure 1** for size requirements.

<sup>2</sup> Sand Density Method is **KDOT** method only. **AASHTO** has no similar method.

**4.1.1.1.** Fill the cylinder of known volume and mass to slightly overflowing by pouring the dry sand at a uniform rate from the spout of the pouring container. The spout is held approximately 2 in (50 mm) above the top of the container.

**4.1.1.2.** Strike off the excess sand level with top of the container, being extremely careful to avoid jarring the container during the process. Weigh the cylinder and sand. Conduct a total of three tests to determine the loose unit weight of the sand and use the average value obtained when computing the “in-place” density of the material being tested.

**4.1.2.** Select the area where density is to be measured, determine and record the station, distance from center line, and elevation as distance below the final grade.

**4.1.3.** Trim off all raised or uneven spots to produce a smooth, flat surface not less than 18 in (450 mm) square, using a square point shovel or other suitable tool, and remove all loose material from the area.

**4.1.4.** Drill or cut a test hole through the depth of the material being tested and save all material removed, protecting the sample from weather conditions which might change the moisture content.

**4.1.5.** Weigh the material, record the mass, and dry the entire sample or a representative portion to constant mass. Weigh and record the dry mass.

**NOTE:** If the “Speedy” moisture tester is used to determine the moisture content, the procedure set forth in **KT-11** is followed. The dry mass of material is calculated as shown in **Section 5.1.5** of this test method.

**4.1.6.** Determine and record the mass of the pouring container with a volume of sand somewhat greater than the volume of the test hole.

**4.1.7.** Fill the hole level full of sand by pouring the sand at a uniform rate while holding the spout 2 in (50 mm) above the top of the test hole, as was done when calibrating the sand. The straight edge should be used to ensure that the sand is level with the surface of the material surrounding the test hole.

**4.1.8.** Weigh the pouring container and remaining sand and record the mass.

**4.2.** Alternate Sand Density Method for Test Holes Exceeding Two Feet in Depth.

**4.2.1.** Using a funnel, deposit the sand through a small pipe (about 3/4 of an inch in diameter).

**4.2.2.** Let the pipe rest on the bottom of the hole and pour the sand into the pipe until it is full, then raise the pipe about 8”. Continue to pour sand until the pipe is again full, and again raise the pipe the same distance, being careful not to let the pipe settle in the sand. The number of sections of pipe used does not affect the accuracy of the results, and each section may be removed as necessary. Care must be taken to prevent the pipe from settling in the sand during this process.

**4.2.3.** Use fine sand as described in **Section 3.2.** of this test method.

**4.2.4.** The sand must be calibrated by the same method as it is deposited, that is, by setting a short section of pipe in the bottom of the 1/10 ft<sup>3</sup> bucket and pouring sand into the pipe until it is full. Raise it 8” and continue to pour sand, keeping the pipe full, until the bucket is filled with sand.

## **5. CALCULATIONS**



**5.1. Density of dry sand ( $D_s$ ):**

$$D_s = \frac{M_{SC}}{V_C}$$

Where:  $M_{SC}$ = Mass of sand in container lb (kg)  
 $V_C$ = Volume of container  $ft^3$  ( $m^3$ )

**NOTE: 1  $m^3$  = 1000 L      1 L = 1000 mL      1000 kg = 1  $m^3$  Water**

**5.1.1. Percent moisture content of material ( $W$ ):**

$$W = \frac{100 (M_W - M_D)}{M_D}$$

Where:  $M_W$ = Wet Mass of material removed from test hole  
 $M_D$ = Dry Mass of material removed from test hole

**5.1.2. Mass of sand in test hole lb (kg) ( $M_{SH}$ ):**

$$M_{SH} = (M_I - M_F)$$

Where:  $M_I$ = Initial Mass of sand plus pouring container  
 $M_F$ = Final Mass of sand plus pouring container

**5.1.3. Volume of test hole ( $V$ )  $ft^3$  ( $m^3$ ):**

$$V = \frac{M_{SH}}{D_s}$$

Where:  $M_{SH}$  = Mass of sand in test hole lb (kg)  
 $D_s$ = Density of sand  $lb/ft^3$  ( $kg/m^3$ )

**5.1.4. In-place dry density of material being tested ( $D$ )  $lb/ft^3$  ( $kg/m^3$ ):**

$$D = \frac{M_D}{V}$$

Where:  $M_D$ = Dry mass of material removed from test hole  
 $V$ = Volume of test hole

**5.1.5. Mass of dry material removed from the test hole (when “Speedy” moisture tester or a portion of the sample is used to determine moisture content) ( $M_D$ ):**

$$M_D = \frac{100 (M_W)}{(W + 100)}$$

Where:  $M_W$ = Mass of wet material removed from test hole, lb (kg)  
 $W$ = Percent moisture of wet material removed from test hole

## 6. SAND CONE METHOD

**6.1.** Determination of volume of jar and attachment up to and including the volume of the valve orifice as follows:

**NOTE:** The volume in this procedure is constant as long as the jar and attachment are in the same relative position. If the two are to be separated, match marks should be made to permit reassembly to this position.

**6.1.1.** Weigh the assembled apparatus and record.

**6.1.2.** Place the apparatus upright and open the valve.

**6.1.3.** Fill the apparatus with water until it appears over the valve.

**6.1.4.** Close the valve and remove excess water.

**6.1.5.** Weigh the apparatus and water.

**6.1.6.** Repeat the procedure described in **Section 6.1.2 to 6.1.3** of this test method, at least twice. Convert the mass of water, in grams, to milliliters. The volume used shall be the average of three determinations with a maximum variation of 3 mL.

**6.1.7.** Calculate the volume of the density apparatus as follows:

English:

$$V_1 = \frac{G}{62.4 \text{ lb/ft}^3}$$

Metric:

$$V_1 = \frac{G}{1000 \text{ kg/m}^3}$$

Where:  $V_1$  = volume of the density apparatus,  $\text{ft}^3$  ( $\text{m}^3$ )  
G = mass of water required to fill apparatus lbs (kg)

Calculate the volume of the density apparatus to the nearest  $0.001 \text{ ft}^3$  ( $0.00003 \text{ m}^3$ ).

**6.2.** Determination of Bulk Density of Sand.

**NOTE:** Vibration of the sand during any mass-volume determination may increase the bulk density of sand and decrease the accuracy of the determination. Appreciable time intervals between the bulk density determinations of the sand and its use in the field may result in change in the bulk density caused by a change in the moisture content or effective gradation.

**NOTE:** It is possible to determine the bulk density of the sand in other containers of known volume that dimensionally approximate the largest test hole that will be dug. The general procedure used is that given in **Section 4.1.1** of this test method, for determining the density of dry sand. If this procedure is to be followed it shall be determined that the resulting bulk density equals that given by the jar determination.

**6.2.1.** Place the empty apparatus upright on a firm, level surface; close the valve and fill the funnel with sand.

**6.2.2.** Open the valve and keeping the funnel at least half full of sand, fill the apparatus. Close the valve sharply and empty excess sand.

**6.2.3.** Weigh the apparatus and sand. Determine the net mass of sand by subtracting the mass of the apparatus.

**6.2.4.** Calculate the bulk density of the sand as follows:

$$D_S = \frac{M_{SA}}{V_1}$$

Where:  $D_S$ = Bulk density of the sand, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
 $M_{SA}$ = Mass of sand required to fill apparatus lb (kg) and  
 $V_1$ = Volume of apparatus in ft<sup>3</sup> (m<sup>3</sup>)

Calculate the bulk density of the sand to the nearest 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>).

**6.3.** Determination of mass of sand filling the funnel.

**NOTE:** This determination may be omitted if the procedure given in **NOTE** in **Section 6.2** regarding bulk densities is followed. When the base plate is used, it shall be considered a part of the funnel.

**NOTE:** Where test holes of maximum volume are desired it is possible, after the bulk density determination, to settle the sand by vibration and increase the mass of sand available shall be determined by re-weighing.

**6.3.1.** Put sand in the apparatus and obtain the mass of the apparatus and sand.

**6.3.2.** Seat the inverted apparatus on a clean, level, plane surface.

**6.3.3.** Open the valve and keep open until the sand stops running.

**6.3.4.** Close the valve sharply. Weigh the apparatus with remaining sand and determine the loss of the sand. This loss represents the mass of sand required to fill the funnel.

**NOTE:** For each container/bag of sand there will be a unique cone correction and sand calibration factor. Each sand-cone and matched base plate will also have a set of unique cone corrections and bulk sand densities. If more than one sand-cone apparatus is available, the sand-cone and base plate should be marked and the associated correction/density factors recorded.

**6.3.5.** Replace the sand removed in the funnel determination and close the valve.

**6.4.** Determination of Density of Soil In-Place.

**6.4.1.** Prepare the surface of the location to be tested so that it is a level plane.

**6.4.2.** Seat the inverted apparatus on the prepared plane surface and mark the outline of the funnel. Drill or cut a test hole. Carefully save all material.

**NOTE:** In soils such that leveling is not successful, a preliminary test shall be run at this point measuring the volume bounded by the funnel and ground surface. This step requires balances at the test site or

emptying and refilling the apparatus. After this measurement is complete, carefully brush the sand from the prepared surface.

**6.4.3.** Seat the apparatus in the previously marked position, open the valve, and after the sand has stopped flowing, close the valve.

**6.4.4.** Weigh the apparatus and remaining sand. Determine the mass of sand used in the test.

**6.4.5.** Weigh the material that was removed from the test hole.

**6.4.6.** Mix the material thoroughly and secure and weigh a representative sample for moisture determination.

**6.4.7.** Determine the moisture content in accordance with **KT-11**.

**6.4.8.** The minimum test hole volumes suggested in determining the in-place density of soil mixtures are given in **Table 1**. This table shows the suggested minimum mass of the moisture content sample in relation to the maximum particle size in soil mixtures.

**Table 1**  
**Minimum Field Test Hole Volumes and Minimum Moisture Content Sample Sizes Based on Maximum Size of Particle**

Maximum Particle Size		Minimum Test Hole Volume		Minimum Moisture Content Sample
Sieve	mm	ft <sup>3</sup>	cm <sup>3</sup>	g
No. 4	(4.75)	0.025	(700)	100
1/2 in	(12.5)	0.050	(1400)	250
1 in	(25.0)	0.075	(2100)	500
2 in	(50.0)	0.100	(2800)	1000

**6.5.** Calculations.

**6.5.1.** Calculate the volume of the hole:

$$V_H = \frac{M_{SH}}{D_S}$$

$$M_{SH} = M_I - M_C - M_F$$

Where:

- $D_S$ = Bulk density of the sand, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)
- $M_{SH}$ = Mass of sand required to fill hole lb (kg)
- $V_H$ = Volume of hole in ft<sup>3</sup> (m<sup>3</sup>)
- $M_C$ = Mass of the sand in the cone lb (kg)
- $M_I$ = Initial Mass of the apparatus + sand lb (kg)
- $M_F$ = Final mass of the apparatus + sand lb (kg)

Calculate the volume of the hole to the nearest 0.001 ft<sup>3</sup> (0.00003 m<sup>3</sup>)

**6.5.2.** Calculate the wet density of the material removed from the hole:

$$D_w = \frac{M_w}{V_H}$$

Where:  $D_w$ = Wet density of the material, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
 $M_w$ = Mass of material from the hole, lb (kg)  
 $V_H$ = Volume of hole in ft<sup>3</sup> (m<sup>3</sup>)

Calculate the wet density of the material to the nearest 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>)

**6.5.3.** Calculate the in-place dry density of the material tested:

$$D = \frac{D_w}{W + 100} \times 100$$

Where:  $D_w$ = Wet density of the material, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
 $D$ = Dry density of the material, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
 $W$ = Percent moisture as determined per **Section 5.1.1** of this test method.

Calculate the in-place dry density of the material tested to the nearest 0.1 lb/ft<sup>3</sup>

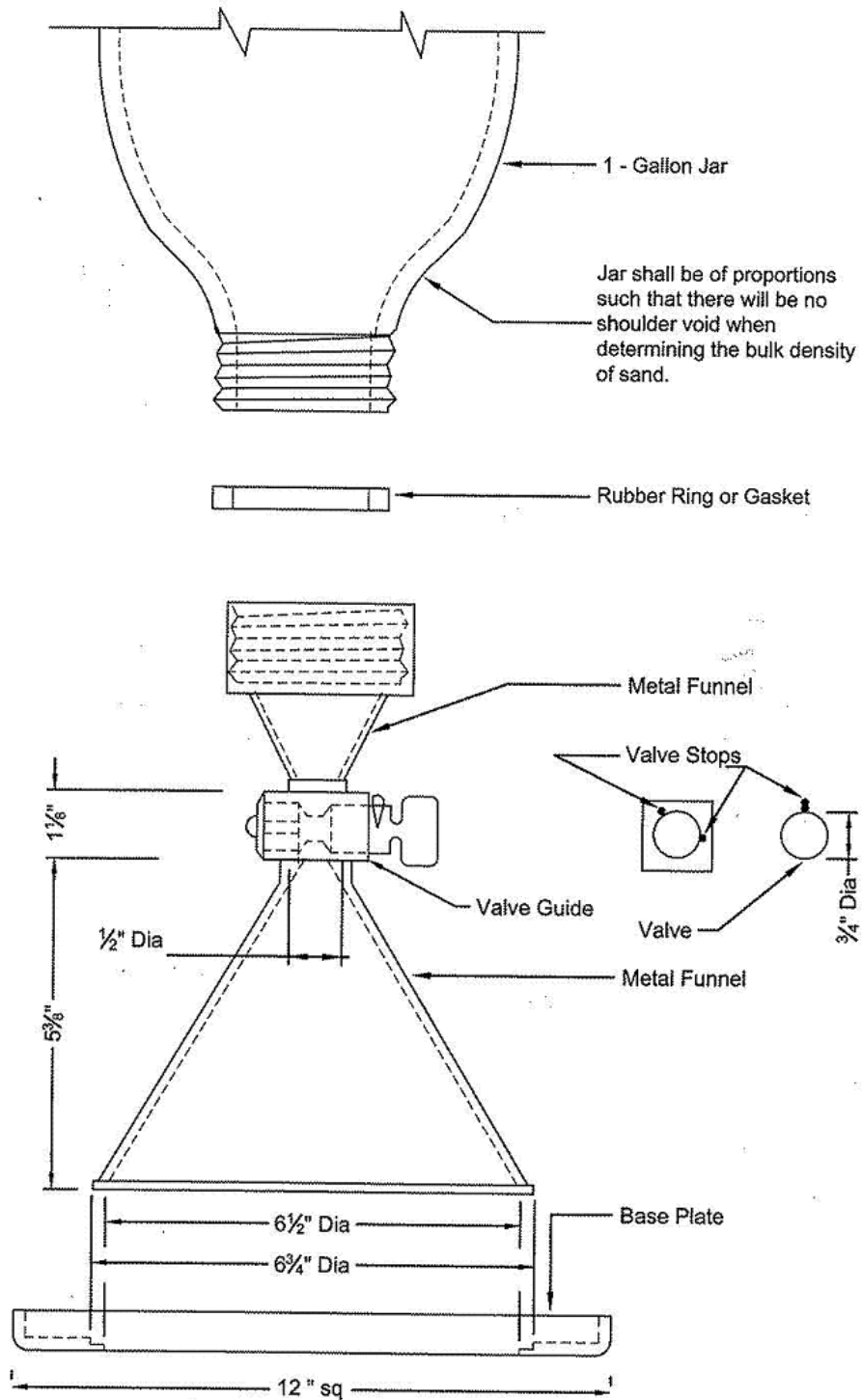
**NOTE:** It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory maximum density determined in accordance with **AASHTO T 99**. This relation can be determined by dividing the in-place density by the maximum density and multiplying by 100.

**NOTE:** 0.001 g/cm<sup>3</sup> = 1 kg/m<sup>3</sup>

**Figure 1**



Figure 2



5.9.14 (5.16.14) MARSHALL TESTS OF BITUMINOUS MIXES  
(Kansas Test Method KT-14)

**a. SCOPE**

This method of test covers the procedures for testing bituminous mixes to determine:

**a.1.** Optimum Asphalt Content.

**a.2.** Density Characteristics, including voids content.

**a.3.** Stability Characteristics, including resistance to plastic flow and flow properties.

**a.4.** This method is limited to mixes containing asphalt cement and containing aggregate having a maximum size of 25 mm (1 in). KT-14 reflects testing procedures found in AASHTO T 245 and T 269.

**b. REFERENCED DOCUMENTS**

**b.1.** KT-15; Bulk Specific Gravity and Unit Weight of Compacted Bituminous Mixtures

**b.2.** KT-57; Determination of Asphalt Content and Gradation of Hot Mix Asphalt Concrete by the Ignition Method

**b.3.** KT-58; Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor

**b.4.** AASHTO M 231; Balances Used in Testing of Materials

**b.5.** AASHTO T 245; Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus

**b.6.** AASHTO T 269; Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures



## **c. APPARATUS**

**c.1. Specimen Mold Assembly:** A cylindrical mold having an inside diameter of  $101.6 \pm 0.25$  mm ( $4.000 \pm 0.010$  in)<sup>1</sup> and a length of approximately 90 mm ( $3 \frac{7}{16}$  in). The mold is open at each end and is equipped with a removable collar and a base plate about 15 mm ( $\frac{9}{16}$  in) in thickness. A minimum of three molds is recommended.

**c.2. Compaction Hammer:** The compaction hammer consists of a hammer having a flat circular tamping face, 98.4 mm ( $3 \frac{7}{8}$  in) in diameter, and appropriate extension rod with handle which acts as guide for a free falling weight. The weight shall weigh  $4,536 \pm 18$  g ( $10 \pm 0.04$  lb) and have a free fall of  $457.2 \pm 2.5$  mm ( $18 \pm 0.1$  in). The hammer may be operated manually or be driven with a motor. Two compaction hammers are recommended.

**c.3. Compaction Pedestal:** The compaction pedestal is a wood block approximately 300 by 300 by 450 mm (12 by 12 by 18 in). A 300 by 300 by 25 mm (12 by 12 by 1 in) steel plate is securely fastened to the top of the block. The pedestal is set on and securely fastened to a solid concrete slab with the vertical axis plumb and the top level.

**c.4. Specimen Mold Holder:** The specimen mold holder has a semi-circular base and a flanged top to hold the specimen mold in place during the compaction process. Any equivalent hold down device which performs the same function is satisfactory.

**c.5. Specimen Extruder:** An extruder for the removal of the specimens from the mold is recommended. The unit may consist of a steel frame to hold the mold, a hydraulic jack and a steel disc approximately 13 mm ( $\frac{1}{2}$  in) thick and 100 mm (3.9 in) in diameter.

**c.6. Testing Assembly:** This includes a breaking head, a load measuring device and two flow meters, dial micrometers or an automatic stability/flow recording device. The testing assembly shall be calibrated at intervals not exceeding two years.

**c.6.a. Breaking Head:** The breaking head consists of two accurately machined cylindrical segments having an inside radius of 50 mm (2 in). The lower segment is mounted on a base having two perpendicular guide rods or posts extending upward. Sleeves in the upper segment are positioned to guide

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<sup>1</sup> AASHTO T 245 requires the specimens to be  $101.6 \pm 0.1$  mm ( $4.000 \pm 0.05$  in).

the two segments together without appreciable binding or loose motion on the guide rods.

**c.6.b.** Flow Meters: Two flow meters graduated in 0.25 mm (0.01 in) increments and conforming to the details set forth in AASHTO T 245 or two micrometer dials graduated in 0.025 mm (0.001 in) increments are used to measure plastic flow. Instead of the flowmeter, a micrometer dial or stress-strain recorder graduated in 0.25 mm (0.01 in) divisions.

**c.6.c.** Loading Device: The loading device may be either a screw jack or a hydraulic system, manually or motor operated to produce a constant vertical movement of  $50 \pm 2$  mm/min ( $2 \pm 0.1$  in/min) during application of load.

**c.6.d.** Load Measuring Device:

**c.6.d.1.** Proving ring assembly consisting of a 20 kN (5,000 lb) capacity proving ring, sensitive to 44.5 N (10 lb) up to 4.45 kN (1,000 lb) and to 111.2 N (25 lb) above 4.45 kN (1,000 lb). The proving ring is equipped with a micrometer dial graduated in 0.0025 mm (0.0001 in) increments.

The upper portion of the ring is attached to the testing frame and the lower portion transmits the load to the breaking head.

**c.6.d.2.** In lieu of the proving ring assembly, any suitable load measuring device may be used providing the capacity and sensitivity meet the above requirements.

**c.7.** Heating Equipment: Ovens or hot plates for heating aggregates, bituminous material, specimen molds, compaction hammers and other associated items required for mixing and molding. It is recommended that, when possible all heating units be thermostatically controlled to maintain the required temperature within  $\pm 2.8^{\circ}\text{C}$  ( $\pm 5^{\circ}\text{F}$ ). Suitable shields, thick steel plates or pans of sand shall be used on the surfaces of hot plates to minimize localized overheating.

**c.8.** Mixing Apparatus: Mechanical mixing is recommended. Any type of mechanical mixer may be used provided it will produce a well coated, homogeneous mixture of the required amount in the allowable time and further that the mixing paddle or whip does not fracture or pulverize aggregate fractions during the mixing process. The bowl employed with the mixer shall be of such a nature that essentially all of the batch can be removed. More than one mixing bowl is recommended unless the mixer is equipped

with a heating jacket to keep the bowl heated during the mixing process.

**c.9.** Water Bath: The water bath shall be approximately 140 mm (5 1/2 in) deep and shall be thermostatically controlled so as to maintain the bath at  $60 \pm 1^{\circ}\text{C}$  ( $140 \pm 2^{\circ}\text{F}$ ). The tank shall have a perforated false bottom or be equipped with a shelf for adequately supporting specimens approximately 50 mm (2 in) above the bottom of the bath.

**c.10.** Miscellaneous Equipment:

**c.10.a.** Containers for heating aggregates, flat-bottom metal pans or other suitable containers.

**c.10.b.** Containers for heating bituminous material, beakers, ointment cans, pouring pots, etc. may be used.

**c.10.c.** Mixing tool, steel towel or spatula, for spading and hand mixing.

**c.10.d.** Thermometers for determining temperatures of aggregate, bitumen and bituminous mixtures. Armored glass or dial type with metal stem thermometers may be used. A range of at least 10 to  $200^{\circ}\text{C}$  ( $50$  to  $400^{\circ}\text{F}$ ) with a sensitivity of  $2.8^{\circ}\text{C}$  ( $5^{\circ}\text{F}$ ) is required.

**c.10.e.** Thermometer for water bath sensitivity to  $0.1^{\circ}\text{C}$  ( $0.2^{\circ}\text{F}$ ).

**c.10.f.** The balance shall conform to the requirements of AASHTO M 231 for the class of general purpose balance required for the principal sample mass of the sample being tested.

**c.10.g.** Large Spoon, for cleaning of mixing bowl or placing mixture in mold cylinders.

**c.10.h.** Specimen height measuring device.

**c.10.i.** Gloves for handling hot equipment.

**c.10.j.** 100 mm (4 in) dia. paper discs.

**d. DETERMINATION OF MIXING AND COMPACTING TEMPERATURE**

**d.1.** The temperatures to which the asphalt cement must be heated to produce a viscosity of  $170 \pm 20$  cSt ( $85 \pm 10$  SFS) shall be the mixing temperature.

**d.2.** The temperature to which the asphalt cement must be heated to produce a viscosity of  $280 \pm 30$  cSt ( $135 \pm 15$  SFS) shall be the compacting temperature.

**e. SAMPLE PREPARATION**

**e.1.** Hot Plant Mixes with Asphalt: Mix the sample of mixed material thoroughly and split out not less than three increments weighing approximately 1,200 g for a 100 mm (4 in) diameter plug. Bring the increments to within the limits of the compacting temperature determined in **d.2.** prior to compacting. See KT-57 **d.** for method of quartering to obtain proper sized sample.

**e.2.** Laboratory Prepared Mixes: *If using hydrated lime as an antistripping agent, then refer to the attached Addendum.*

**e.2.a.** Number of Specimens: It is recommended that each aggregate combination be tested at six different asphalt contents, in 1/2 percent increments. At least three specimens are prepared for each percentage of asphalt. Prepare one extra aggregate and asphalt sample to be mixed first and then thrown away. This sample is to "butter" the mixing bowl and paddle and thus reduce material loss when mixing the test specimens.

**e.2.b.** Preparation of Virgin Aggregates: Dry individual aggregates to constant mass at 105 to 110°C (221 to 230°F). Separate the individual aggregates by dry screening into desired fractions. The following size fractions are recommended as a minimum:

25.0 to 19.0 mm	(1 to 3/4 in)	4.75 to 2.36 mm	(No.4 to No.8)
19.0 to 12.5 mm	(3/4 to 1/2 in)	2.36 to 1.18 mm	(No.8 to No.16)
12.5 to 9.5 mm	(1/2 to 3/8 in)	Passing 1.18 mm	(Passing No.16)
9.5 to 4.75 mm	(3/8 in to No.4)		

**e.2.c.** Preparation of Reclaimed Material: Place the reclaimed material in a 50 to 80°C (125 to 175°F) draft oven for 1 1/2 to 2 hours, to soften. Transfer the materials to the mixing bowl and mix for two minutes in order to breakdown the reclaimed material to the recommended sizes. (Mixer will mix approximately 3,500 g.) Other methods of breakdown are acceptable provided they do not fracture aggregates or lose an

excessive amount of material in the process. Separate the reclaimed material into desired fractions by screening, when cool enough to screen. The following size fractions are recommended:

19.0 to 12.5 mm (3/4 to 1/2 in)	4.75 to 2.36 mm (No.4 to No.8)
12.5 to 9.5 mm (1/2 to 3/8 in)	Passing 2.36 mm (Passing No.8)
9.5 to 4.75 mm (3/8 in to No.4)	

Weigh each fraction and record percentage of total sample.

**e.2.d.** Preparation of Mixes: Combine the individual aggregates or reclaimed material and virgin aggregates by weighing out in a separate pan for each test specimen, proportionate amounts of each size fraction for each individual aggregate to produce the desired combined aggregate with a batch mass of approximately 1,125 g. This should be sufficient to produce a compacted specimen  $64 \pm 3$  mm ( $2.5 \pm 1/8$  in) thick<sup>2</sup>. Adjust the mass of the batch as needed to produce compacted specimens of  $64 \pm 3$  mm ( $2.5 \pm 1/8$  in) thickness.

Heat the aggregate and asphalt within the limits of mixing temperature determined in **d.1**. Charge the mixing bowl with the heated aggregate and form a crater in the top. Add the required amount of asphalt and mix the aggregate and asphalt until thoroughly coated, at least 2 minutes. Care should be taken to keep all of the sample in the mixing bowl during this process.

Place the mix in a  $135^{\circ}\text{C}$  ( $275^{\circ}\text{F}$ ) oven and age<sup>3</sup> the material for 2 hours as outlined in KT-58 **g.5**. At the end of the aging time place the mix in an oven set at the compaction temperature or reset the  $135^{\circ}\text{C}$  ( $275^{\circ}\text{F}$ ) oven temperature to reflect the compaction temperature. Allow the mix to adjust to the new temperature prior to removing for compaction.

**e.2.e.** Compaction of Specimens: Prior to the addition of the asphalt to the batches, thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat the mold assembly and hammer in boiling water, in an oven or on a hot plate, to a temperature between  $90$  and  $175^{\circ}\text{C}$  ( $200$  and  $350^{\circ}\text{F}$ ). Assemble the mold, base plate and collar and place a paper disc cut to size in the bottom of the mold.

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<sup>2</sup> AASHTO T 245 4.1. requires compaction height to be 25.4 mm (1.0 in.) to 76.2 mm (3.0 in.).

<sup>3</sup> The aging process reflects information found in the proposed AASHTO R 30 Standard Practice for Mixture Conditioning of Hot-Mix Asphalt (HMA).

Place the entire hot batch of aggregate-asphalt mixture in the mold, spade vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior of the mold. Smooth the surface of the mix to a slightly rounded shape. The temperature of the mix just prior to compaction shall be within the limits determined in **d.2**. Place a paper disc on top of the mix.

Place the mold assembly, including the collar, on the pedestal, fasten securely with the mold holder and apply 50 or 75 blows<sup>a</sup> with the compaction hammer. Each blow must have the prescribed free fall of 457 mm (18 in) with the axis of the compaction hammer held perpendicular to the base of the mold assembly during the compaction process. Remove the base plate and collar, and reverse and reassemble the mold. Apply the specified number of blows to the reversed specimen. After compaction, remove the mold assembly from the pedestal. Place the mold into the extractor and pop the plug loose from the mold. Permit the plug to cool in this state until the next plug has been processed. Extrude the initial plug out of the mold and pop the next plug loose. Carefully transfer the extruded plug to a smooth, flat surface and allow it to stand until the plug reaches room temperature.

Note **a**: Traffic volume in the Design Lane determines the number of blows. **(See subsection 5.18.02 a.5.a. for traffic volume criteria.)**

**e.2.f.** Thickness of Specimen: Measure the specimen thickness to the nearest 0.025 mm (0.001 in). If the specimen thickness is less than 60 mm (2.375 in) or more than 67 mm (2.625 in), discard it and mold a replacement having a thickness within these limits.

**e.2.g.** Determination of Specific Gravity and Unit Weight: Determine the specific gravity and unit weight by the appropriate method as outlined in KT-15.

**e.2.h.** After determining the specific gravity for all of the specimens, proceed to **f**.

## f. TEST PROCEDURE

Immerse the specimens in a  $60 \pm 1^\circ\text{C}$  ( $140 \pm 2^\circ\text{F}$ ) water bath for 30 to 40 minutes<sup>4</sup>. Thoroughly clean the guide rods and inside surfaces of the test heads prior to making the test. Lubricate the guide rods so that the upper test head slides freely over them. Remove the specimen from the water bath and place in the breaking head. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 sec. Place the complete breaking head assembly in position on the testing machine. Place the flow meters, where used, in position over the guide rods and adjust the flow meters to zero. Hold the flow meters firmly against the upper segment of the breaking head while the test load is being applied. Avoid using excess pressure against the testing head while determining flow.

Apply the load to the specimen by a constant rate of movement of the load jack or testing machine head of 50 mm (2 in) per minute until a maximum load is reached and the load decreases as indicated by the proving ring dial. Record the maximum load noted on the testing machine or converted from the proving ring micrometer dial reading.

Release the flow meter sleeves or note the micrometer dial readings, where used, the instant the maximum load begins to decrease. Note and record the indicated flow values or equivalent units in 0.25 mm (0.01 in) if micrometer dials are used to measure flow.

For specimens other than 62.9 - 64.1 mm (2.476 - 2.525 in) in thickness, adjust the load using the proper correction factor from Table 5.16.14-1.

Table 5.16.14-1 Stability Correction Ratio

Thickness of Specimen in mm (in)	Correction Ratio
60.3 - 61.2 (2.375 - 2.410)	1.07
61.3 - 62.9 (2.411 - 2.475)	1.04
63.0 - 64.1 (2.476 - 2.525)	1.00
64.2 - 65.3 (2.526 - 2.570)	0.97
65.4 - 66.7 (2.571 - 2.625)	0.94

<sup>4</sup> AASHTO T 245 5.2. also permits placing the plug in an oven for 2 hours.

NOTE: The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5 mm (2 1/2 in) specimen.

**g. EVALUATION OF SPECIFIC GRAVITY AND STABILITY DATA:**

**g.1. Specific Gravity of Molded Specimens:**

**g.1.a.** If the difference between the specific gravity of a single specimen in a set of three specimens and the average of the set is greater than 0.025, discard the entire set and mold a new set.

**g.1.b.** If the difference between the specific gravity of a single specimen in a set of three specimens and the average of the set is greater than 0.014 and not greater than 0.025, discard the results of the single specimen and use the results of the tests on the remaining two specimens to compute the average specific gravity of the set.

**g.1.c.** If the difference between the specific gravity of a single specimen in a set of three specimens and the average specific gravity of the set in question is not greater than 0.014, the specific gravity of the specimen is acceptable and may be used to determine the average specific gravity.

**g.2. Stability of Molded Specimens:**

If the difference between the stability of a specimen and the average stability of the set of three specimens is not greater than the CV<sub>1</sub> values shown in Table 5.16.14-2 the specimen is acceptable for use in determining the average stability of the set.

If this difference is greater the CV<sub>1</sub> value but not greater than the CV<sub>2</sub> values, the specimen will be eliminated in the calculation of the average stability. Not less than two specimens will be used when determining the set average stability.

If the difference between the stability of any specimen of a set and the average stability of the set is greater than CV<sub>2</sub> values shown in Table 5.16.14-2, the entire set will be discarded and another set obtained.



Table 5.16.14-2 Stability Evaluation

Stability Range in N (lbf) (Based on Mean of Set)		CV <sub>1</sub>	CV <sub>2</sub>
0 - 2224	(0 - 500)	160 (35)	310 (70)
2228 - 4448	(501 - 1000)	290 (65)	580 (130)
4452 - 6672	(1001 - 1500)	440 (100)	890 (200)
6676 - 8896	(1501 - 2000)	580 (130)	1160 (260)
8900 - 11120	(2001 - 2500)	730 (165)	1470 (330)
11124 - 13344	(2501 - 3000)	870 (195)	1730 (390)
13348 - 15568	(3001 - 3500)	1000 (225)	2000 (450)
15572 - 17792	(3501 - 4000)	1160 (260)	2310 (520)
17796 - 20016	(4001 - 4500)	1290 (290)	2580 (580)
20020 - 22240	(4501 - 5000)	1420 (320)	2850 (640)

**h. REPORT (See section 5.10.04 (5.17.04) for methods of calculation)**

The report includes the following information for each combination of aggregates and each asphalt content:

- h.1.** Average density, kg/m<sup>3</sup> (lb/ft<sup>3</sup>) for each set of specimens.
- h.2.** Average maximum stability in N (lbf), corrected when required, for each set of specimens.
- h.3.** Average flow value, in 0.25 mm (hundredths of an inch), for each set of specimens.
- h.4.** Average mixing temperature, °C (°F), for each set of specimens.
- h.5.** Average compacting temperature, °C (°F), for each set of specimens.
- h.6.** Stability and flow test temperature, °C (°F).
- h.7.** Average % voids, total mix, for each set of specimens, (Pa) (See Section 5.10.4 (5.17.04)).
- h.8.** Average % of total voids filled with asphalt for each set of specimens (VFA).

**h.9.** Average % of voids in aggregate only (VMA).

**h.10.** Maximum percentage of asphalt allowed for high temperature protection (P'b).

**h.11.** Recommended asphalt percentage for initial plant operation.

**h.12.** Bearing Capacity.

**h.13.** Theoretical Maximum Specific Gravity.

Show values for **h.1.**, **h.2.**, **h.7.**, **h.8.**, **h.9.**, **h.12.**, and **h.13.** using KDOT Form 701.

**ADDENDUM TO KT-14  
FOR INCLUDING LIME AS AN ANTISTRIPPING AGENT**

The following information provides KT-14 with steps to incorporate hydrated lime as an antistripping agent.

**Delete e.2.d.** and replace with the following:

**e.2.d.** Preparation of Mixes: Combine the virgin aggregates by weighing in a separate pan for each test specimen, proportionate amounts of each size fraction for each individual aggregate to produce the desired combined aggregate with a batch mass of approximately 1,125 g. Include the hydrated lime mass required to meet the specified percent of lime for the project as part of the total batch mass. The total aggregate mass should include lime, virgin aggregate, and reclaimed material (if applicable). This should be sufficient to produce a compacted specimen  $64 \pm 3$  mm ( $2.5 \pm 1/8$  in) thick. Adjust the mass of the batch as needed to produce compacted specimens of  $64 \pm 3$  mm ( $2.5 \pm 1/8$  in) thickness.

**e.2.d.1.** Determine the SSD for the combined aggregate gradation. Add three percent of moisture to the percent moisture required to reach the SSD condition of the combined aggregate.

**e.2.d.2.** Place the combined virgin aggregate and hydrated lime in a mixing bowl. Carefully mix until the hydrated lime is combined with the aggregate. Add the appropriate water content, as determined in **e.2.d.1.**, and thoroughly mix.

**e.2.d.3.** Oven dry the aggregate mix at approximately  $110^{\circ}\text{C}$  ( $230^{\circ}\text{F}$ ) to a constant mass.

**e.2.d.4.** Combine the virgin aggregate material with the reclaimed material, if applicable, and thoroughly mix. Heat the combined aggregate and asphalt within limits of the mixing temperature determined in **d.1.** Charge the mixing bowl with the heated aggregate and form a crater in the top. Add the required amount of asphalt and mix the aggregate and asphalt until thoroughly coated, at least 2 minutes. Care should be taken to keep all of the sample in the mixing bowl during this process.

5.9.15 BULK SPECIFIC GRAVITY AND UNIT WEIGHT OF COMPACTED HOT MIX ASPHALT (HMA) (Kansas Test Method KT-15)

**1. SCOPE**

This method of test covers the procedure for determining the bulk specific gravity of specimens of compacted asphalt mixtures. The specimens may have been molded in the laboratory or cut or cored from compacted pavements. **KT-15** reflects testing procedures found in **AASHTO T 166** and **AASHTO T 331**.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9.; Sampling and Test Methods Foreword

**2.2.** AASHTO T 166; Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface – Dry Specimens

**2.3.** AASHTO T 331; Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Wire basket formed of No. 4 (4.75 mm) mesh hardware cloth, 1/4 in (6.3 mm) mesh or perforated shelf or suitable bucket. The size shall be sufficient to fully support the specimen.

**3.3.** Container with overflow device, for immersing the wire basket, shelf or bucket in water and maintaining a constant water level.

**3.4.** Measuring device to establish the physical dimensions of a specimen.

**3.5.** Vacuum chamber with a 1.25 h (0.93kW) pump capable of evacuating a sealed and enclosed chamber to 29.5 in Hg vacuum (100 kPa vacuum) in less than 60 seconds. The chamber shall be large enough to seal samples of 6 in (150 mm) wide by 14 in (350 mm) long by 6 in (150 mm) thick. The device shall automatically seal the plastic bag and exhaust air back into the chamber in a controlled manner to ensure proper conformance of the plastic to the asphalt specimen.

**3.6.** Plastic bags used with the vacuum device shall be one of the two following sizes. The smaller bags shall have a minimum opening of 9.25 in (235 mm) and a maximum opening 10.25 in (260 mm). The larger bags shall have a minimum opening of 14.75 in (275 mm) and a maximum opening of 15.5 in (294 mm).

**3.7.** Specimen sliding plate used within the vacuum chamber for reduction of friction on the plastic bags.

## 4. PROCEDURE

**4.1.** The bulk specific gravity of a compacted asphalt mix specimen is determined by computing the ratio of its mass in air to its bulk volume. Procedure I is a rapid method which generally provides sufficient accuracy for the routine testing of specimens with dense, impermeable surfaces. Procedure II corresponds to **AASHTO T 331** test method for Bulk Specific Gravity and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method. Procedure III is a laboratory method which is used to determine the bulk specific gravity of saturated specimens, and corresponds to **AASHTO T 166, Method A**. This method is most suitable for testing specimens with slightly permeable surfaces in order to obtain the water absorption. Procedure IV is a method which establishes the bulk specific gravity of specimens which are composed of “open” mixes that typically display high porosity and permeability. In the event of dispute, Procedure IV will take precedence over Procedures I & II. Marshall and Superpave design specimens molded at the estimated “optimum” asphalt content will be subjected to Procedure III to determine the water absorption (by volume). If the water absorption is equal to or greater than 2.0%, Procedure II shall be used for both design and routine or field purposes.

**4.1.1.** Constant mass shall be defined as the mass at which further drying does not alter the mass by more than 0.05%. Initially dry the specimen overnight by either placing in an oven at  $125 \pm 5^\circ \text{F}$  ( $52 \pm 3^\circ \text{C}$ ) or by placing in front of a fan on an elevated wire rack and then weigh the next day at one-hour<sup>1</sup> intervals.

**4.1.2.** Specimens are defined to be at room temperature when meeting the following procedure: Check surface temperature. Let the specimen set for 5 minutes while at ambient air conditions (no flow of any type should be flowing across the specimen). Recheck the surface temperature. The original check and recheck must fall within  $77 \pm 5^\circ \text{F}$  ( $25 \pm 3^\circ \text{C}$ ) or the specimen temperature has not stabilized to room temperature.

### 4.2. Procedure I

**4.2.1.** Weigh specimen at room temperature to the nearest 0.1 g after it has attained room temperature.

**4.2.2.** Place the specimen in the basket or bucket and determine its mass to the nearest 0.1 g while immersed in water with a temperature of  $77 \pm 2^\circ \text{F}$  ( $25 \pm 1^\circ \text{C}$ ). The mass of the specimen in water shall be determined as quickly as possible after the specimen is immersed. This method should not be used if the specimen contains open or interconnecting voids.

### 4.3. Procedure II

**4.3.1.** Dry the specimen to constant mass and weigh it to the nearest 0.1g.

**4.3.2.** Cool the specimen to room temperature.

**4.3.3.** Select an appropriate size bag. For all 4 in (100 mm) diameter samples and samples with 6 in (150 mm) diameter and less than 2 in (50 mm) thickness, it is possible to use the bag with the smaller opening size.

**4.3.4.** Place a bag inside the vacuum chamber on top of the sliding plate.

**4.3.5.** Gently open the bag and place the specimen in the plastic bag on top of the sliding plate, while being careful not to handle the bag in such a manner that would create a puncture.

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<sup>1</sup> **AASHTO T 166** and **T 331** require a two-hour interval.

**4.3.6.** Allow the vacuum chamber to remove the air from the chamber and the plastic bag. The vacuum chamber shall automatically seal the bag once the air is removed.

**4.3.7.** Exhaust air into the chamber until the chamber door opens indicating atmospheric pressure within the chamber. The chamber door latch can be used to avoid automatic opening of the door after completion of the test.

**4.3.8.** Remove the sealed specimen from the vacuum chamber. Handle the sealed specimen with extreme care.

**4.3.9.** Weigh the sealed specimen in air to the nearest 0.1g.

**4.3.10.** Weigh the sealed specimen while immersed in water at  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ) to the nearest 0.1 g. Verify that no air bubbles are entrapped underneath the plastic bag material. This can be accomplished by placing the sealed specimen in water with the plastic bag oriented in a vertical direction.

**4.3.11.** Reweigh the sealed specimen in air to the nearest 0.1 g.

#### **4.4. Procedure III**

**4.4.1.** For cores, dry the specimen to constant mass. Cool the specimen to room temperature and weigh the dry mass to the nearest 0.1 g, and record as A. Immerse the specimen in a  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ) water bath, let saturate for  $4 \pm 1$  minutes, then weigh and record mass as C. Remove the immersed and saturated specimen from the water bath, quickly damp dry the saturated specimen with a damp absorbent cloth and as quickly as possible, weigh and record the specimen as B. Any water which seeps from the specimen during the weighing operation is considered as part of the saturated specimen.

**NOTE:** If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of saturated damp dry specimen can be taken. Then the saturated specimen in water can be weighed. The dry mass of the specimen can be determined last.

**NOTE:** Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

#### **4.5. Procedure IV**

**4.5.1.** Dry the specimen to constant mass.

**4.5.2.** After the specimen has cooled to room temperature, weigh it to the nearest 0.1 g (see **Section 4.4.1.1** of this test method).

**4.5.3.** Measure the height of the specimen to the nearest 0.001 in (0.025 mm) at four approximately equally spaced locations and average the four measurements. The diameter of the test specimen shall be determined to the nearest 0.001 in (0.025 mm) by averaging three diameters measured at approximately  $120^{\circ}$  from each other at about mid-height of the specimen. The average diameter shall be used in calculations.

## 5. CALCULATIONS

A = Mass of dry specimen in air, g.

B = Mass of saturated specimen in air after 4 minutes in water, g.

C = Mass of saturated specimen in water, g.

D = Mass of sealed specimen in air, g.

E = Mass of sealed specimen in water, g.

F = Apparent specific gravity of plastic sealing material at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ).

V = Calculated volume of specimen at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ).

G = Mass of specimen weighed immediately in water, g.

d = Specimen diameter (in [mm]).

h = Specimen height (in [mm]).

### 5.1. Procedure I: Bulk Specific Gravity ( $G_{mb}$ )

$$G_{mb} = \frac{A}{(A-G)}$$

### 5.2. Procedure II: Bulk Specific Gravity of Plastic Sealed Specimens

$$G_{mb} = \frac{A}{(D - E) - \left(\frac{D-A}{F}\right)}$$

### 5.3. Procedure III: Bulk Specific Gravity and Absorption of Saturated Samples

$$G_{mb} = \frac{A}{(B-C)}$$

Calculate the percent of water absorbed by the specimen as follows:

$$\% \text{ Water Absorbed (Volume Basis)} = \frac{100 \times (B - A)}{(B - C)}$$

#### 5.4. Procedure IV: Bulk Specific Gravity by Physical Dimensions

$$\text{Vol (in}^3\text{)} = (0.7854) (d^2) (h) \text{ (English)}$$

$$\text{Vol (mm}^3\text{)} = (0.7854) (d^2) (h) \text{ (SI)}$$

$$\text{Unit wt. (lb/ft}^3\text{)} = \frac{3.8096 (\text{mass in grams})}{\text{Volume in in}^3} \text{ (English)}$$

$$\text{Unit wt. (kg/m}^3\text{)} = \frac{1,000,000 (\text{mass in grams})}{\text{Volume in mm}^3} \text{ (SI)}$$

$$G_{mb} = \frac{\text{Unit weight in lb/ft}^3}{62.243^d} \text{ (English)}$$

$$G_{mb} = \frac{\text{Unit weight in kg/m}^3}{997.04^d} \text{ (SI)}$$

**NOTE:** Density of water varies based on temperature. Since the water bath temperature is fixed at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ), use the specified values. For tests not restrained by the  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ) requirement, temperature correction can be determined by selecting the proper density for water from **Table 1**.



**Table 1  
Density of Water**

°C	Temperature		kg/m <sup>3</sup>	Density	
		°F			lb/ft <sup>3</sup>
15		59.0	999.09		62.371
16		60.8	998.94		62.362
17		62.6	998.77		62.351
18		64.4	998.60		62.341
19		66.2	998.40		62.328
20		68.0	998.20		62.316
21		69.8	997.99		62.302
22		71.6	997.77		62.289
23		73.4	997.54		62.274
24		75.2	997.30		62.259
25		77.0	997.04		62.243
26		78.8	996.78		62.227
27		80.6	996.50		62.209
28		82.4	996.23		62.193
29		84.2	995.94		62.175
30		86.0	995.65		62.156
31		87.8	995.34		62.137
32		89.6	995.03		62.118
33		91.4	994.70		62.097
34		93.2	994.37		62.077
35		95.0	994.03		62.055

**NOTE:** The table was derived from the table 10-28 of Lange’s Handbook of Chemistry; Twelfth Edition; Copyright 1979.

**5.5. SG<sub>corr.</sub>**

$$SG_{corr.} = \left( \frac{d_w}{997.04} \right)$$

Where:  $d_w$  = density of water at temperature other than 77 ± 2°F (25 ± 1°C).

**6. PRECISION**

**6.1.** Duplicate determinations by multi laboratory, multi operator shall check to within 0.031. This value is derived from the 2006 Independent Assurance Gyratory Comparisons.

5.9.16. VOLATILE DISTILLATE CONTENT AND MOISTURE CONTENT OF BITUMINOUS MIXES (Kansas test Method KT-16)

**DELETED**

(April 2010)



## 5.9.17 SAMPLING FRESHLY MIXED CONCRETE (Kansas Test Method KT-17)

### **1. SCOPE**

This method describes the procedures for obtaining representative samples of freshly mixed concrete as delivered to the project site and on which tests are to be performed to determine conformance with quality requirements of the specifications under which the concrete is furnished.

**NOTE:** Composite samples are required by this method, unless specifically expected by procedures governing the tests to be performed such as tests to determine uniformity of consistency and mixer efficiency. Procedures used to select the specific test batches are not described in this method, but it is recommended that random sampling be used to determine overall specification compliance.

### **2. REFERENCED DOCUMENTS**

**2.1.** None

### **3. APPARTUS**

**3.1.** Square point shovel.

**3.2.** Wheelbarrow or other suitable water-tight container for transporting the sample to the site where it will be remixed and tested.

**3.3.** Metal or plywood sheet or concrete slab on which the concrete can be placed for remixing and testing.

**3.4.** Shade-windbreak combination that will protect the fresh concrete from the sun and wind during testing.

**3.5.** A sample receptacle designed and constructed so that it can be passed through a stream of fresh concrete being discharged from a mixer or pump.

### **4. SAMPLE SIZE**

**4.1.** Strength and yield tests: not less than 1 ft<sup>3</sup> (0.03 m<sup>3</sup>). Smaller samples may be permitted for routine air content and slump tests and size shall be dictated by the maximum aggregate size.

### **5. SAMPLING PROCEDURE**

**5.1.** The procedures used in sampling shall include the use of every precaution that will assist in obtaining samples that are truly representative of the nature and condition of concrete sampled.

**NOTE:** As routine air content and slump tests are not readily adaptable to sampling the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch as specified in this method, the sample for air content, slump, and temperature may be taken after at least one-quarter cubic yard of concrete has been discharged.

### **5.1.1 Sampling from pavement and bridge deck overlays:**

Using a square point shovel, collect portions of the sample from three different locations within the batch after placement. In any case do not obtain samples until after all of the water has been added to the mix; also do not obtain samples from the very first or last portions of the batch discharge. Use caution to avoid contamination of the sample from subgrade or other foreign material. Composite the samples so obtained into one sample for test purposes.

### **5.1.2 Sampling from shafts, piers, caps and other formwork:**

Sample the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch. Care should be taken to sample from the same elevation as the concrete is being placed. For example: If placing concrete for a haunch slab deck, try to sample from the discharge at the deck elevation not from the ground if the pump is placed below the deck. Take the samples so obtained within the limit specified in **Section 5.3** of this test method and composite them into one sample for test purposes. In any case do not obtain samples until after all of the water has been added to the mix; also do not obtain samples from the very first or last portions of the batch discharge. Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Composite the samples so obtained into one sample for test purposes.

**NOTE:** No sample should be taken before 10% or after 90% of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and end of the load.

**5.2.** Immediately transport the sample to the place where test specimens are to be molded or where the test is to be made, and remix with a shovel the minimum amount that will ensure uniformity and compliance with the minimum time limits specified in **Section 5.3** of this test method. The sample shall be protected at all times from sunlight and wind.

**5.3.** The elapsed time between obtaining the first and final portions of the composite samples shall be as short as possible, but in no instance shall it exceed 15 minutes.

**5.3.1.** Tests for air and/or slump shall be started within 5 minutes after sampling is completed. These tests should then be completed as expeditiously as possible. Molding of specimens for strength tests shall be started within 15 minutes after obtaining the sample.

**5.3.1.1.** Concrete used in one test may not be reused for any other test. It may be returned to the forms if maximum time from batching has not been exceeded or adverse conditions have not caused excessive drying of the concrete.

## **6. DETERMINING TEMPERATURE OF THE SAMPLE**

**6.1.** Determine the temperature of a sample by submerging the thermometer at least 3 in (75 mm) in the fresh concrete. Leave the thermometer in place until the thermometer reading stabilizes, then read and record temperature. This process should take place within 5 minutes of receiving the sample.

5.9.18 AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD  
(Kansas Test Method KT-18)

**1. SCOPE**

**1.1.** This method of test covers the procedure for determining the air content of freshly mixed concrete by the pressure method. **KT-18** reflects testing procedures found in **AASHTO T 152**.

**1.2.** This method is intended for use with concrete and mortar made with relatively dense aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in **Section 4** of this test method. It is not applicable to concrete made with lightweight aggregates, air-cooled blast furnace slag or aggregates of high porosity. This test method is not applicable to nonplastic concrete such as commonly used in the manufacture of pipe and concrete masonry units.

**2. REFERENCED DOCUMENTS**

**2.1.** KT-17; Sampling Freshly Mixed Concrete

**2.2.** KT-20; Mass Per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete

**2.3.** AASHTO T 152; Air Content of Freshly Mixed Concrete by the Pressure Method<sup>1</sup>

**3. APPARATUS**

**3.1** An air meter consisting of a measuring bowl and cover assembly conforming to the requirements of **Section 3.2** of this test method. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure being calibrated in terms of percent air for observed pressure at which equalization takes place. Working pressures of 7.5 to 30.0 psi (51 to 207 kPa) have been used satisfactorily.

**3.2.** The measuring bowl shall be essentially cylindrical in shape, made of steel, hard metal or other hard material not readily attacked by the cement paste, having a minimum diameter equal to 0.75 to 1.25 times the height, and a capacity of at least 0.20 ft<sup>3</sup> (0.006 m<sup>3</sup>). It shall be flanged or otherwise constructed to provide for a pressure-tight fit between the measuring bowl and cover assembly. The interior surfaces of the measuring bowl and surfaces of rims, flanges and other component fitted parts shall be machined smooth. The measuring bowl and cover assembly shall be sufficiently rigid to limit the expansion factor, D, of the apparatus assembly (see **Section 7.4.1** of this test method) to not more than 0.1 % of air content on the indicator scale when under normal operating pressure.

**3.3.** Cover Assembly:

**3.3.1.** The cover assembly shall be made of steel, hard metal or other hard material not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between measuring bowl and cover assembly and shall have machined-smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover shall be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in **Section 3.2** of this test method.

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<sup>1</sup> While **AASHTO** and **ASTM** allow use of two types of pressure meters, Type A and Type B, **KDOT** allows only Type B meters.

**3.3.2.** The cover shall be fitted with a dial for direct reading of the air content. The dial of the pressure gauge shall be calibrated to indicate the percent air. Graduations shall be provided for a range in air content of at least 8 % easily readable to 0.1 % as determined by the proper air pressure calibration test.

**3.3.3.** The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary. Suitable means for clamping the cover to the measuring bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and measuring bowl. A suitable hand pump shall be provided with the cover either as an attachment or as an accessory.

**3.4.** The calibration vessel is a measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent of air in the concrete to be tested; or if smaller, it shall be possible to check calibration of the meter indicator at the approximate percent of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape and of an inside depth 0.5 in (13 mm) less than that of the measuring bowl. A satisfactory measure of this type may be machined from No. 16 gauge brass tubing, of a diameter to provide the volume desired, to which a brass disk 0.5 in (13 mm) in thickness is soldered to form an end. When the design of the meter requires withdrawing of water from the water-filled measuring bowl and cover assembly to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above described cylinder.

**3.5.** Tamping rod shall be a round straight steel rod, 0.625 in  $\pm$  0.0625 in (16 mm  $\pm$  2 mm) in diameter and not less than approximately 16 in (400 mm) in length but not greater than 24 in. (600 mm), in length having the tamping end rounded to hemispherical tip the same diameter as the rod.

**3.6.** A mallet (with a rubber or rawhide head) weighing approximately 1.25  $\pm$  0.50 lb (0.57  $\pm$  0.23 kg) for use with measures of 0.5ft<sup>3</sup> (0.014 m<sup>3</sup>) or smaller, and a mallet weighing approximately 2.25  $\pm$  0.50 lb (1.02  $\pm$  0.23 kg) for use with measures larger than 0.5 ft<sup>3</sup> (0.14 m<sup>3</sup>).

**3.7.** The strike off bar is a flat straight bar of steel or other suitable metal at least 0.125 in (3 mm) thick and 0.75 in (20 mm) wide by 12 in (300 mm) long.

**3.8.** The strike off plate is a flat rectangular metal plate at least 0.25 in (6 mm) thick or a glass or acrylic plate at least 0.5 in (12 mm) thick with a length and width at least 2 in (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 0.0625 in (1.5 mm).

**3.9.** Vibrators, internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 per minute or greater while in use. The outside diameter or side dimension of the vibrating elements shall be at least 0.75 in (19 mm) and not greater than 1.50 in (38 mm). The combined length of the shaft and vibrating element shall exceed the maximum depth of the section being vibrated by at least 3 in (76 mm). External vibrators may be of two types: table or plank. The frequency for external vibrators shall not be less than 3,600 per minute, and preferably higher. For both table and plank vibrators, provision shall be made for clamping the measuring bowl securely to the apparatus. A vibrating-reed tachometer should be used to check the frequency of vibration.

**3.10** A scoop of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measuring bowl.

## 4. DETERMINATION OF AGGREGATE CORRECTION FACTOR

### 4.1. Procedure:

**4.1.1.** Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in **Section 4.2 and 4.4** of this test method. It is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount and proportions occurring in the concrete sample under test.

### 4.2. Aggregate Sample Size:

**4.2.1.** Calculate the mass of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$$(1) F_s = \frac{(S)(F_b)}{B}$$

$$(2) C_s = \frac{(S)(C_b)}{B}$$

Where:

- $F_s$  = Mass of fine aggregate in concrete sample under test, lb (kg)
- $S$  = Volume of concrete sample (same as volume of measuring bowl), ft<sup>3</sup> (m<sup>3</sup>)
- $B$  = Volume of concrete produced per batch, ft<sup>3</sup> (m<sup>3</sup>)
- $F_b$  = Total mass of fine aggregate in the moisture condition used in batch, lb (kg)
- $C_s$  = Mass of coarse aggregate in concrete sample under test, lb (kg)
- $C_b$  = Total mass of coarse aggregate in the moisture condition used in batch, lb (kg)

**NOTE:** The volume of concrete produced per batch can be determined in accordance with applicable provisions of **KT-20**.

### 4.3. Placement of aggregates in measuring bowl:

**4.3.1.** Mix representative samples of fine aggregate  $F_s$  and coarse aggregate  $C_s$  and place in measuring bowl filled one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly. Tap the sides of the bowl and lightly rod the upper 1 in (25 mm) of the aggregate about ten times. Stir after each addition of aggregate to eliminate entrapped air.

### 4.4. Aggregate Correction Factor Determination:

#### 4.4.1. Initial Procedure:

**4.4.1.1.** When all the aggregate has been placed in the measuring bowl, remove excess foam and keep the aggregate inundated for a period approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in **Section 4.4.1.2** of this test method.

**NOTE:** The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be easily made and



must not be ignored. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

**4.4.1.2.** Remove a volume of water from the assembled and filled apparatus approximately equivalent to the volume of air that would be contained in a typical concrete sample of a size equal to the volume of the bowl. Remove the water in the manner described in **Section 7.4.1** of this test method. Complete the test as described in **Section 5.8** of this test method. The aggregate correction factor, G, is equal to the reading on the air-content scale minus the volume of water removed from the bowl expressed as a percentage of the volume of the bowl.

## **5. TEST PROCEDURE**

**5.1.** Obtain a sample of freshly mixed concrete in accordance with **KT-17**.

**5.1.1.** Dampen the inside of the bowl with a damp cloth prior to running the test.

**5.2.** Methods of Consolidation:

**5.2.1.** Concrete at different slump levels require different methods of consolidation to prepare satisfactory test specimens. The methods listed below should be used as a guide in determining the type of consolidation to use:

Slump of Concrete	Type of Consolidation
More than 3 in (75 mm)	Rodding
1 to 3 in (25 to 75 mm)	Rodding or Vibration
Less than 1 in (25 mm)	Vibration

**5.3.** Rodding Procedure:

**5.3.1.** Place the concrete in the measuring bowl ~~base~~ in three equal layers.

**5.3.2.** Consolidate each layer of concrete by 25 strokes of the tamping rod evenly distributed over the cross section. Rod the bottom layer throughout its depth, but avoid forcefully striking the bottom of the container. When rodding successive layers, use only enough force to penetrate the surface of the underlying layer about 1 in (25 mm). Add final layer of concrete in a manner to avoid excessive overfilling.

**5.3.3.** After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air the may have been trapped.

**5.4.** Vibration Procedure:

**5.4.1.** Fill the measuring bowl approximately one-half full of concrete. Place all the concrete required for the layer in the measuring bowl before starting vibration.

**5.4.2.** Consolidate the layer by three insertions of the vibrator evenly distributed over the surface. Vibrate only until the concrete is properly consolidated. The duration of vibration will depend on the effectiveness of the vibrator and the consistency of the concrete, but usually sufficient vibration has been applied when the surface of the concrete becomes relatively smooth and glazed in appearance.

**5.4.3.** After each layer is vibrated, tap the sides of the measuring bowl smartly 10 to 15 times with the mallet using such force as to close any voids left by the vibrator and to release any large

bubbles of air that may have been trapped.

**5.4.4.** Fill the measuring bowl to an elevation somewhat above the top rim and vibrate this second layer. A smaller quantity of concrete may be added to correct a deficiency. If the measuring bowl contains a great excess of concrete at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately and before the measuring bowl is struck off.

#### **5.4.4. Special Precautions.**

**5.4.4.1.** Do not allow the vibrator to rest on the bottom or touch the sides of the measuring bowl when vibrating the bottom layer.

**5.4.4.2.** When vibrating the top layer, penetrate that layer and approximately the 1 in (25 mm) of the bottom layer.

**5.4.4.3.** Withdraw the vibrator in such a manner that no air pockets are left in the specimen.

#### **5.5. Strike Off**

**5.5.1** After consolidation of the concrete, strike off the top surface using the strike off bar or plate. Strike off with the bar by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the measuring bowl is just level full. Strike off the concrete with the strike-off plate by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdraw the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure. Hold the plate at an incline and apply the final strokes to produce a smooth finished surface. On completion of consolidation, the measuring bowl must not contain an excess or deficiency of concrete. Removal of approximately 0.125 in. (3 mm) during strike off is optimum. A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off. Thoroughly clean the flanges of the measuring bowl and the cover to ensure an air-tight fit.

**5.6.** Clamp on the cover with the petcocks open and close the air valve between the air chamber and the measuring bowl.

**5.7.** Using a rubber syringe, inject water through one petcock until water is expelled through the opposite petcock. Jar meter gently until all air is expelled from this same petcock. Leave petcocks open.

**5.8.** Close the air bleeder valve on the air chamber and pump air into the air chamber until the gauge hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding off air as necessary, tapping the gauge lightly by hand. Close both petcocks on the holes through the cover. Open the air valve between the air chamber and the measuring bowl. Hold the air valve open until the gauge reading is complete. Tap the sides of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gauge by hand to stabilize the gauge hand and read the percentage of air on the dial of the pressure gauge. Close the air valve. Failure to close the main air valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber it must be bled from the air chamber through the bleeder valve followed by several strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks before removing the cover.

5.9. Clean the measuring bowl, cover and petcock openings.

## 6. CALCULATION

6.1. Calculate the air content of the concrete in the measuring bowl as follows:

$$A_s = A_1 - G$$

Where:  $A_s$  = air content of sample tested, percent  
 $A_1$  = apparent air content of the sample tested, percent  
 $G$  = aggregate correction factor, percent

## 7. CALBRATION OF METER GAUGE

7.1. Calibration of the Calibration Vessel:

7.1.1. Determine accurately the mass of water,  $w$ , required to fill the calibration vessel, using a scale accurate to 0.1 % of the mass of the vessel filled with water.

7.2. Calibration of the measuring bowl:

7.2.1. Determine the mass of water,  $W$ , required to fill the measuring bowl, using a scale accurate to 0.1 % of the mass of measuring bowl filled with water. Slide a glass plate carefully over the flange of the measuring bowl in a manner to ensure that the measuring bowl is filled with water. A thin film of cup grease smeared on the flange of the measuring bowl will make a watertight joint between the glass plate and the top of the measuring bowl.

7.3. Effective volume of the calibration vessel,  $R$ :

7.3.1. The constant  $R$  represents the effective volume of the calibration vessel expressed as a percentage of the volume of the measuring bowl. Calculate  $R$  as follows:

$$R = (w/W) * 100$$

Where:  $w$  = weight of water required to fill the calibration vessel  
 $W$  = weight of water required to fill the measuring bowl.

7.4. Determination of, or check of, allowance for expansion factor,  $D$ :

7.4.1. The allowance factor for the expansion factor,  $D$ , is included in the difference between the initial pressure indicated on the pressure gauge and the zero percent mark on the air-content scale on the pressure gauge. This allowance shall be checked by filling the apparatus with water (making certain all entrapped air has been removed), pumping air into the air chamber until the gauge hand is stabilized at the indicated initial pressure line, and then releasing the air to the measuring bowl. If the initial pressure line is correctly positioned, the gauge should read zero percent. The initial pressure line shall be adjusted if two or more determinations show the same variation from zero percent and the test repeated to check the adjusted initial pressure line.

**NOTE:** This procedure may be accomplished in connection with the calibration test described in **Section 7.4.3.**

**7.4.2.** Calibration reading, K, is the final meter reading to be obtained when the meter is operated at the correct calibration pressure. The calibration reading, K, equals the effective volume of the calibration vessel as follows:

$$K = R$$

**7.4.3.** Calibration test to check the air content graduations on the pressure gauge:

**7.4.3.1.** Fill the measuring bowl with water as described in **Section 7.2.1** of this test method. For meters with external calibration vessels and tubes provided: Screw the short piece of straight tubing or pipe provided with the apparatus into the threaded petcock hole on the underside of the cover assembly. Assemble the apparatus with the tube extending down into the water in the measuring bowl. Close the air valve between the air chamber and the measuring bowl and open the two petcocks on holes through the cover assembly. Use the syringe to add water through the petcock on the cover assembly with the extension below until all air is expelled from the opposite petcock. For meters with calibration cylinders to be placed in the measuring bowl, lower the calibration cylinder straight down into the water with the open end down, facing the bottom of the measuring bowl. The calibration cylinder must be full of air during the calibration procedure.

**7.4.3.2.** For meters with external calibration vessels and tubes: Pump air into the air chamber until the pressure reaches just beyond the indicated initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature and for the gauge hand to stabilize. Stabilize the gauge hand at the initial pressure line by pumping or bleeding off air as necessary, tapping the gauge lightly. Close both petcocks and open the air valve as described in **Section 7.4.1**. Screw the curved tube provided into the threaded outside opening of the petcock with the straight tube below. Carefully fill the calibration vessel level full of water from the curved tube, using the petcock lever and the air valve between the air chamber and the measuring bowl to control the flow. The flow can be controlled by opening the petcock provided with the tube or pipe extension and cracking open the air valve between the air chamber and the measuring bowl, or by opening the air valve and using the petcock to control flow.

**7.4.3.3.** For meters with external calibration vessels and tubes: Perform the calibration at an air content which is within the normal range of use. If the calibration vessel has a capacity within the normal range of use, remove exactly that amount of water. With some meters the calibrating vessel is quite small and it will necessary to remove several times that volume to obtain air content within the normal range of use. In this instance, carefully collect the water in an auxiliary container and determine the amount removed by weighing to the nearest 0.1 %.

**7.4.3.4.** Calculate the correct air content, R. For meters with external calibration vessels and tubes, use the equation in **Section 7.3.1** of this test method. Release the air from the apparatus at the petcock not used for filling the calibration vessel and if the apparatus employs an auxiliary tube for filling the calibration container, open the petcock to which the tube is connected to drain the tube back into the measuring bowl. At this point of the procedure the measuring bowl contains the percentage of air determined by the calibration test of the calibrating vessel. For meters with calibration cylinders to be placed in the measuring bowl, the correct air content is indicated on the calibration cylinder.

**7.4.3.5.** With both petcocks open, pump air into the air chamber until the pressure reaches the initial pressure line marked on the pressure gauge, close both petcocks in the cover assembly, and then open the valve between the air chamber and the measuring bowl. The indicated air content on the pressure gauge dial should correspond to the percentage of air determined to be in the measuring bowl. If two or more determinations show the same variations from the correct air content, the dial hand shall reset to the correct air content and the test repeated until the gauge reading corresponds to the calibrated air content with 0.1 %.

If the dial hand was reset to obtain the correct air content, recheck the initial pressure mark as in **Section 7.4.1** of this test method. If a new initial pressure reading is required, repeat the calibration to check the accuracy of the gradation on the pressure gauge described earlier in this section. If difficulty is encountered in obtaining consistent readings, check for leaks, for the presence of water in the air chamber, or the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool aerated water. In this latter instance use de-aerated water which can be obtained by cooling hot water to room temperature.

**NOTE:** If the calibrating vessel is an integral part of the cover assembly, the petcock used in filling the vessel shall be closed immediately after filling the calibration vessel and not opened until the test is complete.

## **8. Record**

**8.1.** The masses determined to the nearest 0.001 lbs. (0.1 g).

**8.2.** The volume of the measuring bowl to the nearest 0.0001 cu.ft.

**8.3.** The effective volume of the calibration vessel (R) to the nearest 0.1 %.

## **9. Report**

**9.1.** The air content of the concrete sample to the nearest 0.1 % after subtracting the aggregate correction factor, unless the gauge reading of the meter exceeds 8 %, in which case the corrected reading shall be reported to the nearest one-half scale division on the dial.

**9.2.** The time and date of the test.

5.9.19 AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE VOLUMETRIC METHOD  
(Kansas Test Method KT-19)

**1. SCOPE**

This method of test covers the procedure for determining the air content of freshly mixed concrete. It is applicable to concrete containing normal, dense, light weight or cellular aggregate. **KT-19** reflects testing procedures found in **AASHTO T 196**.

**2. REFERENCED DOCUMENTS**

**2.1.** KT-17; Sampling Freshly Mixed Concrete

**2.2.** KT-20; Mass Per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete

**2.3.** AASHTO T 196; Air Content of Freshly Mixed Concrete by the Volumetric Method

**3. APPARATUS**

**3.1.** Air meter consisting of a bowl and top section meeting the following requirements.

**3.1.1.** The bowl shall be constructed of sufficient thickness and rigidity to withstand normal field use and resistant to attack by cement paste. The bowl shall have a diameter equal to 1 to 1.25 times the height and be constructed with a flange at or near the top surface. The bowl will have a capacity of not less than 0.075 ft<sup>3</sup> (0.002 m<sup>3</sup>).

**3.1.2.** The top section shall be constructed of material of sufficient thickness and rigidity to withstand normal field use and resistant to attack by cement paste. The top section shall have a capacity at least 20% larger than the bowl and shall be equipped with a flexible gasket and with hooks or lugs to attach to the flange on the bowl to make a watertight connection. The top section shall be equipped with a glass lined or transparent plastic neck, graduated in increments not greater than 0.5% for 0 at the top to 9%, or more, of the volume of the bowl. Graduations shall be accurate to  $\pm 0.1\%$  by the volume of the bowl. The upper end of the neck shall be threaded and equipped with a screw cap having a gasket to make watertight fit.

**3.2.** Metal funnel with a spout of a size permitting it to be used inserted through the neck on the top section and long enough to extend to a point just above the top of the bottom section. The discharge end of the spout shall be constructed that when water is added to the container there will be a minimum disturbance of the concrete.

**3.3.** Tamping rod shall be a straight steel rod, 5/8 in (16 mm) in diameter and approximately 12 in (300 mm) in length with both ends rounded to a hemispherical tip of the same diameter.

**3.4.** Strike-off bar a flat, straight steel bar at least 1/8 by 3/4 by 12 in (3 by 20 by 300 mm) or a flat, straight bar at least 0.23 by 0.75 by 12 in (6 by 20 by 300 mm) high density polyethylene or other plastic of equal or greater abrasion resistance.

3.5. Glass plate<sup>1</sup>.

3.6. Measuring cup having a capacity equal to  $1.03 \pm 0.04\%$  of the volume of the bowl of the air meter.

3.7. Rubber bulb syringe having a capacity at least that of the measuring cup.

3.8. Pouring vessel of suitable capacity.

3.9. Trowel.

3.10. Small metal scoop.

3.11. Mallet with rubber or rawhide head weighing approximately  $1.25 \pm 0.50\text{lb}$  ( $0.57 \pm 0.23\text{ kg}$ ) for use with measures of  $0.5\text{ ft}^3$  ( $0.014\text{ m}^3$ ) or smaller, and a mallet weighing approximately  $2.25 \pm 0.50\text{ lb}$  ( $1.02 \pm 0.23\text{ kg}$ ) for use with measures larger than  $0.5\text{ ft}^3$  ( $0.014\text{ m}^3$ ).

3.12. Use 70% by volume isopropyl alcohol (approximately 65% by mass).

**NOTE:** The volume of the measuring cup is slightly larger than 1.0% of the volume of the bowl to compensate for the volume contraction that takes place when 70% isopropyl alcohol is mixed with water. Other alcohol or defoaming agents may be used if calculations show that their use will result in an error in indicated air content less than 0.1%.

**NOTE:** 70% isopropyl alcohol is commonly available as rubbing alcohol. More concentrated grades can be diluted with water to the required concentration.

#### 4. CALBRATION OF APPARATUS

4.1. Determine the volume of the bowl of the air meter, in cubic feet (meters), as outlined in **KT-20**, by accurately weighing the amount of water required to fill the bowl, and dividing this mass by the unit weight of water at the same temperature (see **KT-15**). Use a glass plate to cover the bowl to remove excess water to ensure that the container is full.

4.2. Determine the accuracy of the graduations on the neck of the top section of the air meter by filling the assembled measuring bowl and top section with water to a preselected air content graduation and then determining the quantity of 70°F (21.1°C) water required to fill the meter to the zero mark. The quantity of water added shall equal the preselected air content graduation with  $\pm 0.1$  volume percent of the measuring bowl. Repeat the procedure to check a minimum of three graduations within the expected range of use.

4.3. Determine the volume of the measuring cup using water at 70°F (21.1°C) by the method outlined in **Section 4.2** of this test method. A quick check can be made by adding 1 or more cups of water to the assembled apparatus and observing the increase in the height of the water column after filling to a given level as described in **Section 4.2** of this test method.

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<sup>1</sup> **AASHTO T 196** uses only a straight edge to level the top of the bowl. The glass plate ensures the volume of the bowl is properly filled with visual confirmation.

## 5. TEST PROCEDURE

**5.1.** Obtain a sample of fresh concrete in accordance with **KT-17**.

**5.2.** Wet the inside of the bowl and dry it to a damp but not shiny appearance. Using the scoop in **Section 3.10** of this test method, fill the bowl with freshly mixed concrete in two layers of equal depth. Rod each layer 25 times with the tamping rod. Do not forcibly strike the bottom of the bowl when rodding the first layer. When rodding the second layer, penetrate the prior layer approximately 1 in (25mm).

**5.2.1.** After each layer is rodded, tap the sides of the measure 10 to 15 times smartly with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.

**5.3.** Strike off the excess concrete, level full, with the strike-off bar or a glass plate. Thoroughly clean the flanges of the bowl and cover to ensure an air-tight fit.

**5.4.** Clamp the top section into position on the bowl, insert the funnel, and add water until it appears in the neck. Remove the funnel and adjust the water level, using the rubber syringe, until the bottom of the meniscus is level with the zero mark. Attach and tighten the screw cap.

**NOTE:** For low slump or sticky mixes, a small diameter metal rod suitably bent may be used to break up the concrete before the cap is placed on the apparatus.<sup>2</sup>

**NOTE:** When filling the air meter with water, the addition of a minimum of 1 pt (500 mL) of alcohol facilitates the removal of air from high air content or high cement content concretes, or mixtures with midrange water reducers.

**5.5.** Invert and agitate the unit until the concrete settles free from the base; and then, with the neck elevated, roll and rock the unit until the air appears to have been removed from the concrete. Set the apparatus upright, jar it lightly, and allow it to stand until the air rises to the top. Repeat the operation until no further drop in the water column is observed.

**5.6.** When all the air has been removed from the concrete and allowed to rise to the top of the apparatus, remove the screw cap. Add, in small increments, one measuring cupful of isopropyl alcohol, using the syringe to dispel the foamy mass on the surface of the water.

**5.7.** Make a direct reading of the liquid in the neck, reading to the bottom of the meniscus, and estimating the air to the nearest 0.25%.

**5.8** Disassemble the apparatus and examine the contents to be sure that there are no portions of undisturbed, tightly packed concrete in the base. If portions of undisturbed concrete are found, the test is invalid.

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<sup>2</sup> This technique is not found in **AASHTO T 196**. It does permit the material to break up quicker when dealing with low slump or sticky mixes.



## 6. CALCULATIONS

**6.1.** Calculate the air content of the concrete in percent by adding to the reading from **Section 5.7.**, of this test method the amount of alcohol used in accordance with **Section 5.6.**, of this test method. An example would be determining the air content reading to be 5.7% and 1.0% of alcohol was used (one cup full). The total air content would be 6.7%.

5.9.20 MASS PER CUBIC FOOT (METER), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF FRESHLY MIXED CONCRETE (Kansas Test Method KT-20)

## 1. SCOPE

This method of test covers the procedure for determining the mass per cubic foot (meter) of freshly mixed concrete and gives formulas for calculating the following values: Yield, Relative Yield, Actual Cement Factor and Air Content. **KT-20** reflects testing procedures found in **AASHTO T 121**.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-05 Unit Weight of Aggregate

2.3. KT-17; Sampling Freshly Mixed Concrete

2.4. KT-18; Air Content of Freshly Mixed Concrete by the Pressure Meter

2.5. KT-19; Air Content of Freshly Mixed Concrete by the Volumetric Method

2.6 AASHTO T 121; Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete

## 3. APPARATUS

3.1. The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

3.2. Tamping rod shall be a straight steel rod, 5/8 in (16 mm) in diameter and approximately 24 in (600 mm) in length with both ends rounded to a hemispherical tip of the same diameter.

3.3. A cylindrical container made of steel or other suitable material. It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures that are machined to accurate dimensions on the inside and provided with handles are preferred. The minimum capacity of the measure shall conform to the requirements in **Table 1**. All measures, except for measuring bowls of air meters which are also used for **KT-20** of this manual, shall conform to the requirements of **KT-05** of this manual. When measuring bowls of air meters are used, they shall conform to the requirements of **KT-18** of this manual. The top rim of the air meter bowls shall be smooth and plane within 0.01 in (0.25 mm).

**NOTE:** The metal or other suitable material should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where, as a consequence of an initial reaction, a surface film is rapidly formed which protects the metal against further corrosion.

**NOTE:** The top rim is satisfactorily planed if a 0.01 in (0.25 mm) feeler gauge cannot be inserted between the rim and a piece of 1/4 in (6 mm) or thicker glass plate laid over the top of the measure.

**Table 1**  
**Minimum Capacity of Measures**

Maximum Nominal Size of Coarse Aggregate		Capacity of Measure, min	
in	Mm	ft <sup>3</sup>	m <sup>3</sup>
1	25.0	0.2	0.006
1 1/2	37.5	0.4	0.011
2	50	0.5	0.014
3	75	1.0	0.028
4 1/2	114	2.5	0.071
6	152	3.5	0.099

**NOTE:** For maximum nominal aggregate sizes 1 in (25 mm) or less, the pressure meter bowl may be used.

**NOTE:** Aggregate of a given maximum nominal size may contain up to 10% of particles retained on the sieve referred to.

**NOTE:** To provide for wear, measures may be up to 5% smaller than indicated in this table.

**3.4.** <sup>1</sup>A rigid, flat glass or heavy plastic cover plate at least 1/2 (13 mm) thick and at least 2 in (50 mm) larger than the diameter of the measure for accurately striking off and leveling the surface of the concrete. The edges of the plate shall be straight and smooth with a tolerance of 1/16 in (1.6 mm).

**3.5.** Hand scoop.

**3.6.** Trowel.

**3.7.** Mallet with rubber or rawhide head having a mass approximately  $1.25 \pm 0.50$  lb ( $600 \pm 200$  g) for use with measures of  $0.5$  ft<sup>3</sup> ( $0.014$  m<sup>3</sup>) or smaller. Mallet having a mass of  $2.25 \pm 0.50$  lb ( $1000 \pm 200$  g) for use with measures larger than  $0.5$  ft<sup>3</sup> ( $0.014$  m<sup>3</sup>).

**3.8.** Internal vibrators may have rigid or flexible shafts, preferably powered by an electric motor. The diameter of the vibrating element shall be not less than 0.075 in (19 mm) or more than 1.50 in (38 mm) and the length of the shaft should be 24 in (600 mm) or more. The frequency of vibration shall be 7000 vibrations per minute (117 Hz) or greater. A tachometer should be used to check the frequency of vibration.

#### **4. CALIBRATION OF MEASURE, AND CALIBRATION FACTOR**

**4.1.** Determine the mass of the empty measure to the nearest 0.05 lb (20 g) and record this mass as A. Determine the mass of the empty measure (coated with grease on the top rim if necessary) and cover plate to the nearest 0.05 lb (20 g) and record this mass as C.

**4.2.** Fill the measure with water, using the cover plate to ensure that it is exactly full. Wipe excess water from sides and bottom of the measure with an absorbent cloth.

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<sup>1</sup> AASHTO T 121 allows the use of a metal plate.

4.3. Weigh and record the mass of the measure, water, and cover plate. Record this mass as B.

4.4. Measure and record the temperature of the water and determine the density as found in **KT-15**, interpolating if needed.

4.5. Calculations:

$$V = \frac{B - C}{D}$$

Where: V = Volume of the measure, ft<sup>3</sup> (m<sup>3</sup>)  
B = Mass of the measure filled with water plus cover plate, lb (kg)  
C = Mass of the measure and cover plate, lb (kg)  
D = Density of water (see **KT-15**), lb/ft<sup>3</sup> (kg/m<sup>3</sup>)

$$F = \frac{D}{B - C} = \frac{1}{V}$$

Where: F = Calibration factor, 1/ft<sup>3</sup> (1/m<sup>3</sup>)

## 5. TEST PROCEDURE

5.1. Obtain a sample of freshly mixed concrete in accordance with **KT-17** of this manual.

5.2. Weigh the measure and record the mass as A.

5.3. Concrete at different slump levels requires different methods of consolidation to prepare satisfactory test specimens. The methods listed below should be used as a guide in determining the type of consolidation to use:

<u>Slump of Concrete</u>	<u>Type of Consolidation</u>
More than 3 in (75 mm)	Rodding
1 to 3 in (25 to 75 mm)	Rodding or Vibration
Less than 1 in (25 mm)	Vibration

5.4. Rodding procedure.

5.4.1 Place concrete in the measure in three equal layers.

5.4.2. Rod each layer 25 times when 0.5 ft<sup>3</sup> (0.014 m<sup>3</sup>) or smaller measures are used and 50 times when the 1 ft<sup>3</sup> (0.28 m<sup>3</sup>). When rodding the first layer, avoid striking the bottom of the container and when rodding successive layers, use only enough force to penetrate the surface of the underlying layer about 1 in (25 mm).

5.4.3. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.

5.4.4. After consolidation, strike-off the top surface of the concrete and finish it smoothly with the flat strike-off plate using great care to leave the measure just full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about 2/3 of the surface and

withdrawing the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original 2/3 of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure. Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

**5.4.5.** Clean all excess concrete from the exterior of the filled measure. Weigh the filled measure to the nearest 0.1 lb (50 g) and record the mass as D.

## **5.5. Vibration Procedure.**

**5.5.1.** Fill the measure approximately 1/2 full of concrete. Place all the concrete required for the layer in the measure before starting vibration.

**5.5.2.** Consolidate the layer by three insertions of the vibrator evenly distributed over the surface. Do not let the vibrator rest or touch the bottom or sides of the measure. The duration of vibration will depend on the effectiveness of the vibrator and the consistency of the concrete, but usually sufficient vibration has been applied when the surface of the concrete becomes relatively smooth in appearance.

**5.5.3.** Fill the measure to an elevation somewhat above the top rim and vibrate this second layer. In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 1 in (25 mm). Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen. A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete at completion of consolidation, remove most of the excess concrete with a trowel or scoop immediately before the measure is struck-off.

**5.5.4.** Strike-off the surface as in **Section 5.4.4** of this test method.

**5.5.5.** Proceed as in **Section 5.4.5** of this test method.

## **6. CALCULATIONS**

**6.1.** Mass per cubic foot (meter) of fresh concrete.

$$W = F (D - A)$$

Where:

- W = Mass of concrete lb/ft<sup>3</sup> (kg/m<sup>3</sup>)
- D = Mass of measure filled with concrete, lb (kg)
- A = Mass of measure, lb (kg)
- F = Calibration factor

**6.2. Volume of Concrete produce per batch.**

$$S = \frac{W_c + W_{fa} + W_{ca} + W_w + W_o}{W}$$

Where: S = Volume of concrete produced per batch, ft<sup>3</sup> (m<sup>3</sup>)  
W<sub>c</sub> = Total mass of cement in batch, lb (kg)  
W<sub>fa</sub> = Total wet mass of fine aggregate in batch, lb (kg)  
W<sub>ca</sub> = Total mass of coarse aggregate in batch lb (kg)  
W<sub>w</sub> = Total mass of mixing water added to batch, lb (kg)  
W<sub>o</sub> = Total mass of any other solid or liquid material used, lb (kg)

**6.3. Relative yield** is the ratio of actual volume of concrete obtained to the volume as designed for the batch and shall be calculated as follows:

(English)

$$RY = \frac{S}{27(V_d)}$$

(SI)

$$RY = \frac{S}{V_d}$$

Where; RY = Relative density  
V<sub>d</sub> = Volume of concrete which the batch was designed to produce, yd<sup>3</sup> (m<sup>3</sup>)  
S = Volume of concrete produced per batch, ft<sup>3</sup> (m<sup>3</sup>)

**NOTE:** A value for RY greater than 1.00 indicates that an excess volume of concrete is being produced. Whereas, a value less than 1.00 indicates the batch to be “short” of its designed volume.

**6.4. Air Content:** calculate as follows:

$$A = \frac{100(T - W)}{T}$$

Where: A = Air content in the concrete  
T = Theoretical mass of the concrete, lb/ft<sup>3</sup> (kg/m<sup>3</sup>), air free basis  
W = Mass of concrete lb/ft<sup>3</sup> (kg/m<sup>3</sup>)

**NOTE:** When the same materials and proportions are used to prepare different batches of concrete, it is assumed that the theoretical, air free, mass per cubic foot (meter) of the concrete is constant for all batches. It is calculated from the formula:

$$T = \frac{W_1}{V}$$

Where: W<sub>1</sub> = W<sub>c</sub> + W<sub>fa</sub> + W<sub>ca</sub> + W<sub>w</sub> + W<sub>o</sub>  
V = Total absolute volume of the component ingredients in the batch, ft<sup>3</sup> (m<sup>3</sup>)

The absolute volume of each ingredient is calculated in accordance with **subsection 5.10.1** of this manual. For aggregate components, the bulk specific gravity and mass should be based on the saturated, surface-dry condition.

**6.5. Actual Cement Factor:** Cement factor based on theoretical yd<sup>3</sup> (m<sup>3</sup>) of concrete required and actual quantity of cement used is calculated as follows:

$$ACF = \frac{A}{B}$$

Where:      A = Actual cement used lb (kg)  
              B = Theoretical volume of concrete, yd<sup>3</sup> (m<sup>3</sup>)

## 5.9.21 SLUMP OF PORTLAND CEMENT CONCRETE (Kansas Test Method KT-21)

### 1. SCOPE

This method of test covers the procedure for determining the slump of freshly mixed concrete. **KT-21** reflects testing procedures found in **AASHTO T 119**.

**NOTE:** This test method was originally developed to provide a technique to monitor the consistency of unhardened concrete. It is not applicable to nonplastic and noncohesive concrete, nor for the concrete that contains 1.5 in (37.5 mm) or larger aggregate particles. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength.

**NOTE:** Concrete having slumps less than 0.5 in (13 mm) may not be adequately plastic and concretes having slumps greater than about 9 in (230 mm) may not be adequately cohesive for this test to have significance. Caution should be exercised in interpreting such results.

### 2. REFERENCED DOCUMENTS

2.1. KT-17; Sampling Freshly Mixed Concrete

2.2. AASHTO T 119; Slump of Hydraulic Cement Concrete

### 3. APPARATUS

3.1. Mold or slump cone fabricated from metal not readily attacked by cement paste. The metal shall not be thinner than 0.060 in. (1.5 mm) or if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 in (1.15 mm). The mold shall have the shape of a frustum of a right circular cone and be equipped with handles and foot plates. The dimensions shall meet requirements in **Table 1**:

Inside diameter at top	Inside diameter at bottom	Height
4 ± 1/8 in (102 ± 3.2 mm)	8 ± 1/8 in (205 ± 3.2 mm)	12 ± 1/8 in (305 ± 3.2 mm)

3.2. Molds other than metal are permitted provided they meet the dimensional requirements in **Table 1**.

3.2.1. The mold shall be sufficiently rigid to maintain the specified dimensions and tolerances during use, resistant to impact forces, and shall be nonabsorbent.

3.2.2.1. Comparability shall be demonstrated on behalf of the manufacturer by an independent laboratory. Test for comparability shall consist of not less than 10 individual comparisons performed at each of three different slumps ranging from 2 in (50 mm) to 8 in (200 mm). No individual test results shall vary by more than .50 in (15 mm) from the obtained using the metal mold. The average test results of each slump range shall not vary more than 0.25 in (6 mm) from the average of test results obtained using the metal mold.

3.2.2.2. If any changes in material or method of manufacture are made, tests for comparability shall be repeated.



**3.2.3.** If the condition of any individual mold is suspected of being out of tolerance, a single comparative test shall be performed. If the test results differ by more than 0.50 in (15 mm) from that obtained using a metal mold, the mold shall be removed from service.

**3.3.** Tamping rod shall be a straight steel rod, 5/8 in (16 mm) in diameter and approximately 24 in (600 mm) in length with one or both ends rounded to a hemispherical tip of the same diameter.

**3.4.** Hand scoop.

## **4. TEST PROCEDURE**

**4.1.** Obtain a sample of fresh concrete in accordance with **KT-17** of this manual.

**4.2.** Dampen the mold, place it on a flat, moist, nonabsorbent, rigid surface. It shall be held firmly in place during filling by the operator standing on the two foot pieces.

**4.3.** Fill the mold with concrete in three layers, each approximately one third the volume of the mold.

**NOTE:** One-third of the volume of the mold fills to a depth of 2 5/8 in (67 mm); two-thirds of the volume fills to a depth of 6 1/8 in (155 mm).

**4.4.** Rod each layer with 25 strokes of the tamping rod uniformly distributed over the cross-section of each layer. For the bottom layer, this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spiraling toward the center. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout its depth, so that the strokes just penetrate into the underlying layer.

**4.4.1.** In filling and rodding the top layer, heap the concrete above the mold before rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod. Remove the mold immediately from the concrete by raising it carefully in a vertical direction.

**NOTE:** The operation of raising the mold shall be performed in  $5 \pm 2$  sec. by a steady upward lift with no lateral or torsional motion being imparted to the concrete. The entire operation from the start of the filling through removal of the mold shall be carried out without interruption and shall be completed within an elapsed time of 2 1/2 minutes.

**4.5.** Immediately measure the slump by determining the difference between the height of the mold and the height over the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs disregard the test and make a new test on another portion of the sample.

**4.5.1.** If two consecutive tests on a sample of concrete show a falling away or shearing of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

## 5. REPORTING

**5.1.** Record the slump in terms of in (mm) to the nearest 1/4 inch (5 mm) of subsidence of the specimen during the test as follows:

$$S = A - B$$

Where:        S = Slump of the concrete  
                  A = Height of mold  
                  B = Height of concrete after removal of mold



5.9.22 MAKING AND CURING COMPRESSION AND FLEXURAL TEST SPECIMENS IN THE FIELD  
(Kansas Test Method KT-22)

**1. SCOPE**

This method covers procedures for making and curing test specimens in the field, using freshly mixed concrete produced for construction or maintenance work. **KT-22** reflects testing procedures found in **AASHTO R 100**.

**2. REFERENCED DOCUMENTS**

**2.1.** KT-17; Sampling Freshly Mixed Concrete

**2.2.** KT-18; Air Content of Freshly Mixed Concrete by the Pressure Method

**2.3.** KT-19; Air Content of Freshly Mixed Concrete by the Volumetric Method

**2.4.** KT-20; Mass Per Cubic Foot (Meter) Yield and Air Content (Gravimetric) of Freshly Mixed Concrete

**2.5.** KT-21; Slump of Portland Cement Concrete

**2.6.** AASHTO R 100; Making and Curing Concrete Test Specimens in the Field

**2.7.** ASTM C192; Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory

**2.8.** AASHTO M 201; Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

**2.9.** AASHTO M 205; Molds for Forming Concrete Test Cylinders Vertically

**3. APPARATUS**

**3.1.** Compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position. The cylinder diameter shall be at least 3 times the nominal maximum size of the coarse aggregate. Specimen may be the 6 by 12 in (150 by 300 mm) cylinder when the maximum size of the coarse aggregate does not exceed 2 in (50 mm). When the nominal maximum size of the coarse aggregate does not exceed 1 in (25 mm) the specimens may be 4 by 8 in (100 by 200 mm) cylinders. All cylinder molds are to conform to the requirements of **AASHTO M 205**. Individual molds that deviate from dimensional or other requirements or have been damaged should be discarded. All plastic molds are to be provided with plastic lids.

**3.2.** Beam molds for flexural strength specimens shall be rectangular in shape and of the dimensions required to produce test specimens that are nominally 6 by 6 in (150 by 150 mm) with a minimum length of 21 in (530 mm). The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 1/8 in (3.2 mm) for molds with depth or breadth of 6 in (152 mm) or more. Molds shall produce specimens not more than 1/16 in (1.6 mm) shorter than the required length of 21 in (530 mm) but may exceed it by more than that amount. They should be checked for configuration and fit prior to each use to ensure that the test specimen will be molded to specified dimensions. During use, check for excessive leakage of mortar. Remove molds from service that leak excessively.

**3.3.** Tamping Rods--Two sizes are specified. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded if preferred.

**3.3.1.** Large Rod: 5/8 in (16 mm) in diameter and approximately 24 in (610 mm) long.

**3.3.2.** Small Rod: 3/8 in (10 mm) in diameter and approximately 12 in (305 mm) long.

**3.4.** Vibrators.

**3.4.1.** Internal vibrators may have rigid or flexible shafts, preferably powered by an electric motor. The diameter of the vibrating element shall not be less than 0.75 in (19 mm) or more than 1.50 in (38 mm) and the length of the shaft should be 24 in (600 mm) or more. The frequency shall be 7,000 vpm or greater during usage.

**3.4.2.** External vibrators may be either a table type or a plank type, with provision for securely clamping the mold to the apparatus. The frequency shall be 3,600 vpm or higher during usage.

A vibrating reed tachometer should be used to check the frequency of vibration of each type.

**NOTE:** Vibratory impulses are frequently imparted to plank vibrators through electromagnetic means or by use of an eccentric weight on the shaft of an electric motor, or on a separate shaft driven by a motor.

**3.5.** Small tools and other items such as shovels, pails, trowels, wood float, blunted trowels, straightedge, scoops, rules and a wheelbarrow or cart for transporting the fresh concrete to the place where test specimens will be molded.

**3.6.** Slump apparatus as specified in **KT-21**.

**3.7.** Sampling and mix apparatus as specified in **KT-17**.

**3.8.** Air content apparatus as specified in **KT-18**, **KT-19**, or **KT-20**.

## **4. PROCEDURE**

**4.1.** Obtain a sample of concrete in accordance with **KT-17**. Note and record the place where the batch of concrete represented by the sample was deposited.

**4.2.** Measure and record the slump of the concrete in accordance with **KT-21**. The concrete used for the test may be returned to the forms or discarded.

**4.3.** Determine the air content, when required, in accordance with **KT-18**, **KT-19** or **KT-20** and record. Concrete used in performing the air content test shall not be used in fabricating test specimens.

**4.4.** Determine and record the temperature of the concrete as specified in **KT-17 Section 6**.

**4.5. Molding Specimens:** The following procedures are applicable to both compression and flexure specimens.

**4.5.1.** Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

**4.5.2. Placing the concrete:** Place the concrete in the molds using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the

batch. Remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of the specimens. Move the scoop, shovel, or trowel around the perimeter of the mold opening when adding concrete to ensure an even distribution of the concrete and to minimize segregation. Further distribute the concrete by use of a tamping rod prior to the start of consolidation. In placing the final layer, the operator shall attempt to add an amount of concrete that will exactly fill the mold after consolidation. Do not add nonrepresentative concrete to an underfilled mold.

**4.5.3. Number of layers:** Make specimens in layers as indicated in **Table 1**.

**4.6. Consolidation:**

**4.6.1. Methods of consolidation:** Preparation of satisfactory specimens requires different methods of consolidation. The methods of consolidation are rodding, and internal or external vibration. Base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed. Rod concrete with a slump greater than 3 in (75 mm). Rod or vibrate concrete with slump of 1 to 3 in (25 to 75 mm). Vibrate concrete with slump of less than 1 in (25 mm). Concrete of such low water content that it cannot be properly consolidated by the methods described herein, or requiring other sizes and shapes of specimens to represent the product or structure, are not covered by this method. Specimens for such concrete shall be made in accordance with the requirements of **ASTM C192** with regard to specimen size and shape and method of consolidation.

**4.6.2. Rodding:** Place the concrete in the mold, in the required number of layers of approximately equal volume. For cylinders, rod each layer with the rounded end of the rod using the number of strokes specified in **Table 1**. The small rod shall be used when the diameter or the width of the mold is less than 6 in (150 mm). The number of roddings per layer required for beams is one for each 2 in<sup>2</sup> (1250 mm<sup>2</sup>) top surface area of the specimen. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to penetrate about 1/2 in (12 mm) into the underlying layer when the depth of the layer is less than 4 in (100 mm), and about 1 in (25 mm) when the depth is 4 in (100 mm), or more. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gauge single-use molds which are susceptible to damage if tapped with a mallet. After tapping, spade the concrete along the sides and ends of beam molds with a trowel or other suitable tool.

**4.6.3. External and internal vibration:** Maintain a uniform time period for duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation. Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. When placing the final layer, avoid overfilling by more than 1/4 in (6 mm). Finish the surface either during or after vibration where external vibration is used. When the finish is applied after vibration, add only enough concrete with a trowel to overfill the mold about 1/8 in (3 mm). Work it into the surface and strike it off.

**4.6.4. Internal vibration:** The diameter of the vibrating element, or thickness of a square vibrating element, shall be in accordance with the requirements of **Section 3.4** of this test method. For beams, the vibrating element shall not exceed one-third of the width of the mold. For cylinders, the ratio of the diameter of the cylinder to the diameter of the vibrating element shall be 4.0 or higher. Place all the concrete for one layer in the mold before starting vibration of that layer. Insert the vibrator slowly and do not allow the vibrator to rest on the bottom or sides of the mold. Continue vibration only long enough to achieve proper consolidation of the concrete. Slowly withdraw the vibrator in such a manner that no air pockets are left in the specimen.

**4.6.4.1. Cylinders:** Follow the molding requirements of **Table 2**. Allow the vibration to penetrate through the layer being vibrated, and into the layer below, approximately 1 in (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gauge single-use molds which are susceptible to damage if tapped with a mallet.

**4.6.4.2. Beam:** Insert the vibrator at intervals not exceeding 6 in (150 mm) along the centerline of the long dimension of the specimen. For specimens wider than 6 in (150 mm), use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer approximately 1 in (25 mm). After each layer is vibrated, tap the outside of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped.

**4.6.5. External vibration:** When external vibration is used, take care to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface.

**4.7. Finishing:** After consolidation, unless the finishing has been performed during the vibration, strike off the surface of the concrete and float or trowel as required. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than 1/8 in (3 mm).

**4.7.1. Cylinders:** After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a wood float or trowel. If desired, cap the top surface with a thin layer of stiff Portland cement paste which is permitted to harden and cure with the specimen. If using plastic molds and lids, cap the cylinder with the supplied lid immediately after finishing.

**4.7.2. Beams:** After consolidation of the concrete, strike off the top surface to the required tolerance to produce a flat even surface. A wood float may be used.

**4.8. Initial storage:** Immediately after being struck off, the specimens shall be moved to the storage place where they will remain undisturbed for the initial curing period. If specimens made in single-use mold are moved, lift and support the specimens from the bottom of the molds with a large trowel or similar device.

**Table 1 Molding Requirements by Rodding**

Specimen Type and Size	Number of layers of approximately equal depth	Number of Roddings per Layer
Cylinders: Diameter in (mm)		
4 (100)	2	25
6 (150)	3	25
9 (225)	4	50
Beams: Width in (mm)		
6 (150 to 8 (200)	2	See Section 4.6.2.
Over 200 (8)	3 or more equal depths, each not to exceed 6 in (150 mm)	See Section 4.6.2.

**Table 2 Molding Requirements by Vibration**

Specimen Type and Size	Number of layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer,
Cylinders: Diameter in (mm)			
4 (100)	2	1	One-half depth of specimen
6 (150)	2	2	One-half depth of specimen
9 (225)	2	4	One-half depth of specimen
Beams: Width in. (mm)			
6 (150) to 8 (200)	1	See Section 4.6.4.2.	Depth of specimen up to 8 in (200 mm)
Over 8 (200)	2 or more	See Section 4.6.4.2.	One-half depth of specimen up to 8 in (200 mm)

## 5. CURING SPECIMENS

**5.1.** Immediately after finishing, precautions shall be taken to prevent evaporation and loss of water from the specimens. Protect the outside surfaces of cardboard molds from contact with wet burlap or other sources of water. Cardboard molds may expand and damage specimens at an early age if the outside of the mold absorbs water. Cover specimens with a nonabsorbent, nonreactive plate or sheet of impervious plastic. Wet burlap may be used over the plate or plastic sheet to help retard evaporation, but the burlap must not be in contact with the surface of the concrete.

**5.2.** Initial Curing: After molding, the specimens shall be stored in a temperature range between 60 to 80 °F (16 to 27 °C), and in a moist environment preventing any loss of moisture up to 48 hours. At all times the temperature in and between specimens shall be controlled by shielding from direct rays of the sun and radiant heating devices. Specimens that are to be transported to the laboratory for standard curing (See **Section 5.3.** of this test method) before 48 hours shall remain in the molds in a moist environment, until they are received in the laboratory, demolded and placed in standard curing. If specimens are not transported within 48 hours, the mold shall be removed within 24 ± 8 hours and standard curing used until transported. Specimens shall not be exposed to dripping or running water.  
(See **Section 6.** of this test method)



**5.2.1.** Under no circumstances should the lid be removed from plastic molds, until the mold is stripped from the cylinder.

**NOTE:** It may be necessary to create an environment during initial curing to provide satisfactory moisture and to control the temperature. The specimens may be immersed immediately in saturated limewater, and/or stored in tightly constructed wooden boxes, damp sand pits, temporary buildings at construction sites, under wet burlap, or in heavyweight closed plastic bags. Immersing in saturated limewater is not acceptable for specimens in cardboard or other molds that expand when immersed in water. Other suitable methods may be used provided the foregoing requirements limiting specimen temperature and moisture loss are met. The temperature may be controlled by ventilation, or thermostatically controlled cooling devices, or by heating devices such as stoves, light bulbs, or thermostatically controlled heating elements. Temperature records of the specimens may be established by means of maximum-minimum thermometers. Early age results may be lower when stored near 60°F (16°C) and higher when stored near 80°F (27°C).

### **5.3. Standard Curing for Cylinders**

Note: Beams are only used for opening to traffic. See Section 5.5 of this test method.

**5.3.1.** Cylinders: Upon completion of initial curing and within 30 minutes after removing the molds, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ). Temperatures between 68 and 86°F (20 and 30°C) are permitted for a period not to exceed 3 hours immediately prior to test if free moisture is maintained on the surfaces of the specimen at all times, except when capping with sulfur mortar capping compound. When capping with this material, the ends of the cylinder will be dried. Specimens shall not be exposed to dripping or running water. The required moist storage can be obtained by immersion in saturated limewater or by storage in a moist room or cabinet meeting the requirements of **AASHTO M 201**.

### **5.4. Curing at Remote Sites:**

**5.4.1.** Specimens prepared and stored at remote sites which do not have facilities for controlling temperature within the tolerance  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) shall be cured in accordance with the provisions of **Section 5.3.** of this test method except as modified by **Section 5.4.** of this test method.

**5.4.2.** Initial curing at remote sites shall be in accordance with **Section 5.2.** of this test method.

**5.4.2.1.** Specimens not to be transported or to be transported after 48 hours age may be cured without demolding in accordance with **Section 5.2.** of this test method until the time of transportation or testing provided that loss of moisture is prevented.

**NOTE:** Curing of specimens at remote sites in accordance with **Section 5.4.** of this test method may yield significantly different results as compared to specimens cured in accordance with **Section 5.3.** of this test method.

### **5.5. Curing for Determining Form Removal Time or When a Structure May be put into Service:**

**5.5.1.** Cylinders: Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified curing treatment. To meet

these conditions, specimens made for the purpose of determining when a structure may be put in service shall be removed from the molds at the time of removal of formwork.

**5.5.2. Beams:** As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of  $48 \pm 4$  hours after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements or slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the sides and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structure concrete as near to the point in the structure they represent as possible and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in lime water at  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) for  $24 \pm 4$  hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Drying of the surfaces of the beam shall be prevented between removal from water storage and completion of testing. Note that relatively small amounts of surface drying of flexural specimens can induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

NOTE: Beams to be tested prior to  $72 \pm 4$  hours after molding will follow the procedures outlined in **5.5.2** up till the time they are to be tested. Thus, if a 2-day break is desired, the beams will be demolded and tested as soon as possible after demolding. This may result in the beam being in the lime water less than  $24 \pm 4$  hours.

## **6. SHIPPING SPECIMENS**

Suitable shipping containers are available through the District Materials Engineer. Care should be taken to ensure concrete cylinders do not freeze during shipment.

Properly identify each cylinder and encase in a plastic bag or pack in damp sawdust. Schedule the shipment so that the cylinders will arrive in the laboratory approximately one week before they are to be tested so that they can be capped and conditioned prior to testing.

Attach a copy of the sample ID, and place the identification number on each shipping container and forward copies to the Engineer of Tests or the District Materials Engineer as applicable by mail.

If the cylinders are to be tested for compressive strength at any age other than 28 days, the desired age of test should be noted in AWP. If cylinders are to be tested for rapid chloride, boil test or surface resistivity, it should be noted in AWP.

Concrete beams are tested at the project or District Laboratory.



5.9.23 FLEXURAL STRENGTH OF CONCRETE (THIRD-POINT LOADING METHOD)  
(Kansas Test Method KT-23)

**1. SCOPE**

This method of test covers the procedure for determining the flexural strength of concrete by test of a simple beam with third-point loading. **KT-23** reflects testing procedures found in **AASHTO T 97**.

**2. REFERENCED DOCUMENTS**

**2.1.** KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

**2.2.** AASHTO T 23; Making and Curing Concrete Test Specimens in the Field

**2.3.** AASHTO T 97; Flexural Strength of Concrete (Using Simple Beam with Third Point Loading)

**3. APPARATUS**

**3.1.** A testing machine which will apply a measured load to the beam at the third points of the span. The machine will have a span length of 18 in (460 mm). Suitable machines are made available to the Field Engineer by the District Materials Engineer.

**3.1.1.** Clean and lubricate the apparatus every six months.

**3.2.** Caliper and a 12 in (300 mm) steel rule graduated in 0.01 in (0.1 mm).

**3.3.** Leather shims, 1/4 by 1 1/2 by 6+ in (6.4 by 38 by 160 mm). The shim must be slightly longer than the 6 in (160 mm) width of the test specimen.

**3.4.** Feeler gauges.

**4. TEST SPECIMEN**

**4.1.** A nominal 6 by 6 by 21 in<sup>1</sup> (152.4 by 152.4 by 530 mm) concrete beam, molded and cured according to **KT-22** of this manual. The beam must be kept moist until time of test.

**4.2.** Draw lines on the beam at 6" intervals equally spaced from the end of the beam representing the support and load applying block locations. Use these marks when installing the beam in the test fixture.

**5. TEST PROCEDURE**

**5.1.** Age of testing:

**5.1.1.** Beams tested to determine the safe date for removal of forms from structures shall be tested at ages mutually agreed upon by the Engineer and the Contractor. Other times for testing are contained in the standard specifications.

**5.2.** Install specimen:

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<sup>1</sup> The length dimension is 1 in (25.4 mm) longer than **AASHTO T 23**.

**5.2.1.** Place the specimen on its side, centered in the machine in such a manner that a minimum of 1 in (25 mm) of the beam extends outside the support rollers. Apply a load of between 3 and 6% of the expected ultimate load. If full contact is obtained between the specimen and the load-applying blocks and the supports so that there is no gap longer than 1 in (25 mm) or the gap is less than 0.004 in (0.1 mm) deep, test the specimen without further preparation. If full contact is not obtained between the specimen and the load-applying blocks and the supports so that there is a 1 in (25 mm) or longer gap in excess of 0.004 in (0.1 mm) and not more than 0.015 in (0.38 mm) deep, grind the contact surfaces of the specimen, or shim with leather strips.

**5.2.1.1** If full contact is not obtained between the specimen and the load-applying blocks and the supports so that there is a 1 in (25 mm) or longer gap in excess 0.015 in (0.38 mm), grind the contact surfaces of the specimen until it complies with the requirements stated in **Section 5.2.1.** above.

**5.2.1.2.** If the specimen is twisted or warped 1/8 inch (3.2 mm) or more in any plane, discard the specimen and repair or replace the mold.

### **5.3.** Application of load:

**5.3.1.** The load may be applied rapidly until approximately 50% of the breaking load has been reached. Beyond that point, reduce the rate of loading so that the rate of increase in extreme fiber stress remains within 125 to 175 psi (861 to 1207 kPa) per minute until the specimen breaks, (1500 to 2100 lbf per minute).

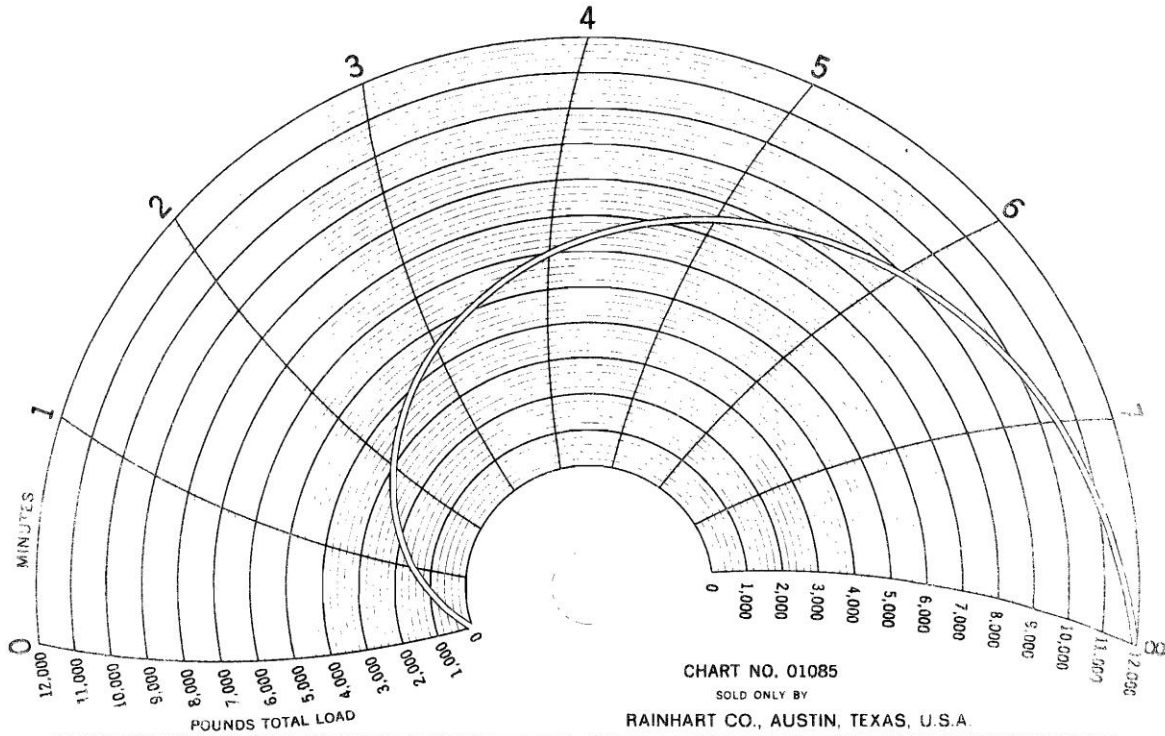
**5.3.1.1. Chart No. 01085, Figure 1** is the correct chart to use on the Rainhart Beam Breaker. This chart loads at a rate of 1746 lbf/min (1016 kPa/min).

Note and record the total load required to break the beam.

### **5.4.** Measurement:

**5.4.1.** Take and record three measurements at the fracture across each dimension (one at each edge and at the center) to the nearest 0.05 in (1.3 mm) to determine the average width, average depth and line of fracture location of the specimen at the section of failure.

Figure 1 Chart No. 01085



**CONCRETE BEAM FLEXURAL STRENGTH TEST - A.S.T.M. PROCEDURE C78**

CONTRACTOR \_\_\_\_\_ PROJECT \_\_\_\_\_

BEAM NO. \_\_\_\_\_ MADE \_\_\_\_\_ TESTED \_\_\_\_\_ AGE \_\_\_\_\_

LOAD \_\_\_\_\_ LBS., WIDTH \_\_\_\_\_ IN., DEPTH \_\_\_\_\_ IN., FACTOR \_\_\_\_\_

FLEXURAL STRENGTH \_\_\_\_\_ PSI., SPECIFICATION \_\_\_\_\_ PSI.

REMARKS \_\_\_\_\_

TESTING AGENCY \_\_\_\_\_

TESTED BY \_\_\_\_\_

CHECKED BY \_\_\_\_\_

PRINTED IN U.S.A.

## 6. CALCULATIONS

**6.1.** If the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture to the nearest 5 psi as follows:

(ENGLISH)

$$R = \frac{(P)(L)}{bd^2}$$

(SI)

$$R = \frac{1000(P)(L)}{bd^2}$$

Where: R= Modulus of rupture in psi (kPa)  
P= Maximum applied load in lbf (N)  
L= Span length in (mm)  
b= Avg. Width of specimen in (mm) (as tested)  
d= Avg. Depth of specimen in (mm) (as tested)

Sample Calculations (English):

Depth of beam = 5.70 in  
Width of beam = 6.12 in  
Load at break = 4800 lbf

$$R = \frac{4800 (18)}{6.12 (5.70)(5.70)} = 435 \text{ psi}$$

Sample Calculations (SI):

Depth of beam = 145 mm  
Width of beam = 155mm  
Span length = 460 mm  
Load at break = 21400 N

$$R = \frac{1000 (21400)(460)}{155 (145)(145)} = 3020 \text{ kPa}$$

**6.2** If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5% of the span length, calculate the modulus of rupture as follows:

(ENGLISH)

$$R = \frac{3(P)(a)}{bd^2}$$

(SI)

$$R = \frac{3000(P)(a)}{bd^2}$$

Where:            a = average distance between line of fracture and the nearest support measured on the tension surface of the beam, in (mm).

If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5% of the span length, discard the results of the test.





5.9.24 DETERMINATION OF FREE MOISTURE OR ABSORPTION OF AGGREGATE FOR USE IN CONCRETE (Kansas Test Method KT-24)

**1. SCOPE**

This method of test covers the procedure for determining the free moisture or absorption of aggregates for use in concrete. Other methods may be used by permission from the District Materials Engineer.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-06; Specific Gravity and Absorption of Aggregate

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Bucket approximately 8 in (200 mm) in diameter and 8 in (200 mm) height, with suitable suspension device for determining the mass of aggregate when immersed and weighed in water.

**3.3.** Container with overflow in which the bucket may be immersed and weighed in water.

**3.4.** Drying pans.

**4. SAMPLE**

**4.1.** Secure a representative sample of the aggregate to be tested from a location as close to the point of use as possible.

**4.2.** Reduce by splitting to a weight of approximately 10,000 g for coarse or mixed aggregate, or 5000 g for fine aggregate.

**4.3.** Stir sample thoroughly and divide into two approximately equal portions, "A" and "B".

**4.4.** Place each portion in a container and cover to prevent loss of moisture.

**5. TEST PROCEDURE**

**5.1.** If not available from previous tests, determine the bulk specific gravity (saturated, surface dry basis) of the aggregate in accordance with **KT-06** of this manual.

**5.2.** If free moisture is present on the surface of the aggregate, proceed as follows:

**5.2.1.** Bring portion "A" to a saturated, surface dry condition. For CPA and MA aggregates, split sample into two portions on the No. 4 (4.75 mm) sieve, bring each portion to a saturated, surface dry condition as described in **KT-06** of this manual. For FA aggregates it will not be necessary to divide the sample.

**5.2.2.** Recombine the materials and weigh out a 2000 g for coarse aggregate (1000 g for MA or FA) sample of the saturated, surface dry aggregate.

**5.2.3.** Pour the sample slowly into a bucket which is about half filled with water and stir aggregate thoroughly to remove entrapped air.

**5.2.4.** Fill bucket with water and let material settle before carefully immersing the bucket and contents in the water in the large container.

**5.2.5.** Determine and record the mass of the saturated surface dry material in water ( $W_1$ ).

**NOTE:** Unless aggregate sources change, the value for the mass in water of a 1000 or 2000 g sample of saturated, surface dried aggregate may be used for all moisture determinations made during the progress of the work.

**5.2.6.** Weigh out 2000 g of coarse aggregate (1000 g for MA or FA) sample from portion “B” and follow steps in **section 5.2.3** through **section 5.2.5** of this test method. Record this weight as  $W_2$ .

**5.3.** If free moisture is not present on the surface of the aggregate, proceed as follows:

**5.3.1.** Cover portion “A” with water and let stand for not less than 20 or more than 21 minutes.

**5.3.2.** Remove the sample from the water and bring to a saturated, surface dry condition as in **section 5.2.1**.

**5.3.3.** Recombine the materials and weigh out a 1000 or 2000 g test sample of the saturated, surface dry material.

**5.3.4.** Proceed as directed in **sections 5.2.3, 5.2.4 and 5.2.5** of this test method.

**5.3.5.** Weigh out a 1000 or 2000 g sample from portion “B”.

**5.3.6.** Pour the sample slowly into a bucket which is about half filled with water and stir aggregate thoroughly to remove entrapped air.

**5.3.7.** Fill bucket with water and let material settle before carefully immersing the bucket and contents in the water in the large container.

**5.3.8.** Wait 20 to 21 minutes after immersing the sample in the bucket.

**5.3.9.** Determine the mass of the sample in water ( $W_2$ ).

## 6. CALCULATIONS

### 6.1. Percent Moisture (or absorption).

$$\text{Percent Moisture} = (W_1 - W_2) \cdot \left( \frac{G_s}{(G_s - 1)} \right) \cdot \left( \frac{100}{s} \right)$$

Where:  $W_1$ = Mass of 1000 or 2000 g saturated, surface dry sample (portion "A") immersed in water  
 $W_2$ = Mass of 1000 or 2000 g saturated, test sample (portion "B") immersed in water  
 $G_s$ = Bulk Specific Gravity (Saturated, Surface Dry) of the aggregate being tested  
 $s$ = Mass of sample (in g) in air

**NOTE:** A positive (+) answer indicates the percent of free moisture on the aggregate. A negative (-) answer indicates the amount of moisture the aggregate absorbed during the 20 minutes that was immersed during the test.

Example:

$G_s$ = Bulk Specific Gravity (Saturated, Surface Dry Basis)	= 2.631
$S$ = Wt. of portion "A" in air	= 2000 g
$W_1$ = Wt. of portion "A" in water	= 1246 g
$W_2$ = Wt. of 2000 g portion "B" test sample in water	= 1220 g

$$\text{Percent Moisture} = (1246 - 1220) \cdot \left( \frac{2.631}{(2.631-1)} \right) \cdot \left( \frac{100}{2000} \right) = 2.1\% \text{ free moisture in the aggregate}$$

**NOTE:** If  $W_2$  had been larger than  $W_1$ , the result would have been negative and the aggregate would have had 20 minute moisture absorption potential.

## 7. TABLE FOR DETERMINATION OF MOISTURE CONDITION OF AGGREGATE

**7.1.** The following table may be used in lieu of the formula to determine the moisture condition of aggregates. The table has been set up on the basis of a 1000 g or 2000 g sample of an aggregate with specific gravity of 2.62. It is correct to within 0.1 % for aggregate of specific gravity within the range of 2.50 to 2.70.

It is advisable to use the formula at first and occasionally thereafter in order to become familiar with the method. The formula must always be used when the specific gravity of the material in question is at the extreme limits, or outside of the range quoted above.

Table 1  
Determination of the Moisture Content of Concrete  
Aggregates by Displacement Method

% of Absorption or Moisture			% of Absorption or Moisture		
$W_1 - W_2$	S= 1000 g	S= 2000 g	$W_1 - W_2$	S= 1000 g	S= 2000 g
0	0.0	0.0			
1	0.2	0.1	21	3.4	1.7
2	0.3	0.2	22	3.5	1.8
3	0.5	0.2	23	3.7	1.8
4	0.6	0.3	24	3.9	2.0
5	0.8	0.4	25	4.0	2.0
6	1.0	0.5	26	4.2	2.1
7	1.1	0.6	27	4.3	2.2
8	1.3	0.6	28	4.5	2.2
9	1.4	0.7	29	4.7	2.4
10	1.6	0.8	30	4.8	2.4
11	1.8	0.9	31	5.0	2.5
12	1.9	1.0	32	5.1	2.6
13	2.1	1.0	33	5.3	2.6
14	2.2	1.1	34	5.5	2.8
15	2.4	1.2	35	5.6	2.8
16	2.6	1.3	36	5.8	2.9
17	2.7	1.4	37	5.9	3.0
18	2.9	1.4	38	6.1	3.0
19	3.1	1.6	39	6.3	3.2
20	3.2	1.6	40	6.4	3.2

$W_1$ = Mass of 1000 or 2000 g saturated, surface dry sample immersed in water  
 $W_2$ = Mass of 1000 or 2000 g saturated, test sample immersed in water

If  $W_2$  is larger than  $W_1$  the result would be negative and the aggregate would have 20 minute moisture absorption potential.

## 8. Report

**8.1.** Record the absorption or moisture to the nearest 0.01 percent. Report the absorption or moisture to the nearest 0.1 percent.

5.9.25 SAMPLING AND SPLITTING PLANT MIXED ASPHALT MIXTURES  
(Kansas Test Method KT-25)

**1. SCOPE**

This method covers the procedure for sampling plant mixed asphalt mixtures from truck beds, continuous mix plants, and roadways. The procedure for sampling from trucks may be followed when sampling asphalt mixtures from other containers or in stockpiles. **KT-25** reflects testing procedures found in **AASHTO R 97**.

**2. REFERENCED DOCUMENTS**

**2.1.** AASHTO T 168; Standard Method of Test for Sampling Bituminous Paving Mixtures

**2.2.** AASHTO R 47; Standard Practice for Reducing Samples of Asphalt Mixtures to Testing Size

**3. APPARATUS**

**3.1.** Square pointed shovel or scoop.

**3.2.** Sampling Devices.

**3.2.1.** Plants shall be equipped with sampling devices capable of providing a sample of sufficient size from the full width of the mixer discharge flow. Sampling devices shall be designed so those samples may be taken while the plant is operating at normal production rates.

**3.2.2.** A container that will hold a minimum of 55 lb (25 kg) of loose, hot asphalt mixtures. The container should be equipped with a handle or handles that will permit it to be easily carried.

**4. SAMPLING PROCEDURE**

**4.1.** Plant Discharge.

**4.1.1.** Drum plants shall be capable of sampling at the discharge outlet. When a sample is taken at the discharge, the sampling container shall be of sufficient size to accommodate the entire stream uniformly. If a by-pass chute is utilized, a representative sample shall be obtained.

**4.1.2.** Take the sample in at least three increments to obtain the total sample. Combine the increments and mix thoroughly.

**4.1.3.** The combined sample size shall be at least four times the amount required for testing.

**4.2.** Truck Beds.

**4.2.1.** Divide the truck bed into at least three areas of approximately equal size.

**4.2.2.** Dig a hole about 1 ft (0.3 m) deep at a point that will be representative of each area.

**4.2.3.** Take a sample weighing 4 to 6 lb (2 to 3 kg) near the bottom of each hole, taking care to prevent segregation.

**4.2.4.** Combine the individual samples into a single sample at least four times the amount required for testing.

**4.3. Roadways Prior to Compaction.**

**4.3.1.** Randomly select the truckload in which the sample is to be obtained. Calculate the expected yield of that truckload and obtain at least three approximately equal increments from the roadway within the randomly selected truckload. These increments shall be the full depth of the lift, full width of the laydown machine minus 2 ft (ignore 1 ft on both edges of the laydown machine).

**4.3.2.** Insert the template through the full depth of the lift and remove all of the loose material above the tack layer from the template. Combine the increments and mix thoroughly.

**NOTE:** An approximate 12 in (300 mm) square template can be used to obtain the sample. Size and shape of the template can be altered to best fit the required sampling quantity without segregating the material. Take the number of squares required to obtain the necessary quantity for testing.

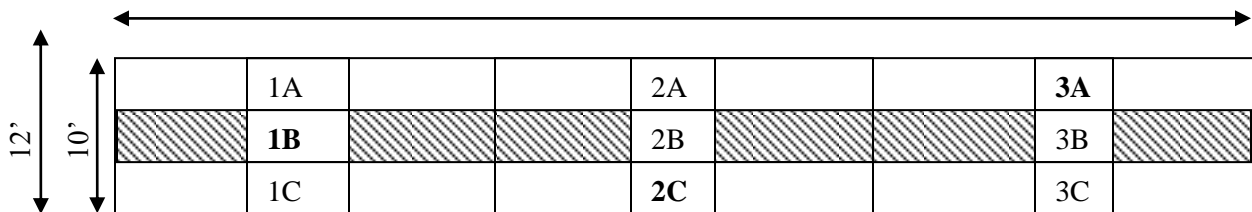
**4.3.3.** The sample size shall be at least four times the amount required for testing. For Superpave projects, the minimum sample size is shown in the specifications.

**4.3.4. EXAMPLE:**

Assume the yield for the random truckload of HMA is 100' long for a 12' wide roadway. Excluding the outside 1' edges, the width of the sampled area is 10'. Divide both the width and the length by 3 to obtain potentially 9 equal sublots for obtaining the sample. If only 3 sublots (the minimum) are to be used to create the sample, then select the sublots so that each third of the length is represented and each third of the width is represented by the sublots. In this example, sublots 1B, 2C and 3A were selected. When more than 3 sublots are to be used, then continue to select the additional material from sublots not yet selected varying the length segment and width segment i.e., sublots 3C, 2B and 1A etc.

3 segments at ~33'each = 100'

The expected yield of the truckload in this example is 100' x 12'



## **5. SAMPLE SPLITTING AND REHEATING**

**5.1.** Reduce sample to the required size by splitting or quartering in the following manner:

**5.1.1.** Spread a sheet of paper (Kraft or similar) on a hard, clean, smooth and level surface. Place the sample in a pile near the center of the paper and mix by alternately lifting each corner towards the opposite corner thereby rolling the mixture to the opposite corner. This should be performed in a vigorous manner. Placing the sample on clean sheet metal and mixing thoroughly with a trowel is an acceptable alternative.

**5.1.2.** Divide the pile into four equal quarters with a straightedge (trowel or similar metal blade) and completely remove two pre-selected diagonally opposite quarters.

**5.1.3.** Continue this quartering procedure until the original sample is reduced to the approximately desired size. On the final quartering step, if the sample is too large before quartering, but will be too small after quartering, the sample pile is divided into equal opposite sectors but unequal adjacent sectors. This can be accomplished by varying the dividing angle at the center of the sample pile from the normal 90°. Opposite sections can then be selected to obtain the desired sample size.

**5.2.** After mixing and reducing, samples may be reheated briefly, if necessary, to bring to specified compaction temperature. Care must be exercised to avoid overheating any part of the sample. Insulated containers are recommended for transporting and storing samples until used.





## 5.9.26 SAMPLING ASPHALT MATERIALS (Kansas Test Method KT-26)

### **1. SCOPE**

This test method covers the procedures for sampling asphalt, cutback, and emulsifier materials, at the point of production and at destination. **KT-26** reflects testing procedures found in **AASHTO R 66**.

### **2. REFERENCED DOCUMENTS**

**2.1. AASHTO R 66; Standard Practice for Sampling Asphalt Materials**

### **3. APPARATUS**

**3.1. Sampling containers used shall conform to the following:**

**3.1.1. Performance Graded Asphalt Binders:** Friction lid 1 qt (1 L) cans.

**3.1.2. Cutback Asphalts:** Friction lid 1 qt (1 L) cans.

**3.1.3. Emulsified Asphalts and Asphalt Rejuvenating Agents:** Wide mouth plastic 1 gal (4 L) containers. The containers must be free of solder flux or other material that might contaminate the sample.

**3.2. Holding device for lowering the sampling containers through the entire depth of material to be sampled.**

### **4. SAMPLING PROCEDURES**

**4.1. Samples received at the M & R Center that are over 14 days old will be discarded without testing.**

**4.2. Asphalt materials are currently accepted on the basis of a producer's certification of compliance for each shipment. To verify the certifications and to evaluate the producer's product control procedures, State representatives obtain random samples from shipping containers consigned to State work. Therefore, these sampling methods cover procedures for obtaining samples from shipping containers only.**

**4.3. Safety precautions are mandatory at all times when sampling and handling asphaltic materials.**

**4.3.1. Do not hold the container in the hand during sampling by the valve method. Tongs or some other device must be used to hold the container while the sample is being taken.**

**4.3.2. The sampler must stand above and away from sampling valves as far as practical and on the windward side.**

**4.3.3. The sample must be taken slowly to prevent splashing of the hot material.**

**4.3.4. Place the container on a firm, level surface to prevent splashing, dropping or spilling the material during sealing.**

**4.3.5. Watch for asphalt products which have been spilled onto the loading platform of the truck or tank car. Walking on this material can be hazardous.**

**4.4.** Thief method. (This is the preferred method for sampling).

**4.4.1.** Attach a new clean friction lid can to the holding device.

**4.4.2.** Remove the lid and slowly lower the holding device through the full depth of material being sampled. The rate at which the device is lowered should be such that the container will be filled when it reaches the bottom of the material.

**4.4.3.** Withdraw the device from the liquid, clean the outside of the container with dry wiping rags and transfer the contents to a clean, new container. Never use solvents or solvent saturated rags for cleaning sample containers.

**4.5.** Sampling Valve Method. The contents of shipping containers equipped with an approved submerged sampling valve may be sampled by this method.

**4.5.1.** Drain off and discard not less than 5 gal (20 L) of the material before taking the sample.

**4.5.2.** When practical, fill the sample container by holding it under the valve discharge pipe. If this procedure is not practical, permit the material to flow into a large, clean container and transfer a portion into a friction lid can for transportation and storage.

**4.6.** Repeat steps in **Sections 4.4** or **4.5** of this test method for a second sample.

**4.6.4.** Carefully clean the outside of the sample containers with dry wiping rags. Never use solvents or solvent saturated rags for this purpose.

## **5. SHIPPING INFORMATION**

**5.1.** Label each quart of material with at least the following:

**5.1.1.** Grade of material.

**5.1.2.** Producer.

**5.1.3.** Producer's location.

**5.1.4.** Sample ID number.

**5.1.5.** Pack and ship two (2) one quart samples to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.

## 5.9.27 SAMPLING JOINT COMPOUND MATERIALS (Kansas Test Method KT-27)

### 1. SCOPE

This method covers procedure for sampling joint compound materials including materials for filling and sealing joint in concrete pavements and structures, and joints in clay and concrete pipe.

### 2. REFERENCED DOCUMENTS

2.1. ASTM D5167; Melting of Hot-Applied Joint and Crack Sealant and Filler for Evaluation

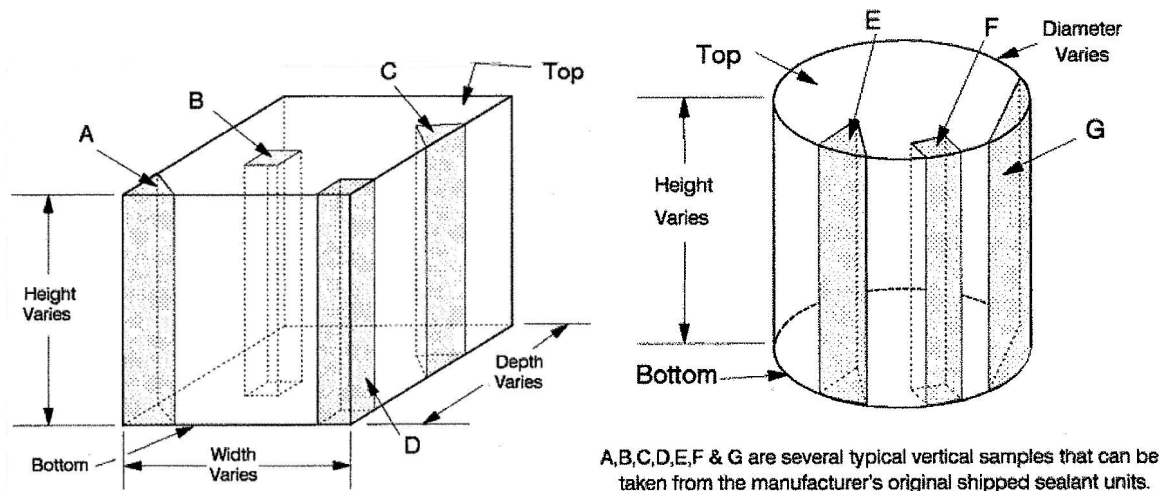
### 3. SAMPLING PROCEDURES FOR INFORMATION OR VERIFICATION

3.1. If the lot of material to be sampled is from a producer's single run or batch, select one package or container at random and obtain a sample as follows:

3.1.1. Hot type joint sealing compound:

3.1.1.1. Using a knife with a broad stiff blade, heated if necessary, remove a 5 lb (2.3 kg) sample from the package. Cut a complete vertical section from the material block as illustrated in **Figure 4 of ASTM D5167**.

Figure 4



3.1.2. Plastic joint compound for filling and sealing joints in pipe:

3.1.2.1. Using a paddle, mix the material until homogeneous. Then transfer a representative amount to fill 1 gal (4 L) can with a friction type lid.

3.1.3. Cold applied chemically cured joint sealant:

3.1.3.1. The material is to be sampled from dispensing nozzle in the same manner as it is being pumped into a joint. Completely fill two 1 qt (1 L) cans having friction type lids.

3.2. If the sample fails, resample if possible.

**3.3.** If the lot of material to be sampled is not from a producer's single run or batch, or if a single sample representing the lot has failed, select at random a number of packages equivalent to the cube root of the total number of packages in the lot. Remove not less than 1/4 lb (115 g) of material from each package or container. When practical, take the 1/4 lb (115 g) of material from a point at least 3 in (75 mm) from the top and 3 in (75 mm) from the side of the package. For hot type compound, combine into a single sample weighing not less than 5 lb (2.3 kg). For cold type or plastic joint compounds, combine into a single sample approximately 1 gal (4 L).

#### **4. SHIPPING INFORMATION**

**4.1.** Label each sample with at least the following information:

**4.1.1.** Producer.

**4.1.2.** Lot number.

**4.1.3.** Sample ID number.

**4.1.4.** Pack and ship samples to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.

## 5.9.28 SAMPLING BRIDGE PAINT (Kansas Test Method KT-28)

### **1. SCOPE**

This method covers the procedures for sampling paint materials in warehoused and in the field.

### **2. APPARTUS**

**2.1.** Supply of clean, one pint and one quart friction top containers (metal or plastic) for single component paint, paste and pigment.

**2.2.** Wide-mouth screw-top plastic containers or plastic –lined cans for the liquid components of multi-component inorganic zinc paints. Never place samples of these materials in unlined metal screw or friction top cans.

**2.3.** Stirring paddles.

**2.4.** Mechanical agitator (for mixing paint in storage tanks).

### **3. SAMPLING PROCEDURES**

**3.1.** Mixed paints.

**3.1.1.** Paint sampled from storage tanks at the factory must be thoroughly mixed by mechanical agitation just prior to taking the sample. If sample is taken from a spigot or valve at the bottom of the tank, draw off 2 gallons or more and return to the tank before collecting the sample.

**3.1.2.** Sample paint packaged in 1 gallon cans by selecting one can at random from the lot and submitting the unopened can to the laboratory for test.

**3.1.3.** Sample paint packaged in containers larger than one gallon in accordance with the following procedure:

**3.1.3.1.** Mix the paint thoroughly prior to taking the sample. Stirring with a paddle or a mechanical stirring device, or with a mechanical shaker will not ensure complete mixing and the removal of all pigment from the sides and bottom of the container. Therefore, the following operations must be performed to properly mix the paint before a sample is taken:

**3.1.3.1.1.** Secure an empty, clean, dry, metal container the same size as the paint container.

**3.1.3.1.2.** Pour the liquid portion into the second container.

**3.1.3.1.3.** Work the semi-solid material remaining in the first container with a paddle until it becomes a smooth homogeneous paste. Loosen any pigment or cake that adheres to the sides of the container. Continue mixing and stirring the paste until it is smooth and free from lumps.

**3.1.3.1.4.** Add the liquid from the second container to the paste in small increments, mixing well after each addition.

**3.1.3.1.5.** After the liquid has been added and mixed into the paste, pour in small increments, mixing well after each addition.

**3.1.3.1.6.** Leave the paint in the second container and examine the inside of the original container. If caked or settled pigment is present, work it into a smooth paste and mix with the paint in the second can. If the paint is so badly caked or livered” that it cannot be properly mixed by the above procedure, reject it without sampling.

**3.1.3.2.** After proper mixing, take two separate one quart samples in clean, friction top cans for submission to the laboratory.

### **3.2. Two-Component Paints.**

**3.2.1.** Sample paint packaged in one gallon containers by selecting one package at random from the lot and submitting the unopened package to the laboratory. This will enable the laboratory to mix the vehicle and pigment or paste in the exact ratio recommended by the manufacturer.

**3.2.2.** Sample two-component paints in packages larger than one gallon by taking a one quart sample of the vehicle and one pint of paste or pigment. If the vehicle component contains pigment, mix the material thoroughly in accordance with **Section 3.1.3** of this manual of this method before taking the sample.

**3.3. Dry pigment:** Sample dry pigment by opening the package and taking at random, sufficient material to fill a one pint can. Do not mix the pigment before taking the sample.

**3.4. Liquid paint materials:** (Varnish, thinners, clear vehicles, drying oils, solvents and similar materials).

**3.4.1.** Prior to taking samples of liquid paint materials, check for the presence of water and suspended matter or sediment and take necessary steps to ensure that the sample will contain a representative portion of the materials.

**3.4.2.** Before taking samples of liquids containing a high proportion of volatile materials, rinse out the sample container several times with a portion of the liquid to be sampled.

**3.4.3.** Screw-top containers having tight fitting lids with seals that are not soluble in the liquid being sampled should be used for shipping the samples to the laboratory.

### **3.5. Field sampling;**

**3.5.1.** Samples of paint and paint materials are to be taken, in accordance with the instructions set forth above, from the manufacturer’s sealed containers immediately after they are opened on the project. Samples of two component paints should include a sample of the pigment or paste and a sample of the vehicle. Samples should never be taken after the paint has been thinned, from a paint pot of the spraying system or from a spray nozzle as such sample are not representative of the paint as it was originally tested and accepted.

#### **4. SHIPPING INFORMATION**

**4.1.** Label all samples of vehicle, pigment or paste with at least the following:

**4.1.1.** Producer.

**4.1.2.** Product name or number.

**4.1.3.** Producer's recommended mix ratio, if available.

**4.1.4.** Sample ID number.

**4.1.5.** Pack and ship samples of vehicle, paste or pigment to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.





**5.9.29 FIELD SAMPLING OF PORTLAND CEMENT, LIME, SLAG, SILICA FUME AND FLY ASH**  
**(Kansas Test Method KT-29)**

**1. SCOPE**

This method covers the procedures for sampling Portland Cement, lime, slag, silica fume, and fly ash in the field. Procedures for sampling these materials at producing plants are governed by production, storage, sampling and loading facilities and are not covered in this method.

**2. APPARATUS**

**2.1.** Clean, 1 gal (4 L) friction top pails for shipping samples to the laboratory.

**2.2.** Tube designed for sampling cement.

**2.3.** Drying pans.

**2.4.** Shovel, hand scoop and other miscellaneous equipment.

**3. SAMPLING PROCEDURES**

**3.1.** Portland cement.

**3.1.1.** Cement used by ready mix and central mix plants is commonly sampled by passing a suitable container, such as a drying pan through the discharge stream between the cement weigh hopper and the mixing chamber. Make several passes through the stream to ensure that the combined sample will be representative of the cement going into the work.

**3.1.1.1.** Other points and methods of sampling are permissible as long as the samples are representative of the cement being used and they are not contaminated with foreign material.

**3.1.2.** Cement being used to produce job-mixed concrete is usually sampled by opening the loading hatch of the truck or car, digging a trench in the exposed surface of the cement and taking samples below the bottom of the trench by means of the sampling tube. Other methods of sampling are permissible if they produce representative, uncontaminated samples.

**3.2.** Hydrated lime and fly ash.

**3.2.1.** Field samples of hydrated lime and fly ash are most conveniently obtained by discharging a small amount of material from the spreading truck on to a canvas or large sheet of paper placed on the ground and selecting a representative portion for the sample.

**3.2.2.** Sample may also be taken by opening the loading hatches of cars or trucks, digging a trench in the exposed surface and taking samples below the bottom of the trench by means of the sampling tube.

**3.3.** Quicklime.

**3.3.1.** Field samples of quicklime are most conveniently obtained from a windrow after the quicklime is discharged from the transporting truck. Material must be selected so that it will represent an average of all parts of the discharge from a single truck. Quicklime absorbs moisture quite readily and, therefore, the following sampling procedure must be carried out quickly and immediately after discharge from the truck.

Place a quartering canvas on the ground in the intended path of the vehicle depositing the pebble quicklime. After the vehicle has deposited the material on the quartering canvas, quarter the sample in the standard manner until a sample of the proper size has been obtained, approximately 1 gal (4 L). Care should be taken to minimize the loss of fines due to the wind. This sample shall be placed in an airtight container preferably a 1 gal (4 L), friction top can. Care must be taken that lumps of quicklime are not crushed excessively during handling.

### **3.4. Silica Fume and Slag.**

**3.4.1.** Field samples of silica fume and slag are most conveniently obtained by discharging a small amount of material from the bags delivered either to the plant or the project site. Other methods of sampling are permissible if they produce representative, uncontaminated samples. This sample shall be placed in an airtight container preferably a 1 gal (4 L), friction top can.

## **4. SAFETY PRECAUTIONS**

**4.1.** Quicklime can cause burns if contact is made with the eyes or with the face and arms or other exposed parts of the body, especially in hot weather when the worker is perspiring. Workers should remain at a safe distance when the quicklime is being discharged from the truck, avoiding the dust that is created. Safety goggles are recommended when working around quicklime. If quicklime should get into the eyes or on the skin, flush the effected area immediately with large amounts of water and notify you immediate supervisor. If irritation or burning persists, seek medical attention.

## **5. SHIPPING INFORMATION**

**5.1.** Label each sample with at least the following:

**5.1.1.** Product.

**5.1.2.** Producer.

**5.1.3.** Producer's location.

**5.1.4.** Sample ID number.

**5.2.** Pack and ship samples to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.

5.9.30 FIELD SAMPLING OF THERMOPLASTIC PAVEMENT MARKING MATERIAL  
(Kansas Test Method KT-30)

**1. SCOPE**

This procedure outlines the proper method for sampling Thermoplastic Pavement Marking Materials on the roadway.

**2. APPARATUS**

**2.1.** Metal gallon-can lids.

**2.2.** Protective barrier to keep material from overflowing the lid on to the roadway. Two possible suggestions are cardboard and sheet metal.

**2.3.** Core sample bag (or equivalent) to keep material clean for shipping.

**3. SAMPLING PROCEDURES**

**3.1.** Avoid obtaining a sample immediately on startup of the striping contractor. The sampler should wait until the unit has been operating for one hour prior to obtaining the sample.

**3.2.** Obtain a representative sample from individual lots of material when possible. If the contractor is using multiple lots in the melter from a single manufacturer, then verify proper certifications are available for the lots and secure a sample from that blended quantity. **Mixing multiple manufacturers' lots is not permitted.**

**3.3.** Once **Section 3.1 and 3.2** of this test method have been satisfied, place a metal gallon can lid under the spray nozzle, so the lid lip is up (see **Figure 1**), with a protective barrier beneath the lid.

**3.4.** Do not permit any drop-on beads to come in contact with the representative sample during the sampling process or while it is cooling. It is necessary to determine the amount of beads in the thermoplastic mix itself. Drop-on beads will provide a false value for the quantity of beads in the thermoplastic.

**3.5.** While the material is still at the proper temperature to be in a molten state, have the contractor dispense enough thermoplastic from the melter to fill the lid completely to the top of the lip. Permit the thermoplastic to cool (see **Figure 2**). Place the sample in a location out of the way so as not to allow it to get dirty. **Do not write on the sample or allow it to get fingerprints, splatter from other samples, dirt, debris, etc.**

**3.6.** Once the thermoplastic has cooled, and keeping the sample clean and free from dirt, finger prints, and other foreign matter, break excess material off the outer edge of the lid and place in a plastic bag to keep clean for shipping to MRC (see **Figure 3 and 4**). Shipped sample should be clean, smooth, and filled to the top lip of the gallon can lid.

**4. SHIPPING INFORMATION**

**4.1.** Label each sample with at least the following (write on the bag or a separate piece of paper, NOT on the sample itself):

**4.1.1.** Manufacturer.

**4.1.2.** Lot number.

**4.1.3. Sample ID.**

**4.2. Pack and ship samples to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.**

**FIGURE 1**



Metal can lid with protective material underneath handle

**FIGURE 2**



Lid after thermoplastic has cooled to

**FIGURE 3**



Removal of excess thermoplastic from lid

**FIGURE 4**



Sample placed in bag for shipment

**FIGURE 5**



Shipping documentation

5.9.31 DETERMINATION OF PERCENTAGE OF CRUSHED PARTICLES IN CRUSHED GRAVEL  
(Kansas Test Method KT-31) AKA: COARSE AGGREGATE ANGULARITY

**1. SCOPE**

This method of test covers the procedure for determining the percent, by mass, of particles, which by visual inspection, exhibit characteristics of crushed aggregate. **KT-31** reflects testing procedures found in ASTM D5821.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2** KT-01; Sampling and Splitting of Aggregates

**2.3.** ASTM E11; Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Sieves meeting **ASTM E11** of appropriate sizes.

**3.3.** Drying Pans.

**3.4.** Oven capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**4. SAMPLE PREPARATION**

**4.1.** Obtain the test sample by quartering or splitting according to **KT-01** from material which has been thoroughly mixed. The sample shall be of sufficient size to yield the minimum dry mass shown in **Table 1** after washing over the No. 4 (4.75 mm) sieve. Screen the sample over a No. 4 (4.75 mm) sieve and discard all material passing the sieve. Wash the retained material over a No. 4 (4.75 mm) sieve and dry the sample to a constant mass at  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**TABLE 1**

Nominal Maximum Aggregate Size		Minimum Dry Sample Mass
1 ½" (37.5 mm)		6 lb (2500 g)
1" (25.0 mm)		3.5 lb (1500 g)
¾" (19.0 mm)		2.2 lb (1000 g)
½" (12.5 mm)		1.5 lb (700 g)
⅜" (9.5 mm)		0.9 lb (400 g)
No. 4 (4.75 mm)		0.5 lb (200 g)

**NOTE:** Nominal maximum aggregate size is one size larger than the first sieve to retain more than 10%.

## 5. TEST PROCEDURE

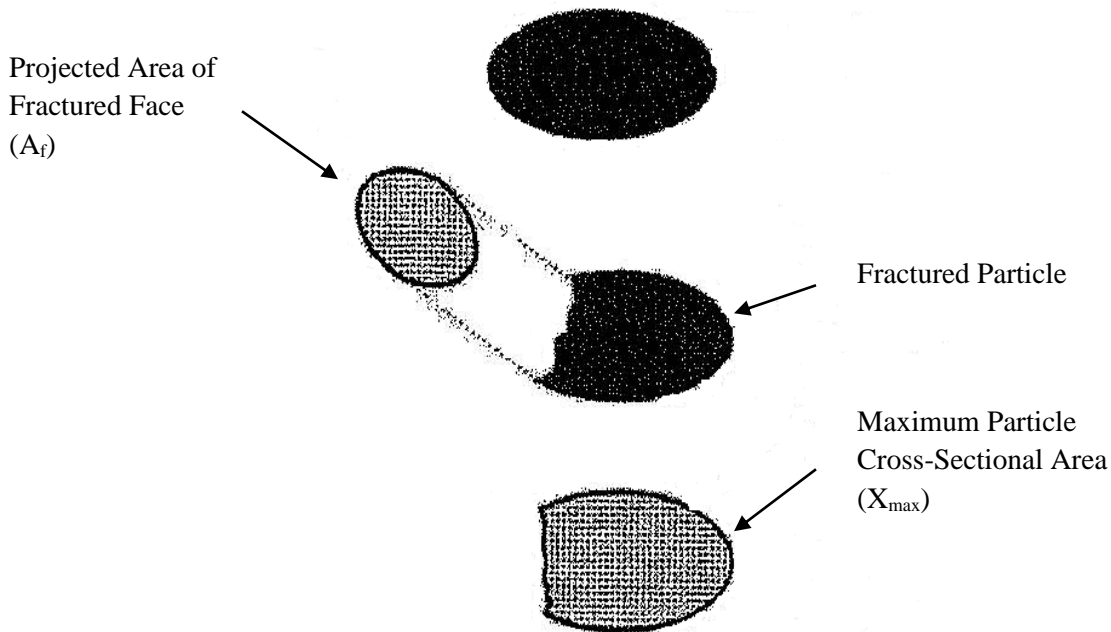
**NOTE:** For test procedures requiring the determination of two or more fractured faces go to Section 6. of this test method.

**5.1.** Weigh the material retained on the No. 4 (4.75 mm) sieve to the nearest gram. Record this mass as the original dry mass.

**5.2.** Spread the material in a thin layer on a clean flat surface so that each particle can be examined.

**5.3.** Separate the crushed particles from uncrushed particles. Any particle appearing to have one or more fractured faces shall be considered a crushed particle.

**NOTE:** Crushed particles are defined as 25% or more of the particle having a fractured face. A fractured face is defined as an angular, rough or broken surface of an aggregate particle. (See Figure 1)



**Figure 1**  
**Schematic of a Fractured Particle with One Fractured Face**

A face will be considered a “Fractured Face” only if  $A_f \geq 0.25 X_{max}$

**5.4** Determine the mass to the nearest gram and record as mass of crushed particles.

## 6. TEST PROCEDURE FOR SPECIFICATIONS REQUIRING DETERMINATION OF ONE OR MORE AND TWO OR MORE FRACTURED FACES

**6.1.** Weigh the material retained on the No. 4 (4.75 mm) sieve to the nearest gram. Record this mass as the original dry mass.



**6.2.** Spread the material in a thin layer on a clean flat surface so that each particle can be examined.

**6.3.** Separate the crushed particles into three piles; uncrushed particles, particles with two or more fractured faces and particles with one fractured face.

**NOTE:** Crushed particles are defined as 25% or more of the particle having a fractured face. A fractured face is defined as an angular, rough or broken surface of an aggregate particle. (See **Figure 1**)

**6.4.** Determine the mass to the nearest gram of each pile with crushed faces and record as:

F<sub>1</sub>=Mass of particles with one fractured face

F<sub>2</sub>=Mass of particles with two or more fractured faces

## **7. CALCULATIONS**

**7.1. For specifications requiring determination of only one or more fractured faces:**

$$\text{Percent Crushed Particles} = \frac{100(\text{Mass of Crushed Particles})}{\text{Original Dry Mass}}$$

**7.2. For specifications requiring determination of one or more and two or more fractured faces:**

**NOTE:** Skip **Sect. 7.2.** for specifications not requiring the determination of two or more fractured faces.

Compute the percentage of crushed particles for specifications requiring the determination of two or more fractured faces using the following formulas:

$$\text{Percent Crushed Particles with 1 or more Fractured Faces} = \frac{100(F_1 + F_2)}{\text{Original Dry Mass}}$$

$$\text{Percent Crushed Particles with 2 or more Fractured Faces} = \frac{100(F_2)}{\text{Original Dry Mass}}$$

## **8. REPORT**

**8.1.** Record to the nearest 0.1% of crushed particles. Report the results to 1% crushed particles.



5.9.32 METHOD OF TEST FOR DENSITY OF COMPACTED ASPHALT MIXTURES BY NUCLEAR METHOD (Kansas Test Method KT-32)

## 1. SCOPE

This method of test covers the procedure for measuring the “in-place” density of compacted asphalt materials by attenuation of gamma radiation. The intensity of the radiation detected is dependent in part on the density of the material being tested. **Gauge calibration shall follow Section 5.8.2. of this manual INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES.** KDOT gauges shall be calibrated-annually.

**The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken. (For KDOT field personnel only: Refer to Standard Operating Manual No. 1.13.2.).**

## 2. REFERENCED DOCUMENTS

2.1. KT-14; Marshall Test of Bituminous Mixes

2.2. KT-15; Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)

2.3. KT-39; Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures

2.4. Section 5.2.2.2.; Random Sampling

## 3. APPARATUS

**NOTE:** Check gauge to verify it is in asphalt mode.

3.1. Nuclear density gauge with supporting equipment including reference standard, survey meter, and instructional material.

3.2. Core drilling equipment capable of drilling a nominal 4 in (100 mm) diameter core.

3.3. Standardization.

3.3.1. Standardization of the nuclear gauge on a reference standard block is required at the start of each day’s use and when test measurements are suspect.

3.3.2. Warm up the nuclear gauge in accordance with the manufacturer’s recommendations.

3.4. Properly seat the nuclear gauge on the standard block. Take a four-minute reading on the reference standard. The density standard should be within 1% of the density for the previous day’s reading. If not,

repeat the standard count. The two numbers should now be within 1% of each other and within 2% of the density for the previous day's reading. If not, check the machine for malfunction.

#### **4. TEST SITE SELECTION AND PREPARATION**

**4.1.** Location of the test site should be on a random basis as described in **Section 5.2.2.2. RANDOM SAMPLING** of this manual. Regardless of the method of random selection chosen, it shall satisfy the requirement that any area of the surface shall have an equal chance of being sampled, except sampling shall not be conducted on sites closer than 1 ft (0.3 m) to an unconfined edge or vertical surface such as a raised edge of curb and gutter, etc. When the randomized selection method indicates a site within 1 ft (0.3 m) of an exposed edge or vertical surface, it is permissible to move the gauge transversely to clear the 1 ft (0.3 m) restriction. It is also permissible to determine an alternate location using the tables again.

**4.2.** Since the measured values of density are affected by the surface texture of the material immediately beneath the gauge, a flat surface should be tested for best results, both during calibration and density testing. If the mix has a coarse surface, it is likely that the results will vary widely.

**4.3.** It may be necessary to use a leveling sand of minus No. 30 (600  $\mu\text{m}$ ) material to obtain the best results with the density gauge. The leveling sand, as defined for this test, is minus No. 30 (600  $\mu\text{m}$ ) with no more than 20% represented by minus No. 100 (150  $\mu\text{m}$ ). It is recommended that the leveling sand material be from the same source as one of the individual aggregates in the mixture.

**4.4.** For HMA mix designs designated as A mixes, no sand is required. All other mix designs should be checked to determine if the leveling sand is needed before any field calibration of the nuclear density gauge is attempted. This is accomplished by doing the following:

**4.4.1.** Sit the gauge on a smooth level location and mark location with lumber crayon.

**4.4.1.1.** For uniformity, the gauge operator shall position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**4.4.2.** Take 5 one-minute readings with the density gauge, record wet density values, discard the single highest and lowest values, average the three remaining values, and record the average value.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**4.4.3.** Inside the location marked with the lumber crayon (test site) thinly spread a sufficient amount of minus No. 30 (600  $\mu\text{m}$ ) material. Smooth and level the minus No. 30 (600  $\mu\text{m}$ ) material with the metal plate or a straight edge.

**4.4.4.** Place the density gauge on the test site after the placement of minus No. 30 (600  $\mu\text{m}$ ) material and take another density reading. Take care to use the same count time and location of source rod. Record wet density information obtained. It is recommended that this process be completed at three locations.

**4.4.5.** After the information has been obtained, determine the need for the minus No. 30 (600 μm) material leveling sand. Use the leveling sand if an increase of 1 lb/ft<sup>3</sup> (16 kg/m<sup>3</sup>) or more is noted. If the leveling sand demonstrates a decrease in density, then the leveling sand is not beneficial and should not be used. An example of this calculation is as follows:

<b>TEST SITE LOCATION</b>	<b>TEST SITE DENSITY</b> lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	<b>TEST SITE DENSITY WITH LEVELING SAND</b> lb/ft <sup>3</sup> (kg/m <sup>3</sup> )	<b>DIFFERENCE</b> lb/ft <sup>3</sup> (kg/m <sup>3</sup> )
1	138.45 (2215)	139.50 (2232)	+1.05 (17)
2	140.35 (2246)	141.60 (2266)	+1.25 (20)
3	141.95 (2271)	143.06 (2289)	+1.11 (18)

**NOTE:** Density readings in above example are the average 3 one-minute readings (see **Section 4.4.2.** of this test method).

The difference in the example shows an increase in the density of more than 1 lb/ft<sup>3</sup> (16 kg/m<sup>3</sup>) when the leveling sand is used. If it is determined that leveling sand will be used during the calibration process of the nuclear gauge then it is required that leveling sand be used during in-place density testing of the compacted asphalt.

## 5. CALIBRATION CURVE ADJUSTMENT

**5.1.** The manufacturer’s calibration curve may require adjustment for chemical composition or density. Examination to determine the need for such adjustment should be made whenever a change is made in either the material to be tested or testing equipment. This test is generally conducted by comparing nuclear gauge to core density values for four or more random locations. The difference between the two average density values are used to determine the correction factor (d<sub>b</sub>) in **Section 7.6.1.1.** of this test method.

## 6. CALIBRATION LOCATIONS

**6.1.** For rural areas: Select locations starting after the second truck load. Each transverse and longitudinal random location shall fall within every other truck load.

**6.2.** For urban areas: If the asphalt mix quantities are large enough, use the rural criteria. If not, then decide if coring alone is a more feasible approach; or use best judgment to get a representative calibration for the nuclear gauge.

## 7. CALIBRATION PROCEDURE

**7.1.** Select a minimum of five locations that are typical of the asphalt mix being produced.

**7.1.1.** For uniformity, the gauge operator shall position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**7.2.** Take 5 one-minute readings in each location with the nuclear gauge in the backscatter or direct transmission (see **Section 8.2.** of this test method) position and mark the outline of the gauge in these locations. Record wet density values, discard the single highest and lowest values, average the three remaining values, and record the average value.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**7.3.** Record the wet density (WD) directly from the nuclear gauge. Specific instructions on the individual gauges are in the manufacturer's instruction manual which is in the packet accompanying each gauge.

**7.4.** Take three cores from each of the marked areas. For lifts other than base course, it may be necessary to use a bond breaker.

**7.5.** Obtain the core density using **KT-15**.

#### **7.6.** Calculations

**7.6.1.** For each location subtract the average nuclear density from the average core density. Evaluate these differences for outliers by the "T" Statistic Test at the 95% confidence level. The following example illustrates the point:

##### **7.6.1.1.** "T" STATISTIC EXAMPLE:

#### CALCULATIONS FOR CALIBRATION OF NUCLEAR GAUGES ON ASPHALT PAVEMENT

n = Number of locations

$d_i$  = Core Density – Nuclear Density

$d_b = \sum d_i / n$  = Correction Factor = Mean

s = Sample Standard Deviation

lb/ft<sup>3</sup> (kg/m<sup>3</sup>) Nuclear = Nuclear Density, Average of 3 one-minute readings

lb/ft<sup>3</sup> (kg/m<sup>3</sup>) Cores = Core Density, Average of three cores

**Table 1**  
**REJECTION QUOTIENTS ( $T_{0.95}$ )**

n	$T_{0.95}$
2	-----
3	1.15
4	1.46
5	1.67
6	1.82
7	1.94
8	2.03
9	2.11
10	2.18

Assume cores and nuclear readings for the calibration are as follows. Calculate the difference ( $d_i$ ) between cores and nuclear gauge readings.

**SI EXAMPLE:**

Location	Cores ( $\text{kg/m}^3$ )	Nuclear ( $\text{kg/m}^3$ )	Difference( $d_i$ ) ( $\text{kg/m}^3$ )
1	2176	2133	43
2	2187	2160	27
3	2176	2141	35
4	2197	2168	29
5	2185	2152	<u>33</u>
Total			+167

Calculate the correction factor ( $d_b$ )

$$d_b = \frac{\sum d_i}{n} = \frac{+167}{5} = +33.4$$

and standard deviation ( $s$ ) between the cores and nuclear readings as follows:

Location	Cores	Nuclear	$d_i$	$d_i - d_b$	$(d_i - d_b)^2$
1	2176	2133	+43	+9.6	92.16
2	2187	2160	+27	-6.4	40.96
3	2176	2141	+35	+1.6	2.56
4	2197	2168	+29	-4.4	19.36
5	2185	2152	<u>+33</u>	<u>-0.4</u>	<u>0.16</u>
Total			+167		155.20

$$s = \sqrt{\frac{\sum (d_i - d_b)^2}{(n-1)}} = \sqrt{\frac{155.20}{4}} = 6.23$$

**ENGLISH EXAMPLE:**

Location	Cores (lb/ft <sup>3</sup> )	Nuclear (lb/ft <sup>3</sup> )	Difference(d <sub>i</sub> ) (lb/ft <sup>3</sup> )
1	136.0	133.3	2.7
2	136.7	135.0	1.7
3	136.0	133.8	2.2
4	137.3	135.5	1.8
5	136.4	134.4	<u>2.0</u>
Total			10.4

Calculate the correction factor (d<sub>b</sub>)

$$d_b = \frac{\sum d_i}{n} = \frac{+10.4}{5} = +2.1$$

and standard deviation (s) between the cores and nuclear gauge readings as follows:

Location	Cores	Nuclear	d <sub>i</sub>	d <sub>i</sub> -d <sub>b</sub>	(d <sub>i</sub> -d <sub>b</sub> ) <sup>2</sup>
1	136.0	133.3	+2.7	+0.6	0.36
2	136.7	135.0	+1.7	-0.4	0.16
3	136.0	133.8	+2.2	+0.1	0.01
4	137.3	135.5	+1.8	-0.3	0.09
5	136.4	134.4	<u>+2.0</u>	<u>-0.1</u>	<u>0.01</u>
Total			+10.4		0.63

$$s = \sqrt{\frac{\sum (d_i - d_b)^2}{(n-1)}} = \sqrt{\frac{0.63}{4}} = 0.40$$

Application of the “T” test requires the following steps:

1. Arrange the deviations (d<sub>i</sub>) in ascending order of magnitude.

(SI)	(ENGLISH)
d <sub>1</sub> = 27	1.7
d <sub>2</sub> = 29	1.8
d <sub>3</sub> = 33	2.0
d <sub>4</sub> = 35	2.2
d <sub>5</sub> = 43	2.7

2. Calculate the difference between the questionable measurement (d<sub>1</sub> or d<sub>n</sub>) and the mean (d<sub>b</sub>). Then divide the deviation from the mean (d<sub>b</sub> - d<sub>1</sub> or d<sub>n</sub> - d<sub>b</sub>) by the sample standard deviation (s), demonstrated by the



formula "T" (illustrated below). Thus, if the questionable measurement (the measurement demonstrating the greatest variance from the other measurements) is the first measurement ( $d_1$ ) in the arranged set of results.

$$T = \frac{d_b - d_1}{s}$$

If the questionable measurement is the last measurement ( $d_n$ ) in the arranged set of results.

$$T = \frac{d_n - d_b}{s}$$

3. If the "T" is equal to or greater than the  $T_{0.95}$  value (for 95% confidence limits) for the number (n) of results considered (See Table 1) the questionable measurement may be rejected with 95% confidence that some definite error is involved in this measurement which was not involved in the other measurements of the set. For this example, the questionable measurement is  $d_5$  because it demonstrates the largest spread from the other measurements.

$$T \text{ (SI)} = \frac{d_n - d_b}{s} = \frac{43 - 33.4}{6.23} = 1.54$$

$$T \text{ (ENGLISH)} = \frac{d_n - d_b}{s} = \frac{2.7 - 2.1}{0.40} = 1.50$$

For  $n = 5$ ,  $T = 1.67$  (Table 1). Calculated T is less than 1.67; therefore, this value is not rejected (not an outlier). If the T value had been equal to or greater than 1.67, discard the core results from this location. Recalculate **Section 7.6.1.1** of this test method using the remaining core results.

**NOTE:** When calibrating multiple gauges, if it becomes necessary to discard a location or locations because the location or locations failed either the standard deviation ( $s$ ) or the "T" test, then the same location or locations **must** be discarded for all gauges being calibrated using these set of cored locations.

**7.6.2.** A minimum of four data points must pass the T-test in **Section 7.6.1** of this test method. The standard deviation ( $s$ ) should be less than or equal to 2.0 lb/ft<sup>3</sup> (32 kg/m<sup>3</sup>). If it is larger than 2.0 lb/ft<sup>3</sup> (32 kg/m<sup>3</sup>), this calibration shall be discarded.

**7.6.3.** The correction factor ( $d_b$ ) is applied to each nuclear density reading on the project to obtain a corrected nuclear density.

## 8. TEST PROCEDURE (HOT MIX)

**8.1.** For uniformity, the gauge operator shall position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**8.1.1.** Backscatter mode: Properly seat the gauge as stated in **Section 4.4.1** of this test method and expose the source by depressing the source rod (or handle) to the first stop. Take 5 one-minute readings

with the density gauge, record wet density values, discard the single highest and lowest values, average the three remaining values, and record the average value.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**8.2.** For uniformity, the gauge operator shall position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**8.2.1.** Direct transmission mode: Create a hole 2" (50 mm) deeper than the thickness of the material being tested with the rod and hole forming device that is provided with the gauge. Lower the source rod into the hole to the predetermined depth.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**NOTE:** Always double check to make sure the probe is fully seated in the appropriate notch. This should be confirmed in the safe, backscatter, or any direct transmission position.

## **9. TEST PROCEDURE (COLD RECYCLE)**

**9.1.** Develop compaction growth curves (rolling sequence) for cold recycle material using the backscatter position. Compaction growth curves will help to determine optimum density of material for a given roller. Curves are developed by plotting the density of material against the accumulative roller passes (**D.O.T. FORM NO. 608 or 608M**).

**NOTE:** In determining data for compaction growth curves, it is not necessary to calibrate the gauge to the material. Also, a single one-minute count can be used to establish each point for the curve.

**9.2.** To determine in place density use either direct transmission or backscatter as approved by the district.

**9.3.** For uniformity, the gauge operator shall position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**9.3.1.** Take 5 one-minute readings with the density gauge, record wet density values, discard the single highest and lowest values, average the three remaining values, and record the average value.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

## 10. CALCULATIONS

**10.1.** Calculation methods applicable to the various gauge types are covered in the Manufacturer's Operating Manual which accompanies the gauge and are not reproduced in this procedure.

**10.2.** Wet density (WD) values, as determined by the method appropriate to the type of gauge and method of calibration shall be compared to the "Density Standard" for determination of Percent of the Standard and Percent of Voids.

**10.3.** Density Standards.

**10.3.1.** Density Standard for Nuclear Density shall be defined as the average value of the most recent three laboratory density determinations (Field Mold Density) as determined by **KT-14** and **KT-15** for Marshall mix designations. When fewer than three laboratory densities for the particular mix designation or revised asphalt content are available, the "Density Standard" shall be the average of those determinations made until a total of three may be averaged.

**10.3.2.** For Superpave mixes, the "Density Standard" is established with the use of the average daily  $G_{mm}$  value (**KT-39**) as outlined in the specifications.

**10.4.** Calculate the Wet Density (WD) value from the following:

**10.4.1.** Wet Density (WD) = indicated  $\text{lb/ft}^3$  ( $\text{kg/m}^3$ ) with the adjustment factor applied as determined in **Section 7. CALIBRATION PROCEDURE** of this test method.

**10.5.** Calculate the percent of standard from the following formula:

$$\text{Percent of Standard} = \frac{100 (\text{WD})}{\text{Density Standard}}$$

**10.6.** Calculate the percent voids from the following formula:

$$\text{Percent Voids} = 100 - \frac{100(\text{WD})}{\text{Density of Water}^d (G_{mm})}$$

Where:  $G_{mm}$  = Theoretical maximum specific gravity of the mixture (refer to **KT-39**).

**NOTE:** Density of water varies based on temperature. Determine the temperature and select the proper density for water (see **KT-15, Table 1**).

## 11. REPORT AND RECORD

**11.1.** Report and record as 0.1  $\text{lb/ft}^3$  ( $1 \text{ kg/m}^3$ ) or 0.01% of optimum density.

**KANSAS DEPARTMENT OF TRANSPORTATION**

APPROVED ROLLING PROCEDURE

Project \_\_\_\_\_ County \_\_\_\_\_ Lab. No. \_\_\_\_\_

Contractor \_\_\_\_\_ Field Engineer \_\_\_\_\_

Gauge Type \_\_\_\_\_ Number \_\_\_\_\_ Std. Count \_\_\_\_\_

Operator \_\_\_\_\_ Date \_\_\_\_\_ Mix Design No. \_\_\_\_\_

Mix Type \_\_\_\_\_ Thickness \_\_\_\_\_ Base \_\_\_\_\_ OR Surface \_\_\_\_\_

Weather \_\_\_\_\_

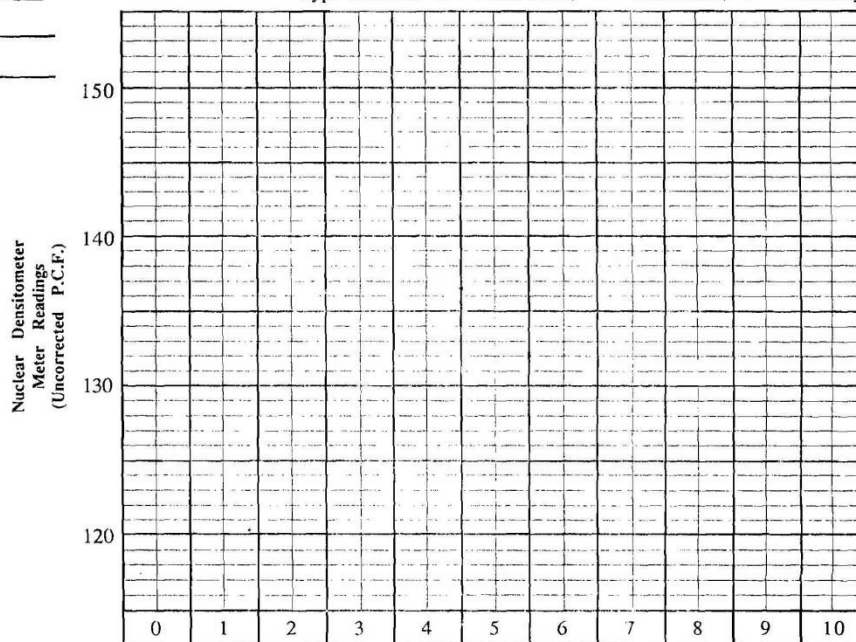
Description	Pass	0	1	2	3	4	5	6	7	8	9	10
	Roller #1											
	Roller #2											
	Roller #3											
	Temp											
	P.C.F.											
	Time											

V-Roller No. \_\_\_ No. \_\_\_

Type of Roller S - Static Steel, P - Pneumatic, V - Vibratory

Frequency(VPM) \_\_\_\_\_

Speed(FPM) \_\_\_\_\_



**PASSES**

Note: 1 Pass - 1 Time Over A Given Spot

Recom. Rolling Procedure \_\_\_\_\_

DISTRICT ENGINEER  
FIELD ENGINEER  
DISTRICT MATERIALS ENGINEER

\_\_\_\_\_  
District Materials Engineer

\_\_\_\_\_  
Date

DOT Form No. 608





5.9.33 BITUMEN CONTENT OF PAVING MIXTURES BY REFLUX EXTRACTION  
(Kansas Test Method KT-33)

**DELETED**

**03-2007**  
**See KTMR-39**





## 5.9.34 SIEVE ANALYSIS OF EXTRACTED AGGREGATE (Kansas Test Method KT-34)

### **1. SCOPE**

This method of test covers the procedure for determination of the particle size distribution of aggregate extracted from asphalt mixtures. **KT-34** reflects testing procedures found in **AASHTO T 30**.

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-02; Sieve Analysis of Aggregates

**2.3.** KT-57; Determination of Asphalt Content and Gradation of Hot Mix Asphalt Concrete by the Ignition Oven

**2.4.** ASTM E11; Woven Wire Test Sieve Cloth and Test

**2.5.** AASHTO T 30; Mechanical Analysis of Extracted Aggregate

### **3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Appropriate sieves meeting ASTM E11.

**3.3.** Oven capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

**3.4.** Drying Pans.

**3.5.** Wetting Agent. Any dispersing agent, such as dishwashing detergent, that promotes separation of the fine materials.

**3.6.** Container. Any container of sufficient size to contain the sample covered with water and to prevent any loss of material during agitation.

**3.7.** Large Spoon

**NOTE:** The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

### **4. SAMPLE**

**4.1.** The sample shall consist of the entire sample of aggregate from the test for asphalt binder content of paving mixtures by ignition method (**KT-57**) from which the asphalt material has been extracted.

## 5. TEST PROCEDURE

**5.1.** The sample shall be dried to a constant mass at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ) and weighed to the nearest 0.1%. The total mass of the aggregate shall be the sum of the extracted aggregate and the mineral matter (ash) from the extracted asphalt binder.

**5.2.** The test sample shall be placed in a container and covered with water containing a sufficient amount of wetting agent to assure a thorough separation of the material finer than the No. 200 (75  $\mu\text{m}$ ) sieve. The use of a large spoon to stir and agitate the aggregate in the wash water has been found satisfactory.

**NOTE:** There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

**5.3.** The agitation shall be sufficiently vigorous to result in the complete separation from the coarse particles of all particles finer than the No. 200 (75  $\mu\text{m}$ ) sieve and bring them into suspension in order that they may be removed by decantation of the wash water. Care shall be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. Repeat the operation without the wetting agent until the wash water is clear.

**5.4.** All materials retained on the sieves shall be returned to the container. The washed aggregate in the container shall be dried to constant mass at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ) and weighed to the nearest 0.1%.

**5.5.** The aggregate shall then be sieved according to procedures found in **KT-02 Section 6.1** through **Section 6.3**, of this manual. The cumulative mass of material retained on all of the sieves including the No. 200 (75  $\mu\text{m}$ ) sieve, plus the mass of dry material passing the No. 200 (75  $\mu\text{m}$ ) sieve by dry sieving must check the dried mass after washing within 0.2% of the total mass. The cumulative mass of the material retained on the various sieves shall be recorded. The mass of the material passing the No. 200 (75  $\mu\text{m}$ ) sieve, determined by subtracting the cumulative mass of the material retained on all sieves from the total mass of the sample, shall also be recorded.

## 6. CALCULATIONS

**6.1.** The mass of the material retained on the various sieves and the total passing the 75 $\mu\text{m}$  (No. 200) sieve shall be converted to percentages by dividing each by the total mass of the aggregate and multiplying by 100.

## 7. REPORT

**7.1.** The report shall include the results of the sieve analysis reported as the cumulative percentage retained on each sieve. The percent passing the No. 200 (75  $\mu\text{m}$ ) sieve shall also be reported. Percentages shall be reported to the nearest whole percent except for the percentage retained and passing the No. 200 (75  $\mu\text{m}$ ) sieve which shall be reported to the nearest 0.1%.

## 8. PRECISION

**8.1.** The estimates of precision for this test method are listed in **Table 1**. The estimates are based on the results from the **AASHTO Materials Reference Laboratory Proficiency Sample Program**, with testing conducted by **AASHTO T 30**. The data are based on the analyses of the test results from 47 to 90

laboratories that tested 17 pairs of proficiency test samples (Samples 1 through 34). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

**Table 1  
Precision**

	Total Percentage of Material Passing a Sieve		Standard Deviation (1S) Percent	Acceptable Range of Two Result—(D2S) Percent
Extracted Aggregate Single Operator Precision	<100	≥95	0.49	1.4
	<95	≥40	1.06	3.0
	<40	≥25	0.65	1.8
	<25	≥10	0.46	1.3
	<10	≥5	0.29	0.8
	<5	≥2	0.21	0.6
	<2	≥0	0.17	0.5
Multilaboratory Precision	<100	≥95	0.57	1.6
	<95	≥40	1.24	3.5
	<40	≥25	0.84	2.4
	<25	≥10	0.81	2.3
	<10	≥5	.056	1.6
	<5	≥2	0.43	1.2
	<2	≥0	0.32	0.9

**NOTE:** These numbers represent, respectively, (1S) and (D2S) limits described in Practice **ASTM C 670**.

**NOTE:** The precision estimates are based on aggregates with nominal maximum sizes of 3/4 in (19.0 mm) to 3/8 in (9.5 mm).

## 5.9.35 STICKS IN AGGREGATE (Kansas Test Method KT-35)

### **1. SCOPE**

This method of test covers the procedure for determining the percentage of sticks and similar material (leaves, bark, etc.) in aggregate.

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

### **3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Standard No. 4 (4.75 mm) sieve.

### **4. SAMPLE PREPARATION**

**4.1.** Obtain a representative sample of not less than 25 lb (11.5 kg). Weigh and record the weight of the sample without drying or further preparation and screen over a standard No. 4 (4.75 mm) sieve.

### **5. TEST PROCEDURE**

**5.1.** Remove and weigh all sticks as they appear on the sieve surface.

### **6. CALCULATION**

**6.1.** Calculate the percentage of sticks as follows:

$$\text{Percent Sticks} = \frac{100(\text{Wet Weight of Sticks})}{\text{Original Wet Weight of Sample}}$$

**NOTE:** This test may be performed at the same time and on the same sample as a routine clay lump test.

### **7. REPORT**

**7.1.** Report sticks in aggregate to 0.01% of mass.



5.9.36 DENSITY OF FRESHLY MIXED CONCRETE IN BRIDGE DECK OVERLAYS BY NUCLEAR GAUGE (Kansas Test Method KT-36)

## 1. SCOPE

This method of test covers the procedure for determining the in-place density of freshly mixed concrete in bridge deck overlays using a nuclear density gauge. This method is applicable to all types of concrete. **Gauge calibration shall follow 5.8.2. of this manual INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES.** KDOT gauges shall be calibrated-annually.

**The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken. (For KDOT field personnel only: Refer to Standard Operating Manual No. 1.13.2.).**

## 2. REFERENCED DOCUMENTS

2.1. KT-20; Weight Per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete

## 3. APPARATUS

**NOTE:** Check gauge to verify it is in asphalt mode.

3.1. Nuclear density gauge with supporting equipment including reference standard, survey meter, and instructional material.

3.2. Frame to hold gauge at the concrete surface of the in-place material.

3.3. Shovel, trowels, wash bucket, tire brush, rags.

3.4. Tape measure.

3.5. Pachometer.

3.6. Depth Gauging Wire.

3.7. A supply of No. 30 (600  $\mu\text{m}$ ) sand screened from the fine aggregate in the mix or a pan and a No. 30 (600  $\mu\text{m}$ ) sieve.

3.8. Brush for cleaning up sand.

## 4. DAILY WARM UP AND CHECK

The nuclear gauge shall be turned on for warm-up and checked according to the manufacturer's instructions.

## 5. TEST PROCEDURE

Readings should be taken in a random manner unless there are sound reasons to relocate. Readings should not be taken closer than 1 ft (0.3 m) to a vertical surface.

## 5.1. Direct Transmission Readings

**5.1.1.** For uniformity, the gauge operator shall position the source rod so it is closest to the finish machine (point the gauge towards the placement of the concrete overlay).

**5.1.2.** Place the gauge on the surface and depress the probe to the appropriate depth, when exceeding 2 in (50 mm). On very stiff mixes, it may be necessary to make a hole in the fresh concrete with the 5/8 in (15 mm) graduated pin and hole-forming device furnished with the gauge. The alignment of the hole and the probe is greatly facilitated if the gauge is placed on the concrete surface first. The probe location will show on the fresh concrete as will the outline of the gauge. Take 5 one-minute readings, record wet density values, discard the single highest and lowest values, average the three remaining values, record the average value, and divide this average by the three point moving average of unit weight of fresh concrete.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

## 5.2. Backscatter Readings

**5.2.1.** Backscatter readings are required on overlays 2 in or less (50 mm or less) thick. In addition, the effect of the underlying layer on the readings needs to be taken into account. This is done as follows:

**5.2.1.1.** Obtain a supply of minus No. 30 (600  $\mu\text{m}$ ) sand.

**5.2.1.2.** Mark the location of the top reinforcing steel using a pachometer in at least three relatively smooth areas.

**5.2.1.3.** Place some sand in the area between the reinforcing steel and screed off the excess using a rule or other straight edge. The area covered by the sand should be slightly larger than the bottom of the nuclear gauge and should have all the surface voids filled with the fine sand. There should only be enough sand to fill the voids. Excessive quantities can be counterproductive.

**5.2.1.4.** For uniformity, the gauge operator shall position the source rod so it is closest to the finish machine (point the gauge towards the placement of the concrete overlay).

**5.2.1.5.** Place the gauge on the prepared area, lower the probe to the backscatter position, take 5 one-minute readings, record wet density values, discard the single highest and lowest values, average the three remaining values, record the average value.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**5.2.2.** Repeat **Section 5.2.1.5** of this test method in at least two other locations. Average all of these for an average density of the underlying layer. Low readings originating from an air gap under the gauge should not be included in the average.

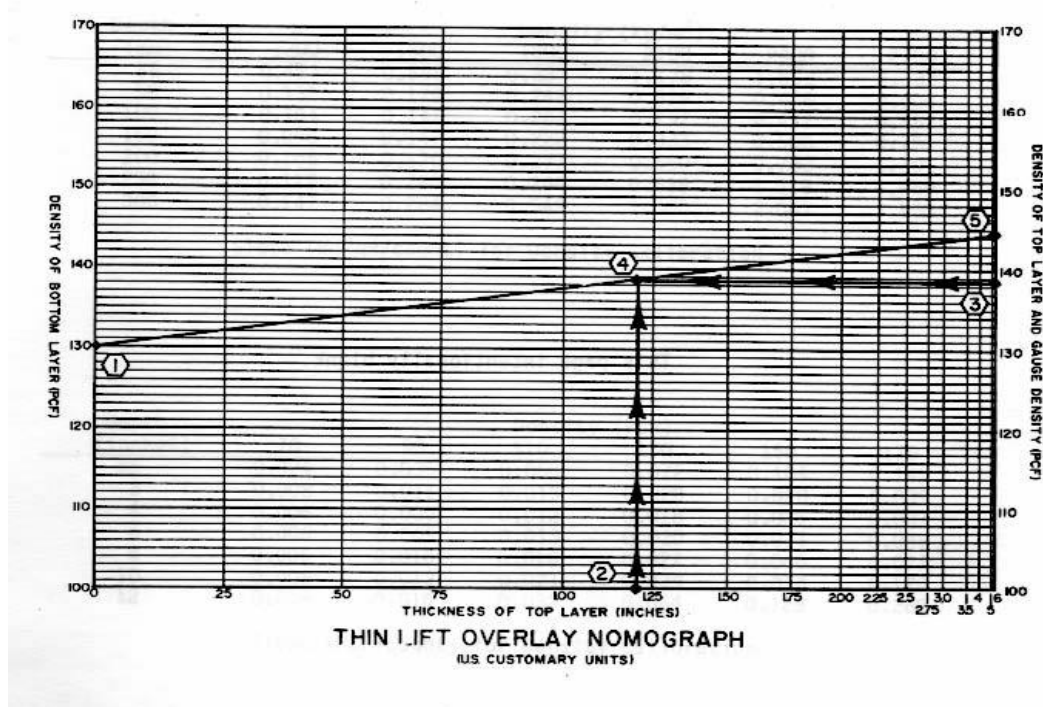
**5.2.3.** The nuclear readings on the overlay are corrected by using the formula in **Section 5.2.3.1.** or by using the nomograph and the procedure in the manufacturer's manual, as shown in the examples below:



**\*\*NOTICE\*\***

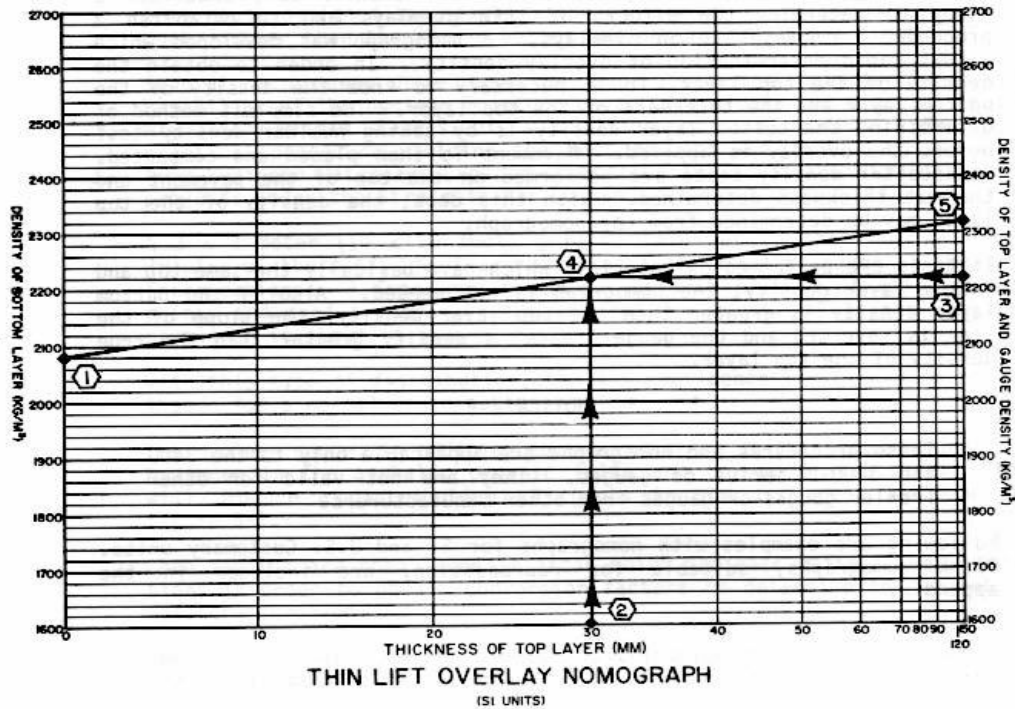
This procedure and nomograph are applicable only to the 3400 series gauge. It is not valid for other Troxler gauges or gauges from other manufacturers. The Troxler 3440 gauge contains software which can make the corrections described above within itself. Refer to operators manual.

IN ENGLISH UNITS



In this example, the bottom layer density (left scale) is 130 lb/ft<sup>3</sup> with a mat of 1.2 inches thick overlaying it. A backscatter density test on the top of the mat (right scale) yielded a result of 138.5 lb/ft<sup>3</sup>. A line is then drawn from 130 lb/ft<sup>3</sup> on the left scale through the intersection of 1.2 inches (bottom) and 138.5 lb/ft<sup>3</sup> (right) and extended to the right. The correct density for the top layer is then read from the nomograph as 144.5 lb/ft<sup>3</sup> on the right scale.

IN SI UNITS:



In this example, the bottom layer density (left scale) is 2080 kg/m<sup>3</sup> with a mat of 30 mm thick overlaying it. A backscatter density test on the top of the mat (right scale) yielded a result of 2220 kg/m<sup>3</sup>. A line is then drawn from 2080 kg/m<sup>3</sup> on the left scale through the intersection of 30 mm (bottom) and 2220 kg/m<sup>3</sup> (right) and extended to the right. The correct density for the top layer is then read from the nomograph as 2320 kg/m<sup>3</sup> on the right scale.

**5.2.3.1.** The following formula may be used to correct thin layer measurements of overlays of 1 to 3 inches (25 to 75 mm) in thickness when using Troxler 3401, 3411-B and 3430:

$$DT = \frac{DG - DB * K}{1 - K}$$

Where:

DT = Corrected overlay density

DG = Density read by gauge

DB = Bottom layer density

K = Effect of top layer thickness on the gauge (From Table 1 below)

**Table 1**

Thickness (inches)	Thickness (mm)	K	Thickness (inches)	Thickness (mm)	K
1.0	25	0.46152	2.1	53	0.14617
1.1	28	0.42042	2.2	56	0.12880
1.2	30	0.38235	2.3	58	0.11275
1.3	33	0.34710	2.4	61	0.09790
1.4	36	0.31462	2.5	63	0.08418
1.5	38	0.28454	2.6	66	0.07149
1.6	41	0.25673	2.7	69	0.05976
1.7	43	0.23102	2.8	71	0.04892
1.8	46	0.20725	2.9	74	0.03889
1.9	48	0.18527	3	76	0.02962
2.0	51	0.16495			

**5.2.4.** For uniformity, the gauge operator shall position the source rod so it is closest to the finish machine (point the gauge towards the placement of the concrete overlay).

**5.2.5.** Number of readings: Take 5 one-minute readings at a single location, record wet density values, discard the single highest and lowest values, average the three remaining values, record the average value, and divide this average by the three point moving average of unit weight of fresh concrete.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

## 6. CALCULATION

**6.1.** The average wet density reading is divided by the three point moving average of the unit weight of concrete and multiplied by 100 to obtain a percent density. When fewer than three unit weights are available, the “Density Standard” shall be the average of those determinations made until a total of three may be averaged.

$$\text{Percent of Standard} = \frac{100(\text{WD})}{\text{Density Standard}}$$

## 7. REPORT AND RECORD

**7.1.** Report and record wet density values as 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>).

**7.2.** Report and record Percent of Standard Density to the nearest whole percent.



5.9.37 MAKING, CURING AND TESTING CEMENT TREATED AND UNBOUND BASES (Kansas Test Method KT-37)

**1. SCOPE**

This method covers the procedure for making and curing compression test specimens of Cement Treated and Unbound Base under accurate control of quantities of materials and test conditions. Bound bases are considered the same as Cement Treated Bases.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-11; **Section 2.** Moisture Tests, **Section 4.** Constant Mass Method

**2.3.** KT-12; Standard Compaction Test

**2.4.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

**2.5.** AASHTO T 99; Moisture-Density Relations of Soils Using a 5.5 lb (2.5kg) Rammer and a 12 in (305 mm) Drop

**2.6.** ASTM C1231; Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens

**3. APPARATUS**

**3.1.** A calibrated cylindrical mold, solid or split, of predetermined volume approximately 6 in (150 mm) in diameter and 6 in (150 mm) in height and having a volume of approximately 1/10 ft<sup>3</sup> (2.8 L). The mold is equipped with a removable base plate. Example of acceptable mold assembly is the Humboldt compaction mold, model number H-4163, Durham GEO S-328, or a Durham GEO S-319. Note that a minimum of 3 molds are required for production testing and a minimum of 9 molds are required for mix design.

**NOTE:** The volume of the mold (without the collar) is measured by coating one end with cup grease or Vaseline to form a seal and then placing it on a glass plate which should be placed in a level position on a scale. The other end of the mold is coated with cup grease or Vaseline and then the mold and two glass plates are weighed. The mold may then be filled with  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ) water after which the second glass plate should be placed on top of the mold in such a way as to eliminate air bubbles and excess water. Any excess water thus removed must be carefully wiped off after which the final weight of the mold, water and glass plates may be determined. The volume of the mold may then be calculated using 62.243 lb/ft<sup>3</sup> (997 kg/m<sup>3</sup>) as the density of water.

**3.2.** Rigid steel straight edge meeting standards set forth in **AASHTO T 99, Section 3.6.**

**3.3.** A mechanically operated metal rammer equipped to control the height of drop to 12.00 + 0.06 in (305 + 2 mm) above the elevation of the material and to distribute the blows uniformly over the material surface. The rammer has a rigid “pie-shaped” (sector) foot. The foot shall be a sector of a 6 in (150 mm) diameter circle and shall have an area equal to that of a 2 in (50 mm) diameter circle. The nominal mass of the rammer is 5.50 ± 0.02 lb. (2.495 ± 0.009 kg).

**3.4.** Manually operated. Metal rammer with a mass of  $5.5 \pm 0.02$  lb ( $2.495 \pm 0.009$  kg) and having a flat circular face of 2.000 in (50.80 mm) diameter with a tolerance of  $\pm 0.01$  in ( $\pm 0.25$  mm). The in-service diameter of the flat circular face shall be not less than 1.985 in (50.42 mm). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of  $12.00 \pm 0.06$  in ( $305 \pm 2$  mm) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes, no smaller than 3/8 in (9.5 mm) diameter spaced at 90 degrees apart and 3/4 in (19 mm) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

**3.5.** Sieves meeting requirements set forth under for 1 in (25.0 mm), 3/4 in (19.0 mm), 1/2 in (12.5 mm), 3/8 in (9.5mm), No. 4 (4.75 mm), No. 8 (2.36 mm ASTM E11 and No. 16 (1.18 mm).

**3.6.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.7.** A thermostatically controlled drying oven capable of maintaining a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**3.8.** Sample extruder (desirable) should consist of a frame, jack and circular metal loading plate or other suitable device for removing specimens from the mold.

**3.9.** Drying pans.

**3.10.** Trowels, spatulas and other mixing tools or a mechanical mixer that will thoroughly mix the material, cementitious material and water.

**3.11.** A moist room or cabinet (CTB only) capable of maintaining a temperature of  $73 \pm 3^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) and a relative humidity of not less than 96%.

**3.12.** A tamping rod (CTB only) 5/8 in (16 mm) diameter and approximately 24 inches (600 mm) in length that is round with at least one end having a hemispherical tip.

**3.13.** Soft rubber mallet.

#### **4. SAMPLE PREPARATION.**

**4.1.** For mix design, dry the base aggregate to a constant mass at approximately  $230^\circ\text{F}$  ( $110^\circ\text{C}$ ).

Separate the base aggregate by dry screening into the desired fractions and compute the percentage retained on each sieve. The following size fractions are recommended as a minimum:

1 1/2 in to 1 in (37.5 mm to 25 mm)	No. 4 to No. 8 (4.75 mm to 2.36 mm)
1 in to 3/4 in (25 mm to 19 mm)	No. 8 to No. 16 (2.36 mm to 1.18 mm)
3/4 in to 1/2 in (19 mm to 12.5 mm)	No. 16 to No. 30 (1.18 mm to 600 $\mu\text{m}$ )
1/2 in to 3/8 in (12.5 mm to 9.5 mm)	No. 30 to No. 100 (600 $\mu\text{m}$ to 150 $\mu\text{m}$ )
3/8 in to No. 4 (9.5 mm to 4.75 mm)	No. 100 to No. 200 (150 $\mu\text{m}$ to 75 $\mu\text{m}$ )

**4.2.** Make six portions of base aggregate for each percent of cementitious material to be tested. Recombine the aggregate fractions at the percentage determined in **Section 4.1** of this test method. Each portion shall weigh 7000 g minus the amount of cementitious material to be added.

4.3 Thoroughly mix each sample portion of aggregate with the required amount of cementitious material and place the mixture in a separate pan if applicable.

4.4. For production (QC/QA) control, prepare field material in the following manner:

4.4.1. Acquire a random sample of at least 35 lbs (15 kg) of material. Split the material as follows:

4.4.1.1. Place the sample on clean sheet metal and mix thoroughly with a trowel.

4.4.1.2. Divide the pile into two equal halves with a straightedge (trowel or similar metal blade) and completely remove the back half of the sample.

4.4.1.3. If the sample isn't the proper size (approximately 7000 g), then use the trowel (or metal blade) to remove or add a portion to achieve the proper size.

## 5. MOISTURE DENSITY RELATIONSHIP TEST PROCEDURE

5.1. For mix design purposes, add a measured amount (approximately 5%) of water and thoroughly mix with one-7000 g portion. After the addition of water and thorough mixing, compact immediately. **DO NOT CURE OR AGE THE SPECIMEN AT THIS POINT.** For field production obtain a 7000 g portion of combined material.

5.2. Determine the mass of the mold. Place the assembled mold and collar on the rigid base and compact by one of the following methods:

5.2.1. For samples with 1 in (25 mm) slump or less, compact the material in four lifts. Place enough loose moist material in the mold to fill half the mold (not the collar and mold depth). Compact the layer with 56 blows of the rammer with the blows being distributed uniformly over the surface of the layer. Place three, approximately equal, additional layers of material in the mold and compact each layer in a similar manner.

5.2.2. For samples with a slump greater than 1 inch (25 mm), it may be more appropriate to rod the sample instead of using the rammer. Compact the material in three lifts. Place enough material in the mold to fill half the mold (not the collar and mold depth). Rod the material 25 times throughout its depth with the strokes being uniformly distributed over the cross section of the mold. After rodding, tap the outsides of the mold lightly 10 to 15 times with a soft rubber mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped. Repeat this process for the second and third lifts. The second lift should completely fill the mold, while the third lift should come close to filling the mold and collar. While rodding the second and third lifts, be sure to penetrate the lower lifts by about 1/2 in (12 mm).

5.3. After the final layer has been compacted, remove the collar and trim excess material level with the top of the mold.

5.4. Remove the base and weigh the specimen while it is in the mold. Subtract the mass of the mold to determine the wet mass of the compacted specimen. Then remove the specimen from the mold and place it in an individual drying pan.

5.5. **(For Laboratory Prepared Material Only):** Repeat the compaction procedure using the other 7000 g increments of the sample to which different measured amounts of water have been added and thoroughly mixed. This procedure will be continued with varying moisture contents until at least three points are obtained on the dry side of "optimum moisture" and at least two points are obtained on the wet side of

“optimum moisture.” This can usually be accomplished by compacting different specimens at moisture intervals of 2 to 3%, starting on the dry side of “optimum moisture” and ending on the wet side.

**5.6.** Dry each specimen to constant mass or remove a small representative increment from each specimen (at least 500 g) and determine its moisture content in accordance with **KT-11, Section 3**.

## 6. CALCULATIONS

**6.1.** When the entire specimen is dried:

$$\text{Moisture Content \%} = \frac{100(\text{Wet Mass}-\text{Dry Mass})}{\text{Dry Mass}}$$

$$\text{Dry Density} = \frac{\text{Dry Mass of Specimen}}{\text{Volume of Mold}}$$

Where:

Dry density	= lb/ft <sup>3</sup> (kg/m <sup>3</sup> )
Dry mass of specimen	= lb (kg)
Volume of mold	= ft <sup>3</sup> (m <sup>3</sup> )

**6.2.** When a small increment of each specimen is dried, compute dry mass of specimen as follows:

$$\text{Dry Mass of Specimen} = \frac{100(\text{Wet Mass of Specimen})^1}{100 + \% \text{ Moisture}}$$

Compute dry density of specimen as in **Section 6.1** of this test method.

## 7. LABORATORY PREPARED MATERIAL COMPACTION CURVE

**7.1.** Plot a density/moisture curve on coordinate paper (**KDOT Form No. 638**) to determine the maximum density and optimum moisture. The dry density values are plotted as ordinates, the corresponding moisture contents are plotted as abscissa and a smooth curve is drawn to best fit the points.

**NOTE:** In drawing a curve by this method all of the points will not necessarily be on the curve and the maximum density may be more or less than the highest test point (See **KT-12** for examples).

The optimum moisture content is the moisture content at which the maximum density occurs on the curve.

## 8. COMPRESSION TEST PROCEDURE (FOR CTB ONLY)

**8.1.** Prepare the molds by lightly oiling the inside of the mold and placing a filter paper disk in the bottom of the mold prior to introducing the material for the first lift.

**8.1.1. For mix designs:** Prepare nine essentially identical specimens at the selected mix design parameter by the procedures shown in **Section 4. through Section 5.3** of this test method except scratch the surface of each lift after it is compacted to facilitate bonding between lifts.

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<sup>1</sup> “Wet mass of the specimen” is the mass of the molded plug.



**8.1.2. For production (QC/QA) control:** Mold 1 specimen per test as stated in **Section 4. through Section 5.4.** of this test method except scratch the surface of each lift after it is compacted to facilitate bonding between lifts.

**8.2.** Cure the specimens in a moist room from the time compaction is complete until tested.

**NOTE:** If a moisture room is not available, then place each of the specimens in a sealable plastic container (plastic bags are not acceptable), drape a damp cotton towel over the specimen and seal the container for the specified time. The object is to achieve and maintain near 100% moisture conditions throughout the curing process.

**8.2.1. For mix designs:** demold 3 specimens at  $24 \pm 4$  hours, three at  $48 \pm 4$  hours, and three at  $72 \pm 4$  hours.

**8.2.2. For production (QC/QA) control:** demold specimen at  $24 \pm 4$  hours. If this falls on a non-working day, then adjust as stipulated in **Section 9.4** of this test method.

**8.3.** When the cure is completed; the specimens are removed from the moist room, measured for diameter, capped, weighed and measured for height after capping and broken. **Use sulfur or unbonded caps to cap the CTB specimens.** Follow the procedures set forth in KT-77 for sulfur caps and ASTM C1231 for unbonded caps. Allow sulfur caps to cure for a minimum of 2 hours prior to breaking.

**8.4.** Test specimens at 7 days  $\pm 4$  hours. Place the specimen on the table of the compression-testing machine. Make sure the vertical axis of the specimen is aligned with the center of thrust of the load head. Apply the load continuously and without shock. Adjust the loading to a constant rate of 10-12 psi/sec (69-83 kPa/sec) for a hydraulic system. Record the total load to the nearest 10 lbf (50 N).

**8.5.** After testing, place each specimen in a drying pan and put in a 230°F (100°C) oven for 24 to 48 hours until a constant mass is attained. Determine the mass of the dry specimen.

## 9. CALCULATIONS

**9.1.** Determine the moisture content at the time of testing and the dry density of the specimen using the methods shown in **Section 6.1** of this test method.

**NOTE:** The moisture and density determined in this section will not be used in the plotting of the control charts, but can be used for comparison purposes should other tests results fail to meet criteria.

**9.2.** Determine the correction factor for the value of the ratio of the length of the specimen to the diameter (L/D) from the following table:

L/D	Correction Factor	L/D	Correction Factor
1.94 – 2.00	1.00	1.23 – 1.28	0.93
1.82 – 1.93	0.99	1.19 – 1.22	0.92
1.69 – 1.81	0.98	1.15 – 1.18	0.91
1.56 – 1.68	0.97	1.11 – 1.14	0.90
1.46 – 1.55	0.96	1.06 – 1.10	0.89
1.38 – 1.45	0.95	1.02 – 1.05	0.88
1.29 – 1.37	0.94	1.00 – 1.01	0.87

**9.3.** Multiply the failure load by the correction factor determined from the table above and divide by the area of the test specimen to determine the corrected compressive strengths in psi (kPa)] at failure. Record this value as P.

$$P = \frac{F_{cor}}{A}$$

Where:

$F_{cor}$  = failure load x correction factor

$$A = \pi r^2$$

**9.4. Design:** During the Design phase develop a time adjustment factor for the 48-hour and 72-hour molded specimens to correlate back to the 24-hour molded specimens in the following manner:

**9.4.1.** Determine the average corrected compressive strengths for each of the three sets (24, 48, 72-hour) of molded specimens.

**9.4.2.** Determine the time adjustment factor by dividing the base time compressive strength (24-hour) by the extended times compressive strengths in the following manner:

$$T_{48} = \frac{P_{24}}{P_{48}}$$

$$T_{72} = \frac{P_{24}}{P_{72}}$$

Where:  $T_{48}, T_{72}$  = Time adjustment factor for a given (either 48-hour or 72-hour) molded specimen.  
 $P_{24}, P_{72}$  = Average compressive strength values for a given (either 48-hour or 72-hour) set of molded specimens.

**9.5. Production:** During the field production phase, apply the appropriate time adjustment whenever specimens are not removed from the mold in  $24 \pm 4$  hours in the following manner:

$$P_{adj} = P \times T_{48} \quad \text{or} \quad P_{adj} = P \times T_{72}$$

## 10. REPORTING

**10.1.** For laboratory prepared material, report the pressure at failure of each specimen in the three-specimen set in addition to the average failure pressure of the three specimens. For field prepared material, report the pressure at failure for each specimen. The report should reference this test procedure. Record the compressive strength to the nearest 1 psi (0.01 MPa). Report the compressive strength to the nearest 10 psi (0.1 MPa). Record the density to 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>). Report the density to the nearest to whole number.

5.9.38 DENSITY OF FRESHLY MIXED CONCRETE IN PAVEMENT BY NUCLEAR METHOD  
(Kansas Test Method KT-38)

**1. SCOPE**

This method of test covers the procedure for determining the in-place density of freshly mixed concrete in pavements using nuclear density gauge. This method is applicable to all types of concrete. **KT-38** reflects testing procedures found in **ASTM C1040. Gauge calibration shall follow 5.8.2. INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES.** KDOT gauges shall be calibrated-annually.

**The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken (For KDOT field personnel only: Refer to Standard Operating Manual No. 1.13.2.).**

**2. REFERENCED DOCUMENTS**

- 2.1.** KT-20; Weight Per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete
- 2.2.** C1040; In-Place Density of Unhardened and Hardened Concrete, Including Roller Compacted Concrete, By Nuclear Methods

**3. APPARATUS**

**NOTE:** Check gauge to verify it is in asphalt mode.

**3.1.** Nuclear density gauge with supporting equipment including reference standard, survey meter, and instructional material.

**4. DAILY WARM-UP CHECK**

The nuclear gauge shall be turned on for warm-up and checked according to the manufacturer's instructions.

**5. TEST PROCEDURE**

**5.1.** For uniformity, the gauge operator shall position source rod so it is closest to the paving machine (point the gauge toward the concrete placement).

**5.1.1.** Transverse Profile of Densities: A transverse profile of wet densities shall be taken to evaluate the effectiveness of the consolidation system. This profile is developed by taking a single one-minute density reading in each vibrator path and in each gap between two vibrators across the entire placement width. Although not all readings can be obtained at one station, an effort should be made to develop the profile in as short a time as possible. A complete profile needs to be run each time a change is made in the placement machine which could affect consolidation.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**5.2.** For uniformity, the gauge operator shall position source rod so it is closest to the paving machine (point the gauge toward the concrete placement).

**5.2.1. In-Place Concrete Densities:** The daily wet density readings should be taken in both the vibrator paths and the gaps between vibrators to verify the density profile as well as document the percent of required consolidation taking place. Take 5 one-minute readings, record wet density values, discard the single highest and lowest values, average the three remaining values, and record the average value. These readings should be taken no closer than 1 ft (0.3 m) to a vertical edge nor within 2 ft (0.6 m) of a dowel basket assembly.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**5.3.** Place the gauge on the surface and depress the probe to the appropriate depth, normally 8 in (200 mm). After the readings are taken, lift the gauge from the concrete by the case and clean the probe before restoring the probe to its safe position.

## **6. CALCULATION**

**6.1.** The wet density (WD) is divided by the three point moving average of the consolidated unit weight of concrete, **KT-20**, and multiplied by 100 to obtain a percent density. When fewer than three consolidated unit weights of concrete are available, the “standard density” shall be the average of those determinations made until a total of three may be averaged.

$$\text{Percent of Consolidation} = \frac{100(\text{WD})}{\text{Density Standard}}$$

**NOTE:** For concrete, record the WD reading from the nuclear density gauge.

## **7. REPORT AND RECORD**

**7.1.** Report and record wet density values as 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>).

**7.2.** Report and record Percent of Standard Density to the nearest whole percent.

5.9.39 THEORETICAL MAXIMUM SPECIFIC GRAVITY OF ASPHALT PAVING MIXTURES  
(Kansas Test Method KT-39)

**1. SCOPE**

This method covers the determination of the theoretical maximum specific gravity of uncompacted asphalt paving mixtures. **KT-39** reflects testing procedures found in **AASHTO T 209**.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-58; Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by means of the Superpave Gyratory Compactor

**2.3.** AASHTO T 209; Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures

**2.4.** ASTM E1; Specifications for ASTM Thermometers

**3. APPARATUS**

**3.1.** Vacuum container.

**3.1.1.** Two different vacuum containers are described. Each must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The hose opening shall be covered with a small piece of No. 200 (75  $\mu$ m) wire mesh to prevent vacuum pickup of particles during transfer of materials.

**3.1.2.** The vacuum container size depends on the minimum sample size requirements given in **Section 5.1.** of this test method. Avoid using a small sample in a large container.

**3.1.3.** Vacuum containers for weighing in water.

**3.1.3.1.** Type A: A glass, plastic or metal bowl with a minimum capacity of 2000 mL.

**3.1.3.2.** Type B: A thick-wall filter flask or a thick-wall vacuum desiccator with a minimum capacity of 2000 mL.

**3.2.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested. The balance shall be readable to 0.1% or better of the sample mass. For the bowl determination method the balance shall be equipped with a suitable suspension apparatus and holder to permit weighing the sample while suspended from the center of the scale pan of the balance.

**3.3.** Vacuum pump or water aspirator capable of evacuating air from the container to a residual pressure of 3.7 kPa (27 mm of Hg).

**3.3.1.** When a vacuum pump is used, a suitable trap of one or more 1000 mL filter flasks, or the equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

**3.4.** Residual pressure manometer or vacuum gauge traceable to NIST (mandatory) to be connected directly to the vacuum vessel and to be capable of measuring residual pressure down to 3.7 kPa (27 mm Hg).

**NOTE:** A residual pressure of 4.0 kPa (30 mm Hg) absolute pressure is approximately equivalent to 97 kPa (730 mm Hg) reading on vacuum gauge at sea level.

**NOTE:** Residual pressure in the vacuum vessel measured in millimeters of mercury, is the difference in the height of the mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum vessel.

**3.5.** Manometer or vacuum gauge, suitable for measuring the vacuum being applied at the source of the vacuum. This device can be connected directly to the vacuum source or be in the vacuum line close to the source. This is required to check the reading given by the residual pressure manometer attached directly to the vacuum vessel.

**NOTE:** The Torricellian vacuum leg of the manometer occasionally acquires one or more bubbles of air that introduce error into the residual pressure reading. By the addition of the vacuum gauge this error can often be quickly detected by the differences between the two vacuum measurements.

**3.6.** Thermometers, calibrated liquid-in-glass, total immersion type, of suitable range with graduations at least every 0.2°F (0.1°C) and a maximum scale error of 0.9°F (0.5°C) as prescribed in **ASTM E1**.

**3.7.** A draft oven capable of maintaining a uniform temperature of  $275 \pm 9^\circ\text{F}$  ( $135 \pm 5^\circ\text{C}$ ).

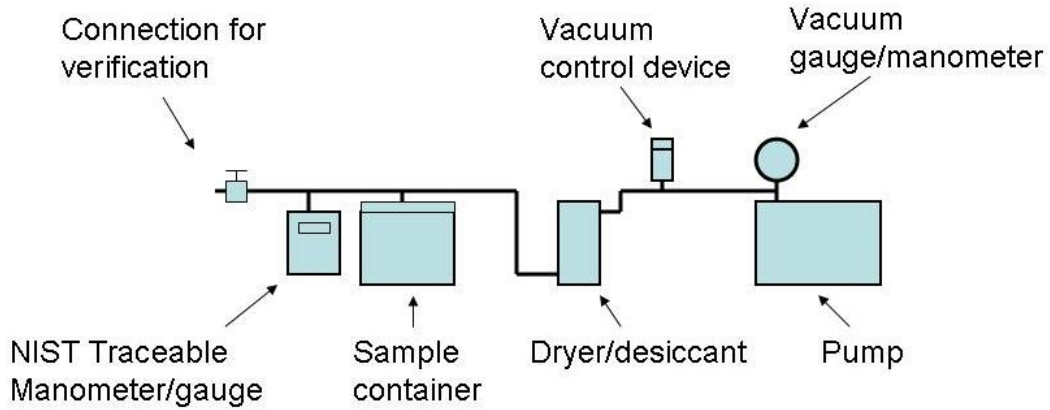
**3.8.** Water bath suitable for immersing the Type A or Type B container in water while suspended under the balance and equipped with an overflow outlet for maintaining a constant water level. Maintain a constant-temperature water bath at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ).

**3.9.** Bleeder valve, attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum vessel.

**3.10.** Mechanical shaker for removing air from asphalt mix with a built-in digital timer capable of 0.25 second accuracy and a maximum time limit of 99 minutes. Also must have ability to adjust vibration frequency to permit maximum release of air and a 3-point switch for off, manual or timed operation. Must have the ability to fully clamp and hold in place a Type A or Type B container full of water and asphalt mix while removing the air from the mix through the vibration process. Must be able to meet or exceed the Gilson Vibro-Deairator (SGA-5R).

**3.11.** Test equipment will be arranged as shown in **Figure 1**, except that the vacuum control can be located anywhere between the pump and the sample container; otherwise incorrect vacuum readings may occur.

Figure 1



#### 4. CALIBRATION OF FLASKS AND BOWLS

4.1. The mass of the Type A or Type B vacuum containers shall be calibrated in water while the water is maintained at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ )<sup>1</sup>.

#### 5. PREPARING MATERIAL

5.1. The sample size shall conform to the requirements of **Table 1**. Samples larger than the capacity of the container may be tested a portion at a time.

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<sup>1</sup> AASHTO T 209 calibrates for a range of temperatures. KDOT specifies the water bath be maintained at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ )

**Table 1**  
**Test Sample Size**

Nominal Maximum Aggregate Size in Mixture	Minimum Sample Size, g
2 in (50.0 mm)	6,000
1 1/2 in (37.5 mm)	4,000
1 in (25.0 mm)	2,500
3/4 in (19.0 mm)	2,000
1/2 in (12.5 mm)	1,500
3/8 in (9.5 mm)	1,000
No. 4 (4.75 mm)	500

## 6. PROCEDURE

**6.1.** If this is a design mix, then age the asphalt material by placing the sample in a preheated draft oven at compaction temperature for 2 hours as outlined in **KT-58 Section 7.5 of this manual**. Remove from the oven and permit to cool. During the cooling process, start separating the particles. Once the sample nears room temperature, separate the particles of the sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 1/4 in (6.3 mm). If the sample is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

**NOTE:** Field samples should be retrieved from the roadway behind the paver, stored in an insulated container and returned to the laboratory. Once the sample arrives at the laboratory and the material is hot enough to separate out as outlined in **Section 6.1** of this test method, then continue with **Section 6.2** of this test method. If the sample has cooled too much, then place in a preheated draft oven at compaction temperature for 30 minutes and continue with **Section 6.1** of this test method. Do not perform the aging process as stated in **Section 6.1** of this test method.

**6.2.** Unless the sample has been prepared in a laboratory using oven-dry aggregates, oven-dry to constant mass at a temperature of  $221^{\circ} \pm 9^{\circ}\text{F}$  ( $105^{\circ} \pm 5^{\circ}\text{C}$ ). This drying and any required warming for particle separation as described in **Section 6.1** of this test method should be combined as a single operation to minimize reheating effects. Any Marshall or Superpave Gyration plugs used must also be dried and softened in an oven (30-60 minutes).

**6.3.** Cool the sample to room temperature, place it in a tared calibrated flask or bowl. The sample is to be placed directly into a Type A or B vacuum container. A container within a container is not to be used. Weigh and designate the net mass of the sample as "A". Add sufficient water at a temperature of  $77^{\circ} \pm 2^{\circ}\text{F}$  ( $25^{\circ} \pm 1^{\circ}\text{C}$ ) to cover the sample completely.

**6.4.** Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads  $3.7 \pm 0.3 \text{ kPa}$  ( $27 \pm 3 \text{ mm of Hg}$ )<sup>2</sup>. Full vacuum shall be applied within 30 seconds. Maintain this residual pressure for  $14 \pm 0.5 \text{ min}$ . Agitate the container and contents during the vacuum period continuously using a mechanical device. Glass vessels should be taken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

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<sup>2</sup> AASHTO T 209 requires a residual pressure of  $27.5 \pm 2.5 \text{ mm of Hg}$ .



**6.4.1.** The frequency on the mechanical shaker shall be set to impart a vibration that maximizes particle turbulence with minimum rotation of the material in a clockwise or counter clock wise direction. Monitor and adjust the frequency to maintain maximum particle turbulence throughout the time under vacuum.

**NOTE:** The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001% or 0.2 grams in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.

**6.5.** At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mm of Hg) per second and proceed with one of the following determinations.

**6.5.1.** Suspend the container and contents in the water bath and determine the mass after  $10 \pm 1$  minute immersion. Measure the temperature of the water bath to verify  $77^\circ \pm 2^\circ\text{F}$  ( $25^\circ \pm 1^\circ\text{C}$ ). Designate the mass of the sample in water as “C”.

## 7. CALCULATIONS

**7.1.** Calculate the theoretical maximum specific gravity ( $G_{mm}$ ) of the sample at  $77^\circ\text{F}$  ( $25^\circ\text{C}$ ) as follows:

$$G_{mm} = A/(A-C)$$

Where:           A= Mass of dry sample in air, g  
                       C= Mass of the sample in water at  $77^\circ\text{F}$  ( $25^\circ\text{C}$ ), g

**7.1.1.** When it is necessary to test a sample a portion at a time, the differences between the theoretical maximum specific gravities for each portion should be within the precision statements listed in **Section 8** of this test method. If the values are within the precision statements, the specific gravities for each portion shall be averaged. If the values are outside the precision statements, the test shall be run again.

**7.2.** Calculate the theoretical maximum specific gravity of the samples as shown on the work sheet below.

Reference				
Project	Date		Lab. No.	
Sample No.				
Mass of Container, g				
Mass of Dry Sample in air, g	A			
Mass of Vacuumed Sample in Water, g	C			
Specific Gravity (in water) = $A/(A-C)$				

## 8. PRECISION

**8.1.** Criteria for judging the acceptability of specific gravity test results obtained by this method are given in **Table 2**. The figures given in column 2 are the standard deviations that have been found to be appropriate for the conditions of test described in column 1. The figures are given in column 3 are the limits that should not be exceeded by the difference between the results of the two properly conducted tests.

**Table 2<sup>3</sup>**  
**Specific Gravity Test Results**

Type <sup>4</sup>	Standard Deviation (1S)	Acceptable Range of Two Results (D2S)
Single-operator precision	0.0051	0.014
Multilaboratory precision	0.0084	0.024

## 9. REPORTING

**9.1.** Reporting Air Voids.  $V_a$  to 0.01%.  $G_{mm}$  and  $G_{mb}$  to 0.001.

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<sup>3</sup> **Table 2** is copied from **AASHTO T 209**.

<sup>4</sup> **AASHTO T 209** provides an additional section, **§13. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE**. This section is not addressed in **KT-39**.

5.9.41 DETERMINATION OF DENSITY AND MOISTURE CONTENT OF PORTLAND CEMENT TREATED BASES, AGGREGATE BASES AND AGGREGATE SHOULDERS BY NUCLEAR METHOD (Kansas test Method KT-41)

## 1. SCOPE

This method of test covers the procedure for calibrating the nuclear gauge and determining density and moisture in Portland Cement treated bases, aggregate bases and aggregate shoulders. **Gauge calibration shall follow 5.8.2. INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES.** KDOT gauges shall be calibrated annually. **KT-41** reflects procedures found in **ASTM C1040**.

**The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken. (For KDOT field personnel only: Refer to Standard Operating Manual No. 1.13.2.).**

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9.; Sampling and Test Methods Foreword

2.2. KT-11; Moisture Tests, Section 4. Constant Mass Method

2.3. KT-13; Field Density Tests of Soils, Treated Base Courses, and Water Bound Base Courses

2.4. KT-32; Method of Test for Density of Compacted Asphalt Mixtures by Nuclear Method

2.5. KT-43; Moisture Content of Asphalt Mixtures or Mineral Aggregates - Microwave Oven Method

2.6. C1040; In-Place Density of Unhardened and Hardened Concrete, Including Roller Compacted Concrete, By Nuclear Methods

## 3. APPARATUS

**NOTE:** Check gauge to verify it is in soil mode.

3.1. Nuclear moisture/density gauge with supporting equipment including reference standard, survey meter, and instructional material.

3.2. KDOT Validator: Device to establish a wet density field correction factor for the nuclear gauge. Each Validator has a certified block density.

3.3. A supply of minus No. 30 (600 $\mu$ m) sand with no more than 20% represented by minus No. 100 (150  $\mu$ m).

3.4. Brush for cleaning up the fine sand.

3.5. The balance shall be readable to 0.01 lb (5 g) and sensitive to 0.005 lb (1 g) and conform to the requirements of **Part V, Section 5.9; Sampling and Test Methods Foreword** of this manual for the class of general purpose balance required for the principal sample mass of the sample being tested.

3.6. Shelter to protect the balance from wind currents and the sample from exposure to the sun or wind.

**3.7.** Oven capable of maintaining a constant temperature of approximately 230°F (110°C). If available, a microwave oven as described in **KT-43** may be used.

**3.8.** Miscellaneous equipment including standard drying pans, trowel, large spoon, hammer, square point shovel, and air tight containers.

#### **4. NUCLEAR GAUGE WARM UP AND CHECK**

The nuclear gauge shall be turned on for warm-up and checked according to the manufacturer's instructions.

#### **5. TEST SITE SELECTION AND PREPERATION**

Test site shall be selected as outlined in **KT-32, section 4.1**. Leveling sand may be needed.

#### **6. VALIDATOR CORRECTION FACTOR**

**6.1.** Use the KDOT Validator to determine the wet density field correction factor for density in the following manner:

**6.1.1.** Place the gauge on the Validator at the depth to be used on the project.

**6.1.2.** Take 5 one-minute readings, discard the single highest and lowest values, record the three remaining wet density values.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**6.1.3.** Determine the average difference (field density correction factor) using **Section 9.1** of this test method.

**6.1.4.** Use this correction factor to determine the final wet density reading for each test site.

#### **7. PERCENT MOISTURE CORRECTION FACTOR**

**7.1.** Use **KT-11, Section 4, Constant Mass Method**, to determine the percent moisture correction factor.

**7.2.** Conduct a minimum of seven tests. Compute the correction factor for each test. The sample standard deviation (*s*) for the percent moisture content correction factors must be less than 1%. If the above criteria is met, use the average correction factor computed. If the *s* criteria is not met, start over again with seven new tests.

**NOTE:** When calibrating multiple gauges, if it becomes necessary to discard a location or locations because the location or locations failed the standard deviation (*s*), then the same location or locations **must** be discarded for all gauges being calibrated using these set of cored locations.

**NOTE:** A test represents 5 one-minute Wet Density (WD) and Percent Moisture (%M) readings from the gauge. Record the lb/ft<sup>3</sup> (kg/m<sup>3</sup>) on Wet Density (WD) and Percent Moisture (%M) for each reading. Discard the single highest and lowest wet density values along with their accompanying percent moisture values, average the three remaining percent moisture values, and record the average value.

**7.3.** Dry the material removed from the test hole to a constant weight at approximately 230°F (110°C). The material shall be dried the same day it is cored. Record the dry weight and calculate the percent moisture.

## **8. TEST PROCEDURE**

**8.1.** Location of the test site should be on a random basis. Any of several methods may be used, however, the use of a set of Random Number Tables (see **Section 5.2.2.2. Random Sampling** of this manual) is recommended. Regardless of the method selection chosen, it shall satisfy the requirement that any area of the surface shall have an equal chance of being sampled. Sampling shall not be conducted on sites closer than 1.0 ft (0.3 m) to an unconfined edge or vertical surface such as a raised edge of curb and gutter, etc. When the randomized selection method indicates a site within 1 ft (0.3 m) of an exposed edge or vertical surface, it is permissible to move the gauge transversely to clear the 1 ft (0.3 m) restriction. It is also permissible to determine an alternate location using the table again.

**8.2.** Since the measured values of density are affected by the surface conformation of the material immediately beneath the gauge, a flat surface should be tested for best results, both during calibration and density testing. If the mix has a coarse surface, it is likely that the results will vary widely. Calibration and testing should be done with leveling sand immediately beneath the gauge. Spread thinly a sufficient amount of minus No. 30 (600 µm) sand on the test site and smooth with the metal plate or a straight edge to obtain a suitable surface with a minimum amount of the sand.

**8.3.** For uniformity, the gauge operator shall position the source rod so it is closest to the laydown machine (point the gauge towards the roller).

**8.4.** After the site selection has been made, a vertical hole is made 2 in (50 mm) deeper than the thickness of the material with the rod and plate provided with the gauge. If the thickness of the material exceeds the depth capability of the gauge, then a hole is made 2 in (50 mm) deeper than the gauge's maximum depth. The same hole depth used for calibration is to be used for normal testing. Set the probe to maximum depth or at a depth equal to the plan thickness, whichever is less. Wet density and percent moisture readings can now be taken using 5 one-minute counts, discard the single highest and lowest wet density values along with their accompanying percent moisture values, average the three remaining wet density values and record, and average the three remaining percent moisture values and record.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

## **9. CALCULATIONS**

**9.1.** Compute Field Density Correction Factor and Corrected Wet Density.

Individual Correction Factor = Validator – Nuclear Gauge

$$\text{Avg. Correction Factor} = \frac{\sum 3 \text{ Individual Correction Factors}}{3}$$

$$WD = WD_i + \text{Avg. Correction Factor}$$

Where:  $WD_i$  = initial gauge reading at test site  
 Validator = certified block density

## 9.2. Compute Percent Moisture Content Correction Factor

### 9.2.1. $U_i = (w - X)$

Where:  $w$  = moisture content, percent (see **KT-11, Section 5.1.** for determination of  $w$ )  
 $X$  = Nuclear Gauge moisture content, percent  
 $U_i$  = Individual difference between  $w$  and  $X$

### 9.2.2. Average percent moisture content correction factor ( $U$ ).

$$U = \frac{\sum U_i}{n}$$

## 9.3. Sample standard deviation ( $s$ ) (see **KT-32, Section 7.6.1.1.** for more detail):

$$s = \sqrt{\frac{\sum (d_i - d_b)^2}{n - 1}}$$

Where:  $d_i$  = Individual difference ( $U_i$ )  
 $d_b$  = Average difference ( $U$ )

## 9.4. Corrected Percent Moisture Content, (%M)

$$\%M = (X + U)$$

## 9.5. Dry Density, lb/ft<sup>3</sup> (kg/m<sup>3</sup>), (DD)

$$DD = \frac{WD}{\left(1 + \frac{\%M}{100}\right)}$$

Where:  $WD$  = Nuclear Gauge Wet Density, lb/ft<sup>3</sup> (kg/m<sup>3</sup>)

### 9.6. Percent of Proctor = $\frac{100 (WD)}{\text{Standard Proctor}}$ or $\frac{100 (DD)}{\text{Standard Proctor}}$

## 10. REPORT AND RECORD

**10.1.** Report and record as 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>) or 0.1% of optimum density.

5.9.42 SIEVE ANALYSIS FOR ACCEPTANCE OF LIME OR CEMENT TREATED SOILS  
(Kansas Test Method KT-42)

**1. SCOPE**

**1.1.** This method of test covers the procedure for determining the amount of material retained on the 2 in (50 mm), 1 1/2 in (37.5 mm) and the No. 4 (4.75 mm) sieves for lime treated soils.

**1.2.** This method of test covers the procedure for determining the amount of material retained on the 1 1/2 in (37.5 mm) and the 1/2 in (12.5 mm) sieves for cement treated soils.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-02; Sieve Analysis of Aggregates

**2.3.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Sieves meeting ASTM E11 of specified sizes for the soil being tested.

**4. SOIL SAMPLES**

**4.1.** Obtain samples of road mixed material from the subgrade or borrow area. The original sample before splitting shall weigh approximately 77 lbs (35,000 g).

**4.2.** Reduce sample by quartering or splitting to a mass of not less than 33 lbs (15,000 g). Exercise extreme care to prevent segregation and/or degradation during the reducing operation.

**5. TEST PROCEDURE FOR LIME TREATED SOIL**

**5.1.** The sample shall be weighed and sieved through a series of sieves to include 2 in (50 mm), 1 1/2 in (37.5 mm), 1/2 in (12.5 mm), 3/8 in (9.5 mm) and No. 4 (4.75 mm).

**5.2.** The sample shall be sieved in accordance with **KT-02** of this manual.

**6. TEST PROCEDURE FOR CEMENT TREATED SOIL**

**6.1.** The sample shall be weighed and sieved through a series of sieves to include 1 1/2 in (37.5 mm) and 1/2 in (12.5 mm).

**6.2.** The sample shall be sieved in accordance with **KT-02** of this manual.

## 7. CALCULATION FOR LIME TREATED SOILS

7.1. The percent retained on the 2 in (50 mm), 1 1/2 in (37.5 mm) and No. 4 (4.75 mm) sieves is calculated as follows:

$$\text{Percent Retained} = \frac{100(A)}{B}$$

Where: A = Mass of the retained fraction of the original sample determined to within 0.1% of the original sample mass as obtained by sieving over the specified sieve.  
B = Original mass of the sample.

**NOTE:** The quantities retained on the 1/2 in (12.5 mm) and 3/8 in (9.5 mm) sieves must be added to the quantity on the No. 4 (4.75 mm) sieve when calculating percent retained.

## 8. CALCULATION FOR CEMENT TREATED SOILS

8.1. The percent retained on the 1 1/2 in (37.5 mm) and 1/2 in (12.5 mm) sieves are calculated as follows:

$$\text{Percent Retained} = \frac{100(A)}{B}$$

Where: A = Mass of the retained fraction of the original sample determined to within 0.1% of the original sample mass as obtained by sieving over the specified sieve.  
B = Original mass of the sample.

## 9. REPORT

9.1 Report sieve analysis for acceptance of lime or cement treated subgrade to 1% mass.



5.9.43 MOISTURE CONTENT OF ASPHALT MIXTURES OR MINERAL AGGREGATES –  
MICROWAVE OVEN METHOD (Kansas Test Method KT-43)

**1. SCOPE**

This method describes a procedure for determining the amount of moisture present in asphalt mixtures or graded mineral aggregates used in asphalt mixtures. Use of this method is limited to asphalt mixtures containing paving grade asphalts. Use of this method with cut-back asphalts or emulsions is not authorized. **KT-43** reflects testing procedures found in **AASHTO T 255**.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-01; Sampling and Splitting of Aggregates

**2.3.** KT-25; Sampling and Splitting Plant Mixed Asphalt Mixtures

**2.4.** AASHTO T 255; Total Evaporable Moisture Content of Aggregate by Drying

**3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.2.** Microwave oven capable of holding 4000 g sample.

**3.3.** Sample containers must be paper, glass or ceramic.

**3.4.** Riffle splitter, 1 in (25 mm) wide riffles – optional.

**3.5.** A 1 gal (4 L) friction lid can.

**4. SAMPLE PREPARATION**

**4.1.** Secure a sample representative of the moisture content in the material being tested, and in the case of normal-weight aggregate, weighing not less than the amount listed in **Table 1**. Protect the sample from loss of moisture prior to weighing.

**Table 1**

**Sample Size for Normal Weight Aggregate**

No. 4 (4.75 mm)	0.5 kg
3/8 in (9.5 mm)	1.5 kg
1/2 in (12.5 mm)	2.0 kg
3/4 in (19.0 mm)	3.0 kg
1 in (25.0 mm)	4.0 kg

Based on sieves with square openings

To determine the minimum sample weight for lightweight aggregate, multiply the value by the approximate dry loose unit weight of the aggregate in kg/m<sup>3</sup> and divide by 1600.

**5. TEST PROCEDURE**

**5.1.** Place the sample in a tared sample container and weigh to the nearest 1.0 g and record the mass.

**5.2.** Place the sample in a microwave oven and turn it on.

**5.3.** After 5 minutes, turn oven off, remove the sample container, weigh the sample and container to the nearest 1.0 g and record the mass.

**5.4.** Return the sample and container to the oven, turn oven on and dry the sample for an additional 5 minutes.

**5.5.** After 5 minutes, turn oven off, remove the sample container and weigh the sample container to the nearest 1.0 g and record the mass.

**5.6.** The sample is thoroughly dry when further heating causes, or would cause, less than 0.1% additional loss in weight.

**5.7.** Weigh the dried sample to the nearest 0.1% after it has cooled sufficiently not to damage the balance.

**CAUTION:** When using a microwave oven, occasionally minerals are present in aggregates which may cause the material to overheat and explode. If this occurs it can damage the microwave oven.

## **6. CALCULATIONS**

**6.1.** Calculate total moisture content as follows:

$$p = 100(W-D)/D$$

Where:  
p = Moisture content of sample, percent  
W = Weight of original sample, g and  
D = Weight of dried sample, g

5.9.44 METHOD OF TESTING THE STRENGTH OF PORTLAND CEMENT CONCRETE USING THE MATURITY METHOD (Kansas Test Method KT-44)

**1. SCOPE**

**1.1.** This method covers the procedure for using the maturity concept as a non-destructive method to determine in-place concrete strength. It may be used for determining the strength of concrete for opening to traffic or for removal of formwork.

**1.2.** This is a two-step procedure. First, a relationship must be established between the measured maturity values and the concrete strength as measured by destructive methods (that is, through testing of beams or cylinders). The development of the maturity-strength curve is done in the field prior to the beginning of construction using project materials and the project proportioning and mixing equipment. The second step is the instrumentation of the in-place concrete. Temperature probes are installed in the concrete and the temperature is measured. From those measurements, along with the age at which the measurements were taken, maturity values are determined. A maturity meter or temperature measuring device and a computer or calculator may be used to determine the maturity values.

**2. REFERENCED DOCUMENTS**

**2.1.** KT-18; Air Content of Freshly Mixed Concrete by the Pressure Method

**2.2.** KT-21; Slump of Portland Cement Concrete

**2.3.** KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

**2.4.** KT-23; Flexural Strength of Concrete (Third Point Loading Method)

**2.5.** KT-76; Method for Testing the Compressive Strength of Molded Cylindrical Concrete Specimens

**2.6.** ASTM C1074; Standard Practice for Estimating Concrete Strength by the Maturity Method

**3. IMPLEMENTATION**

**3.1.** When maturity testing is used, the Contractor and KDOT shall jointly develop a plan. The plan shall include:

- The Contractor shall be responsible for the development of the maturity curve. The curve development shall be monitored by KDOT.
- The temperature monitoring process of the constructed pavement or structure shall be the responsibility of the Contractor and monitored by KDOT.

**3.2.** For concrete furnished from a construction or stationary mixer, which is in place prior to construction of the specified project, a maturity curve may be established ahead of actual construction of the specified project. The test specimens shall be cast with concrete made from the same plant using the same mixture as will be used in the specified project. The engineer shall be informed and have an opportunity to observe the development of the maturity curve.

## 4. THE MATURITY CONCEPT

**4.1.** The hydration of cement and gain in strength of the concrete are dependent on both curing time and temperature. Thus, the strength of the concrete may be expressed as some function of time and temperature. This information can then be used to determine the strength of concrete without conducting physical tests. The time-temperature function commonly used is the maturity concept proposed by Nurse-Saul (**ASTM C1074**).

$$(1) M(^\circ\text{F} \times \text{hours}) = \sum[(T - T_o)\Delta t]$$

**4.2.** Where M is the maturity in degree °F-hours [M is also termed the time-temperature factor (TTF)],  $\Delta t$  is the interval in hours (or days), T is the average concrete temperature during the time interval  $\Delta t$ , and  $T_o$  is the datum temperature at which concrete ceases to gain strength with time. The value of  $T_o = 14^\circ\text{F}$  ( $-10^\circ\text{C}$ ) is most commonly used. As a result, Equation (1) becomes:

$$(2) M(^\circ\text{F} \times \text{hours}) = \sum[(T - 14)\Delta t]$$

**NOTE:** If there are large differences in temperature between the test specimens and the in-place concrete, an equivalent age function may be needed. See **ASTM C1074**.

## 5. APPARTUS

**5.1.** See **KT-22** of this manual for specimen fabrication.

**5.2.** Appropriate testing machine as described in **KT-23** and **KT-76** of this manual.

**5.3.** Maturity meter and sensors that automatically compute and display either temperature-time factor or equivalent age.

**5.4.** Hand-held thermometer with thermocouple wire and connectors.

## 6. PROCEDURE

**6.1.** To establish a maturity-strength relationship for a concrete mix, a maturity meter or a thermal meter and a testing machine are needed. The following procedure shall be used: Note: before using any maturity meter, check to be sure that the datum temperature is set to  $14^\circ\text{F}$  ( $-10^\circ\text{C}$ ).

**6.1.1.** Cast and cure a minimum of twelve 6 in x 6 in x 21 in (152 mm x 152 mm x 530) beams, or twelve 4 x 8 in (102 x 200 mm) or 6 x 12 in (152 x 300 mm) or more cylinders per **KT-22** of this manual. Test the air content and slump of the concrete per **KT-18** and **KT-21** of this manual, and record these values. The concrete shall meet specifications. The specimens shall be cast from a field batch of at least 3 cu. yd. (3 m<sup>3</sup>).

**6.1.2.** Embed a sensor probe in one test specimen to monitor temperature. This specimen will be the last to be tested. The probe shall be inserted at approximately the center of the specimen. Secure the wire to prevent the wire from being inadvertently pulled out of the beam. When the thermal meter is used, the measured temperature should be substituted into Equation (2) to obtain values of maturity. When a maturity meter is used, the meter computes the values. Twelve test specimens shall be tested as described in **Section 6.1.4.** of this test method. An example calculation of the maturity factor is attached.

**6.1.3.** For field cast specimens the meter can be stored in a lab trailer or vehicle with the probes run outside, to the beam in a sandpit. This will allow a maturity meter to be protected from the weather and theft.

**6.1.4.** Determine maturity values and strength at four different ages. Test three specimens for strength at each age and calculate the average strength at each age. The maturity value shall be calculated using the average temperature reading since the previous test for strength. The tests shall be spaced such that they are performed at somewhat consistent intervals of time and span the range of strength(s) required.

**6.1.4.1.** Additional test specimens may be cast at a later time and tested at earlier ages to add data to the strength-maturity relationship as an aid to determine the appropriate time to saw.

**6.1.4.2.** Plot the measured strength against the corresponding values of maturity at different ages, as determined by the maturity meter or by hand methods. The maturity number corresponding to the desired strength shall be used to determine when the concrete has reached the desired strength. An example of Maturity-Strength Development Relationship is attached.

**6.2.** Since the influence of maturity on strength of concrete is somewhat different for various mixtures, a maturity-strength relationship established for one mixture shall not be used for another mixture.

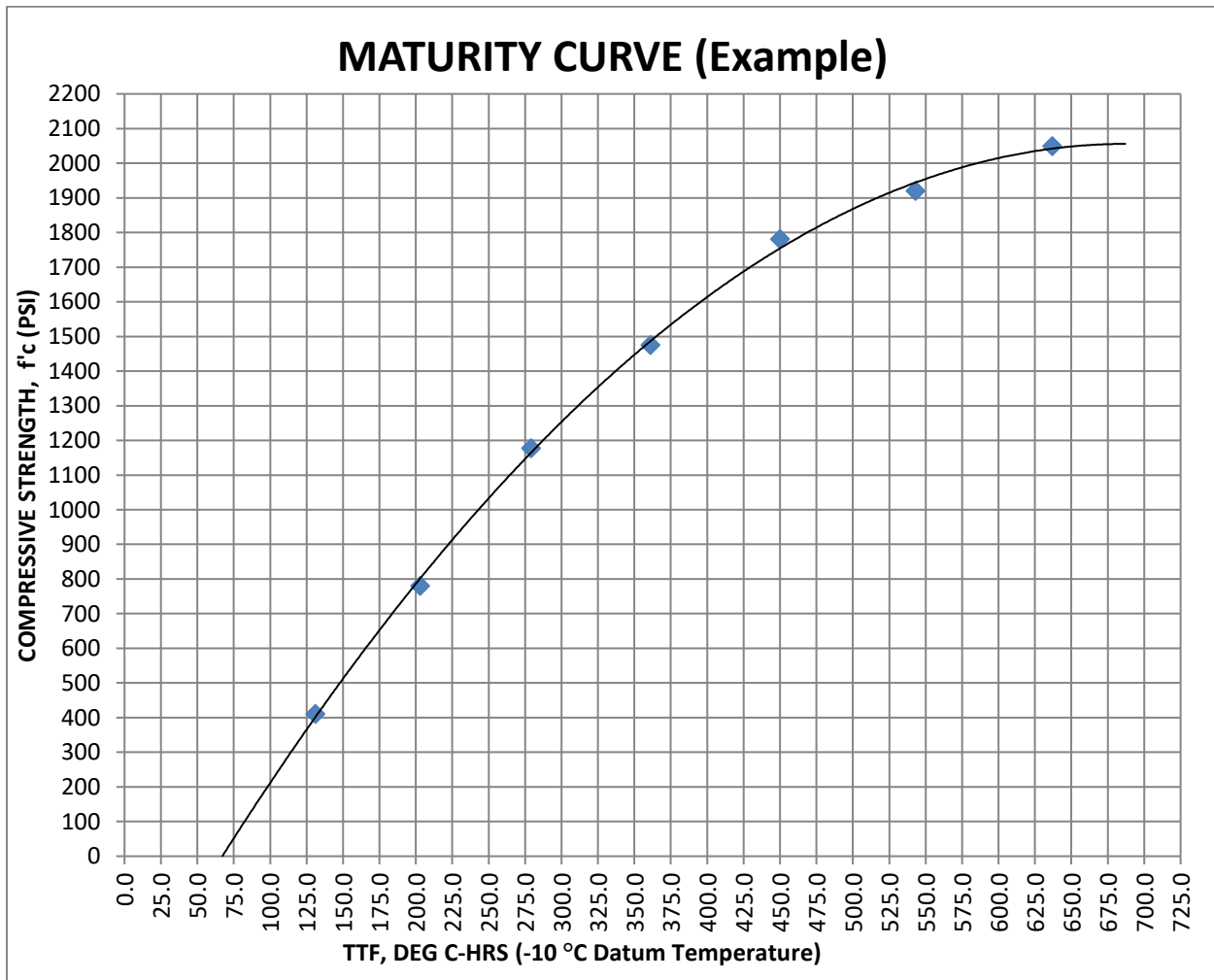
**NOTE:** To be considered the same mixture, no component may vary by more than 5% from the initial value.

## **7. VALIDATION**

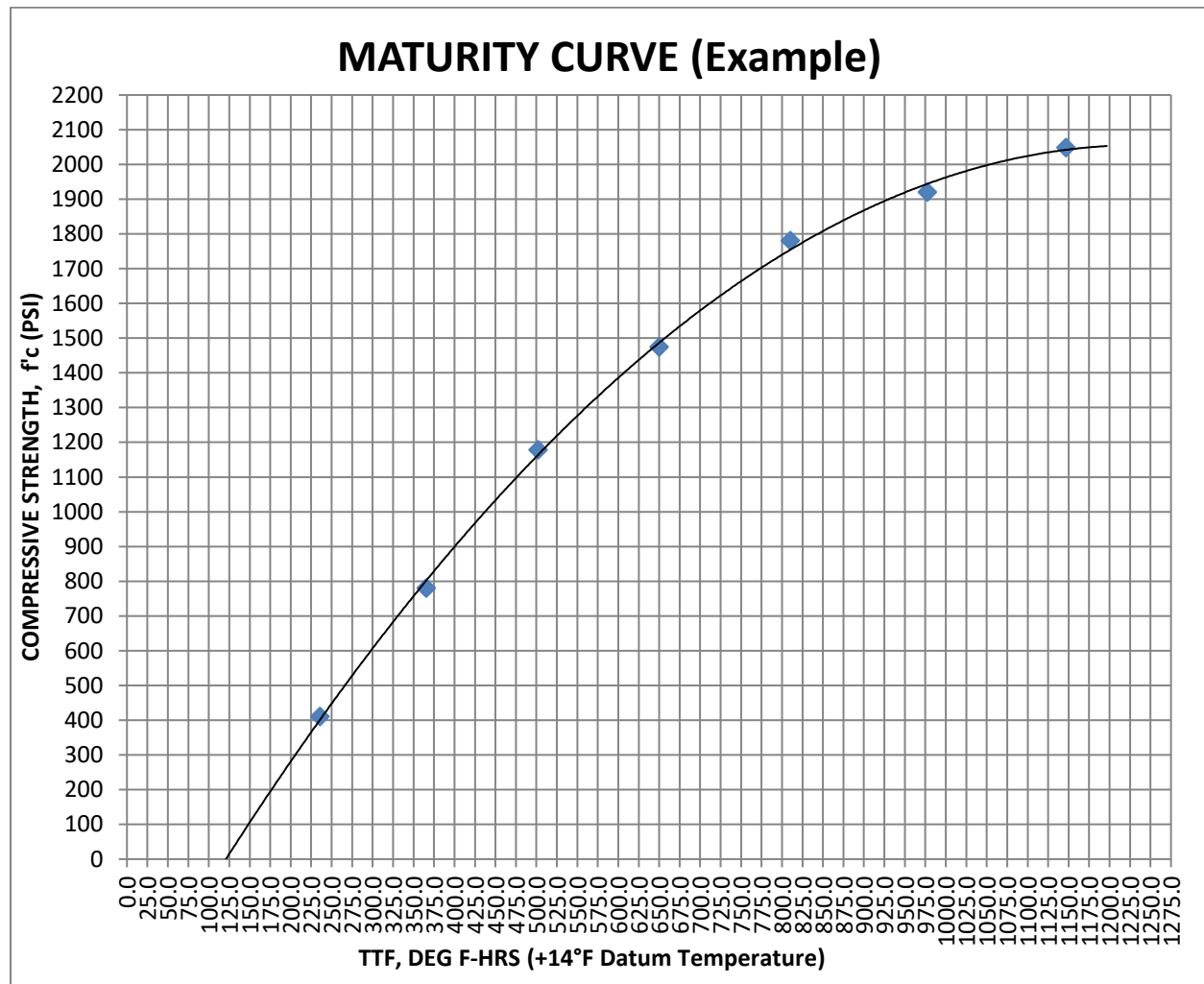
**7.1.** Once per month, a validation test shall be conducted to determine if concrete strength is being accurately represented by the current maturity curve. Cast and cure three specimens using the same procedure and manner as used to develop the current maturity curve. Test all three specimens as close as possible to the maturity value which was determined to represent the desired strength. If the average of these tests is within  $\pm 50$  psi (0.34 MPa) for beams or  $\pm 500$  psi (3.4 MPa) for cylinders of the original curve at the TTF, the original curve shall be considered validated. If the average value varies more than  $\pm 50$  psi (0.34 MPa) for beams or  $\pm 500$  psi (3.4 MPa) for cylinders of the original maturity curve value at the TTF at which the validation beams were tested, a new maturity curve shall be developed.

Examples:

Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees C	Avg Temp, degrees C	(Avg Temp + 10)Δt, degrees C	TTF, C-Hrs	Compressive Strength, PSI
0	22				
2	22	22.0	64.0	64.0	
4	25	23.5	67.0	131.0	411
6	27	26.0	72.0	203.0	780
8	29	28.0	76.0	279.0	1178
10	33	31.0	82.0	361.0	1475
12	36	34.5	89.0	450.0	1781
14	37	36.5	93.0	543.0	1920
16	37	37.0	94.0	637.0	2049



Example of Maturity Calculation					Example of Maturity Data
Age, Hours	Temperature, degrees F	Avg Temp, degrees F	(Avg Temp - 14)Δt, degrees F	TTF, F-Hrs	Compressive Strength, PSI
0	71.6				
2	71.6	71.6	115.2	115.2	
4	77.0	74.3	120.6	235.8	411
6	80.6	78.8	129.6	365.4	780
8	84.2	82.4	136.8	502.2	1178
10	91.4	87.8	147.6	649.8	1475
12	96.8	94.1	160.2	810.0	1781
14	98.6	97.7	167.4	977.4	1920
16	98.6	98.6	169.2	1146.6	2049







5.9.45 DETERMINATION OF DRY PAINT FILM THICKNESS WITH THE MAGNETIC GAUGE  
(Kansas Test Method KT-45)

**1. SCOPE**

This procedure covers nondestructive measurement of the dry film thickness of paints applied over ferrous base materials.

**2. APPARATUS**

**2.1.** Film thickness gauge (magnetic).

**2.2.** Calibration standard.

**3. PROCEDURE**

**3.1.** Girder webs:

**3.1.1.** Select a 10 ft (3 m) length of web, full depth of the girder. Take a minimum of ten random group readings of the primer and average these to establish a mean film thickness for the area. (A group reading is the average of three individual readings taken within a 1/2 in (13 mm) diameter circle).

**3.1.1.1.** After the finish coat has been applied, the procedure is to be repeated, in a random manner, over the same section of web to determine a mean thickness of the two paint coats. The difference between the two means will establish the thickness of the paint coat.

**3.2.** Flanges:

**3.2.1.** Select a 10 ft (3 m) length of flange and take a minimum of five group readings and proceed as for girder webs.

**3.3.** Stiffeners:

**3.3.1.** Take a minimum of three group readings per stiffener and proceed as for girder webs.

**NOTE:** The numbers of ten, five and three group readings are minimums to be taken. Greater accuracy is obtained as the number of group readings is increased.

**3.3.2.** Repeat the dry film thickness determination over as many areas as necessary to assure specification compliance.

**4. CAUTIONS**

**4.1.** Magnetic gauges should be calibrated at least once each day in the position and for the thickness that the gauge will be measuring.

**4.2.** Readings should not be taken within 2 in (50 mm) of a fillet weld, the edge of the plate or other abrupt changes in configuration.

**4.3.** This inspection technique does not eliminate the need for a good visual inspection. All painting should be visually inspected to locate omissions, runs mudcaking, dry spray or other unacceptable work.

## **5. RECORDING**

**5.1.** All individual gauge readings, locations at which the readings were taken and the averages shall be recorded in a bound field book. The inspector's name and the date on which the readings were taken shall also be recorded in the field book.

5.9.46 DETERMINATION OF PAVEMENT PROFILE WITH THE PROFILOGRAPH  
(Kansas Test Method KT-46)

**1. SCOPE**

This method of test covers the procedure for determining the smoothness, i.e. profile index, of both concrete and asphalt pavement using the California type 25-foot (7.6 mm), profilograph or equivalent.

**2. PROCEDURE I: MANUAL PROFILOGRAPH**

**2.1. APPARATUS**

**2.1.1.** California type, 25-foot (7.6 mm), profilograph or equivalent **Figure 1**, with pointer. The 25-foot (7.6 mm) profilograph is a rolling straight edge; which measures vertical deviations from a moving 25-foot (7.6 mm) reference plane. The pavement profile is graphically recorded on a profilogram with scales of 300:1 longitudinally and 1:1 vertically.

**2.1.2.** Blanking band which is a plastic scale 1.70 inch (43 mm) wide and 21.12 inch (333 mm) long representing a pavement length of 528 ft (100 m) or 0.1 mile (0.1 km) at a scale of 1 inch = 25 feet. Near the center of the scale is a dashed line extending the entire length of the plastic scale. On either side of this dashed line are scribed lines 0.1 inch (2 mm) apart, parallel to the dashed line. These lines serve as a convenient scale to measure deviations of the profile trace above or below the dashed reference line. These deviations are called "scallop".

**2.1.3.** Scale graduated in 0.1 inch or 1 mm.

**2.1.4.** Medium point ballpoint pen with red ink or other color contrasting to the profile trace.

**2.1.5.** Electronic calculator.

**2.1.6.** Plain recording chart paper as specified by the manufacturer of the profilograph.

**2.1.7.** Bump template which is a plastic template having a marked length 1 inch (25 mm) long on one face, and a slot (or edge) parallel to the marked length. A distance equal to the maximum bump specified separates the two reference lengths **Figure 2**. The 1 inch (25 mm) line corresponds to a longitudinal distance of 25 feet (7.5 m) on the longitudinal scale of the profilogram.

**2.2. CALIBRATION**

**2.2.1.** All profilographs used on KDOT projects must be calibrated at least annually. Calibration must be checked any time the profilograph has been altered or repaired. The certification includes establishing the proper tire inflation pressure, checking the trueness of the tire travel, checking the chart scale factor, and checking vertical displacement of the sensing wheel.

**2.2.2.** Each District and contractor using a profilograph shall establish a 500 to 1000 ft. (100 to 300 m) distance calibration test section on or near each project. This test section should be fairly straight, relatively flat and used periodically to check the longitudinal calibration and trace reproduction.

**2.2.3.** Longitudinal calibration consists of pushing the profilograph at walking speed approximately 3 mph (approximately 5 km/h), over a pre-measured test distance 500 to 1000 ft. (100 to 300 m) and determining the chart scale factor. Dividing the premeasured test distance in inches (mm) by the profilogram trace length, for

the test distance, in inches (mm) will determine the scale factor. This factor shall be  $300 \pm 0.5$ . If the profilograph produces charts with a different scale factor, adjustment of the profilograph must be made to bring the scale factor within the tolerances specified above.

**2.2.4.** Vertical calibration consists of placing the center recording wheel of the profilograph on a base plate and recording the base elevation. Two plates 0.5 inches (12.5 mm) thick each are added under the center wheel one at a time and the change in elevation noted. The two plates are removed one at a time and the change in elevation noted. Each step in the process shall show a change in height of 0.5 inches  $\pm 0.01$  inch (12.5 mm  $\pm 1.0$  mm). If the profilograph produces results not conforming to the above limits, it must be adjusted to within the tolerance specified.

**2.2.5.** The automatic trace reduction capability of a machine so equipped shall be checked by comparing the machine's results to the results obtained through manual trace reduction. The comparison shall be made for the trace obtained at the Materials and Research test section and for each project, at the project test section. The results of the comparison may not differ by more than 2.0 inches/mile (30 mm/km). All calibration traces and calculations shall be submitted to the Materials and Research Center or to the appropriate construction office to become part of the project file.

### **2.3. TEST PROCEDURE**

**2.3.1.** The profilograph is propelled at walking speed approximately 3 mph (approximately 5 km/h) in the paths indicated for each section of pavement **Figure 1**. Propulsion may be provided by manually pushing or by a suitable propulsion unit such as a garden tractor. **DO NOT** push or pull a profilograph with a vehicle. More than one person may be required to hold the back end of the profilograph exactly in the required path on superelevated or sharp horizontal curves.

**2.3.2.** Use of the pointer to maintain the required trace path is mandatory

**2.3.3.** If excessive "spikes" are encountered, decrease the rate of travel. An excessive number of "spikes" on a trace make it difficult to evaluate and may affect test results.

**2.3.4.** If possible, assemble the profilograph ahead of the location on the pavement where testing is to start. With the distance measuring wheel down and the pen in place on the trace paper, push the machine to the start position in the direction the test will be conducted. The center wheel should be the reference wheel. While the profilograph is stationary at the start location, move the cable attached to the pen thus creating a spike mark on the trace and label that mark as the start location. Using this procedure at the beginning and end of each trace will ensure that all systems are working properly, that slack has been removed from the drive chains, and will clearly define the start and end location. Also mark which direction is up on the trace and the direction the profilograph was pushed.

**2.3.5.** Push the profilograph in the same direction when recording each trace for a given section of pavement.

**2.3.6.** Indicate stationing on the profilogram at least every 500 feet (100 m), using the procedure outlined in **Section 2.4.4** of this test method. More frequent station references of every 100 feet (25 m) or every 200 feet (50 m) are highly desirable where possible. Station referencing on the trace is used to accurately locate 0.40 inch (10 mm) bumps. Notation of landmarks, roadway signs, etc. should also be made on the trace for additional referencing.

**2.3.7.** Completely label both ends of the profilogram with the project number, stationing represented on the roll and name of profilograph operators. Fill out a report form and secure it around the trace roll. This report ensures that the person reducing the trace and reporting results will have all necessary information.

**2.3.8.** A little dirt or debris will spike out and not affect the profilograph readings, however, excessive mud or caked mud must be removed prior to testing. Anything on the pavement surface longer than 2 to 3 inches (50 to 75 mm) may not be considered a spike when reducing the trace and should be removed.

**2.3.9.** When operating the profilograph, all wheels should always be on the pavement for which the contractor is responsible. Test from header to header whenever possible.

**2.3.10.** Pavement not tested at the end of a day's run due to barrier fences, machinery or other obstructions shall be included in a subsequent test run.

## **2.4. TRACE REDUCTION AND BUMP/DIP LOCATING PROCEDURE**

**2.4.1.** Using a red (or other contrasting color), medium point, ballpoint pen; retrace the profilogram through the middle of any spikes. This outlining procedure removes spikes and minor deviations and generally smooths the trace for easier reduction and analysis.

**2.4.2.** Use a bump template (scribed side down) to locate bumps/dips for removal. At each prominent bump/dip or high/low point on the profile trace, place the template so that the scribe marks at each end of the scribed line intersect the profile trace to form a chord across the base of the peak/valley or indicated bump/dip. The line on the template need not be horizontal. With a sharp pencil, draw a line using the narrow slot in the template (or edge) as a guide. Any portion of the trace extending above/below this line will indicate the approximate length and height of the bump/dip in excess of the specification.

There may be instances where the distance between easily recognizable low/high points is less than 1 inch (25 mm). In such cases a shorter chord length shall be used in making the scribed line on the template tangent to the trace at the low/high points. It is the intent, however, of this requirement that the baseline for measuring the height of bumps (or depth of dips) will be as nearly 1 inch (25 mm) as possible, but in no case to exceed this value. When the distance between prominent low/high points is greater than 1 inch (25 mm), make the ends of the scribed line intersect the profile trace when the template is in a nearly horizontal position. A few examples of the procedure are shown in **Figure 2**.

After marking the bump/dip on the profilogram, determine the station number of the center of the bump/dip by scaling from the nearest reference mark. Record the track identification and station of the bump/dip.

**2.4.3.** Place the blanking band (scribed side down) over the profile with the dashed reference line as nearly centered on the profile trace as possible.

The profile trace may move from a generally horizontal position when going around superelevated curves making it impossible to follow the central portion of the trace without shifting the blanking band. When such conditions occur, the profile should be broken into short sections and the blanking band repositioned on each section as shown in the upper part of **Figure 2**.

Indicate the beginning and ending of superelevated curves on the profilogram at the time the profile trace is being made.

**2.4.4.** Begin evaluating each trace from the same point on the road so that sections representing the same length of road can be aligned on the test report form. Measure and total the height of all the scallops appearing both above and below the dashed reference line, measuring each scallop to the nearest 0.05 inch (1 mm). Do not count a scallop as 0.05 inch (1 mm) just because you see the profile line or there is space under the line. Short sections of the profile line may be visible above or below the dashed reference line, but unless they

project 0.03 inch (0.7 mm) or more vertically and extend longitudinally for 0.08 inch (2 mm) or more on the profilogram, they are not included in the count. Spikes are not counted. Double-peaked scallops are only counted once as the highest peak **Figure 3**.

Write the total count in inches (mm) on the profilogram above the profile line (toward the center of the section) and circle it. Outline the position of the blanking band when reducing the trace for later repositioning to check trace reduction procedure. Rotate the blanking band about the previous end position when evaluating the next section **Figure 4**.

When a scallop occurs at the end of the blanking band, count the scallop only once. Place the scallop in the 0.1 mile (0.1 km) section where the peak is highest **Figure 4**.

Always use the measured trace length in computations. This length may not agree exactly with distance by subtracting stationing. Always use  $\pm$  after the total length on the report.

Enter the measured roughness for each 0.1 mile (0.1 km) section and for each track into the worksheet shown in **Figure 6**. Enter the profile index into **KDOT Form 242**.

**2.4.5.** The last section counted is generally not an even 0.1 mile (0.1 km). If not, its length should be scaled to determine its length in miles (km) (Calculated to three decimal places). For the example shown below, the last section measures 7.60 inches (193 mm) in length.

English

$$\frac{(7.60 \text{ in})(25 \text{ ft/in})}{5,280 \text{ ft/mile}} = 0.036 \text{ miles}$$

Metric

$$\frac{(193 \text{ mm})(300)}{1,000,000 \text{ mm/km}} = 0.0579 \text{ km} = 0.058 \text{ km}$$

If the last section is less than or equal to 250 ft (0.047 mile) (0.05 km [50 m]), it is added to and included with the previous 0.1 mile (0.1 km) section to determine compliance with the profile index. If the last section is more than 250 ft (0.047 mile) [0.05 km (50 m)], it is treated as a separate section.

When the profilograph must be picked up or partially disassembled and moved around an unpaved area or structure, a new section will be started.

The profile index is determined as inches/mile (mm/km) using the “zero” blanking band but is simply called the profile index. The procedure for converting counts inches of roughness (mm of roughness) to profile indices is illustrated in **Figure 5**. For 0.1 mile (0.1 km) sections, the profile index can be determined from the counts (inches of roughness (mm of roughness)) by moving the decimal point one position to the right. For odd length sections, the profile index is determined by dividing the counts (inches of roughness (mm of roughness)) by the section length in miles (km). The weighted average for a day's run is determined by dividing the total counts (inches of roughness (mm of roughness)) for the day's run by the total length (in miles (in km)) of the day's run. **See Figure 6**.

### **3. PROCEDURE II: COMPUTERIZED PROFILOGRAPH**

#### **3.1. APPARATUS**

**3.1.1.** California type, 25-foot (7.6 mm), profilograph or equivalent **Figure 1**, with computer and printer. The 25-foot (7.6 mm) profilograph is a rolling straight edge; which measures vertical deviations from a moving 25-foot (7.6 mm) reference plane. The pavement profile is graphically recorded on a profilogram with scales of 300:1 longitudinally and 1:1 vertically.

**3.1.2.** Plain recording chart paper as specified by the manufacturer of the profilograph.

#### **3.2. CALIBRATION**

**3.2.1.** All profilographs used on KDOT projects must be calibrated at least annually. Calibration must be checked any time the profilograph has been altered or repaired. The certification includes establishing the proper tire inflation pressure, checking the trueness of the tire travel, checking the chart scale factor, and checking vertical displacement of the sensing wheel.

**3.2.2.** Each District and contractor using a profilograph shall establish a 500 to 1000 ft. (100 to 300 m) distance calibration test section on or near each project. This test section should be fairly straight, relatively flat and used periodically to check the longitudinal calibration and trace reproduction.

**3.2.3.** Longitudinal calibration consists of pushing the profilograph at walking speed approximately 3 mph (approximately 5 km/h), over a pre-measured test distance 500 to 1000 ft. (100 to 300 m) and determining the chart scale factor. Dividing the premeasured test distance in inches (mm) by the profilogram trace length, for the test distance, in inches (mm) will determine the scale factor. This factor shall be  $300 \pm 0.5$ . If the profilograph produces charts with a different scale factor, adjustment of the profilograph must be made to bring the scale factor within the tolerances specified above.

**3.2.4.** Vertical calibration consists of placing the center recording wheel of the profilograph on a base plate and recording the base elevation. Two plates 0.5 inches (12.5 mm) thick each are added under the center wheel one at a time and the change in elevation noted. The two plates are removed one at a time and the change in elevation noted. Each step in the process shall show a change in height of 0.5 inches  $\pm$  0.01 inch (12.5 mm  $\pm$  1.0 mm). If the profilograph produces results not conforming to the above limits, it must be adjusted to within the tolerance specified.

**3.2.5.** The automatic trace reduction capability of a machine so equipped shall be checked by comparing the machine's results to the results obtained through manual trace reduction. The comparison shall be made for the trace obtained at the Materials and Research test section and for each project, at the project test section. The results of the comparison may not differ by more than 2.0 inches/mile (30 mm/km). All calibration traces and calculations shall be submitted to the Materials and Research Center or to the appropriate construction office to become part of the project file.

#### **3.3. TEST PROCEDURE**

**3.3.1.** The tire pressure should be checked before each run to make sure that it matches the one shown on the prequalified list. The filter value should also match the one on the prequalified list for the profilograph used.

**3.3.2.** The profilograph is propelled at walking speed approximately 3 mph (approximately 5 km/h) in the paths indicated for each section of pavement **Figure 1**. Propulsion may be provided by manually pushing or

by a suitable propulsion unit such as a garden tractor. **DO NOT** push or pull a profilograph with a vehicle. More than one person may be required to hold the back end of the profilograph exactly in the required path on superelevated or sharp horizontal curves.

**3.3.3.** Use of the pointer to maintain the required trace path is mandatory

**3.3.4.** If excessive "spikes" are encountered, decrease the rate of travel. An excessive number of "spikes" on a trace make it difficult to evaluate and may affect test results.

**3.3.5.** Push the profilograph in the same direction when recording each trace for a given section of pavement.

**3.3.6.** A little dirt or debris will spike out and not affect the profilograph readings, however, excessive mud or caked mud must be removed prior to testing. Anything on the pavement surface longer than 2 to 3 inches (50 to 75 mm) may not be considered a spike when reducing the trace and should be removed.

**3.3.7.** When operating the profilograph, all wheels should always be on the pavement for which the contractor is responsible. Test from header to header whenever possible.

**3.3.8.** Pavement not tested at the end of a day's run due to barrier fences, machinery or other obstructions shall be included in a subsequent test run.

## **4. PROCEDURE III: HIGH SPEED OR LIGHTWEIGHT LASER PROFILERS**

### **4.1. APPARATUS**

**4.1.1.** Inertial profiler capable of providing a California profilograph profile index with software capable of identifying bumps and dips in the pavement profile.

### **4.2. CALIBRATION**

**4.2.1.** All profilographs used on KDOT projects must be certified annually. Calibration must be checked any time the profilograph has been altered or repaired. The certification includes verification of laser height, verification of horizontal distance, and comparing the profile index to a known profile.

**4.2.2.** Each District and contractor using a profilograph shall establish a 500 to 1000 ft. (100 to 300 m) distance calibration test section on or near each project. This test section should be fairly straight, relatively flat and used periodically to check the longitudinal calibration and trace reproduction.

**4.2.3.** Longitudinal calibration consists driving the inertial profiler over a pre-measured test distance 500 to 1000 ft. (100 to 300 m).

**4.2.4.** Vertical calibration consists of placing a base plate under the visual laser and recording the base elevation. Then plates of known heights are placed under the visual laser according to the manufacturer's software.

### **4.3. TEST PROCEDURE**

**4.3.1.** The tire pressure should be checked before each run to make sure that it matches the one shown on the prequalified list. The filter value should also match the one on the prequalified list for the profilograph used.



**4.3.2.** The profilograph is propelled at a speed within the parameters given by the manufacturer in the paths indicated for each section of pavement **Figure 1**.

**4.3.3.** If excessive "spikes" are encountered, decrease the rate of travel. An excessive number of "spikes" on a trace make it difficult to evaluate and may affect test results.

**4.3.4.** Run the profilograph in the same direction when recording each trace for a given section of pavement.

**4.3.5.** Pavement not tested at the end of a day's run due to barrier fences, machinery or other obstructions shall be included in a subsequent test run.

## **5. REPORT**

**5.1.** Contractors shall furnish and certify profilograph test reports and supply the summarized report to the Engineer. Stationing shall be indicated on the profile report and the profile traces.

**5.2.** All profile traces (profilograms) become part of the Engineer's permanent project records.

**5.3** **If any corrective actions are made to the pavement another profile should be taken and all test reports, profile traces and summarized reports should be supplied to the Engineer.**

## **6. OPERATOR CERTIFICATION**

**6.1.** Basis of operator certification is attendance at an approved training school and comprehension of the material presented, or by having proof of certification by another agency with requirements similar to KDOT.

**6.2.** A contractor's personnel may be decertified if the test results vary from the KDOT results by more than what is regarded as normal test variation.

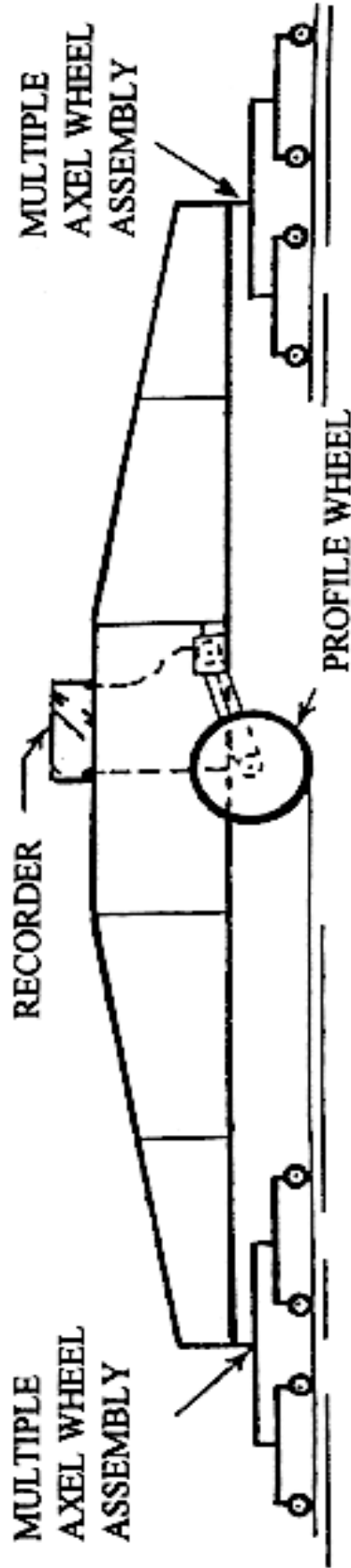
**6.3.** When a contractor's personnel are decertified to issue profilograph reports, such reports will not be recognized until corrections in testing, trace reduction and reporting are made to the satisfaction of the Engineer.

## LOCATION OF PROFILE WHEEL

- LANE EDGE OR CONSTRUCTION JOINT ( PAINT STRIPE)
- ..... TRACE 3 ft FROM LANE EDGE
- ..... TRACE 3 ft FROM CONSTRUCTION JOINT
- CONSTRUCTION JOINT OR LANE EDGE

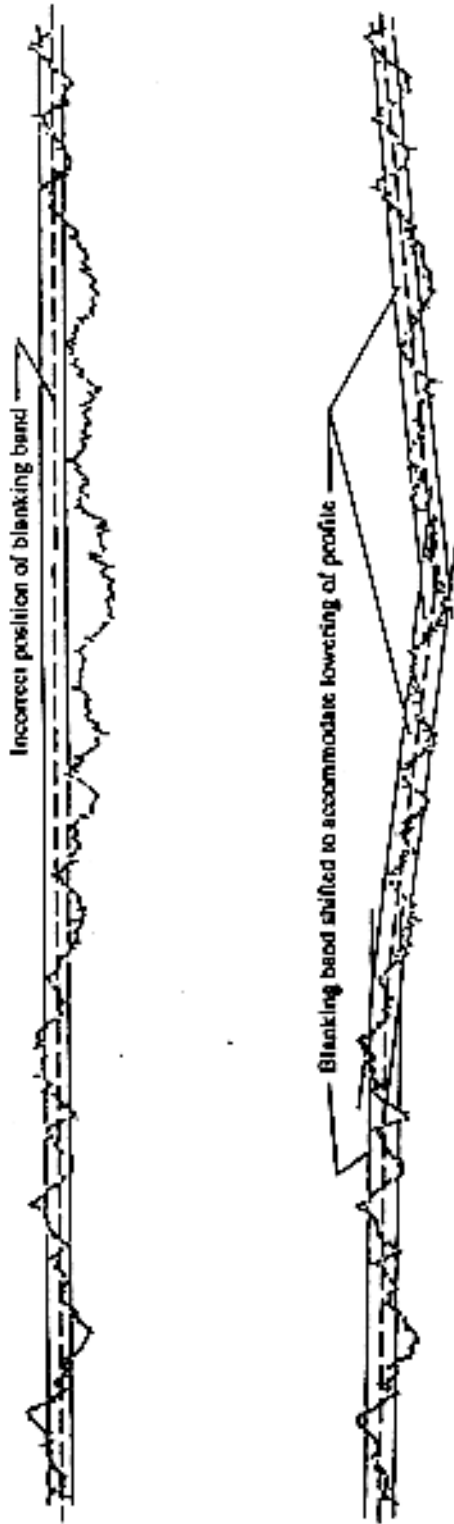
Figure 1.

## PROFILOGRAPH



**METHOD OF COUNTING WHEN POSITION OF PROFILE SHIFTS AS IT MAY  
WHEN ROUNDING SHORT RADIUS CURVES WITH SUPERELEVATION**

Figure 2



**METHOD OF PLACING TEMPLATE WHEN LOCATING BUMPS TO BE REDUCED**

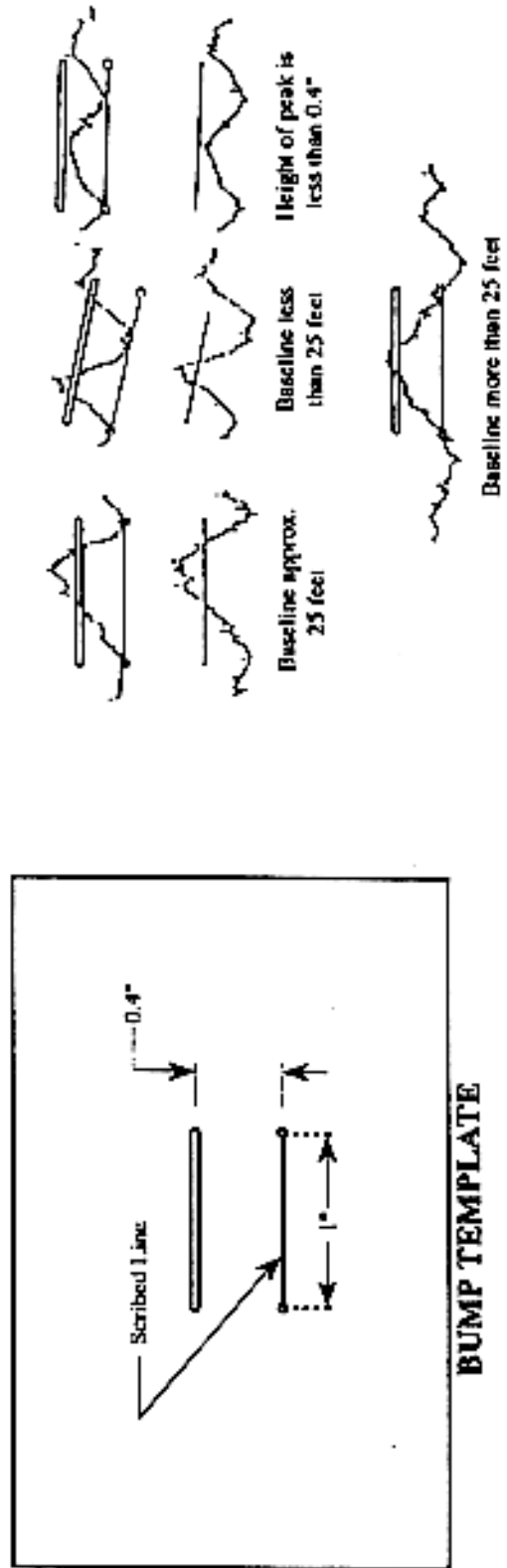
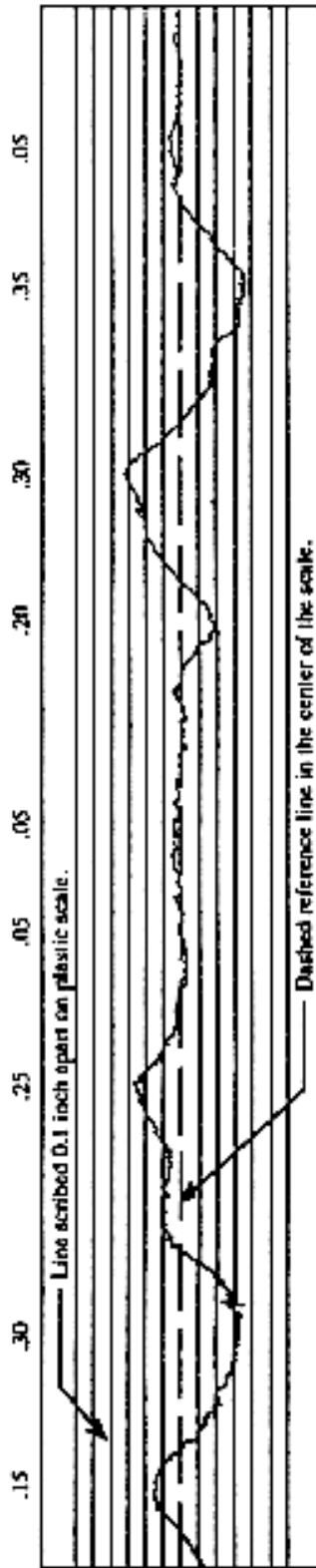


Figure 3

Example Showing Method of Deriving Profile Index From Profilogram



Total count for this 0.1 mile section is 1.70 inches (1.70 tenths of an inch).  
 Profile index for this 0.1 mile section is 1.70 inches per mile. ( $1.70 \div 0.1 = 17.0$ )

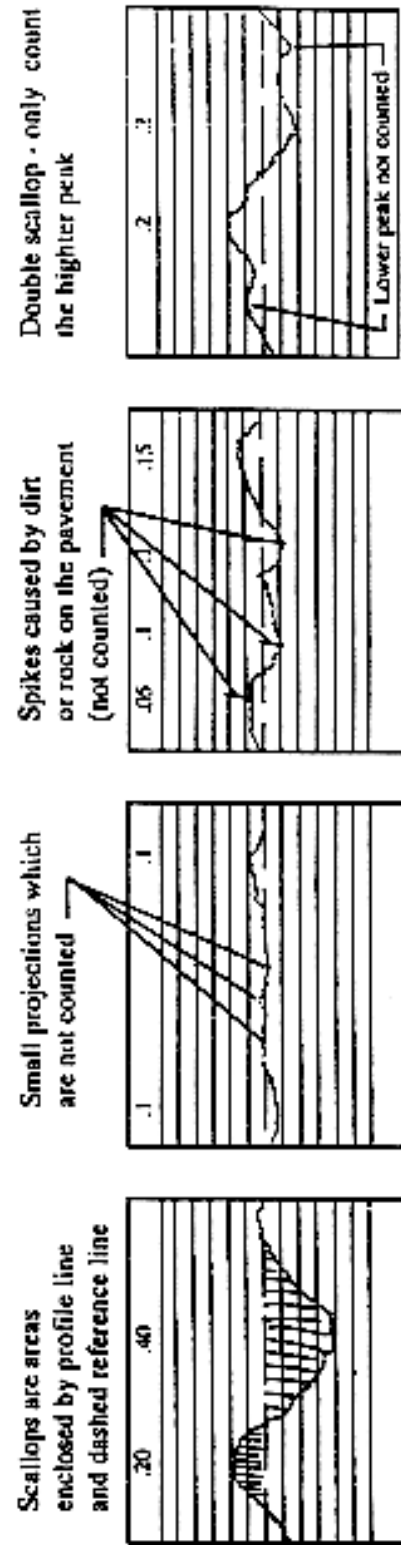
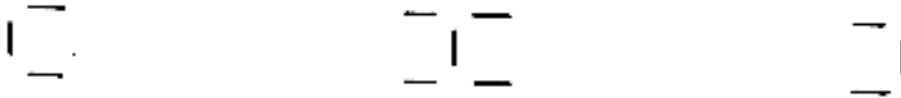


Figure 4

ROTATING BLANKING BAND ABOUT  
LAST END POINT

This



Not This



SCALLOPS OCCURRING AT END  
OF BLANKING BAND

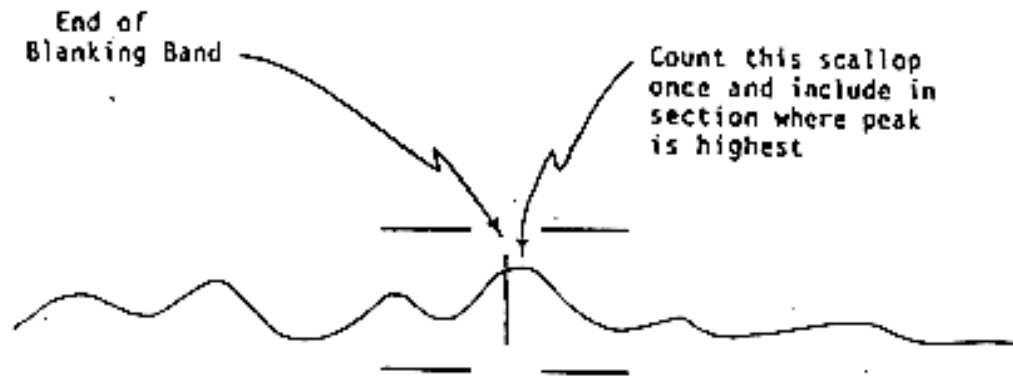


Figure 5

Procedure for Determining Profile Index

<u>Segment Length (miles)</u>	<u>Inches of Roughness Shown on Trace</u>	<u>Reported Roughness (inches/mile)</u>
Example A		
0.1	1.35	13.5
0.1	1.15	11.5
0.1	0.25	2.5
0.1	0.85	8.5
0.1	0.30	3.0
0.1	0.80	8.0
0.1	0.35	3.5
0.1	0.35	3.5
<u>0.055</u> *	<u>0.20</u>	<u>3.6(1)</u>
0.855	5.60	6.5(2)

$$(1) \frac{0.20}{0.055} = 3.6$$

$$(2) \frac{5.60}{0.855} = 6.5$$

Example B

0.1	0.80	8.0
0.1	0.40	4.0
0.1	0.35	3.6(1)
<u>0.037</u> *	<u>0.15</u>	<u>-----</u>
0.337	1.70	5.0(2)

$$(1) \frac{0.35 + 0.15}{0.1 + 0.037} = 3.6$$

$$(2) \frac{1.70}{0.337} = 5.0$$

\* See section (e)(5) of this test method.

Figure 6.

Information  
 X Initial  
 — Intermediate  
 — Final

**PROFILOGRAPH REPORT OF PAVEMENT SMOOTHNESS**

Project No. 75-98 K 1234-01 County Trego  
 Contractor John Doe Construction Company Pavement Type PCC  
 Station 153+00 to Station 168+00 Traffic Direction EB  
 No. of Lanes 2 Direction of Paving EB  
 Date Placed (corrected) 8-9-94 Date Tested 8-10-94  
 Tested and Evaluated by Norman Lee  
 Paving Action 9 inch Reinforced PCC

Length (Miles)	Track 1 Measured	Track 1 Profile	Track 2 Measured	Track 2 Profile	Track 3 Measured	Track 3 Profile	Average Profile Index (In./Mi)
	Roughness (Inches)	Index (In./Mi.)	Roughness (Inches)	Index (In./Mi)	Roughness (Inches)	Index (In./Mi.)	
0.1	0.75	7.5	0.65	6.5			7.0
0.1	0.35	3.5	0.40	4.0			3.8
<u>0.034</u>	<u>0.95</u>	<u>11.3</u>	<u>0.80</u>	<u>9.5</u>			<u>10.4</u>
0.284	2.05	7.2	1.85	6.5			6.9
Weighted Daily Average Computation							weighted Daily Average

2.05  
1.85  
 3.90 inches / 2 tracks = 1.95 inches / 0.284 mile = 6.9 Average inches/mile

Bump Locations Track 2-None; Track 1-None

Certified by: Norman Lee  
 Title Chief Profilograph Pusher  
 Org'n John Doe Const. Co.

Figure 7.

## PROFILOGRAPH REPORT OF PAVEMENT SMOOTHNESS

KDOT Form 242 Back Side

This form shall be prepared and submitted, along with the profilogram, within two working days of the placement or correction of concrete pavement or one working day for bituminous pavement.

**The type of report is as follows:**

**Information** - For check testing by Ks DOT and other situations not required to have testing.

**Initial** - All required testing of pavement for the first time ( may be the only one ).

**Intermediate** - After some corrective action that has not yet been completed.

**Final** - After all corrective action has been completed.

**Pavement Type** - PCC, HR, BM-1, etc.

**Traffic Direction and direction of paving** - NB, SB, EB, or WB depending on the design traffic flow of the numbered route.

**Number of Lanes** - the number of lanes placed at one time.

**Paving Action** - Mill ( 2" ), Hot Recycle (2"), BM-1 ( 1 1/2" ), etc.

**Always compute a weighted daily average Wdt Daily Avg =**

$$\frac{\text{Total count in inches}}{\text{No. of tracks x length}}$$

**Bump locations are by station.**

**Distribution**    Field Office (1)  
                     District Office (1)  
                     Bureau of Const. & Maint. (1)  
                     Pavement Surface Research Engineer (1)



5.9.47 DEPTH DETERMINATION OF HOT-IN-PLACE RECYCLED ASPHALT PAVEMENT (HIR)  
(Kansas Test Method KT-47)

**1. SCOPE**

This tests method describes the procedure for determining the depth using an Engineers level (Method A), weight for a given area (Method B) of HIR, or depth using a stab rod (Method C).

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**3. APPARATUS**

**3.1.** Method A and Method B; Miscellaneous spoons, brushes, shovels and spatulas.

**3.2.** Method A; Engineers level.

**3.3.** Method A; Level Rod.

**3.4.** Method A; Equipment for reference elevation points (cloth or steel tape, rope, string, etc.).

**3.5.** Method B; a 12 in (300 mm) square template.

**3.6.** Method B; Sample pans.

**3.7.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested

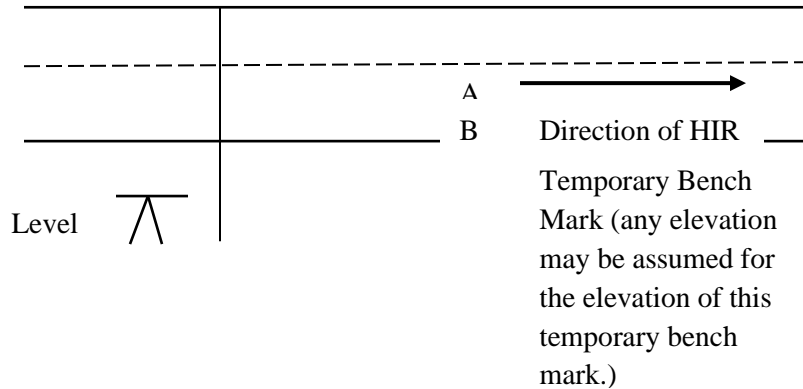
**3.8.** Method C; Stab rod which consists of a solid metal rod tip with an adjustable washer for establishing the proper height of the uncompacted HIR.

**4. TEST PROCEDURE**

**4.1.** Method A

**4.1.1.** Before heat application obtain initial roadway surface elevations ( $E_i$ ) to the nearest 0.005 ft (1 mm) at two or more points (see **Figure 1**). Establish these points on a line transverse to centerline. Reference these points so they may be re-established after the HIR process and before the compaction process.

**Figure 1**  
**Example for Establishing Points and Elevations**



A, B,...Elevation Points – randomly vary their locations across the roadway. Check a minimum of 2 points.

**4.1.2.** After HIR, re-establish the original elevation points. Below these points; remove the HIR and overlay, if any. Take care to remove only the new overlay and/or HIR.

**4.1.3.** Re-establish the original elevation points and determine the final elevation at the bottom of the HIR ( $E_f$ ).

**4.2. Method B**

**4.2.1.** Place the 12 in (300 mm) square template on the HIR. Press downward and tap the sides until the template is fully seated, completely through the uncompacted HIR.

**4.2.2.** Carefully remove the HIR confined by the template by spooning into a container. A brush with stiff bristles may be used to gather all loosened material. Take care to preserve all particles and to remove only particles dislodged by the HIR operation.

**4.2.3.** Weigh the material retained in the container to the nearest 0.01 lb (5 g).

**4.3. Method C**

**4.3.1.** Set the washer on the stab rod for the calibrated height,  $h_s$ .

**4.3.2.** Stab the uncompacted HIR as stipulated in **section 9** of this test method. Be sure to stab at least three times across the pavement width.

**5. CALIBRATION FOR METHOD B**

**5.1.** Calibrate the weight corresponding to the specified depth of HIR in the following manner at the beginning of each week’s production. This calibration may need to be accomplished more often if the material being recycled is different than the material used in the previous calibration.

**5.1.1.** Method A requires a minimum of 2 transverse locations be taken for each test. Select 1 of these locations to calibrate Method B. As stated in **section 9.2** of this test method. Three tests will be taken within the first 1/2 mile of production that day. To perform the calibration, select 1 transverse location from each of these 3 test locations taken with the first 1/2 mile. Average these values to get the required weight of the sample ( $w_T$ ) corresponding to the specified depth in the contract documents ( $h_d$ ). This is the value to be used until a new calibration is accomplished.

**5.1.2.** Take elevations as described in Method A (steps 4.1.1. through 4.1.3.). Remove the HIR from one of the transverse locations as prescribed in **section 4.2** of this test method and weigh ( $W_A$ ). The weight of the HIR corresponding to the depth determined in Method A. Use the following equation to determine the weight corresponding to the depth of HIR specified in the contract documents.

$$W_T = W_A \times h_d \div h_m$$

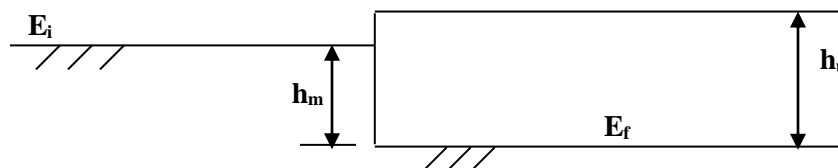
Where:  $W_T$  = Required minimum weight of a  $ft^2$  of HIR, lb/ $ft^2$ .  
 $W_A$  = Weight of the HIR Sample lb/ $ft^2$ .  
 $h_m$  = Depth of the HIR Sample, in.  
 $h_d$  = Specified depth of HIR, in.

## 6. CALIBRATION FOR METHOD C

**6.1.** Calibrate the stab rod in the following manner at the beginning of each week's production.

**6.1.1.** As stated in **section 9.2** of this test method, three tests will be taken within the first 1/2 mile of production that day. To perform the calibration, perform the steps in **sections 6.1.2** through **6.1.4** of this test method for each transverse location from each of these three test locations taken with the first 1/2 mile. Average these values to get the required depth that the washer should be set ( $h_s$ ) for the design HIR depth ( $h_d$ ). This is the value to be used until a new calibration is accomplished.

**6.1.2.** Take elevations as describe in Method A (sections **4.1.1** through **4.1.3** of this test method). Prior to removing the HIR in Method A, section **4.1.2** of this test method stab the HIR with the stab rod until the tip rests on the material directly below the HIR. Loosen the washer prior to the stab and then tightened once the stab rod has fully penetrated the HIR. Measure and record the distance from the tip of the stab rod to the bottom of the washer. This is the depth of the uncompacted HIR ( $h_u$ ). Continue using Method A, sections **4.1.2**, **4.1.3** and **7.1** of this test method to measure and record the depth of the HIR ( $h_m$ ).



Where:  $E_i$  = Original elevation of pavement  
 $E_f$  = Final elevation of pavement  
 $h_m$  = Depth of the HIR  
 $h_u$  = Depth of the uncompacted HIR

**6.1.3.** Calculate the depth that the washer should be set ( $h_s$ ) for the design HIR depth ( $h_d$ ) using the following equation:

$$h_s = h_d \times h_u \div h_m$$

**6.1.4.** Repeat sections **6.1.1** and **6.1.3** of this test method for all locations described in **section 6.1.1** of this test method. Average the values set the washer height to this average value.

## 7. CALCULATIONS

**7.1.** For Method A, calculate the average depth of HIR using all elevation points at this transverse location.

**7.2.** For Method B, the weight per unit area of HIR is determined by the following formula:

$$W_A = \frac{W_T}{A_T}$$

Where:  $W_A$  = lb/ft<sup>2</sup> (kg/m<sup>2</sup>) of HIR  
 $W_T$  = Weight of material removed from the template  
 $A_T$  = Area of the template = 1.0 ft<sup>2</sup> (0.1 m<sup>2</sup>)

EXAMPLE:

English

$$W_A = \frac{17.54 \text{ lb}}{1.00 \text{ ft}^2} = 17.54 \text{ lb/ft}^2$$
$$= 17.5 \text{ lb/ft}^2$$

SI

$$W_A = \frac{7.96 \text{ kg}}{0.09 \text{ m}^2} = 88.44 \text{ kg/m}^2$$
$$= 88.44 \text{ kg/m}^2$$

## 8. REPORTING

**8.1.** For Method A, report the average depth of HIR for each transverse location to the nearest 0.01 ft (5 mm).

**8.2.** For Method B, report the lb/ft<sup>2</sup> (kg/m<sup>2</sup>) of HIR ( $W_A$ ) to the nearest 0.1 lb/ft<sup>2</sup> (0.01 kg/m<sup>2</sup>).

**8.3.** For Method C, report any findings that show the average depth to be less than specified in the design (contract documents).

## 9. FREQUENCY

**9.1.** For all Methods, tests will be performed at the frequency necessary to control the production rate.

**9.2.** For Method A and Method B, rate of three tests in the first 1/2 mile of each day's operation. Then, a minimum rate of 1 per hour for the remainder of the day.

**9.3.** For Method C, minimum rate of 3 longitudinal locations per hour.



5.9.49 METHOD FOR OBTAINING AND TESTING DRILLED CORES FROM PCCP AND PRECAST GIRDERS (Kansas Test Method KT-49)

**1. SCOPE**

**1.1.** This test method provides standardized procedures for obtaining and testing specimens to determine the compressive strength and depth of in-place concrete in pavement and precast girders. Sampling and sample preparation requirements are given to ensure that dimensional requirements are met and that the specimens are made of intact, sound concrete, and are as free of flaws as the particular pavement or precast girder will allow.

**2. REFERENCED DOCUMENTS**

**2.1.** AASHTO T 22; Compressive Strength of Cylindrical Concrete Specimens

**2.2.** AASHTO T 148; Measuring Length of Drilled Concrete Cores

**2.3.** AASHTO T 24; Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

**2.4.** KT-77; Method for Capping Cylindrical Concrete Specimens

**3. SIGNIFICANCE AND USE**

**3.1.** The strength of concrete measured by tests of cores is affected by the amount and distribution of moisture in the specimen at the time of test. There is no standard procedure to condition a specimen that will ensure that, at the time of test, it will be in the identical moisture condition as concrete in the pavement or precast girder. The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize within-laboratory and between-laboratory variations and to reduce the effects of moisture introduced during specimen preparation. See AASHTO T 24 for additional information on the significance and use of obtaining concrete cores.

**4. APPARATUS**

**4.1.** Testing Machine – The testing machine shall comply with requirements set forth in **AASHTO T 22**. The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading corresponding to a stress rate on the specimen of  $35 \pm 7$  psi/s ( $0.25 \pm 0.05$  MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase. The testing machine shall be capable of testing cores up to and including 12 in (300 mm) in length.

**4.1.1.** Verify that the faces of the bearing blocks are plane every 12 months.

Except for the concentric circles described in AASHTO T 22, Section 5.2., the bearing block faces shall not depart from a plane by more than 0.001 in. (0.02 mm) along any 6 in. (150mm) length for bearing blocks with a diameter of 6 in. (150mm) or larger, or by more than 0.001 in. (0.02 mm) in any direction for smaller bearing blocks. New bearing blocks shall be manufactured within one half of this tolerance.

**4.1.2.** Clean and lubricate the curved surfaces of the socket and spherical portion of the upper bearing block every six months. Check for any visible wear on the spherical portion of the upper bearing block during the cleaning and lubrication. Any noticeable wear is cause for replacement of the upper bearing block. The lubricant shall be conventional motor oil.

**4.2.** Core Drill - For obtaining cylindrical core specimens, a diamond drill shall be used.

**4.3.** Caliper and a 12 in (300 mm) steel rule graduated in 0.01 in (0.25 mm).

## **5. SAMPLING**

**5.1.** Core Drilling - A core specimen taken perpendicular to a horizontal surface shall be located, when possible, so that its axis is perpendicular to the bed of the concrete as originally placed and not near formed joints or obvious edges of a concrete pour. A specimen taken perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a concrete pour when possible and not near formed joints or obvious edges of a concrete pour.

**NOTE:** All coring for the purpose of determining compressive strength must be performed a minimum of 21 days after the pavement has been placed, and in time to determine the 28-day compressive strengths.

## **6. DETERMINING LENGTH OF DRILLED CORE SPECIMENS**

**6.1.** A core specimen for the determination of length shall have a minimum diameter as stated in the applicable specification.

**6.2.** Determining Length of Core using Calipers.

**6.2.1.** Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used. If a core drilled from a pavement or structure placed on dense-graded aggregate base course includes particles of the aggregate bonded to the bottom surface of the concrete, the bonded particles shall be removed by wedging or by chisel and hammer applied so as to expose the lower surface of the concrete. If the concrete is placed on an open-graded aggregate base course, the mortar in the concrete may penetrate into the base and surround some particles. Use sufficient force with a wedge or chisel and hammer to remove bonded particles but not such force as to fracture particles substantially surrounded by mortar. If during the removal of bonded aggregate the concrete is broken so that the instructions of **section 6.2.3** of this test method cannot be followed, the core shall not be used for length measurement<sup>1</sup>

**6.2.2.** Take three caliper measurements at 120 degree intervals along the circumference of the circle of measurement to the nearest 0.01 in (0.25 mm), to determine the average length.

**6.2.3.** If, in the course of the measuring operation, it is discovered that at one or more of the measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, the specimen shall be rotated slightly about its axis and a complete set of three measurements made with the specimen in the new position.

## **7. SPECIMENS**

**7.1.** Test Specimens – For concrete greater than or equal to 8 inches in thickness the nominal diameter of core specimens for the determination of compressive strength shall be at least 3.75 in (95 mm). Core diameters less than 3.75” are permitted when it is impossible to obtain cores with length-to-diameter (L/D) ratio  $\geq 1$  for compressive strength evaluations. For concrete with a thickness of less than 8 inches the

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<sup>1</sup> AASHTO T 148



nominal core diameter should preferably be at least three times the nominal maximum size of the coarse aggregate and must be at least twice the nominal maximum size of the coarse aggregate.

**7.2. Moisture Conditioning** - Test cores after moisture conditioning as specified in this test method. The moisture conditioning procedures specified in this test method are intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and specimen preparation.

**7.2.1.** After cores have been drilled, wipe off surface drill water and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than one hour after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as practical. Keep cores in the sealed plastic bags or nonabsorbent containers at all times except during end preparation and for a maximum time of two hours to permit capping before testing.

**7.2.2.** If water is used during sawing or grinding of core ends, complete these operations as soon as practicable, but no later than two days after drilling of cores. After completing end preparation, wipe off surface moisture, allow the surfaces to dry, and place the cores in sealed plastic bags or nonabsorbent containers. Minimize the duration of exposure to water during end preparation.

**7.2.3.** When direction is given to test cores in a moisture condition other than achieved by conditioning according to **sections 7.2.1.** and **7.2.2** of this test method, report the alternative procedure.

**7.3. End Preparation Prior to Capping** - The ends of specimens to be tested in compression shall be essentially smooth, perpendicular to the longitudinal axis, and of the same diameter as the body of the specimen. Saw or grind the top of the specimen no more than 0.375 inches (10 mm) to remove surface tining or roughness. Saw or grind the bottom of the specimen only the amount that is required for the specimen to fit into the testing machine. No point on either end of compressive test specimens shall protrude by more than 0.125 inches (3 mm) from a plane perpendicular to the axis of the specimen at the lowest point of the surface *prior to capping with sulfur*.

**NOTE:** Prior to capping, the density of a core may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

## **8. CAPPING**

**8.1.** Cap the specimen according to the procedures contained in **KT-77**.

**8.2. Measurement** - Prior to testing, measure the length of the capped specimen to the nearest 0.01 inch (0.25 mm) and use this length to compute the length-diameter ratio. Take three caliper measurements at 120 degree intervals along the circumference of the circle to determine the average length. Determine the average diameter by averaging two measurements taken at right angles to each other about the mid-height of the specimen. Measure core diameters to the nearest 0.01 inch (0.25 mm). Do not test cores if the difference between the largest and smallest diameter exceeds five percent of their average.

## **9. TESTING**

**9.1.** Test the specimens for the 28th day compression strength within seven days after coring, unless specified otherwise.

**9.2.** Specimens shall be tested at the age required by the applicable specification within the time tolerances shown in **Table 1**.

**Table 1 Permissible Time Tolerances**

Test Age	Permissible Tolerance
12 h	± 0.25 h
24 h	± 0.5 h
3 days	± 2 h
7 days	± 6 h
28 days	± 20 h
56 days	± 40 h
90 days	± 2 days

**9.3.** Placing the Specimen - Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically-seated (upper) bearing block. Wipe clean the bearing faces of the upper- and lower-bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

**9.4.** Zero Verification and Block Seating - Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator. As the spherically-seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

**NOTE:** The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

**9.5.** Rate of Loading - Apply the load continuously and without shock.

**9.5.1.** The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of  $35 \pm 7$  psi/s ( $0.25 \pm 0.05$  MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

**NOTE:** For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

**9.5.2.** During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. Apply the higher loading rate in a controlled manner so that the specimen is not subjected to shock loading.

**9.5.3.** Do not adjust the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

**9.5.4.** Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (See **Figure 1**). For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95% of the peak load. A setting of 60% of peak is recommended. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained and a clear

fracture pattern is discernable. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to **Figure 1**. If the fracture pattern is not one of the typical patterns shown in **Figure 1**, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with **section 8.1** of this test method.

## 10. CALCULATIONS

**10.1.** Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen as follows:

Compressive strength=peak load/area

$$Area = \pi r^2$$

**10.2.** Determine the length/diameter ratio (LD), and round the result to the nearest hundredth using the following formula:

$$LD = \text{Length} / \text{Diameter}$$

Determine a correction factor to the nearest thousandth by using the appropriate formula in **TABLE 2**. Correct the compressive strength by multiplying the compressive strength determined in **10.1** by the correction factor.

<b>TABLE 2: COMPRESSIVE STRENGTH CORRECTION FACTOR FORMULAS</b>	
<b>LD</b>	<b>Correction Factor</b>
LD < 2	$\frac{100}{95 + 0.2\left(\frac{1}{LD}\right) + 19.5\left(\frac{1}{LD}\right)^2}$
LD = 2	1.00
LD > 2	$\frac{100}{110 - 5(LD)}$

The compressive strength correction factor may also be obtained by using TABLE 3 below. If a discrepancy should arise due to rounding numbers or the appropriate value is not shown in the table, the value determined by the above formulas shall govern.

Correct the compressive strength determined during testing by multiplying that amount by the compressive strength correction factor.

Table 3 – COMPRESSIVE STRENGTH CORRECTION FACTOR			
LD	Compressive Strength Correction Factor	LD	Compressive Strength Correction Factor
1.00	0.872	2.60	1.031
1.10	0.898	2.70	1.036
1.20	0.920	2.80	1.042
1.30	0.937	2.90	1.047
1.40	0.952	3.00	1.053
1.50	0.963	3.10	1.058
1.60	0.973	3.20	1.064
1.70	0.982	3.30	1.070
1.80	0.989	3.40	1.075
1.90	0.995	3.50	1.081
2.00	1.000	3.60	1.087
2.10	1.005	3.70	1.093
2.20	1.010	3.80	1.099
2.30	1.015	3.90	1.105
2.40	1.020	4.00	1.111
2.50	1.026		

## 11. REPORT

11.1. Report the results as required by the Contract Document with the addition of the following information:

11.1.1. Identification number.

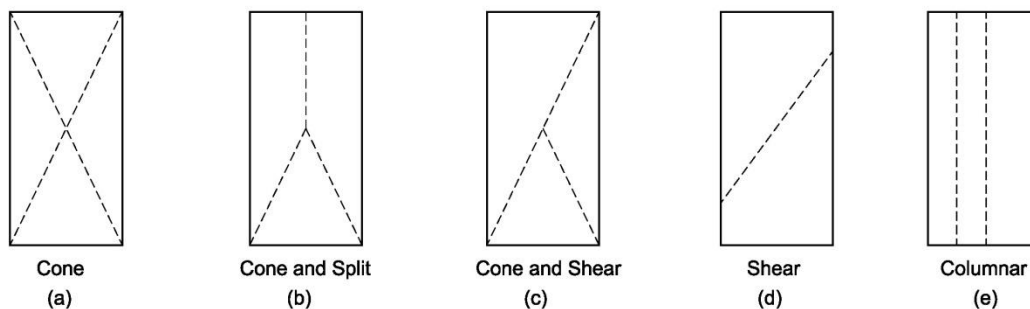
11.1.2. Diameter and length, inch (mm).

11.1.3. Cross-sectional area, in<sup>2</sup> (cm<sup>2</sup>).

11.1.4. Maximum load, lbf (kN).

11.1.5. Compressive strength (corrected) calculated to the nearest 1 psi (0.01 MPa).

11.1.6. Type of fracture, if other than the usual cone. (See **Figure 1**)



**Figure 1 - Sketches of Types of Fracture**

**11.1.7.** Defects in either specimen or caps.

**11.1.8.** Age of specimen.

**11.1.9.** Length of core as drilled to the nearest 0.01 inch (0.25 mm).

**11.1.10.** Length of test specimen before and after capping or end grinding to the nearest 0.01 inch (0.25 mm), and average diameter of core to the nearest 0.01 inch (0.25 mm).

**11.1.11.** Direction of application of the load on the specimen with respect to the horizontal plane of the concrete as placed.

**11.1.12.** The moisture conditioning history.

**11.1.12.1.** The date and the time core was obtained and first placed in sealed bag or nonabsorbent container.

**11.1.12.2.** If water was used during end preparation, the date and time end preparation was completed and the core placed in sealed bag or nonabsorbent container.

**11.1.13.** The date and time when tested.

**11.1.14.** If determined, the density.

**11.1.15.** If applicable, description of defects in cores that could not be tested.

**11.1.16.** If any deviation from this test method was required, describe the deviation and explain why it was necessary.

## **12. PRECISION AND BIAS**

**12.1.** From AASHTO T 24, the single-operator coefficient of variation on cores has been found to be 3.2% for a range of compressive strength between 4500 psi (32.0 MPa) and 7000 psi (48.3 MPa). Therefore, results of two properly conducted tests of single cores by the same operator on the same sample of material should not differ from each other by more than nine percent of their average.

**12.2.** From AASHTO T 24, the multi-laboratory coefficient of variation on cores has been found to be 4.7% for range of compressive strength between 4500 psi (32.0 MPa) and 7000 psi (48.3 MPa). Therefore results on two properly conducted tests on cores sampled from the same hardened concrete (where a single test is defined as the average of two observations (cores), each made on separate adjacent drilled 4 in (100 mm) diameter cores), and tested by two different laboratories should not differ from each other by more than 13 percent of their average.

**12.3.** From AASHTO T 24, since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

## 5.9.50 UNCOMPACTED VOID CONTENT OF FINE AGGREGATE (Kansas Test Method KT-50)

### 1. SCOPE

This method of test covers the determination of the uncompact void content of a sample of aggregate based on a given gradation. It provides a measure of aggregate angularity, sphericity, and texture compared to other fine aggregates tested. **KT-50** reflects testing procedures found in **AASHTO T 304**.

### 2. REFERENCED DOCUMENTS

- 2.1. Part V, 5.9; Sampling and Test Methods Foreword
- 2.2. KT-03; Material Passing No. 200 (75  $\mu$ m) Sieve by the Wash Method
- 2.3. AASHTO T 304; Uncompact Void Content of Fine Aggregate
- 2.4. ASTM B88; Specification for Seamless Copper Water Tube
- 2.5. ASTM C778; Specification for Standard Sand

### 3. APPARATUS

- 3.1. Drying oven capable of maintaining a uniform temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).
- 3.2. The funnel shall be smooth on the inside and at least 1.5 in (38 mm) high. It shall have a volume of at least 200 mL or shall be provided with a supplemental container to provide the required volume. The lateral surface of the right frustum of a cone sloped  $60 \pm 4$  degrees from the horizontal with an opening of  $0.50 \pm 0.024$  in ( $12.7 \pm 0.6$  mm) diameter. The funnel and supplemental container shall comply with the apparatus shown in **Figure 1**.
- 3.3. A funnel stand capable of holding the funnel firmly in position with its axis collinear with the axis of the measure and funnel opening  $4.5 \pm 0.1$  in ( $115 \pm 2$  mm) above the top of the cylinder. A suitable arrangement is shown in **Figure 1**.
- 3.4. A right angle cylinder of approximately  $6.1 \text{ in}^3$  (100 mL) capacity having an inside diameter of  $1.53 \pm 0.05$  in ( $39 \pm 1.3$  mm), and an inside height of approximately 3.37 in (86 mm), made of drawn copper water tubing meeting **ASTM B88**, Type M or equally rigid material. The bottom of the measure shall be at least 0.24 in (6 mm) thick, shall be firmly sealed to the tubing, and shall be provided with means for aligning the axis of the cylinder with that of the funnel. See **Figure 2**.
- 3.5. A metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material. The purpose of the pan is to catch and retain aggregate grains that overflow the measure during filling or strike off.
- 3.6. Metal spatula about 4 in (100 mm) long with sharp straight edges. The straight edge of the spatula is used to strike off the fine aggregate.
- 3.7. The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.
- 3.8. 200 mL volumetric flasks TC at  $68^{\circ}\text{F}$  ( $20^{\circ}\text{C}$ ) accurate and readable to  $\pm 0.10$  mL.

**3.9.** A brush small enough to use to dislodge aggregate from the measure's base while inside the funnel stand.

**3.10.** A small plastic or metal or glass funnel with a neck small enough to insert into the 200 mL volumetric flasks but sufficiently large enough in inside diameter to transfer all the contents of the measure to the flask.

#### 4. DETERMINATION OF THE VOLUME OF CYLINDRICAL MEASURE

Apply a light coat of grease to the top edge of the dry, empty measure. Weigh the measure, grease, and a flat glass plate slightly larger than the diameter of the measure. Fill the measure with distilled/deionized water at a temperature of  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ). Place the glass on the measure, being sure that no air bubbles remain. Dry the outer surfaces of the measure and determine the combined mass of measure, glass plate, grease and water by weighing. This procedure should be done at least once a year.

Calculate the volume of the measure as follows:

$$V_c = \frac{W}{0.99704}$$

Where:  $V_c$  = volume of cylinder, mL  
 $W = d - c$  = net mass of water, g  
 $c$  = cylinder + glass + grease, g  
 $d$  = cylinder + glass + grease + water, g  
0.99704 g/mL is the density of water at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ).

Determine the volume to the nearest 0.1 mL.

NOTE: Density of water varies based on temperature. Since the water bath temperature is fixed at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ), use the specified value of 0.99704 g/mL. For tests not restrained by the  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ) requirement, select the proper density for water from KT-15, Table 1. Divide the value given in the table by 1000 for g/mL.

#### 5. SAMPLE PREPARATION

**5.1.** Wash the sample over the No. 200 (75  $\mu\text{m}$ ) sieve using the equipment and procedures listed in **KT-03, section 3 and section 5**. Dry the plus No. 200 (75  $\mu\text{m}$ ) material to a constant mass. Sieve the dry aggregate over the No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600  $\mu\text{m}$ ), No.50 (300  $\mu\text{m}$ ) and No. 100 (150  $\mu\text{m}$ ) sieves. Discard all the material retained on the No. 8 (2.36 mm) and passed through the No. 100 (150  $\mu\text{m}$ ).

**5.2.** Weigh out and combine the following quantities of dry aggregate from each of the sizes:

Individual Size Fraction	Mass, g
No. 8 (2.36 mm) to No. 16 (1.18 mm)	44
No. 16 (1.18 mm) to No. 30 (600 $\mu\text{m}$ )	57
No. 30 (600 $\mu\text{m}$ ) to No. 50 (300 $\mu\text{m}$ )	72
No. 50 (300 $\mu\text{m}$ ) to No. 100 (150 $\mu\text{m}$ )	<u>17</u>
<b>TOTAL</b>	<b>190</b>

The tolerance on each of these amounts is  $\pm 0.2$  g

**5.3.** Prepare two test samples of the above recipe.

**NOTE:** If  $U_k$  values below the specified (full pay) value have been obtained from previous tests on this project, the Engineer may increase the number of test samples from two to four, and go directly to the  $U_k$  determination specified in **section 9.** of this test method. This is in lieu of performing a two-sample test, discarding a failed result, and retesting with four samples.

## **6. TEST PROCEDURE**

**6.1.** Mix the test sample until it is homogenous. Using a finger to block the opening of the funnel, pour the test sample into the funnel. Level the material in the funnel with the spatula. Center the measure under the funnel, remove the finger and allow the sample to fall freely into the measure.

**6.2.** After the funnel empties, remove excess heaped aggregate from the measure by a single pass of the spatula with the blade vertical using the straight part of its edge in light contact with the top of the measure. Until this operation is complete, exercise care to avoid vibration or disturbance that could cause compaction of the fine aggregate in the measure. After strike-off the measure may be tapped lightly to compact the sample to make it easier to transfer the measure. Brush adhering grains from the outside of the measure.

**6.3.** Pour contents of cylinder into 200 mL volumetric flask using a funnel to assure total transfer of aggregate.

**6.4.** Weigh the flask and sample, record as A.

**6.5.** Add distilled water (deionized water can be substituted). Rotate the flask in an inclined position to eliminate all air bubbles. Do not shake. Allow the flask to sit for several minutes then roll flask again. Continue the process until there are no visible air bubbles present or for a maximum of 15 minutes, whichever comes first. Distilled water (and entire test) should be at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ).

**NOTE:** Bubbles or foam may be dispelled by touching them carefully with a hot wire or the tip of a paper towel.

**6.6.** Adjust distilled water to the calibrated volume mark on the neck of the flask.

**6.7.** Weigh flask and contents, record as B.

**6.8.** Repeat procedure for the second test sample and record results.

## **7. CALCULATIONS**

**7.1.** Calculate the uncompacted void content, ( $U_k$ ), by this method:

$$U_k = \frac{U_1 + U_2}{2}$$

Where:  $U_1$  and  $U_2$  are the uncompacted void content for Trial No. 1 and Trial No.2 respectively, and are determined by:

$$U_{1,2} = \frac{100 [V_w - V_f + V_c]}{V_c}$$



Where:  $V_f$  = Volume of flask (manufacturer's calibrated volume), 200 mL  
 $V_c$  = Calibrated volume of cylinder, mL  
 $V_w$  = Volume of the water, mL =  $\frac{B - A}{0.99704}$

Where: B = mass of flask, water and aggregate, g  
A = mass of flask and aggregate, g  
0.99704 g/mL is the density of water at 77 ± 2°F (25 ± 1°C).

NOTE: Density of water varies based on temperature. Since the water bath temperature is fixed at 77 ± 2°F (25 ± 1°C), use the specified value of 0.99704 g/mL. For tests not restrained by the 77 ± 2°F (25 ± 1°C) requirement, select the proper density for water from KT-15, Table 1. Divide the value given in the table by 1000 for g/mL.

## 8. REPORT

**8.1.** Record uncompacted voids to the nearest 0.1%. Report uncompacted voids to the nearest 1%.

## 9. CONFIRMATION OF TEST VALUES

**9.1.** If two samples are prepared in **Section 5.3** of this test method, and the raw values of  $U_1$  and  $U_2$  differ by more than 1.0%, discard those  $U_1$  and  $U_2$  values and rerun the full test. Prepare four trial samples instead of two, as specified in **Section 5.3** of this test method. Determine the four trial values,  $U_1$ ,  $U_2$ ,  $U_3$  and  $U_4$  and calculate  $U_k$  using the following formula:

$$U_k = \frac{U_1 + U_2 + U_3 + U_4}{4}$$

Use this four test value for determining the pay

**9.2.** If the  $U_k$  value is below the specified (full pay) value and based on only two values ( $U_1$  and  $U_2$ ), discard those values and rerun the full test. Prepare four trial samples in **Section 5.3** of this test method and proceed with the testing. Calculate  $U_k$  using the four tests as shown in **Section 9.1.** of this test method. Use this  $U_k$  value for determining the pay factor.

## 10. PRECISION AND BIAS<sup>1</sup>

### 10.1. Precision

**10.1.1.** The single-operator standard deviation has been found to be 0.13% voids (1s), using the graded standard silica sand as described in **ASTM C778**. Therefore, results of two properly conducted tests by the same operator on similar samples should not differ by more than 0.37% (d2s).

**10.1.2.** The multilaboratory standard deviation has been found to be 0.33% (1s) using the standard fine aggregate as described in **ASTM C778**. Therefore, results of two properly conducted tests by laboratories on similar samples should not differ by more than 0.93% (d2s).

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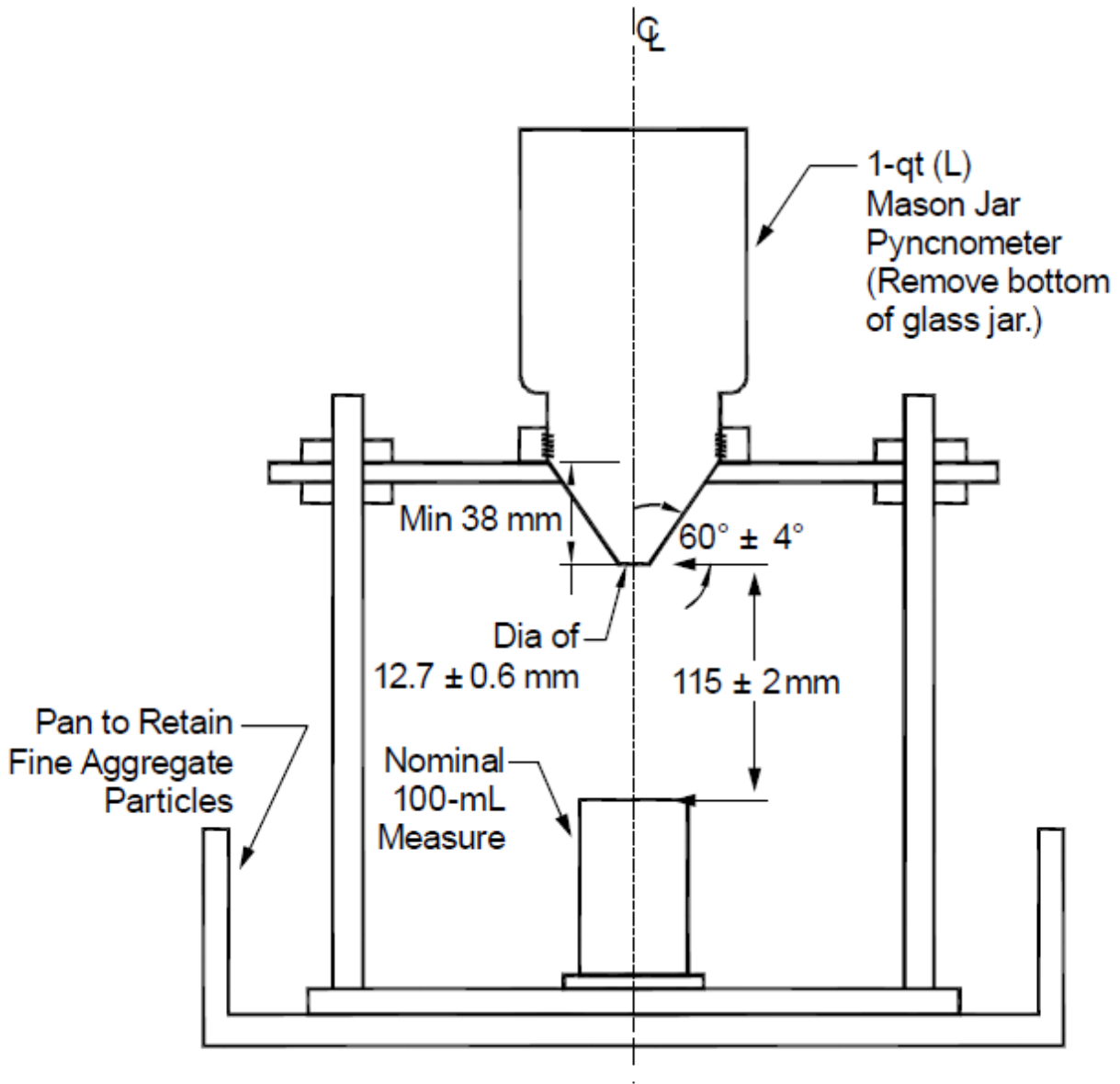
<sup>1</sup> Precision and Bias Statement is taken directly from **AASHTO T 304, Section 13.**

**10.1.3.** The above statements pertain to void contents determined on “graded standard sand” as described in **ASTM C788**, which is considered rounded, and is graded from No. 30 (600  $\mu\text{m}$ ) to No. 100 (150  $\mu\text{m}$ ), and may not be typical of other fine aggregates. Additional precision data are needed for tests of fine aggregates having different levels of angularity and texture in accordance with these test methods.

## **10.2.** Bias

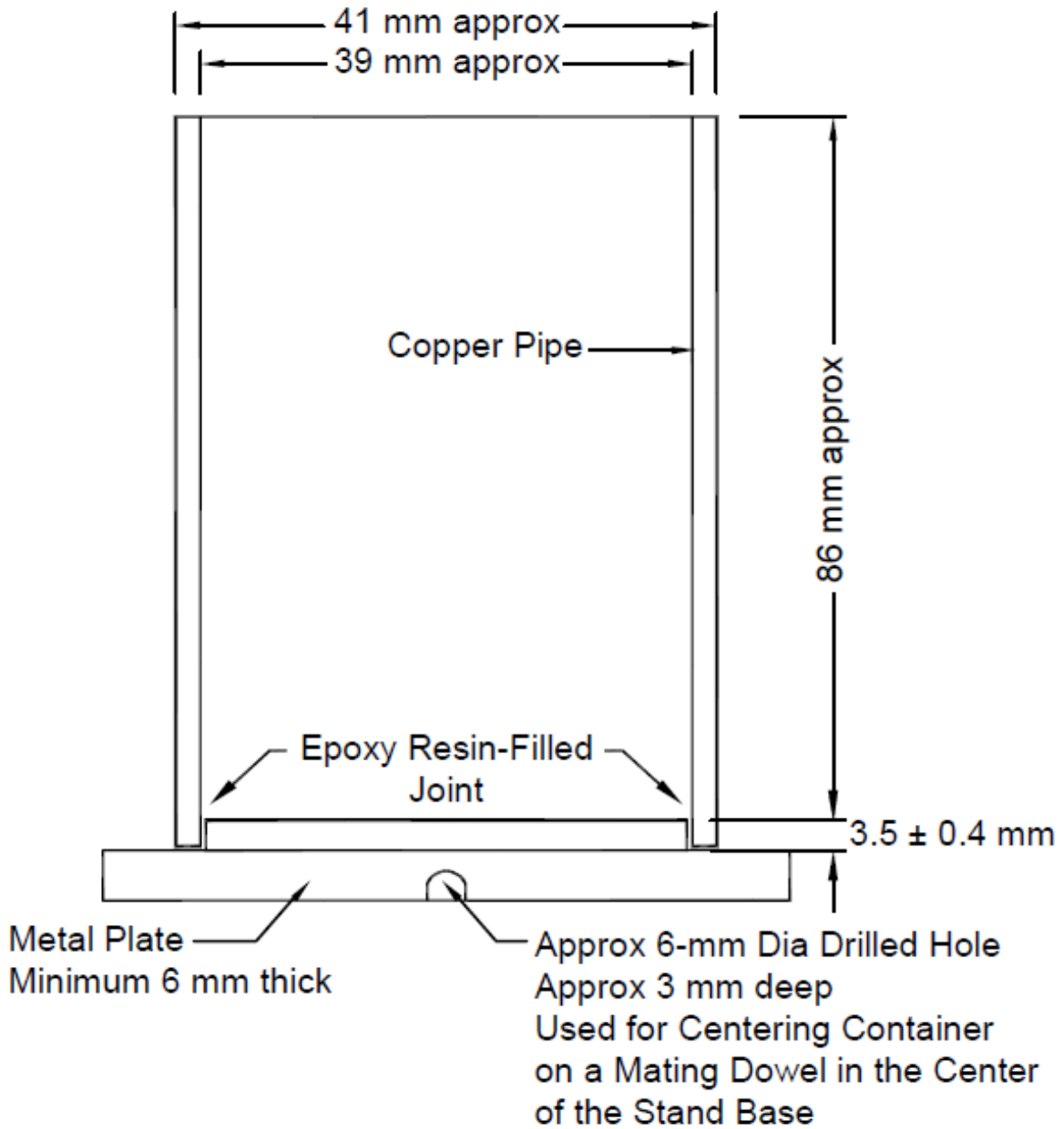
**10.2.1.** Since there are no accepted reference material suitable for determining the bias for the procedures in these test methods, bias has not been determined.

**Figure 1**  
**Suitable Funnel Stand Apparatus with Cylindrical Measure in Place**



Section through Center of Apparatus

Figure 2  
Nominal 100 mL Cylindrical Measure





## 5.9.51 FIELD DENSITY AND MOISTURE TESTS OF SOILS BY NUCLEAR GAUGE

(Kansas Test Method KT-51)

### **1. SCOPE**

This method of test covers the procedure for measuring the “in-place” density and moisture of soils by the attenuation of gamma and neutron radiation. The intensity of the radiation detected is dependent in part on the density of the material being tested. It should be recognized that the density and moisture determined by this method is not necessarily the average value within the measured volume at any one location. **Gauge calibration shall follow section 5.8.2 of test method, INDEPENDENT ASSURANCE REPLICATE (ASR) CHECK FOR NUCLEAR DENSITY GAUGES.** KDOT gauges shall be calibrated-annually. **KT-51** reflects procedures found in **AASHTO T 310**.

**The equipment utilizes radioactive materials which may be hazardous to the health of users unless proper precautions are taken. (For KDOT field personnel only; Refer to Standard Operating Manual No. 1.13.2).**

### **2. REFERENCED DOCUMENTS**

**2.1.** KT-11; Moisture Tests

**2.2.** AASHTO T 310: In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Method (Shallow Depth)

**2.3.** KT-41; Determination of Density and Moisture Content of Portland Cement Treated Bases, Aggregate Bases and Aggregate Shoulders by Nuclear Method

### **3. APPARATUS**

**NOTE:** Check gauge to verify it is in soil mode.

**3.1.** General.

**3.1.1.** Probe: Either the gamma source or the gamma detector shall be housed in a probe for insertion into a preformed hole of the material to be tested. The probe shall be marked in increments of 2 in (50 mm) for tests with probe depths from 2 in (50 mm) to a maximum of 12 in (300 mm). The probe shall be mechanically held in place when it is manually moved to the desired depth.

**3.1.2.** Housing: The source, detector, readout device, probe, and power supply shall be in housings of rugged construction that are moisture and dust proof.

**3.1.3.** Guide: A guide used for the hole forming device to make a hole, normal to the prepared surface.

**3.1.4.** Hole-forming Device: An auger, pin, or similar device for forming a hole in the soil to accommodate the probe. The hole-forming device shall have a nominal diameter equal to or up to 1/8 in (3 mm) greater than the probe diameter.

**3.1.5.** Extraction tool.

**3.1.6.** Miscellaneous equipment including shovel or auger, drying pans, and air tight containers.

### 3.2. Standardization.

3.2.1. Standardization of the nuclear gauge on a reference standard block is required at the start of each day's use and when test measurements are suspect.

3.2.2. Warm up the nuclear gauge in accordance with the manufacturer's recommendations.

## 4. DETERMINING MOISTURE CORRECTION FACTOR USING THE NUCLEAR GAUGE

**NOTE:** If **KT-11** is used for moisture determination instead of the nuclear gauge, then skip **Section 4.** of this test method, Determining Moisture Correction Factor Using The Nuclear Gauge.

4.1. For uniformity, the gauge operator shall position the source rod so it is closest to the compaction equipment (point the gauge towards the roller).

4.2. A Determination\* by the nuclear method is to be compared with moisture quantities described under **KT-11, Section 4.0., CONSTANT MASS METHOD.** Moisture samples shall be extracted from the same location the nuclear gauge readings are taken. At least six separate locations are required. Discard the location(s) with the greatest deviation to leave five pair of samples for analysis. Prepare the test site and proceed as stated in **Section 5. TEST PROCEDURE** of this test method.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

\* A determination represents 5 one-minute Wet Density (WD) and Percent Moisture (%M) readings from the gauge. Record the lb/ft<sup>3</sup> (kg/m<sup>3</sup>) on Wet Density (WD) and Percent Moisture (%M) for each reading. Discard the single highest and lowest wet density values along with their accompanying percent moisture values, average the three remaining percent moisture values, and record the average value.

4.3. Compare the six or more sample pairs of oven dry and nuclear gauge results from the locations listed above in **Section 4.2** of this test method. Discard the sample pair(s) that deviate the greatest from the remaining five. Oven dry samples are to be at least 1,000 g and are to be taken under the center of the gauge to a depth of 6 to 8 in (150 to 200 mm). Nuclear tests are to be taken without any type of internally applied corrections.

4.4. Prepare a chart of sample pairs as shown below:

Sample No.	(%M OD)	(%M NUCLEAR)	Moisture Difference (%M OD - %M NUCLEAR)
1	4.5	8.6	-4.1
2	4.0	5.9	-1.9
3	7.2	9.7	-2.5
4	6.7	8.6	-1.9
5 *	3.9 *	9.5 *	-5.6 *
6	<u>4.7</u>	<u>8.6</u>	<u>-3.9</u>
Average	5.4	8.3	-2.9

**NOTE:** "\*" represents the discarded sample pair.

**NOTE:** If the Average Moisture Difference exceeds  $\pm 1\%$ , a Moisture Correction Factor will be required for that soil type.

**4.5.** To determine the correction factor, calculate the average moisture difference value and proceed as follows:

**4.5.1.** Calculate the Moisture Correction Factor using the average difference values, as follows:

$$\text{Moisture Corr. Factor} = \frac{100 (\text{Avg. Oven \%M} - \text{Avg. \%M Gauge})}{100 + \text{Avg. \%M Gauge}}$$

In the example above, the moisture correction would be as follows:

$$\text{Moisture Corr. Factor} = \frac{100 (5.4 - 8.3)}{100 + 8.3} = -2.7$$

The correction is independent of dry density and adjusts the apparent moisture to true moisture regardless of dry density. This value can be used for all future tests on the same soil type.

**NOTE:** Each soil type having an Average Moisture Difference exceeding  $\pm 1\%$  will have a moisture correction factor.

## **5. TEST PROCEDURE**

**5.1.** Determine the number of soil types to be encountered on the project. If the number is substantial, then use **KT-11 MOISTURE TESTS** to determine the correct moisture content of the soil instead of calibrating the nuclear density gauge to moisture. **KT-11, Section 9. TEST PROCEDURE FOR SPEEDY METHOD** can be used if the Speedy was calibrated within the last year.

**5.2.** Randomly select a test site where the gauge will be at least 12 in (300 mm) away from any slight vertical projection. If the vertical projection is significant, then maintain a distance of 10 ft (3 m) including all stationary vehicles and construction equipment. Vehicles and construction equipment in motion should maintain a minimum distance of 3 to 4 ft (1 to 1.5 m) from the gauge.

**5.3.** Prepare the test site in the following manner:

**5.3.1.** Remove all loose and disturbed material, and remove additional material as necessary to expose the top of the material to be tested.

**5.3.2.** Prepare a horizontal area, sufficient in size to accommodate the gauge by planing a level area to a smooth condition. This will create a maximum contact surface between the nuclear gauge and material being tested.

**5.3.3.** The maximum void beneath the gauge shall not exceed approximately 1/8 in (3 mm). Use native soil or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 1/8 in (3 mm).

**5.3.4.** Place the nuclear gauge on the test site and trace the outline of the gauge onto the test surface. After the site selection has been made, a vertical hole is made 2 in (50 mm) deeper than the thickness of the material, with the rod and plate provided with the gauge. If the thickness of the material exceeds the depth capability of the gauge, then a hole is made 2 in (50 mm) deeper than the gauge's maximum depth.



Set the probe to the maximum depth or at a depth equal to the project specification thickness, whichever is less. Maintain alignment so the insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**5.4.** Proceed with testing in the following manner:

**5.4.1.** Tilt the gauge and extend the probe to the position required for the desired depth of test.

**5.4.2.** For uniformity, the gauge operator shall position the source rod so it is closest to the compaction equipment (point the gauge towards the roller).

**5.4.3.** Insert the probe in the hole.

**5.4.4.** Seat the gauge firmly by moving it about the probe with a back and forth motion.

**5.4.5.** Pull gently on the gauge in the direction that will bring the side of the probe which faces the center of the gauge into intimate contact with the side of the hole.

**5.4.6.** Set the time for a one-minute reading interval. Initiate the gauge to take the readings.

**5.5.** Take Gauge Readings.

**5.5.1.** Take and record 5 one-minute readings. Record the lb/ft<sup>3</sup> (kg/m<sup>3</sup>) on Wet Density (WD) and Percent Moisture (%M) for each reading. Discard the single highest and lowest wet density values along with their accompanying percent moisture values, average the three remaining wet density values and record, and average the three remaining percent moisture values and record.

**NOTE:** Check tip of source rod to assure it is free of any foreign substance (i.e. grease, asphalt, concrete, etc.).

**5.6.** Determining Moisture Readings Using **KT-11**. Determine the moisture content of soil directly under the gauge according to **KT-11**.

**5.7.** If the soil fails to meet the designated compaction at a single location, rotate the gauge 180° and take new readings. If the soil compaction still fails, then the compaction is inadequate.

## **6. CALCULATIONS WHEN USING KT-11**

**6.1.** Calculate the Dry Density (DD) from the Moisture Reading obtained in **Section 5.6** and the Wet Density (WD) determined by the gauge using the following equation.

$$DD = \frac{100 (WD)}{100 + \%M}$$

$$\%PR = \frac{100 (DD)}{SD}$$

Where: M = Moisture content in lb/ft<sup>3</sup> (kg/m<sup>3</sup>)

DD = Dry Density in lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
WD = Wet Density in lb/ft<sup>3</sup> (kg/m<sup>3</sup>)  
%PR = Percent of Proctor Density (also referred to as the Percent of Standard Density)  
SD = Standard Density (Proctor) lb/ft<sup>3</sup> (kg/m<sup>3</sup>)

**6.2.** Dry Density may also be calculated using the equation found in **Sect. 9.5.** of **KT-41.**

## **7. SOIL IDENTIFICATION**

**7.1.** Identification of the soil is required for several reasons. These include the comparison to the standards for optimum moisture content and target density which are required in order to determine compliance with the specifications, determining the proper moisture correction factors to be applied for the soil under the test, and the reporting of the moisture and density tests results.

**7.2.** A selection of soil type is necessary in order to set the moisture correction factor for the gauge.

**7.3.** Nonhomogeneous soils may be encountered in which differences between gauges and oven are not consistent between samples. In this case, the use of **KT-11, MOISTURE TESTS** is the proper method for analyzing the moisture content of the soil.

## **8. TESTING**

**8.1.** Wet density and moisture are the only items the density gauge is capable of reading. All other values are calculated from wet density, moisture, and initialized information in the gauge.

## **9. REPORT AND RECORD**

**9.1.** Report and record as 0.1 lb/ft<sup>3</sup> (1 kg/m<sup>3</sup>) or 0.1% of optimum density.



5.9.54 DETERMINATION OF PAVEMENT PROFILE WITH THE PROFILOGRAPH  
(Kansas Test Method KT-54)

**DELETED**

**04-2010**  
**See KT-46**



5.9.55 PLASTIC FINES IN COMBINED AGGREGATES BY USE OF THE SAND EQUIVALENT TEST (Kansas Test Method KT-55)

**1. SCOPE**

This test is intended to serve as a rapid test to show the relative proportions of fine dust or claylike material in minus No. 4 (4.75 mm) combined aggregates. **KT-55** reflects testing procedures found in **AASHTO T 176**.

**2. REFERENCED DOCUMENTS**

**2.1.** AASHTO T 176; Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

**3. APPARATUS**

**3.1.** A graduated plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly and siphon assembly, all conforming to their respective specifications and dimensions described in **AASHTO T 176, Section 4.1**. Fit the siphon assembly to a 1 gal (4 L) bottle of working calcium chloride solution (see **Section 3.7** of this test method) placed on a shelf  $36 \pm 1$  in ( $915 \pm 25$  mm) above the work surface.

**3.2.** A  $3 \pm 0.2$  oz ( $85 \pm 5$  mL) tinned box approximately 2.25 in (57 mm) in diameter, with Gill style cover.

**3.3.** A wide mouth funnel approximately 4 in (100 mm) in diameter.

**3.4.** A clock or watch reading in minutes and seconds.

**3.5.** A mechanical shaker as described in **AASHTO T 176, Section 4.6**. Prior to use, fasten the mechanical sand equivalent shaker securely to a firm and level mount.

**3.6.** Stock calcium chloride solution: Prepare the stock calcium chloride solution as follows:

1 lb (454 g) technical grade Anhydrous Calcium Chloride  
2050 g (1640 mL) USP Glycerin  
47 g (45 mL) Formaldehyde (40% solution)

**3.6.1.** Dissolve the calcium chloride in 1/2 gal (1.89 L) of distilled water. Cool the solution and then filter it through Whatman No. 12 or equivalent paper. Add the glycerin and formaldehyde to the filtered solution, mix well, and dilute to 1 gal (3.78 L) with distilled water.

**3.7.** Working calcium chloride solution: Prepare the working calcium chloride by diluting  $3 \pm 0.2$  oz ( $85 \pm 5$  mL) of the stock calcium chloride solution to 1 gal (3.78 L) with water. Use distilled or demineralized water for the normal preparation of the working solution. Working solutions more than 30 days old shall be discarded.

**3.8.** A straightedge or spatula, suitable for striking off the excess material from the tin measure.

**3.9.** A thermostatically controlled drying oven capable of maintaining a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

## **4. CONTROL**

**4.1.** Maintain the temperature of the working solution at  $72 \pm 5^{\circ}\text{F}$  ( $22 \pm 3^{\circ}\text{C}$ ) during the performance of this test. If field conditions prevent temperatures from staying within this temperature range, submit frequent referee samples to the district laboratory for comparison. Temperature correction factors can also be established for each combined aggregate being tested.

**4.2.** Perform the test in a location free of vibrations; vibrations may cause the suspended material to settle at a rate greater than normal.

**4.3.** Do not expose the plastic cylinders to direct sunlight any more than is necessary.

**4.4.** To remove organic growth from the working calcium chloride solution container and from the inside of the flexible tubing and irrigator tube, prepare a cleaning solvent by diluting sodium hypochlorite with an equal quantity of water. Fill the solution container with the prepared cleaning solvent. Allow about a liter of the cleaning solvent to flow through the siphon assembly and irrigator tube, allow to stand overnight. After soaking, allow the cleaning solvent to flow out through the siphon assembly and irrigator tube. Remove the siphon assembly from the solution container and rinse both with clear water. The irrigator tube and siphon assembly can be rinsed easily by attaching a hose between the tip of the irrigator tube and water faucet and backwashing fresh water through the tube.

**4.5.** Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening.

## **5. SAMPLE PREPARATION**

**5.1.** Perform the sand equivalent test on combined aggregate materials passing the No. 4 (4.75 mm) sieve. Pulverize all aggregate of fine-grained soil materials to pass the No. 4 (4.75 mm) sieve, and clean all fines from the particles retained on the No. 4 (4.75 mm) sieve and include with the material passing the No. 4 (4.75 mm) sieve.

**5.2.** Split or quarter enough of the original sample to yield slightly more than four 3 oz (85 mL) tin measures of material passing the No. 4 (4.75 mm) sieve. Use extreme care to obtain a truly representative portion of the original sample. Dampen the material to avoid loss or segregation of the fines if necessary.

**5.3.** Prepare two test samples using the following method.

**5.3.1.** Split or quarter enough material from the portion passing the No. 4 (4.75 mm) sieve to fill the 3 oz. (85 mL) tin measure so it is slightly rounded above the brim. While filling the measure, tap the bottom edge of the tin on the work table or other hard surface to cause consolidation of the material and allow the maximum amount to be placed in the tin. Strike off the tin measure level full with a spatula or straightedge.

**5.3.2.** Dry the test sample to constant mass at  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ), cool to room temperature before testing.

## 6. PROCEDURE

**6.1. For each test sample:** Siphon  $4 \pm 0.1$  in ( $101.6 \pm 2.5$  mm) of working calcium chloride solution into the plastic cylinder. Pour the prepared test sample from the measuring tin into the plastic cylinder using the funnel to avoid spillage. Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.

**6.2.** Allow the wetted sample to stand undisturbed for  $10 \pm 1$  minutes. At the end of the 10 minute soaking period, stopper the cylinder, then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.

**6.3.** After loosening the material from the bottom of the cylinder, place the stoppered cylinder in the mechanical<sup>1</sup> sand equivalent shaker and secure. Make sure the timer is set for 45 seconds then turn the shaker on.

**6.4.** Following the shaking operation, set the cylinder upright on the work surface and remove the stopper.

**6.5.** Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. This flushes the fine material into suspension above the coarser sand particles. Continue to apply the stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 15 in (381 mm) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at 15 in (381 mm) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 15 in (381 mm).

**6.6.** Allow the cylinder and contents to stand undisturbed for 20 minutes  $\pm$  15 seconds. Start the timing immediately after withdrawing the irrigator tube.

**6.7.** At the end of the 20-minute sedimentation period, read and record the top level of the clay suspension. This is referred to as the “clay reading”. If no clear line of demarcation has formed at the end of the specified 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the top level of the clay suspension and total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual samples of the same material. Read and record the clay column height of that sample requiring the shortest sedimentation period only.

**6.8.** Obtain the ‘sand reading’ after the clay reading has been taken. The sand reading is determined by placing the weighted foot assembly over the cylinder and gently lowering the assembly toward the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. As the weighted foot comes to rest on the sand, tip the assembly toward the graduations on the cylinder until the indicator touches the inside of the cylinder. Subtract 10 in (254 mm) from the level indicated by the extreme top edge of the indicator and record this value as the sand reading.

**6.9.** If the clay or sand readings fall between the 0.1 in (2.5 mm) graduations, record the level of the higher graduation as the reading. For example, a clay reading of 7.95 in (199 mm) would be recorded as 8.0 in (200 mm), and a sand reading of 3.32 in (83 mm) would be recorded as 3.4 in (85 mm).

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<sup>1</sup> AASHTO T 176 Section 8.4.2. and 8.4.3 provides alternative means of the sample; the Manual and Hand Method. The alternatives are not options under KT-55.



## 7. CALCULATIONS

7.1. Calculate the sand equivalent (SE) to the nearest 0.1 using the following formula:

$$SE = \frac{100(\text{Sand Reading})}{\text{Clay Reading}}$$

7.2. If the calculated sand equivalent is not a whole number, report it as the next higher whole number, as in the following example:

$$SE(\text{English}) = \frac{100(3.4)}{8} = 42.5, \text{ which is reported as } 43$$

$$SE(\text{Metric}) = \frac{100(85)}{200} = 42.5, \text{ which is reported as } 43$$

7.3. Average the whole number values determined as described above. If the average of these values is not a whole number, raise it to the next higher whole number.

## 8. REPORT

8.1. Record and report to the whole number.

5.9.56 RESISTANCE OF COMPACTED ASPHALT MIXTURE TO MOISTURE INDUCED DAMAGE (Kansas Test Method KT-56)

**1. SCOPE**

This test covers preparation of specimens and measurement of the change of tensile strength resulting from the effects of saturation and accelerated water conditioning of compacted asphalt mixtures in the laboratory. **KT-56** reflects testing found in **AASHTO T 283**. The results may be used to:

1. Predict the ability of an asphalt mix to withstand long-term stripping,
2. Evaluate liquid anti-stripping additives which are added to the asphalt cement, or
3. Evaluate pulverized solids, such as hydrated lime, which are added to the mineral aggregate.

**2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9.; Sampling and Test Methods Foreword

**2.2.** KT-06; Specific Gravity and Absorption of Aggregate

**2.3.** KT-14; Marshall Tests of Bituminous Mixes

**2.4.** KT-15; Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)

**2.5.** KT-25; Sampling and Splitting Plant Mixed Asphalt Mixtures

**2.6.** KT-32; Method of Test for Density of Compacted Asphalt Mixtures by Nuclear Method

**2.7.** KT-39; Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures

**2.8.** KT-58; Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor

**2.9.** AASHTO T 283; Resistance of Compacted Asphalt Mixture to Moisture Induced Damage

**3. APPARATUS**

**3.1.** Equipment for preparing and compacting specimens from **KT-58** of this manual.

**3.2** Vacuum container with a minimum inside diameter of 8 in (200 mm) and an inside height capable of placing a minimum of 1 in (25 mm) of water above specimen plus base plate prior to vacuum. Vacuum container capable of withstanding a 1.2 in (30 mm) of Hg absolute pressure. Base plates to be made of perforated Polypropylene material with a minimum of 6 in (150 mm) diameter.

**3.3.** Vacuum pump or water aspirator capable of obtaining a 1.2 in (30 mm) of Hg absolute pressure. To include a manometer or vacuum gauge and appropriate hose to accommodate pressure and distance requirements.

**3.4.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**3.5.** Water bath capable of maintaining a temperature of  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ).

**3.6.** Water bath capable of maintaining a temperature of  $140 \pm 2^\circ\text{F}$  ( $60 \pm 1^\circ\text{C}$ ).

**3.7.** Freezer maintained at  $0 \pm 10^\circ\text{F}$  ( $-18 \pm 5^\circ\text{C}$ ).

**3.7.1.** Freezer operation should be checked every 6 months by determining the high and low temperatures reached during compressor cycles. A thermal mass (thermometer well) may be used to reduce temperature fluctuation during compressor cycles. A 2" x 2" x 3.75" (50 mm x 50 mm x 95 mm) aluminum block, drilled at one end to receive a thermocouple, will adequately dampen temperature swings.

**3.8.** A supply of plastic film for wrapping, heavy-duty leak proof plastic bags to enclose the saturated specimens and masking tape.

**3.9.** 10 mL graduated cylinder.

**3.10.** Loading jack and ring dynamometer from **KT-14** of this manual to provide controlled vertical deformation at the rate of 2 in (50.8 mm) per minute.

**3.11.** Breaking head will consist of stainless steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 4 in (102 mm) in diameter the loading strips are to be 0.5 in (12.7 mm) wide, and for specimens 6 in (150 mm) in diameter the loading strips are to be 0.75 in (19.05 mm) wide. The length to thickness ratio of the loading strips is to exceed one. Round the edge of the loading strips.

**3.12.** Pans having a surface area of 75-100 square inches (48,400-64,500 square millimeters) in the bottom and a depth of approximately 1 in (25 mm).

**3.13.** Forced air draft oven, thermostatically controlled, capable of maintaining any desired temperature setting from room temperature to  $350^\circ \pm 5^\circ\text{F}$  ( $176^\circ \pm 3^\circ\text{C}$ ).

#### **4. PREPARATION OF LABORATORY TEST SPECIMENS**

**4.1.** Use specimens that are 6 in (150 mm) in diameter and  $3.75 \pm 0.20$  in ( $95 \pm 5$  mm) thick.

**4.2.** Build the aggregate material in the same manner as described in **KT-14 Sections e.2.b. or e.2.c.** of this manual. A minimum of six specimens will be required to perform this test. The asphalt quantity is based on the optimum design content. Additional material for **KT-39** of this manual may be required.

**4.3.** Preparation of mixes: Combine individual aggregates or reclaimed material and virgin aggregates by weighing out in a separate pan for each test specimen, proportionate amounts of each size fraction for each individual aggregate to produce the desired combined gradation. The combined aggregate should be sufficient to produce a compacted specimen as described in **Section 4.1.**

**4.4.** Heat the aggregate and asphalt within the limits of mixing temperature determined in **KT-14 Section d.1.** of this manual. Charge the mixing bowl with the heated aggregate and form a crater in the top. Add the required amount of asphalt and mix the aggregate and asphalt until thoroughly coated, at least 2 minutes. Care should be taken to keep the entire sample in the mixing bowl during this process.

**4.5.** Either prior to, or after compaction, permit the mix to age at room temperature for  $24 \pm 1$  hours before continuing to **Section 6** of this test method.

**4.6.** Place the mixture in an oven set at the appropriate compaction temperature and age the material for 2 hours as outlined in **KT-58 7.5**<sup>1</sup> of this manual. Compact the mixture to  $7.0 \pm 0.5$  % air voids. This level of voids can be obtained by adjusting the specimen mass or the height in **Sect. 4.1.** of this test method. The exact procedure must be determined experimentally for each mixture before compaction the specimens for each set.

**4.7.** Extract the specimens from the molds and allow cooling to room temperature. Due to the elevated void content and potential instability of the specimens, verify that each specimen is adequately cool and stable prior to removal from the mold.

## **5. PREPARATION OF FIELD TEST SPECIMENS**

**5.1.** Select locations on the completed pavement to be sampled as outlined in **KT-25** of this manual.

**5.2.** Place the field mixture in an oven set at the appropriate compaction temperature. Do not age the field mixture in the oven. Compact the field mixture as outlined in **KT-58** of this manual beginning at **Sect. 7.7.** Compact the mixture to  $7.0 \pm 0.5$  % air voids. This level of voids can be obtained by adjusting the specimen mass or the height in **Sect. 4.1.** of this method. The exact procedure must be determined experimentally for each mixture before compaction the specimens for each set.

**5.3.** Do not age for 24 hours as stated in **Sect. 4.5.**

## **6. EVALUATION OF TEST SPECIMEN AND GROUPING**

**6.1.** Determine the theoretical maximum specific gravity of mixture by **KT-39** of this manual.

**6.2.** Determine the specimen thickness, to the nearest 0.001 in (0.01 mm), at approximately quarter points on the periphery. Average the results and record. For height, a specimen measuring device can also be used in lieu of averaging. Also determine the diameter to the nearest 0.001 in (0.01 mm).

**6.3.** Determine the bulk specific gravity by **KT-15**, Procedure III of this manual. Express volume of specimens in mL.

**6.4.** Calculate air voids by using the following formula:

$$\% \text{ Air Voids} = \frac{100(\text{Theoretical Max. S.G.} - \text{Bulk S.G.})}{\text{Theoretical Max. S.G.}}$$

**6.5.** Sort specimens into two subsets of three specimens each so the average air voids of the two subsets are as equal as mathematically possible.

## **7. PRECONDITIONING OF TEST SPECIMENS**

**7.1.** Test one subset dry and test the other subset after preconditioning.

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<sup>1</sup> **AASHTO T 283 Section 6.34** requires the material to be cooled at room temperature for  $2 \pm 0.5$  h then placed in an oven at  $60 \pm 3^\circ\text{C}$  for 16 hours prior to curing.

**7.2.** Store the dry subset at room temperature until testing. Measure the height and diameter of the dry set. Wrap the specimens with plastic, heavy duty leak proof plastic bag or place in plastic concrete cylinder molds<sup>2</sup>. Place the specimens in the  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ) water bath for 2 hours  $\pm$  10 minutes and then test as described in **Section 8** of this test method.

**7.3.** Condition the other subset as follows:

**7.3.1.** Place the specimen in the vacuum container supported by a base plate positioned above the container bottom. Fill the container with potable water at room temperature so that the specimens have at least 1 in (25 mm) of water above their surface. Apply partial vacuum (10 to 26 in [250 to 650 mm] of Hg) for a short time (5 to 10 minutes). These are only estimates for vacuum and time. Remove the vacuum and leave the specimens submerged in water for a short time (5 to 10 minutes).

**7.3.2.** Determine bulk specific gravity of the three conditioned samples by **KT-15**, Procedure I of this manual with noted exception in **Section 6.3** of this test method. Prior to placing the sample in the water bucket, place a sheet of plastic wrap on the balance and zero the balance. Within two minutes of taking the sample from the water bucket, determine the SSD mass of the sample, calculate the degree of saturation, and determine if the degree of saturation is acceptable as shown in **Section 7.3.3** of this test method. If the degree of saturation is acceptable, wrap the samples with the plastic wrap. All moisture draining from the plug during this process is to be collected by the plastic wrap and is not permitted to be discarded. Compare saturated surface dry mass with dry mass determined in **Section 6.3** of this test method. Calculate volume of absorbed water.

**7.3.3.** Determine degree of saturation by comparing volume of absorbed water with volume of air voids from **Section 6.4** of this test method. If the volume of water is between 70 to 80% of the volume of air, proceed to **Section 7.3.4**. If volume of water is less than 70%, repeat the procedure beginning with **Section 7.3.1** of this test method using more vacuum and/or time. If volume of water is more than 80%, specimen has been damaged and is discarded. Using a new specimen repeat the procedure using less vacuum and/or time.

**7.3.4.** Cover the vacuum saturated specimens tightly with a second layer of plastic wrap. Place each wrapped specimen in a plastic bag containing 10 mL of water and seal the bag.

**7.3.5.** Within 2 minutes, place the plastic bag containing the specimens in a freezer at  $0 \pm 10^\circ\text{F}$  ( $-18 \pm 5^\circ\text{C}$ ) for a minimum of 16 hours.

**7.3.6.** After removal from the freezer, place the specimens into a  $140 \pm 2^\circ\text{F}$  ( $60 \pm 1^\circ\text{C}$ ) water bath for  $24 \pm 1$  hours. Remove the plastic bag and film from the specimens as soon as possible after placement in the water bath.

**7.3.7.** After  $24 \pm 1$  hours in the  $140 \pm 2^\circ\text{F}$  ( $60 \pm 1^\circ\text{C}$ ) water bath, remove the specimens and place them in a water bath already at  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ) for 2 hours  $\pm$  10 minutes. It may be necessary to add ice to the water bath to prevent the water temperature from rising above  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ). Not more than 15 minutes should be required for the water bath to reach  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ).

**7.3.8.** Remove the conditioned plugs from the water bath. Quickly damp dry the saturated specimen with a damp absorbent cloth and weigh the specimen. Any water which seeps from the specimen during the weighing operation is considered part of the saturated specimen. Place the specimen in the basket or

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<sup>2</sup> Concrete cylinder molds have found to successfully keep the plugs from becoming saturated. Care must be taken so the lid is fitted properly thus keeping the plugs dry.

bucket and determine the mass to the nearest 0.5 g while immersed in water at  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ). The mass of the specimen in water shall be determined as quickly as possible after the specimen is immersed.

**7.3.9.** Determine the height and diameter of the specimen prior to testing.

## 8. TESTING

**8.1.** Determine the indirect tensile strength of dry and conditioned specimens at  $77 \pm 1^\circ\text{F}$  ( $25 \pm 0.5^\circ\text{C}$ ).

**8.1.1.** Place the specimens between the two bearing plates in the testing machine. Care must be taken so that the load will be applied along the diameter of the specimen. Apply the load to the specimens by means of the constant rate of movement of the testing head of 2 in (50.8 mm) per minute.

**8.1.2.** Record the maximum compressive strength noted on the testing machine, and maintain continuous loading until a vertical crack appears. Remove the specimen from the machine and pull apart at the crack. Inspect the interior surface for stripping and record the observations.

## 9. CALCULATIONS

**9.1.** Calculate the tensile strength as follows:

$$S_t \text{ (English)} = \frac{2(P)}{\pi (t)(D)}$$

$$S_t \text{ (Metric)} = \frac{2000(P)}{\pi (t)(D)}$$

Where:

- $S_t$ = Tensile strength, psi (kPa)
- $P$ = Maximum load, lbf (N)
- $t$ = Specimen thickness, in (mm)
- $t''$ = Conditioned specimen thickness, in (mm)
- $D$ = Specimen diameter, in (mm), and
- $D''$ = Conditioned specimen diameter, in (mm)

( $D''$  and  $t''$  replace  $D$  and  $t$  when calculating the conditioned specimen's tensile strength)

**9.2.** Express the numerical index or resistance of asphalt mixtures to the detrimental effect of water as the ratio of the original strength that is retained after the freeze-warm water conditioning.

Calculate as follows:

$$\% \text{ Tensile Strength Ratio (\%TSR)} = \frac{100(S_2)}{S_1}$$

Where:

- $S_1$ = Average tensile strength of dry subset, and
- $S_2$ = Average tensile strength of conditioned subset

**NOTE:** If an anti-stripping agent is used, include the agent in all asphalt mixtures for the conditioned and unconditioned subsets.

## 10. ADDITIVES

**10.1.** If additives are found to be necessary, return to **Section 4** of this test method and proceed through the test procedure. If lime is proposed, add to the aggregate portion during **Section 4.3** of this test method. If liquid anti-strip agents are proposed, add to the asphalt material prior to **Section 4** of this test method. The contractor will supply the lime or liquid anti-strip agent along with the quantity and method to be used on the project. Use the proposed quantity and method during the test procedure to determine the effectiveness of additives on the bituminous mixture.

## 11. ESTABLISHING OUTLIERS IN A SUBSET OF PLUGS

**11.1.** The “T” Statistic test, as presented in **KT-32** of this manual, represents a method to statistically analyze a subset for the potential of having an outlier. It requires the calculation of the mean, sample standard deviation and for the subset values to be oriented in an ascending order. Do not determine if there is an outlier, as described in this section, when the range (difference between highest and lowest value) of the three plugs do not exceed 11 psi (75 kPa). The following two examples illustrate how the “T” Statistic would be used to analyze a subset of conditioned plugs.

### *“T” Statistic Analysis of a Conditioned subset of plugs:*

EXAMPLE 1: Subset passing the “T” Statistic Test Conditioned subset plugs strengths:

1 – 430 kPa  
2 – 419 kPa  
3 – 495 kPa

$d_1 = 419$  kPa  
 $d_b = 448$  kPa  
 $d_n = 495$  kPa

$T_{0.95} = 1.15$   
 $S = 41.1$  kPa

$$T_1 = \frac{d_b - d_1}{S}$$
$$= \frac{448 - 419}{41.1}$$

= 0.71

$$T_n = \frac{d_n - d_b}{S}$$
$$= \frac{495 - 448}{41.1}$$

= 1.14

Where:

$d_1$  = The lowest strength plug in the subset  
 $d_b$  = The mean (average) of the subset  
 $d_n$  = The highest strength plug in the subset  
 $S$  = The sample standard deviation (n-1) of the subset  
 $T_{0.95}$  = The “T” Statistic value when n=3  
 $T_1$  = The lower “T” value calculated from the subset  
 $T_n$  = The upper “T” value calculated from the subset

Since  $T_{0.95}$  (1.15) is greater than both  $T_1$  (0.71) and  $T_n$  (1.14) then there is no outlier within the subset of plugs.

#### EXAMPLE 2: Subset Failing the “T” Statistic Test

If  $d_n = 530$  kPa (instead of 495 kPa), then  $d_b = 460$  kPa,  $S = 61.2$  kPa,  $T_{ii} = 0.67$  and  $T_n = 1.14$ . This would cause the highest strength plug ( $d_n$ ) to be classified as an outlier and would therefore be discarded. The two remaining plugs would be used to determine the average tensile strength for the subset (average subset strength =  $(419 + 430)/2 = 424$  kPa).

## 12. Report

**12.1.** Record the TSR to the nearest 0.1% Report the TSR to the nearest 1%.

### ADDENDUM TO KT-56 FOR INCLUDING LIME AS AN ANTISTRIPPING AGENT

The following information provides **KT-56** with steps to incorporate hydrated lime as an antistriping agent.

Delete **sections 4.3 and 4.4** of this test method and replace with the following:

**4.3.** Preparation of mixes: combine the virgin aggregates by weighing in a separate pan for each test specimen, proportionate amounts of each size fraction for each individual aggregate to produce the desired combined aggregate with a batch mass of approximately 1,125 g. Include the hydrated lime mass required to meet the specified percent of lime for the project as part of the total batch mass. The total aggregate mass should include lime, virgin aggregate and reclaimed material (if applicable). The total aggregate should be sufficient to produce a compacted specimen as described in **Section 4.1** of this test method.

**4.3.1.** Determine the SSD condition (**KT-06**) for the combined aggregate gradation. Add three percent of moisture to the percent moisture required to reach the SSD condition of the combined aggregate.

**4.3.2.** Place the combined virgin aggregate and hydrated lime in a mixing bowl. Carefully mix until the hydrated lime is combined with the aggregate. Add the appropriate water content, as determined in **Section 4.3.1** of this addendum to the test method, and thoroughly mix.

**4.3.3.** Oven dry the aggregate mix at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ) to a constant mass.

**4.4.** Combine the virgin aggregate material with the reclaimed material, if applicable, and thoroughly mix. Heat the combined aggregate and asphalt within limits of the mixing temperature determined in **KT-14, Section d.1.**, of this manual. Charge the mixing bowl with the heated aggregate and form a crater in the top. Add the required amount of asphalt and mix the aggregate and asphalt until thoroughly coated, at least 2 minutes. Care should be taken to keep the entire sample in the mixing bowl during this process.





5.9.57 DETERMINATION OF ASPHALT CONTENT AND GRADATION OF HOT MIX ASPHALT CONCRETE BY THE IGNITION METHOD (Kansas Test Method KT-57)

**1. SCOPE**

- 1.1.** This test method covers the determination of asphalt content of hot mix paving mixtures by ignition of the asphalt cement at 932°F (500°C) in a furnace. The aggregate remaining after burning can be used for sieve analysis using **KT-34**.
- 1.2.** The values in metric units are to be regarded as the standard.

**2. REFERENCED DOCUMENTS**

- 2.1.** Part V, 5.9; Sampling and Test Methods Foreword
- 2.2.** KT-01; Sampling and Splitting of Aggregates
- 2.3.** KT-25; Sampling and Splitting Plant Mixed Asphalt Mixtures
- 2.4.** KT-26; Sampling Asphalt Materials
- 2.5.** KT-34; Sieve Analysis of Extracted Aggregate
- 2.6.** AASHTO T 308; Determining the Asphalt Binder Content of Hot-Mix Asphalt (HMA) by the Ignition Method
- 2.7.** Ignition Oven Manufacturer's instruction manual

**3. SUMMARY OF TEST METHODS**

- 3.1.** The asphalt cement in the paving mixture is ignited using the furnace equipment applicable to the particular method. The asphalt content is calculated as the difference between the initial mass of the asphalt paving mixture and the mass of the residual aggregate, and the calibration factor. The asphalt content is expressed as mass percent.

**4. SIGNIFICANCE AND USE**

- 4.1.** This method can be used for quantitative determinations of asphalt binder content and gradation in hot-mixed paving mixtures and pavement samples for quality control, specification acceptance and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for sieve analysis according to **KT-34**.

**5. SAMPLING**

- 5.1.** Obtain samples of aggregate in accordance with **KT-01**.
- 5.2.** Obtain samples of freshly produced hot-mix asphalt in accordance with **KT-25**. Quarter the larger sample in the following manner:
- 5.2.1.** Spread a sheet of paper (Kraft or similar) on a hard, clean, smooth and level surface. Place the sample in a pile near the center of the paper and mix by alternately lifting each corner towards the

opposite corner thereby rolling the mixture to the opposite corner. This should be performed in a vigorous manner. Placing the sample on a piece of cardboard and mixing thoroughly with a trowel is an acceptable alternate.

**5.2.2.** Divide the pile into four equal quarters with a straightedge (trowel or similar metal blade) and completely remove two pre-selected diagonally opposite quarters.

**5.2.3.** Continue this quartering procedure until the original sample is reduced to the approximately desired size. On the final quartering step, if the sample is too large before quartering, but will be too small after quartering, the sample pile is divided into equal opposite sectors but unequal adjacent sectors. This can be accomplished by varying the dividing angle at the center of the sample pile from the normal 90 degrees. Opposite sections can then be selected to obtain the desired sample size.

**5.3.** Obtain samples of asphalt cement in accordance of **KT-26**.

**5.4.** Preparation of Test Specimens:

**5.4.1.** Place the sample in a larger flat pan and warm to 230 ±9°F (110 ± 5°C) for a minimum of 30 minutes or until the sample is dried to a constant mass.

**5.4.2.** The size of the test sample shall be governed by the nominal maximum aggregate size of the mixture and shall conform to the mass requirement shown in **Table 1**. When the mass of the test specimen exceeds the capacity of the equipment used, the test specimen may be divided into a suitable increments, tested and the results appropriately combined for calculation of the asphalt content (weighted average).

**Table 1**

Nominal Max. Agg. Size, in (mm)	Mass of Specimen, g
#4 (4.75)	1200 minimum
3/8 (9.5)	1200-1600
1/2 (12.5)	1500-1900
3/4 (19.0)	2000-2400
1 (25.0)	3000-3400
1 1/2 (37.5)	4000-4400
RAP	2000-2400
RAS	200-300

**NOTE:** Nominal maximum aggregate size is one size larger than the first sieve to retain more than 10%.

**6. CALIBRATION**

**6.1.** This method may be affected by the type of aggregate in the mixture. Accordingly, to optimize accuracy, a calibration factor will be established by testing a set of calibration samples for each mix type. This procedure must be performed before any acceptance testing is completed.

**6.2.** The calibration should be repeated each time there is a change in the mix ingredients or design.

**6.3.** According to the requirements of **Section 5** of this test method, prepare two calibration samples at the design asphalt content. Prior to mixing, prepare a butter mix at the design asphalt content. The purpose of the butter mix is to condition the mixing bowl by providing a coating of asphalt and fines in the bowl. Mix and discard the butter mix prior to mixing any of the calibration specimens to ensure accurate asphalt content. Aggregate used for the calibration specimens shall be sampled from stockpiled material produced in the current construction season and designated to be used on the candidate project. In other words, this calibration process should not be completed until all necessary material has arrived on the project site. An additional “blank” specimen shall be batched and tested for aggregate gradation according to **KT-34**. The wash gradation shall fall within the mix design tolerances.

**6.4.** The freshly mixed specimens may be placed directly in the sample baskets. Allow the sample to cool to room temperature.

**6.5.** Test specimens in accordance with **Sections 7 and 8** of this test method (Test Method A) or **Sections 9 and 10** of this test method (Test Method B).

**6.6.** Perform a gradation analysis on the residual aggregate as indicated in **Section 11** of this test method. Compare the gradation to the gradation of the unburned, “blank” specimen to evaluate the amount of aggregate breakdown. *This evaluation is for information only.*

**6.7.** Once all of the calibration specimens have been burned determine the measured asphalt contents for each sample by calculation.

**6.8.** If the difference between the measured asphalt contents of the two samples exceeds 0.15%, repeat the two tests and from the four tests, discard the high and low result. Determine the calibration factor ( $C_F$ ) from the two remaining results ( $C_A$  and  $C_B$ ). Calculate the difference between the measured and actual asphalt contents for each sample. The calibration is the average of the differences expressed in percent by mass of the asphalt mixture for the Superpave designs and expressed in percent by mass of the remaining aggregate for Marshall Designs.

**Note: Calibration factors ( $C_F$ ) cannot be less than zero. If a calibration factor is calculated to be less than zero record the calibration factor as zero.**

## **7. APPARATUS (TEST METHOD A)**

**7.1.** A forced air ignition furnace, capable of maintaining the temperature at 1072°F (578°C), with an internal balance thermally isolated from the furnace chamber accurate to 0.1 g. The balance shall be capable of weighing a 3500 g sample in addition to the sample baskets. A data collection system will be included so that the mass can be automatically determined and displayed during the test. The furnace shall have a built in computer program to calculate change in mass of the sample baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content (percent), test time, and test temperature. The furnace chamber dimensions shall be adequate to accommodate sample size of 3500 g. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01% of the total sample mass for three consecutive minutes. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and when set up properly shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan with capacity to pull air through the furnace to expedite the test and to reduce the escape of smoke into the laboratory.

**NOTE:** The furnace shall also allow the operator to change the ending mass loss percentage to 0.02%.

**7.2.** Sample basket(s) of appropriate size that allows the samples to be thinly spread and allows air to flow up through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh or perforated stainless steel plate or other suitable material.

**NOTE:** Screen mesh or other suitable material openings of approximately No. 8 (2.36 mm) and No. 30 (600  $\mu\text{m}$ ) has been found to perform well.

**7.3.** Catch pan of sufficient size to hold the sample basket(s) so that aggregate particles and melting asphalt binder falling through the screen mesh are caught.

**7.4.** Oven capable of maintaining  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**7.5.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**7.6.** Safety equipment - safety glasses or face shield, high temperature gloves, long sleeve jacket, a heat resistant surface capable of withstanding  $1202^\circ\text{F}$  ( $650^\circ\text{C}$ ) and a protective cage capable of surrounding the sample baskets during the cooling period.

**7.7.** Miscellaneous equipment consisting of a pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls and wire brushes.

## **8. TEST PROCEDURES (TEST METHOD A)**

**8.1.** Preheat the ignition furnace to  $932^\circ\text{F}$  ( $500^\circ\text{C}$ ). Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

**8.2.** Oven dry field HMA samples to a constant mass at a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**8.3.** Enter the calibration factor for the specific mix to be tested in the ignition furnace as determined by **Section 6** of this test method.

**8.4.** Weigh and record the mass of the sample basket(s) and catch pan (with guards in place).

**8.5.** Prepare the sample as described in **Section 5** of this test method. Record the initial mass while at room temperature. Evenly distribute this sample in the sample basket(s) that have been placed in the catch pan, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

**8.6.** Weigh and record the total mass of the sample, basket(s), catch pan and basket guards. Calculate and record the initial mass of the specimen (total mass minus the mass of the specimen basket assembly).

**8.7.** Input the initial mass of the specimen in whole grams into the ignition furnace controller. Verify that the correct mass has been entered.

**8.8.** Open the chamber door and place the sample baskets in the furnace. Close the chamber door and verify that the sample mass [including the basket(s)] displayed on the furnace scale equals the total mass

recorded in **Section 8.5** of this test method within  $\pm 5$  g. Differences greater than 5 g or failure of the furnace scale to stabilize may indicate that the sample basket(s) are contacting the furnace wall. Initiate the test by pressing the start/stop button. This will lock the sample chamber and start the combustion blower.

**NOTE:** The furnace temperature will drop below the set point when the door is opened, but will recover when the door is closed and ignition occurs. Sample ignition typically increases the temperature well above the set point, depending on sample size and asphalt content.

**8.9.** Allow the test to continue until the stable light and audible stable indicator indicate the test is complete (the change in mass does not exceed 0.01% for three consecutive minutes). Press the start/stop button. This will unlock the sample chamber and cause the printer to print out the test results.

**8.10.** Open the chamber door, remove the sample basket(s) and allow them to cool to room temperature (approximately 30 minutes).

**8.11.** Once the sample has cooled to room temperature, weigh and record the final mass. Calculate the uncorrected asphalt content, then apply correction factor to determine corrected asphalt content.

## **9. APPARTUS (TEST METHOD B)**

**9.1.** A forced air ignition furnace, capable of maintaining the temperature at 1072°F (578°C). The furnace chamber dimensions shall be adequate to accommodate a sample size of 3500 g sample. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside and when set up properly shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan with capacity to pull air through the furnace to expedite the test and to reduce the escape of smoke into the laboratory.

**9.2.** Sample basket(s) of appropriate size that allows the samples to be thinly spread and allows air to flow up through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh or perforated stainless steel plate or other suitable material.

**NOTE:** Screen mesh or other suitable material openings of approximately No. 8 (2.36 mm) and No. 30 (600  $\mu$ m) has been found to perform well.

**9.3.** Catch pan of sufficient size to hold the sample basket(s) so that aggregate particles and melting asphalt binder falling through the screen mesh are caught.

**9.4.** Oven capable of maintaining  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**9.5.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**9.6.** Safety equipment - safety glasses or face shield, high temperature gloves, long sleeve jacket, a heat resistant surface capable of withstanding 1202°F (650°C) and a protective cage capable of surrounding the sample baskets during the cooling period.

9.7. Miscellaneous equipment consisting of, a pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls and wire brushes.

## 10. TEST PROCEDURES (TEST METHOD B)

10.1. Preheat the ignition furnace to 932°F (500°C).

10.2. Oven dry field HMA samples to a constant mass at a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

10.3. Record the calibration factor for the specific mix to be tested as determined in **Section 6** of this test method.

10.4. Weigh and record the mass of the sample basket(s) and catch pan (with guards in place).

10.5. Prepare the sample as described in **Section 5** of this test method. Place the sample basket(s) in the catch pan. Evenly distribute the sample in the basket(s), taking care to keep the material away from the edges.

10.6. Allow the sample to cool to room temperature. Weigh and record the total mass of the sample, basket(s), catch pan, basket guards. Calculate and record the initial mass of the specimen (total mass minus the mass of the specimen basket assembly).

10.7. Burn the HMA sample in the furnace for at least 40 minutes after the ignition oven has cycled through the initial burn off phase.

**NOTE:** The appropriate time for the initial burn of an HMA sample is dependent on sample size and aggregate material. For larger samples, the time could be significantly longer than 40 minutes.

10.8. Remove the sample from the furnace after ignition and allow to cool to approximately room temperature (at least 30 minutes).

10.9. Weigh and record the mass ( $W_A$ ) of the sample after ignition to the nearest 0.1 g.

10.10. Repeat steps in **Sections 10.7 (exception: adjust burn time to 10 minutes)** through **10.9** of this manual until a visual inspection indicates complete burn-off has been accomplished. The material will appear free of asphalt (no small black asphalt particles intermixed in material) and the change in measured mass ( $W_A$ ) does not exceed 0.01% of the initial mass ( $W_S$ ).

It is desirable to accomplish complete burn-off in one sequence. Adjust the 40 minute burn time to achieve this requirement. Additional burn time may indicate a need for a new filter. Filters have been found to last two to four burn-offs.

10.11. Record the last value obtained for ( $W_A$ ) as the mass ( $W_A$ ) of the sample after ignition.

10.12. Calculate the asphalt content of the sample using one of the following equations:

**10.12.1.** For a Superpave design (total mass mix):

$$AC\% = \left[ \frac{(W_S - W_A)}{W_S} \times 100 \right] - C_F$$

Where: AC% = The measured (corrected) asphalt content percent by mass of the HMA sample.  
W<sub>A</sub> = The total mass of aggregate remaining after ignition.  
W<sub>S</sub> = The total mass of the HMA sample prior to ignition  
C<sub>F</sub> = Calibration factor, percent of mass of HMA sample

Where: C<sub>F</sub> = (C<sub>A</sub> + C<sub>B</sub>)/2

C<sub>A</sub> or C<sub>B</sub> = measured asphalt content – actual content

Where:

C<sub>A</sub> or C<sub>B</sub> = Individual sample correction factors, percent by mass of HMA sample as outlined in **Section 6.8** of this test method.

**10.12.2.** For a Marshall mix design (dry aggregate method):

$$AC\% = \left[ \frac{(W_S - W_A)}{W_A} \times 100 \right] - C_F$$

Where: AC% = The measured (corrected) asphalt content percent by dry aggregate mass of the HMA sample.

## 11. GRADATION

**11.1.** Allow the specimen to cool to room temperature in the sample baskets.

**11.2.** Empty the contents of the baskets into a flat pan. Use a small wire sieve brush to so that any residual fines are removed from the baskets.

**11.3.** Perform the gradation analysis according to **KT-34**

## 12. REPORT

**12.1.** Always report the test method (A or B), correct asphalt content, calibration factor, temperature compensation factor (if applicable), total percent loss, sample mass, test temperature and total time. Examples of a spreadsheet available for use with Method B are in **Figure 1** and **Figure 2**.

## 13. PRECISION AND BIAS

**13.1.** The precision estimates in Table 2 are taken from AASHTO T-308.

**NOTE:** The precision estimates given in Table 2 are based on the analysis of test results from three pairs of AASHTO Resource proficiency samples. The data analyzed consisted of results from 353 to 461 laboratories for each of the three pairs of samples. The analysis included two binder grades: PG 52-34 and



PG 64-22. Average results for asphalt content ranged from 4.049 to 5.098 percent. The details of this analysis are in NCHRP Final Report, NCHRP Project No. 9-26, Phase 3.

**NOTE:** The precision estimates are based on 4 aggregate types, 4 replicates, and 12 laboratories participating with 0 laboratory results deleted as outlying observation. All 4 aggregates were tested in surface mixes and had relatively low absorption values.

**Table 2  
Precision Statement**

Asphalt Content	Standard Deviation 1s	Acceptable Range of Two Results, d2s
Single Operator Precision Asphalt Content (%)	0.069	0.196
Multi Lab Precision Asphalt Content (%)	0.117	0.330

**13.2.** Any biases inherent to the ignition oven process used for Test Methods A and B, when testing for asphalt content and aggregate gradation, are accounted for by the determination and application of appropriate correction factors.

**Figure 1  
Determination of Ignition Burn-Off Correction Factor**

Target AC %	5.55	
	Trial #1	Trial #2
Mass of Sample & Basket	7690.4	7675.4
Mass of Basket	6179.1	6171.1
Mass of Sample	1511.3	1504.3
Mass of Aggregate & Basket	7606.2	7591.3
Mass of Basket	6179.1	6171.1
Mass Loss	84.2	84.1
% AC by Mass of Mix (uncorrected)	5.57	5.59
Difference from Target %	0.02	0.04
Correction Factor (2 Trials)	0.03	
		Use this Correction Factor

**Figure 2**  
**Spreadsheet for Calculating Corrected Asphalt Content**

<b>Mix Type:SM-9.5A</b>		<b>Lab. No.09-1511</b>		
<b>Project #:23-90 KA 1429-01</b>		<b>Sample Date: 7/10/09</b>		
<b>Design No.:3G09007A</b>		<b>Report Date: 7/11/09</b>		
<b>Technician: J Doe</b>				
	<b>EXTRACTION</b>	<b>GRADATION</b>		
		<b>SIEVE SIZE</b>	<b>GMS RET</b>	<b>% RET.</b>
		1" (25.0 mm)		
1. Wt. Frame & Sample	7651.0	3/4" (19.0 mm)		
2. Wt. Frame	6064.4	1/2" (12.5 mm)	0	0
3. Wt. Sample (1-2)	1586.6	3/8" (9.5 mm)	74.8	5
4. Final Wt./Frame & Dry Agg.	7560.5	No.4 (4.75 mm)	389.0	26
5. Final Wt. of Sample (4-2)	1496.1	No. 8 (2.36 mm)	658.2	44
6. Wt. Loss (1-4)	90.5	No. 16 (1.18 mm)	957.4	64
7. Corr. Factor	0.05	No. 30 (600 µm)	1166.9	78
8. Measured % AC %AC = ((3-5)/3)100 -7	5.65	No. 50 (300 µm)	1331.4	89
		No. 100 (150 µm)	1406.2	94
		No. 200 (75 µm)	1451.1	97.0
Total Time (min.)	89			
		Pan -No. 200 (-75 µm)	1454.1	
9. Wt. of Agg. Before Washing	1496.0			
10. Wt. of Agg. After Washing	1455.3	(Pan wt. within 0.2% of line 10.		

Copies of the spreadsheet can be obtained from the Construction and Materials Field Engineer. Spreadsheets are currently in Excel format.



5.9.58 METHOD FOR PREPARING AND DETERMINING THE DENSITY OF HOT MIX ASPHALT (HMA) SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR (Kansas Test Method KT-58)

## 1. SCOPE

1.1. This method covers the compaction of cylindrical specimens of hot mix asphalt (HMA) using the Superpave Gyratory Compactor.

1.2. The values stated in SI units are to be regarded as the standard.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-06; Specific Gravity and Absorption of Aggregates

2.3. KT-15; Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)

2.4. KT-39; Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures

2.5. AASHTO T 312; Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

2.6. ASTM D4402; Test Method for Viscosity Determinations of Asphalt at Elevated Temperatures Using Rotational Viscometer

2.7. ANSI/ASME B46.1; Surface Texture (Surface Roughness, Waviness and Lay)

## 3. SIGNIFICANCE AND USE

3.1. This standard is used to prepare specimens for determining the mechanical and volumetric properties of HMA. The specimens simulate the density, aggregate orientation and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

3.2. This test method may be used to monitor the density or test specimens during their preparation. It may also be used for field control of an HMA production process.

## 4. APPARATUS

4.1. Superpave Gyratory Compactor, an electro hydraulic or electromechanical compactor, with a ram and ram heads as described in **Section 4.3** of this test method that are restrained from revolving during compaction. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of  $600 \pm 18$  kPa to a specimen cross section during compaction. The compactor shall tilt specimen molds at an internal angle of  $1.16 \pm 0.02$  degrees and gyrate specimen molds at a rate of  $30.0 \pm 0.5$  gyrations per minute throughout compaction. The compactor shall be designed to permit the specimen mold to revolve freely on its tilted axis during gyration.

**NOTE:** This stress calculates to  $10,600 \pm 106$  N total force for 150 mm specimens.

**4.1.1.** Specimen height measurement and recording device, when specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen to the nearest 0.1 mm during compaction once per gyration.

**4.1.2.** The built-in reporting system shall include a printer connected to a port capable of printing test information. The information shall include specimen height per gyration. The system should include a computer and suitable software for data acquisition and reporting.

**4.2.** Specimen molds shall have steel walls that are at least 0.30 in (7.5 mm) thick and are hardened to at least Rockwell C 48. The inside finish of the molds shall have a root mean square (rms) of 1.60  $\mu\text{m}$  or smoother. Molds shall have an initial inside diameter of 5.902 to 5.906 in (149.90 to 150.00 mm) and at least 10 in (250 mm) high. Molds with an inside diameter of greater than 150.20 mm shall be removed from service.

**NOTE:** Smoothness measurement is in accordance with ANSI B 46.1. One source of supply for a surface comparator, which is used to verify the rms value 1.60  $\mu\text{m}$ , is GAR Electroforming, Danbury, Connecticut.

**4.3.** Ram heads and mold bottoms shall be fabricated from steel with a minimum Rockwell hardness of C 48. The ram heads shall have a means for staying fixed to the ram and perpendicular to its axis. The platen side of each mold bottom shall be flat and parallel to its face. All ram and base plate faces (the sides presented to the specimen) shall be ground flat to meet smoothness requirement in **Section 4.2** of this test method and shall have a diameter of 149.50 to 149.75 mm.

**4.4.** Thermometers shall be armored, glass or dial-type thermometers with metal stems for determining temperature of aggregates, asphalt and asphalt mixtures between 122 to 450°F (50 to 260°C).

**4.5.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**4.6.** An oven thermostatically controlled with a range from 122 to 450°F (50 to 260°C) with 5.4°F ( $\pm 3^\circ\text{C}$ ) tolerance, for heating aggregates, asphalt, asphalt mix and equipment as required. The oven shall be capable of maintaining the temperature required for short-term aging.

**4.7.** Miscellaneous equipment, flat bottom metal pans for heating aggregates; scoop for batching aggregates; containers; gill-type tins; beakers; containers for heating asphalt; large mixing spoon or small trowel; large spatula; welders gloves for handling hot equipment; paper disks; mechanical mixer (optional); and lubricating materials recommended by compactor manufacturer.

## **5. STANDARDIZATION**

**5.1.** Items requiring periodic verification of calibration include the ram pressure, the angle of gyration, the gyration frequency, the LVDT (or other means used to continuously record the specimen height) and oven temperature. Verification of the mold and platen dimensions and the inside finish of the mold are also required. When the computer and software options are used, periodically verify the data processing system output using a procedure design for such purposes. Verification of calibration, system standardization and quality checks may be performed by the manufacturer, other agencies providing such services or in-house personnel.

## 6. PREPARATION OF APPARATUS

**6.1.** Immediately prior to the time when the paving mix is ready for the placement in the mold, turn on the main power for the compactor for the manufacturer's required warm-up period.

**6.2.** Verify machine settings are correct for angle, pressure and number of gyrations.

**NOTE:** The required number of gyrations is shown in **Table 1**.

**6.3.** Pine **AFGC125X** gyratory compactor (Big Pine)

**6.3.1.** Lubricate with an oily rag any bearing surfaces except for the upper roller bearing ring which should be lubricated with an oil can, filled with motor oil. **Do not use graphite on bearings.**

**6.3.2.** Lightly lubricate the surface of the rotating base along with the surface of the four rollers.

**6.4** When monitoring specimen height, the following additional item of preparation is required. Immediately prior to the time when paving mix is ready for placement in the mold, turn on the device for measuring and recording the height of the specimen and verify that the readout is in the proper units, mm, and that the recording device is ready. If used, prepare the computer to record the height data and enter the header information for the specimen.

## 7. MIXING AND COMPACTION PROCEDURE

*Refer to the attached Addendum if using hydrated lime as an anti stripping agent.*

**7.1.** Preparation of Reclaimed Material (if used): Place the reclaimed material in a 125 to 175°F (50 to 80°C) draft oven for 1 1/2 to 2 hours, to soften. Transfer the materials to the mixing bowl and mix for two minutes in order to breakdown the reclaimed material to the recommended sizes. (Mixer will mix approximately 3,500 g.) Other methods of breakdown are acceptable provided they do not fracture aggregates or lose an excessive amount of material in the process. Separate the reclaimed material into desired fractions by screening, when cool enough to screen. The following size fractions are recommended:

3/4 to 1/2 in (19.0 to 12.5 mm)    No.4 to No.8 (4.75 to 2.36 mm)  
1/2 to 3/8 in (12.5 to 9.5 mm)    Passing No.8 (Passing 2.36 mm)  
3/8 in to No.4 (9.5 to 4.75 mm)

**7.1.1.** Weigh the appropriate aggregate and reclaimed material, if applicable, fractions into a separate pan and combine to the desired batch weight. The batch weight will vary based on the ultimate disposition of the test specimens. If a target air void level is desired, as would be the case for Superpave abbreviated mix analysis and/or full mix analysis performance specimens, batch weights will be adjusted to create a given density in a known volume. When specimens are to be used for determination of volumetric properties, the batch weights will be adjusted to result in a compacted specimen having dimensions of either 150 mm in diameter and 115 ± 5 mm in height or 100 mm in diameter and 63.5 ± 2 mm in height at the maximum number of gyrations.

**NOTE:** It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4500 g of aggregate for 150 mm plugs and 1200 g of aggregate for 100 mm plugs are required to achieve this height for aggregates with combined bulk specific of 2.55.

**7.2.** Place the aggregate, reclaimed material, if applicable, and the asphalt binder container in the oven and heat to the required mixing temperature.

**7.2.1.** The mixing temperature range is defined as the range of temperature where the unaged asphalt binder has a kinematic viscosity of  $170 \pm 20$  mm<sup>2</sup>/s (approximately  $0.17 \pm 0.02$  Pa-s for an asphalt binder density of 1.00 g/cm<sup>3</sup>) measured in accordance with **ASTM D 4402**.

**NOTE:** Modified asphalts may not adhere to the equi-viscosity requirements noted and the manufacturer's recommendations should be used to determine mixing and compaction temperature.

**NOTE:** The SI unit of kinematic viscosity is m<sup>2</sup>/s; for practical use, the submultiple mm<sup>2</sup> is recommended. The more familiar centistokes, a cgs, unit of kinematic viscosity, is a ratio of asphalt binder viscosity to density. For an asphalt binder with equal density to 1.000 g/cm<sup>3</sup>, a kinematic viscosity of 170 mm<sup>2</sup>/s is equivalent to a viscosity of 0.17 Pa-s measured in accordance with ASTM D 4402.

**7.3.** Charge the mixing bowl with the heated aggregate in one pan and reclaimed material, if required and dry mix thoroughly. Form a crater in the dry blended aggregate and weigh the required amount of asphalt binder into the mix. Immediately initiate mixing.

**7.4.** Mix the aggregate and asphalt binder as quickly and thoroughly as possible to yield a paving mix having a uniform distribution of asphalt binder. As an option, mechanical mixing may be used.

**7.5.** After completing the mixture preparation, place the loose mix in a shallow, flat pan and short-term age as it follows:

**7.5.1.** Place the mixture on a baking pan and spread it to an even thickness. Place the mixture and pan in the aging oven set at compaction temperature for 2 hours  $\pm$  5 minutes.

**7.5.1.1.** The compaction temperature range is defined as the range of temperature where the unaged asphalt binder as a kinematic viscosity of  $280 \pm 30$  mm<sup>2</sup>/s (approximately  $0.28 \pm 0.03$  Pa-s) measured in accordance with **ASTM D 4402**.

**NOTE:** Modified asphalts may not adhere to the equi-viscosity requirements noted and the manufacturer's recommendations should be used to determine mixing and compaction temperatures.

**7.5.2.** Stir mixture every  $60 \pm 5$  minutes to maintain uniform aging.

**7.5.3.** After 2 hours  $\pm$  5 minutes, remove the mixture from the forced draft oven. The aged mixture is now ready for further conditioning or testing as required.

**7.6.** Place the compaction mold and base plate in an oven permitting the pieces to reach the established compaction temperature prior to the estimated beginning of the compaction process.

**7.7.** If loose HMA plant mix is used, the mixture shall be brought to the compaction temperature range by careful uniform heating in an oven immediately prior to molding.

**7.8.** When compaction temperature is achieved, remove the heated mold and base plate from the oven and place a paper disk on the bottom of the mold.

**7.9.** Thoroughly mix the material and place the mixture quickly into the mold in one lift and verify the temperature of the material. The temperature of the material is to be at the midpoint of the established

compaction temperature  $\pm 3^{\circ}\text{F}$  ( $\pm 1.5^{\circ}\text{C}$ ) for the specified PG asphalt. Care should be taken to avoid segregation in the mold. After all the mix is in the mold, temperature verified, then level the mix and place another paper disk on top of the leveled material and add the top plate.

**7.10.** Load the specimen mold with the paving mix into the compactor and center the mold under the loading ram.

**7.11.** Lower the ram until the pressure on the specimen reaches  $600 \pm 18$  kPa.

**7.12.** Apply a  $1.16 \pm 0.02$  degrees internal angle to the mold assembly and begin the gyratory compaction.

**7.13.** Allow the compaction to proceed until the desired number of gyrations is reached and the gyratory mechanism shuts off.

**7.14.** Remove the angle from the mold assembly, raise the loading ram, remove the mold from the compactor and extrude the specimen from the mold.

**NOTE:** Specimen can be extruded from the mold immediately for most HMA paving mixes. For lean, rich or tender mixtures, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding the specimen.

**7.15.** Remove the paper disks from the top and bottom of the specimens. Before reusing the mold, place it in an oven until the mold reaches compaction temperature. The use of multiple molds will speed up the compaction process.

**NOTE:** The extruded specimen may not be a right angle cylinder. Specimen ends may need to be sawed to conform to the requirements of specific performance tests.

## **8. DENSITY PROCEDURE**

**8.1.** When the specimen height is to be monitored, the following steps are required in addition to those specified **Section 7** of this test method.

**8.1.1.** Determine the maximum specific gravity ( $G_{mm}$ ) of the loose mix in accordance with **KT-39** using a companion sample. The companion sample shall be aged to the same extent as the compaction sample.

**8.1.2.** Record the specimen height to the nearest 0.1 mm after each revolution.

**8.1.3.** Record the mass of the extruded specimen to the nearest gram and determine the bulk specific gravity ( $G_{mb}$ ) of the extruded specimen in accordance with **KT-15, Procedure III** of this manual.

## **9. DENSITY CALCULATIONS**

**9.1.** Calculate the uncorrected relative density ( $C_{ux}$ ) at any point in the compaction process using the following equation:

$$C_{ux} = \frac{100 (W_m)}{V_{mx} G_{mm} G_w}$$

Where:  $C_{ux}$  = Uncorrected relative density at any point during compaction expressed as a percent of the theoretical maximum specific gravity



$W_m$  = The mass of the specimen in grams  
 $G_{mm}$  = Theoretical maximum specific gravity of the mix  
 $G_w$  = The unit of water, 1 g/cm<sup>3</sup>  
 $X$  = The number of gyrations  
 $V_{mx}$  = The volume of the specimen, in cm<sup>3</sup>, at any point based on the diameter (d) and height ( $h_x$ ) of the specimen at the point (use mm for height and diameter measurements).  
 It can be expressed as:

$$V_{mx} = \frac{\pi d^2 h_2}{4(1000)}$$

**NOTE:** This formula gives volume in cm<sup>3</sup> to allow direct comparison with specific gravity.

**9.2.** At the completion of the bulk specific gravity test, determine the percent compaction ( $C_x$ ) at any point in the compaction process as follows:

$$C_x = \frac{100 (G_{mb} h_m)}{G_{mm} h_x}$$

Where:

- $C_{ux}$  = Corrected relative density expressed as a percentage of the maximum theoretical specific gravity
- $G_{mb}$  = Bulk specific gravity of the extruded specimen.
- $h_m$  = Height in mm of the extruded specimen
- $h_x$  = Height in mm of the specimen after “x” gyrations

## 10. REPORT

**10.1.** Project number.

**10.2.** Date of test.

**10.3.** Start time of test.

**10.4.** Specimen identification.

**10.5.** Percent binder in specimen, nearest 0.1%.

**10.6.** Average diameter of the mold used in (d), nearest 0.01 mm.

**10.7.** Mass of the specimen ( $W_m$ ), nearest g.

**10.8.** Theoretical maximum specific gravity ( $G_{mm}$ ) of the specimen by **KT-39**, nearest 0.001.

**10.9.** Bulk specific gravity ( $G_{mb}$ ) of the specimen by **KT-15 Procedure III** of this manual, nearest 0.001.

**10.10.** Height of the specimen after each gyration ( $h_2$ ), nearest 0.1 mm.

**10.11.** Relative density ( $C_x$ ) expressed as a percent of the theoretical maximum specific gravity, nearest 0.1 %.

**Table 1**  
**SUPERPAVE GYRATORY COMPACTION EFFORTS**

DESIGN ESALs (millions)	TRAVELWAY		
	N <sub>ini</sub>	N <sub>des</sub>	N <sub>max</sub>
< 0.3	6	50	75
0.3 to < 6	7	75	115
≥ 6	8	100	160
	SHOULDER		
A*	6	50	75
B*	**	**	**

\*At the contractor's option A or B may be used.

\*\*Use traveled way design traffic properties for B.

**ADDENDUM TO KT-58**  
**FOR INCLUDING LIME AS AN ANTISTRIPPING AGENT**

The following information provides **KT-58** with steps to incorporate hydrated lime as an antistripping agent.

Delete **sections 7.1 and 7.2** of this test method and replace with the following:

**7.1.** Weigh the appropriate aggregate fractions into a separate pan and combine to the desired batch weight. The batch weight will vary based on the ultimate disposition of the test specimens. Include the hydrated lime weight required to meet the specified percent of lime for the project as part of the total batch weight. The total aggregate weight should include lime, virgin aggregate, and reclaimed material (if applicable). If a target air void level is desired as would be the case for Superpave abbreviated mix analysis and /or full mix analysis performance specimens, batch weights will be adjusted to create a given density in a known volume. If specimens are to be used for determination of volumetric properties, the batch weights will be adjusted to result in a compacted specimen having dimensions of 150 mm in diameter and 115 ± 5 mm in height at the maximum number of gyrations.

**NOTE:** It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4500 g of aggregate for 150 mm plugs and 1200 g of aggregate for 100 mm plugs are required to achieve this height for aggregates with combined bulk specific gravities of 2.55.

**7.1.1.** Determine the SSD condition (**KT-06**) for the combined aggregate gradation. Add 3% of moisture to the percent moisture required to reach the SSD condition of the combined aggregate.

**7.1.2.** Place the combined virgin aggregate and hydrated lime in a mixing bowl. Carefully mix until the hydrated lime is combined with the aggregate. Add the appropriate water content, as determined in **Section 7.1.1** of the addendum to this test method and thoroughly mix.

**7.1.3.** Oven dry the aggregate mix at 230 ± 9°F (110 ± 5°C) to a constant mass.

**7.2.** Combine the virgin aggregate material with the reclaimed material, if applicable, and thoroughly mix. Place the aggregate and the asphalt binder container in the oven and heat to the required mixing temperature.



5.9.59 FLAT AND ELONGATED PARTICLES IN COARSE MATERIAL TEST  
(Kansas Test Method KT-59)

## 1. SCOPE

This test method covers the determination of the percentage of flat and elongated particles in coarse aggregates. **KT-59** reflects testing procedures found in **ASTM D4791**.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-01; Sampling and Splitting of Aggregates

2.3. KT-02; Sieve Analysis of Aggregates

2.4. ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

2.5. ASTM D4791; Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

## 3. DEFINITIONS

3.1. Flat and elongated particles of aggregate—those particles of aggregate having a ratio of length to thickness greater than a specified value.

3.2. A flat and elongated particle exists when the particle's small ratio (the 1 in 5:1) slides the full length through the opening established by the large ratio number (the 5 in 5:1). **EXAMPLE:** Checking flat and elongated particles requires comparing the length vs. thickness. After setting the large ratio to the maximum length of the particle, attempt to slide the flattest portion of the particle horizontally through the opening of the small ratio. If the particle passes clear through the opening, then the particle is flat and elongated.

## 4. SIGNIFICANCE AND USE

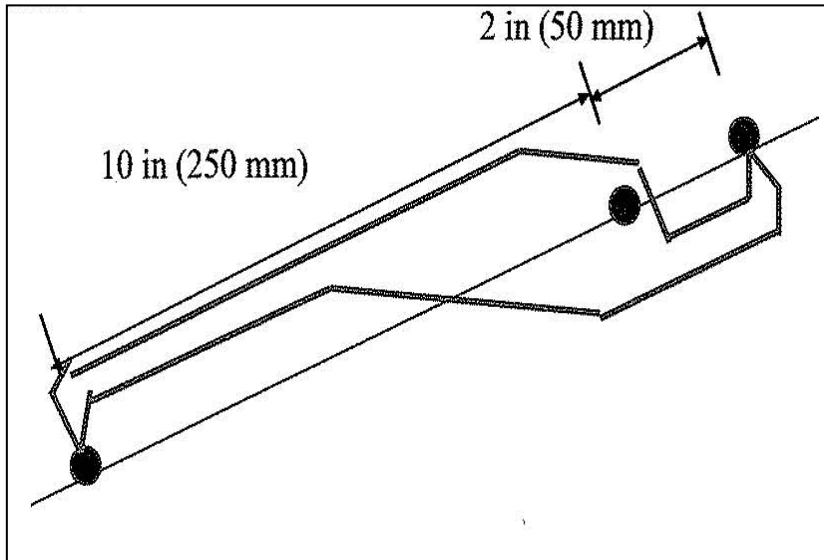
4.1. Flat and elongated particles of aggregates, for some construction uses, may interfere with consolidation and result in harsh, difficult to place materials.

4.2. This test method provides a means for checking compliance with specifications that limit such particles, or to determine the relative shape characteristics of coarse aggregates.

## 5. APPARATUS

5.1. Use apparatus suitable for testing aggregate particles for compliance with the definition in **Section 3.1** of this test method, at the dimensional ratios desired.

5.1.1. The proportional caliper device illustrated in **Figure 1** is an example of all apparatus suitable for this test method. It consists of a base plate with two fixed posts and a swinging arm mounted between them so that the openings between the arms and the posts maintain a constant ratio.



The caliper and pins are to be perpendicular to the base plate and raise at least 2 in (50 mm) in height. Design the caliper to touch the length of the fixed pins simultaneously. Provide a 5:1 ratio between the two fixed pins (or as required by contract documents). Design the center pin so the caliper can be easily locked into position. Make the base plate, caliper and pins of rigid and durable materials.

**Figure 1 Proportional Caliper**

Illustrates a device on which the ratio 5:1 is set.

**5.1.2.** Balance to meet the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

**5.1.3.** Drying oven capable of maintaining a uniform temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**5.1.4.** Sieves meeting **ASTM E11**.

## 6. SAMPLING

**6.1.** Sample the combined aggregate in accordance with **KT-01, Section 3**. Normally the sample is taken from the combined aggregate stream. The procedure may also be used to test individual coarse aggregate stockpiles to determine suitability for use. Obtain a large enough sample to yield the required plus 4 material listed in **Section 6.2 Table 1**.

**6.1.1.** Sieve the material over the No. 4 (4.75 mm) screen. Discard all material passing the No. 4 (4.75 mm) screen.

**6.1.2.** Oven dry the sample to constant mass at a temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

**6.2.** Thoroughly mix the test sample and reduce it to an amount suitable for testing using the mass desired when dry as an end result of the reduction. Reduction to an exact predetermined mass is not permitted. Determine the original dry mass of the sample. The mass of the plus No. 4 material shall conform to the following:

**Table 1**

Nominal Maximum Aggregate Size, in. (mm)	Min. Dry Mass of +4 Sample, lb (kg)
1 1/2 in (37.5 mm)	33 lb (15 kg)
1 in (25.0 mm)	22 lb (10 kg)
3/4 in (19.0 mm)	11 lb (5 kg)
1/2 in (12.5 mm)	4 lb (2 kg)
3/8 in (9.5 mm)	2 lb (1 kg)
No. 4 (4.75 mm)	1 lb (0.5 kg)

**NOTE:** Nominal maximum aggregate size is one size larger than the first sieve to retain more than 10%.

## 7. PROCEDURE

**7.1.** Sieve the sample of coarse aggregate to be tested in accordance with **KT-02, Section 6**. Separately retain and determine the mass of each sieve size fraction. Reduce each size fraction larger than the No. 4 (4.75 mm) sieve present in the amount of 10% or more of the original sample in accordance with **KT-01, Section 4** until approximately 100 particles are obtained. Determine the mass of each reduced size fraction.

**7.2.** Using a proportional caliper device, set at a 5:1 ratio (or as required by the contract documents). Test each of the particles in each size fraction for flat and elongated.

**7.2.1.** Set the larger opening equal to the particle length. The particle is flat and elongated if the flattest portion of the particle can be placed through the smaller opening. Determine the proportion of the sample in each group by mass.

## 8. CALCULATIONS

**8.1.** Calculate the percent of flat and elongate particles to the nearest 1% for each sieve size greater than No. 4 (4.75 mm).

**8.2.** When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of flat and elongated particles as the next smaller or the next larger size, or use the average for the next smaller and larger sizes, if both are present.

**8.3.** Calculate the flat and elongated on each sieve:

$$\% \text{ F\&E} \quad D = \frac{C(100)}{B}$$

Where: C= mass of flat and elongated particles  
B= mass of 100± particles tested  
D= % F&E

Calculate the % weighted of F&E on each sieve:

$$E = \frac{(A)(D)}{100}$$

Where: A = % of original sample retained on sieve  
 D = % F&E  
 E = weighted % Calculate to the % total weighted F&E for a given sample:

Sieve	Individual Sieve Mass (grams)	% Sieve Size Fraction = A	*Mass of Reduced "100 Piece Pile" (grams) = B	Failed Aggregate		
				Failed Mass Fraction (grams) = C	% Failed = D	Weighted % = E
1 1/2"	--	--	--	--	--	--
1"	--	--	--	--	--	--
3/4"	--	--	--	--	--	--
1/2"	1200	60	150	27	18	11
3/8"	740	37	75	8	11	4
#4	60	3	--	--	11	0
Original Dry Mass of + #4	2000			Total % Failed F & E = F		15

Total % Failed F&E (F) = sum of all individual weighted percent F&E

\*individual mass quantities are after reduction to approximately 100 pieces (**Section 7.2**, of this test method)

**NOTE #1:** If percent retained on sieve is less than 10% do not test for flat and elongated.

**NOTE #2:** If percent retained on sieve is less than 10% use %F&E from adjacent sieve or average of next larger and next smaller sieve.

## 9. REPORT

**9.1.** Include the following information in the report:

**9.1.2.** Grading of the aggregate sample, showing percentage retained on each sieve.

**9.1.3.** Percentages, calculated by mass for flat and elongated particles, for each sieve size tested, and the combined aggregate percent for flat and elongated particles.

**9.1.4.** When required, weighted average percentages based on the actual or assumed proportions of the various sieve sizes tested. Report the grading used for the weighted average if different from that in **Section 9.1.2** of this test method.

**9.1.5.** Record the flat and elongated particles to the nearest 1%. Report the flat and elongated particles to the nearest 1%.

## **10. PRECISION AND BIAS**

**10.1.** Precision-The precision of this test method is found in **ASTM D4791**.

**10.2.** Bias-Since there is no accepted reference material suitable for determining the bias for this test method no statement on bias is being made.





## 5.9.60 INDIRECT TENSILE TEST (Kansas Test Method KT-60)

### **1. SCOPE**

This test method provides procedures used to determine tensile creep compliance in hot mix asphalt. It also provides the data to conduct thermal cracking and fatigue cracking analysis.

**KT-60** reflects testing procedures found in **AASHTO T 322**.

**Note:** Procedure for critical cold temperature selection:

Specification temperature shall be chosen using FHWA LTPPBind using the weather station closest to the project. The required temperature for the specification is the coldest temperature at the top of the asphalt concrete layer in the pavement structure. Use 98 percent reliability.

### **2. REFERENCED DOCUMENTS**

**2.1.** KT-15 Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)

**2.2** KT-56 Resistance of Compacted Asphalt Mixture to Moisture Induced Damage

**2.3** KT-58 Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

**2.4** AASHTO T 322; Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device

### **3. SIGNIFICANCE AND USE**

**3.1.** Tensile creep and tensile strength test data are required for Superpave mixtures to determine the master relaxation modulus curve and fracture parameters. This information is used to calculate the thermal cracking of the asphalt concrete. The master relaxation modulus curve controls thermal crack development, while the fracture parameter defines a mixture's resistance to fracture.

**3.2.** The values of creep compliance, tensile strength, and Poisson's ratio determined with this method can be used in linear viscoelastic analysis to calculate the low temperature thermal cracking potential of asphalt concrete.

**3.3.** Tensile creep data may be used to evaluate the relative quality of materials.

**3.4.** This procedure is applicable to newly prepared mixtures, reheated, and recompacted mixtures. Reheated and recompacted mixtures will have lower creep compliance values than newly prepared mixtures when measured under these specific loading conditions and temperatures.

**3.5.** This procedure is applicable for mixtures with a maximum aggregate size of 38 mm (1.5 in.) or less.

## 4. APPARATUS

**4.1** The indirect tensile test system shall consist of an axial loading device, a load measuring device, specimen deformation measurement devices, an environmental chamber, and a control and data acquisition system.

**4.1.1.** The axial loading device shall be capable of providing a fixed or constant load of 100 kN (22,500 lbf) with a resolution of at least 20 N (5 lbf) and constant rate of ram displacement of at least 12 mm (0.5 in.)/minute.

**4.1.2.** The load measuring device shall consist of an electronic load cell, designed for placement between the loading platen and piston, with a sensitivity of 20 N (5 lbf), and a minimum capacity of 100 kN (22,500 lbf).

**4.1.3.** The specimen deformation measurement devices shall consist of four displacement transducers with a range of at least 25 mm (1.0 in.), reducible to 2.5 mm (0.1 in.) through software, and a minimum resolution throughout the range of 0.10  $\mu\text{m}$  (3.936996e-006 in.).

**4.1.4.** The environmental chamber shall be equipped with temperature conditioners and controls capable of generating test temperatures between  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ) and  $+10^{\circ}\text{C}$  ( $+50^{\circ}\text{F}$ ) inside the chamber and maintaining the desired test temperature to within  $\pm 0.5^{\circ}\text{C}$  ( $\pm 0.9^{\circ}\text{F}$ ). The internal dimensions of the environmental chamber shall be sufficient to hold a minimum of three test specimens for a period of 12 hours prior to testing.

**4.1.5.** Specimen behavior in the creep compliance test is evaluated from time records of applied load and specimen deformation. These parameters shall be recorded on an analog to digital data acquisition device.

**4.1.5.1.** When determining the 100-second tensile creep for Superpave, digital data acquisition devices shall provide a sampling frequency of 10 Hz for the first 10 seconds and 1 Hz for the next 90 seconds. When determining the 1000-second tensile creep, digital data acquisition devices shall provide a sampling frequency of 10 Hz for the first 10 seconds, 1 Hz for the next 90 seconds, and 0.1 Hz for the rest of 900 seconds. When determining the tensile strength test, digital data acquisition devices shall provide a sampling frequency of 20 Hz through the entire test. A 16-bit A/D board is normally required to obtain the resolution needed when determining the tensile creep and the range needed when determining the tensile strength.

**4.1.6.** Eight brass gauge points having a diameter of 8 mm (0.315 in.) and a height of 6 mm (0.236 in.) are required per specimen.

**4.1.7.** A mounting template that has been used successfully for placing and mounting the gauge points to each side of the test specimen (four per side) is illustrated in **AASHTO T 322** Figure 1, which shows an example of a template for use with 150-mm (5.9 in.) diameter specimens

**4.1.8.** The specimen load frame shall be capable of delivering test loads coincident with the vertical diametral plane of the test specimen and with less than 20 N (5 lbf) frictional resistance in guides and/or bearings. Often a smaller guide frame with special alignment capabilities is used in conjunction with the larger loading frame to accomplish this. The frame may be configured with two support columns or four support columns.

**4.1.9.** Use metal loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. Strips are to be 19.0 mm (0.75 in) wide with rounded edges.

## 5. STANDARDIZATION

5.1. Calibrate the testing system prior to initial use and at least once a year thereafter.

5.1.1. Calibrate the environmental control component to maintain the required temperature within the accuracy specified.

5.1.2. Calibrate all measurement components (such as load cells and displacement transducers) of the testing system.

5.1.3. If any of the verifications yield data that do not comply with the accuracy specified, correct the problem prior to proceeding with testing. Appropriate action may include correction of menu entries, maintenance on system components, calibration of system components (using an independent calibration agency, or service by the manufacturer, or in-house resources), or replacement of system components.

## 6. SAMPLING

6.1. *Laboratory Molded Specimens*—Prepare a minimum of six laboratory molded samples, in accordance with KT-58.

6.2. *Roadway Specimens*—Obtain core samples with smooth and parallel surfaces that conform to the height and diameter requirements specified in Section 7.2. Prepare a minimum of six samples.

## 7. SPECIMEN PREPARATION AND PRELIMINARY DETERMINATIONS

7.1. Saw at least 6 mm from both sides of each test specimen to provide smooth, parallel (saw-cut) surfaces for mounting the measurement gauges.

**Note 1**—Measurements taken on cut faces yield more consistent results, and gauge points can be attached with much greater bonding strength.

7.2. Specimens using the medium gradation as specified in **Section 5.3.4 page 1 Part V of the Construction Manual**, shall be 150 mm (5.9 in.) in diameter and at least 115 mm (4.5 in.) in height and compacted to air voids  $\pm 1$  percent of design air voids at the design emulsion content. A trial specimen is suggested for this. Test specimens shall be cured at 60°C (140°F) no less than 48 hours and no more than 72 hours. Check specimen mass every 2 hours after 48-hour cure to check with compliance of no more than 0.05% change in mass in 2 hours. After curing, two specimens shall be cut from each compacted specimen to 50 mm (2.0 in.) in height and 150 mm (5.9 in.) in diameter. Perform bulk specific gravity after cutting.

7.3. Determine and record the diameter and height (thickness) of each specimen in accordance with **KT-56**.

7.4. *Determining the Bulk Specific Gravity*—Determine the specific gravity of each specimen in accordance with **KT-15**.

7.5. If specimens were immersed directly into the water, after determining the bulk specific gravity, allow each specimen to dry at room temperature to a constant mass.

7.6. Attach four gauge points with epoxy to each flat face of the specimen (four per face). On each flat face of the specimen, two gauge points shall be placed along the vertical and two along the horizontal axes with a center to center spacing of  $38.0 \pm 0.2$  mm ( $1.50 \pm 0.10$  in.) for a specimen diameter of

150 ± 9 mm (5.9 ± 0.35 in.). The placement and location of the gauge points on each face shall produce a mirror image of each other. Mount the displacement transducers on the gauge points such that the transducer's center line is 6.4 mm (0.25 in.) above the specimen's surface. **AASHTO T 322** Figure 3 shows a system for mounting linear variable differential transducers (LVDT's) that has been successfully used for IDT creep measurements at low temperature.

## **8. TENSILE CREEP/STRENGTH TESTING (THERMAL CRACKING ANALYSIS)**

Select two temperatures at 10°C (18°F) intervals that bracket the required specification. For example, if the required specification temperature is -25°C (-13°F), then select testing temperatures of -20°C (-4°F) and -30°C (-22°F). A temperature of -10°C (14°F) or -40°C (-40°F) should then be selected to complete the third required temperature.

**8.2.** Lower the temperature of the environmental chamber to the test temperature and, once the test temperature ±0.5°C (±0.9°F) is achieved, allow each specimen to remain at the test temperature from 3 ± 1 hours prior to testing. If the test temperature is below 0°C (32°F), allow the specimen to remain at the test temperature for 6 ± 1 hours prior to testing. Under no circumstances shall the specimen be kept at 0°C (32°F) or less for more than 24 hours.

**8.3.** Zero or rebalance the electronic measuring system and apply a static load of fixed magnitude (±2 percent) without impact to the specimen for 100 ± 2 seconds. If a complete analysis is required, a period of 1000 ± 20.5 seconds has been found suitable. Use a fixed load that produces a horizontal deformation of 0.00125 mm (4.921245e-005 in.) to 0.0190 mm (7.480292e-004 in.) for 150 mm (5.9 in.) diameter specimens. If either limit is violated, stop the test and allow a recovery time of 5 minutes before restarting with an adjusted load. Comply strictly with these limits to prevent both nonlinear response, characterized by exceeding the upper limit, and significant problems associated with noise and drift inherent in sensors, when violating the lower deformation limit.

**8.4.** The tensile strength test shall be carried out on each specimen directly after the tensile creep test at the same temperature as the creep test by applying a load to the specimen at a rate of 12.5 mm (0.5 in.) of ram (vertical) movement per minute. Record the vertical and horizontal deformations on both ends of the specimen and the load, until the load starts to decrease.

**Note 3**—In some cases, it is acceptable to unload the specimen between the creep compliance and strength tests. This will facilitate control on certain testing machines.

## **9. CALCULATIONS**

**9.1.** Calculate the air voids for each test specimen in accordance with **KT-56**.

**9.2.** Creep Compliance—Mathematical Model:

**9.2.1.** The three reference specimens are analyzed simultaneously to reduce variability in determining Poisson's ratio and, therefore, creep compliance.

**9.2.2.** Obtain average thickness and diameter in mm and creep load in kN for the three replicates:

$$D_{avg} = \frac{\sum_{n=1}^3 b_n}{3}$$

$$D_{avg} = \frac{\sum_{n=1}^3 D_n}{3}$$

$$P_{avg} = \frac{\sum_{n=1}^3 P_n}{3}$$

where:

$\sum$  = sum of the three specimens, values for thickness, diameter, creep load, in kN;  
 $b_{avg}, D_{avg}, P_{avg}$  = average thickness, diameter, and creep load of three replicate specimens; and  
 $b_n, D_n, P_n$  = thickness, diameter, and creep load of specimen  $n$  ( $n=1$  to 3).

**9.2.3.** Compute normalized horizontal and vertical deformation arrays for each of the six specimen faces (three specimens, two faces per specimen).

$$\Delta X_{n,i,t} = \Delta X_{i,t} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n}$$

$$\Delta Y_{n,i,t} = \Delta Y_{i,t} \times \frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n}$$

where:

$\Delta X_{n,i,t}$  = normalized horizontal deformation for face  $i$  ( $i=1$  to 6) at time  $t$  ( $t=0$  to  $t_{final}$ , where  $t_{final}$  is the total creep time);  
 $\Delta Y_{n,i,t}$  = normalized vertical deformation for face  $i$  at time  $t$ ;  
 $\Delta X_{i,t}$  = measured horizontal deformation for face  $i$  at time  $t$ ; and  
 $\Delta Y_{i,t}$  = measured vertical deformation for face  $i$  at time  $t$ .

**9.2.4.** Obtain the average horizontal and vertical deformation  $\Delta X_{a,i}$  and  $\Delta Y_{a,i}$  at a time corresponding to one half the total creep test time for each of the six specimen faces. Thus, for a 100-second creep test, obtain the deformations corresponding to  $t = 50$  seconds.

$$\Delta X_{a,i} = \Delta X_{n,i,t_{mid}}$$

$$\Delta Y_{a,i} = \Delta Y_{n,i,t_{mid}}$$

where:

$\Delta X_{a,i} + \Delta Y_{a,i}$  = average horizontal and vertical deformations for face  $i$ ;  
 $\Delta X_{n,i,t_{mid}}$  = normalized horizontal deformation at a time corresponding to half the total creep test time for face  $i$ ; and

$\Delta Y_{n,i,t mld}$  = normalized vertical deformation at a time corresponding to half the total creep test time for face  $i$ .

**9.2.5.** Obtain the trimmed mean of the deflections  $\Delta X_t$  and  $\Delta Y_t$ . This is accomplished by numerically ranking the six  $\Delta X_{a,i}$  and  $\Delta Y_{a,i}$  values and averaging the four middle values. Thus, the highest and lowest values of horizontal and vertical deformation are not included in the trimmed mean.

Compute:

$$\Delta X_t = \frac{\sum_{j=2}^5 \Delta X_{r,j}}{4}$$

$$\Delta Y_t = \frac{\sum_{j=2}^5 \Delta Y_{r,j}}{4}$$

where:

$\Delta X_{r,j}$  =  $\Delta X_{a,i}$  values sorted in ascending order;

$\Delta Y_{r,j}$  =  $\Delta Y_{a,i}$  values sorted in ascending order;

$\Delta X_t$  = trimmed mean of horizontal deformations; and

$\Delta Y_t$  = trimmed mean of vertical deformations.

**9.2.6.** Obtain the ratio of the horizontal to vertical deformations,  $X/Y$ , as follows:

$$\frac{X}{Y} = \frac{\Delta X_t}{\Delta Y_t}$$

**9.2.7.** Compute the trimmed mean,  $\Delta X_{tm,t}$ , of the six horizontal deformation arrays.

$$\Delta X_{tm,t} = \frac{\sum_{j=2}^5 \Delta X_{r,j,t}}{4}$$

where:

$\Delta X_{r,j,t}$  =  $\Delta X_{i,t}$  arrays sorted, where the  $i=6$  arrays are sorted according to the sorting order already established in Section 9.2.5. for  $\Delta X_{r,j}$ , and

$\Delta X_{tm,t}$  = Trimmed mean of the  $\Delta X_{i,t}$  arrays.

**9.2.8.** Compute creep compliance,  $D(t)$ :

$$D(t) = \frac{\Delta X_{tm,t} \times D_{avg} \times b_{avg}}{P_{avg} \times GL} \times C_{cmpl}$$

where:

$D(t)$  = creep compliance at time  $t$ (kPa); and

$GL$  = gauge length in meters ( $38 \times 10^{-3}$  for 150 mm diameter specimens); and

$C_{cmpl}$  =  $0.6354 \times \left(\frac{X}{Y}\right)^{-1} - 0.332$

$$\left[ 0.704 - 0.213 \left( \frac{b_{avg}}{D_{avg}} \right) \right] \leq C_{cmpl} \leq \left[ 1.566 - 0.195 \left( \frac{b_{avg}}{D_{avg}} \right) \right]$$

**9.2.9.** Poisson's ration,  $\nu$ , may be computed as:

$$\nu = -0.10 + 1.480 \left( \frac{X}{Y} \right)^2 - 0.778 \left( \frac{b_{avg}}{D_{avg}} \right)^2 \left( \frac{X}{Y} \right)^2$$

where:

$$0.05 \leq \nu \leq 0.50$$

**9.3.** Tensile Strength –Mathematical Model:

**9.3.1.** Calculate tensile strength for each specimen,  $S_{t,n}$ ,as:

$$S_{t,n} = \frac{2 \times P_{f,n}}{\delta \times b_n \times D_n}$$

where:

$P_{f,n}$  = maximum load observed for specimen,  $n$ ;

$S_{t,n}$  = tensile strength of specimen,  $n$ .



**9.3.2.** Compute the average tensile strength:

$$S_t = \frac{\sum_{n=1}^3 S_{t,n}}{3}$$

where:

$S_t$  = average tensile strength of mixture.

**9.3.3.** The critical cracking temperature is defined as the intersection of the calculated pavement thermal stress curve (derived from the creep data) and the tensile strength line (the line connecting the results of the average tensile strength at the two temperatures).

## **10. REPORT**

**10.1.** Report the following information:

**10.1.1.** Bulk specific gravity of each specimen tested to the nearest 0.001;

**10.1.2.** Maximum specific gravity of the asphalt concrete mixture to the nearest 0.001;

**10.1.3.** Air voids of each specimen to the nearest 0.1 percent;

**10.1.4.** Height and diameter of all test specimens to the nearest millimeter;

**10.1.5.** Test temperature to the nearest 0.5°C, and for creep testing the load levels used during the test to the nearest 5 N;

**10.1.6.** Tensile creep compliance values  $D(t)$ ; and

**10.1.7.** Tensile strength ( $\sigma_t$ ) of the mixture to the nearest pascal as computed.

## **11. PRECISION AND BIAS**

**11.1. Precision:** The research required to develop precision estimates has not been conducted.

**11.2. Bias:** The research required to establish the bias of this method has not been conducted.

## 5.9.61 RAVELING TEST ON RECYCLED ASPHALT SPECIMENS (Kansas Test Method KT-61)

### **1. SCOPE**

**1.1.** This method covers the procedure for performing the Raveling Test on recycled asphalt. **KT-61** reflects testing procedures found in **ASTM D7196**.

### **2. REFERENCED DOCUMENTS**

**2.1.** KT-58; Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor

**2.2.** International Slurry Surfacing Association ISSA TB-100: Wet Track Abrasion of Slurry Seals

**2.3.** ASTM D7196; Standard Test Method for Raveling Test of Cold Mixed Emulsified Asphalt Samples

### **3. APPARATUS**

**3.1.** Fixed speed Hobart model A-120 1/3 H.P. mixer or equivalent.

**3.2.** Adapter base. An attachment to hold the sample in place on the mixer without movement. See Fig. 1. (A Raveling Test Adapter Base may be available from Precision Machine and Welding, Salina Kansas 785-823-8760)

**3.3.** Abrasion Head. A free floating head attachment to the mixer with a mass of  $600 \pm 15$ g including the rubber hose, see **Sect. 3.4.** as described in **ISSA TB-100**. (An Abrasion Head may be available from Precision Machine and Welding, Salina Kansas 785-823-8760) See Fig 1.

**3.4** Hose:  $\frac{3}{4}$ " (19 mm) ID general or multipurpose rubber covered hose with a nominal  $\frac{1}{4}$ " (6 mm) wall thickness.

**3.5.** Superpave Gyrotory Compactor as described in **KT-58**.

### **4. Procedure**

**4.1.** Split out two recycled asphalt samples from the medium gradation, or field sample, to a quantity of 2700 g in mass. The 2700 g is an approximate mass to give  $70 \pm 5$  mm of height after compaction. If field samples are used, omit steps 4.2. through 4.4.

**4.2.** The recycled asphalt sample should be placed in a container of adequate size for mixing.

**4.3.** Field or design moisture contents should be added to each of the recycled asphalt samples and mixed for 60 seconds.

**4.4.** The design emulsion content shall be added to each of the recycled asphalt samples and mixed for 60 seconds.

**4.5.** The samples shall be placed immediately into a 150 mm gyrotory compaction mold and compacted to 20 gyrations. If the sample height is not  $70 \pm 5$  mm, the recycled asphalt mass should be adjusted.

**4.6.** After compaction, the samples shall be removed from the compaction mold and placed on a flat pan to cure at ambient lab temperature (18-24°C) for 4 hours ± 5 minutes.

**4.7.** The specimens shall be weighed after the curing, just prior to testing.

**4.8.** The specimens shall be placed on the raveling test apparatus. Care should be taken that the specimen is centered and well supported. The area of the hose in contact with the specimen should not have been previously used. It is allowable to rotate the hose to an unworn section for testing. The abrasion head (with hose) shall be free to move vertically downward a minimum of 5 mm if abrasion allows.

**4.9.** The samples shall be abraded for 15 minutes and immediately weighed.

## **5. CALCULATION**

**5.1** The % Raveling loss shall be determined as follows:

$$[(\text{mass prior to test} - \text{mass after abrasion}) / \text{mass prior to test}] * 100$$

## **6. REPORT**

**6.1.** The average of the two specimens shall be reported as the % Raveling loss.

**6.2.** There should not be a difference of 0.5% Raveling loss between the two test specimens for proper precision. A difference of >0.5% will require the test to be repeated. If both of the samples have a Raveling loss of >10% the numbers shall be averaged and the precision rule will be waived.



**Fig. 1**



5.9.62 PERCENT SOLIDS OF LIME SLURRY (Kansas Test Method KT-62)

**1. SCOPE**

This method of test covers the procedure for determining the amount of solids, by percent, contained in lime slurry.

**2. APPARATUS**

- 2.1. Quart container, not to be made of glass.
- 2.2. US standard Gardner weight per gallon (WPG) cup, with a volume of 83.2 cc.
- 2.3. Thermometer capable of reading 68°F to 214°F (20° to 101°C).

**3. TEST PROCEDURE**

- 3.1. Fill a quart container 3/4 full with lime slurry. Sample can be taken from ports located at either end of the vessel.
- 3.2. Weigh a dry, empty Gardner WPG cup and cover to the nearest 0.01 g. Record this mass as A.
- 3.3. Shake the lime slurry sample well and immediately fill the WPG cup.
- 3.4. Tap the WPG cup lightly on an immovable object to allow for the escape of air bubbles.
- 3.5. Slowly turn the top of the WPG cup until it is completely seated. If the cover is pushed on quickly, lime slurry will squirt out through the hole in the center. Be sure to point the top of the WPG cup away from yourself as well as others while putting on the cap.
- 3.6. Hold the WPG cup by the top and bottom with thumb and forefinger being sure to cover the hole in the cap.
- 3.7. Rinse the WPG cup under running water to remove any lime from the outside of the cup.
- 3.8. Dry the outside of the cup thoroughly.
- 3.9. Weigh the dry filled WPG cup to the nearest 0.01 g. Record this mass as B.
- 3.10. Promptly remove the cover and insert thermometer. Record this temperature as C.

#### 4. CALCULATIONS

##### 4.1. Slurry Density, lbs/gal, (E)

$$E = (B - A) \times 0.1$$

Where:           A= Mass of WPG cup empty  
                  B= Mass of the WPG cup full

##### 4.2. Adjusted Slurry Density, lbs/gal, (G)

$$G = E \times F$$

Where:           F= Temperature Correction Factor (Refer to **Table 2**)

4.3. Using the adjusted slurry density value, determine the percent solids of the lime slurry from **Table 1**.

**TABLE 1 Slurry Solids Chart - 24 °C**

Density lbs./gal.	Slurry Solids		Density lbs./gal.	Slurry Solids		Density lbs./gal	Slurry Solids		Density lbs./gal	Slurry Solids
9.108	15.1%		9.402	20.1%		9.715	25.1%		10.050	30.1%
9.114	15.2%		9.406	20.2%		9.722	25.2%		10.057	30.2%
9.120	15.3%		9.414	20.3%		9.728	25.3%		10.064	30.3%
9.128	15.4%		9.420	20.4%		9.735	25.4%		10.071	30.4%
9.131	15.5%		9.426	20.5%		9.741	25.5%		10.078	30.5%
9.137	15.6%		9.433	20.6%		9.748	25.6%		10.085	30.6%
9.143	15.7%		9.439	20.7%		9.755	25.7%		10.092	30.7%
9.148	15.8%		9.445	20.8%		9.761	25.8%		10.099	30.8%
9.154	15.9%		9.451	20.9%		9.768	25.9%		10.106	30.9%
9.160	16.0%		9.457	21.0%		9.774	26.0%		10.113	31.0%
9.166	16.1%		9.463	21.1%		9.781	26.1%		10.120	31.1%
9.171	16.2%		9.469	21.2%		9.787	26.2%		10.127	31.2%
9.177	16.3%		9.476	21.3%		9.794	26.3%		10.134	31.3%
9.183	16.4%		9.482	21.4%		9.800	26.4%		10.141	31.4%
9.189	16.5%		9.488	21.5%		9.807	26.5%		10.148	31.5%
9.195	16.6%		9.494	21.6%		9.814	26.6%		10.155	31.6%
9.200	16.7%		9.500	21.7%		9.820	26.7%		10.163	31.7%
9.206	16.8%		9.506	21.8%		9.827	26.8%		10.170	31.8%
9.212	16.9%		9.513	21.9%		9.833	26.9%		10.177	31.9%
9.218	17.0%		9.519	22.0%		9.840	27.0%		10.184	32.0%
9.224	17.1%		9.525	22.1%		9.847	27.1%		10.191	32.1%
9.230	17.2%		9.531	22.2%		9.853	27.2%		10.198	32.2%
9.235	17.3%		9.538	22.3%		9.860	27.3%		10.205	32.3%
9.241	17.4%		9.544	22.4%		9.867	27.4%		10.212	32.4%
9.247	17.5%		9.550	22.5%		9.873	27.5%		10.220	32.5%
9.253	17.6%		9.556	22.6%		9.880	27.6%		10.227	32.6%
9.259	17.7%		9.563	22.7%		9.887	27.7%		10.234	32.7%
9.265	17.8%		9.569	22.8%		9.894	27.8%		10.241	32.8%
9.271	17.9%		9.575	22.9%		9.900	27.9%		10.248	32.9%
9.277	18.0%		9.581	23.0%		9.907	28.0%		10.255	33.0%
9.282	18.1%		9.588	23.1%		9.914	28.1%		10.263	33.1%
9.288	18.2%		9.594	23.2%		9.920	28.2%		10.270	33.2%
9.294	18.3%		9.600	23.3%		9.927	28.3%		10.277	33.3%
9.300	18.4%		9.607	23.4%		9.934	28.4%		10.284	33.4%
9.306	18.5%		9.613	23.5%		9.941	28.5%		10.292	33.5%
9.312	18.6%		9.619	23.6%		9.948	28.6%		10.299	33.6%
9.318	18.7%		9.626	23.7%		9.954	28.7%		10.306	33.7%
9.324	18.8%		9.632	23.8%		9.961	28.8%		10.314	33.8%
9.330	18.9%		9.638	23.9%		9.968	28.9%		10.321	33.9%
9.336	19.0%		9.645	24.0%		9.975	29.0%		10.328	34.0%
9.342	19.1%		9.651	24.1%		9.982	29.1%		10.335	34.1%
9.348	19.2%		9.658	24.2%		9.988	29.2%		10.343	34.2%
9.354	19.3%		9.664	24.3%		9.995	29.3%		10.350	34.3%
9.360	19.4%		9.670	24.4%		10.002	29.4%		10.358	34.4%
9.366	19.5%		9.677	24.5%		10.009	29.5%		10.365	34.5%
9.372	19.6%		9.683	24.6%		10.016	29.6%		10.372	34.6%
9.378	19.7%		9.690	24.7%		10.023	29.7%		10.380	34.7%
9.384	19.8%		9.696	24.8%		10.030	29.8%		10.387	34.8%
9.390	19.9%		9.703	24.9%		10.037	29.9%		10.394	34.9%
9.396	20.0%		9.709	25.0%		10.044	30.0%		10.402	35.0%



**TABLE 1 (cont.) Slurry Solids Chart - 24 °C**

Density lbs./gal.	Slurry Solids		Density lbs./gal.	Slurry Solids		Density lbs./gal	Slurry Solids		Density lbs./gal	Slurry Solids
10.409	35.1%		10.795	40.1%		11.210	45.1%		11.658	50.1%
10.417	35.2%		10.803	40.2%		11.218	45.2%		11.667	50.2%
10.424	35.3%		10.811	40.3%		11.227	45.3%		11.677	50.3%
10.432	35.4%		10.819	40.4%		11.236	45.4%		11.686	50.4%
10.439	35.5%		10.827	40.5%		11.244	45.5%		11.695	50.5%
10.447	35.6%		10.835	40.6%		11.253	45.6%		11.705	50.6%
10.454	35.7%		10.843	40.7%		11.262	45.7%		11.714	50.7%
10.462	35.8%		10.851	40.8%		11.270	45.8%		11.724	50.8%
10.469	35.9%		10.859	40.9%		11.279	45.9%		11.733	50.9%
10.477	36.0%		10.867	41.0%		11.288	46.0%		11.743	51.0%
10.484	36.1%		10.875	41.1%		11.297	46.1%		11.752	51.1%
10.492	36.2%		10.883	41.2%		11.305	46.2%		11.762	51.2%
10.499	36.3%		10.892	41.3%		11.314	46.3%		11.771	51.3%
10.507	36.4%		10.900	41.4%		11.323	46.4%		11.781	51.4%
10.514	36.5%		10.908	41.5%		11.332	46.5%		11.790	51.5%
10.522	36.6%		10.916	41.6%		11.341	46.6%		11.800	51.6%
10.530	36.7%		10.924	41.7%		11.349	46.7%		11.809	51.7%
10.537	36.8%		10.932	41.8%		11.358	46.8%		11.819	51.8%
10.545	36.9%		10.941	41.9%		11.367	46.9%		11.828	51.9%
10.552	37.0%		10.949	42.0%		11.376	47.0%		11.838	52.0%
10.560	37.1%		10.957	42.1%		11.385	47.1%		11.848	52.1%
10.568	37.2%		10.965	42.2%		11.394	47.2%		11.857	52.2%
10.575	37.3%		10.974	42.3%		11.403	47.3%		11.867	52.3%
10.583	37.4%		10.982	42.4%		11.412	47.4%		11.877	52.4%
10.591	37.5%		10.990	42.5%		11.421	47.5%		11.886	52.5%
10.599	37.6%		10.998	42.6%		11.430	47.6%		11.896	52.6%
10.606	37.7%		11.007	42.7%		11.439	47.7%		11.906	52.7%
10.614	37.8%		11.015	42.8%		11.447	47.8%		11.915	52.8%
10.622	37.9%		11.023	42.9%		11.456	47.9%		11.925	52.9%
10.629	38.0%		11.032	43.0%		11.465	48.0%		11.935	53.0%
10.637	38.1%		11.040	43.1%		11.475	48.1%		11.945	53.1%
10.645	38.2%		11.048	43.2%		11.484	48.2%		11.954	53.2%
10.653	38.3%		11.057	43.3%		11.493	48.3%		11.964	53.3%
10.661	38.4%		11.065	43.4%		11.502	48.4%		11.974	53.4%
10.668	38.5%		11.074	43.5%		11.511	48.5%		11.984	53.5%
10.676	38.6%		11.082	43.6%		11.520	48.6%		11.994	53.6%
10.684	38.7%		11.090	43.7%		11.529	48.7%		12.004	53.7%
10.692	38.8%		11.099	43.8%		11.538	48.8%		12.014	53.8%
10.700	38.9%		11.107	43.9%		11.547	48.9%		12.023	53.9%
10.707	39.0%		11.116	44.0%		11.556	49.0%		12.033	54.0%
10.715	39.1%		11.124	44.1%		11.566	49.1%		12.043	54.1%
10.723	39.2%		11.133	44.2%		11.575	49.2%		12.053	54.2%
10.731	39.3%		11.141	44.3%		11.584	49.3%		12.063	54.3%
10.739	39.4%		11.150	44.4%		11.593	49.4%		12.073	54.4%
10.747	39.5%		11.158	44.5%		11.602	49.5%		12.083	54.5%
10.755	39.6%		11.167	44.6%		11.612	49.6%		12.093	54.6%
10.763	39.7%		11.175	44.7%		11.621	49.7%		12.103	54.7%
10.771	39.8%		11.184	44.8%		11.630	49.8%		12.113	54.8%
10.779	39.9%		11.193	44.9%		11.639	49.9%		12.123	54.9%
10.787	40.0%		11.201	45.0%		11.649	50.0%		12.134	55.0%

**TABLE 2**  
**Correction Factor to Adjust Slurry Densities for Temperature**

Temp (C)	Factor		Temp (C)	Factor
20	0.99927		61	1.01176
21	0.99944		62	1.01218
22	0.99962		63	1.01262
23	0.99981		64	1.01305
24	1.00000		65	1.01349
25	1.00020		66	1.01394
26	1.00041		67	1.01439
27	1.00063		68	1.01485
28	1.00085		69	1.01531
29	1.00109		70	1.01578
30	1.00132		71	1.01626
31	1.00157		72	1.01673
32	1.00182		73	1.01722
33	1.00208		74	1.01770
34	1.00234		75	1.01820
35	1.00261		76	1.01870
36	1.00289		77	1.01920
37	1.00318		78	1.01971
38	1.00347		79	1.02022
39	1.00376		80	1.02074
40	1.00407		81	1.02126
41	1.00438		82	1.02179
42	1.00469		83	1.02232
43	1.00501		84	1.02286
44	1.00534		85	1.02341
45	1.00567		86	1.02395
46	1.00601		87	1.02451
47	1.00635		88	1.02506
48	1.00670		89	1.02563
49	1.00706		90	1.02619
50	1.00742		91	1.02677
51	1.00779		92	1.02734
52	1.00816		93	1.02793
53	1.00854		94	1.02851
54	1.00892		95	1.02911
55	1.00931		96	1.02970
56	1.00970		97	1.03031
57	1.01010		98	1.03091
58	1.01051		99	1.03152
59	1.01092		100	1.03214
60	1.01134		101	1.03276



## 5.9.63 METHOD FOR DETERMINING DRAINDOWN CHARACTERISTICS IN UNCOMPACTED ASPHALT MIXTURES (Kansas Test Method KT-63)

### **1. SCOPE**

This test method covers the determination of the amount of draindown in an uncompacted asphalt mixture sample when the sample is held at elevated temperatures comparable to those encountered during the production, storage, transport, and placement of the mixture. The test is particularly applicable to mixtures such as open-graded friction course and Stone Matrix Asphalt (SMA).

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

**2.3.** AASHTO T 245; Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus

**2.4.** AASHTO T 305; Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

### **3. SIGNIFICANCE AND USE**

**3.1.** This test method can be used to determine whether the amount of draindown measured is within acceptable levels. The test provides an evaluation of the draindown potential of an asphalt mixture during mixture design and/or during field production. This test is primarily used for mixtures with high coarse aggregate content such as open-graded friction course and SMA.

### **4. DEFINITIONS**

**4.1.** For the purpose of this test method, *draindown* is considered to be that portion of material that separates itself from the sample as a whole and is deposited outside the wire basket during the test. The material that drains may be composed of either asphalt binder or a combination of asphalt binder and fine aggregate.

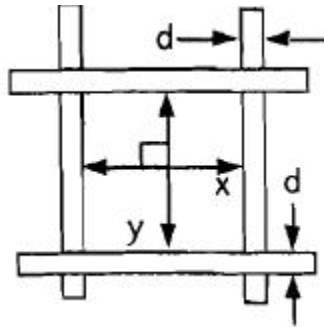
### **5. APPARATUS**

**5.1.** Forced draft oven capable of maintaining the temperature in a range from 250° to 350°F (120° to 175°C). The oven should maintain the set temperature to within  $\pm 3.6^\circ\text{F}$  ( $\pm 2^\circ\text{C}$ ).

**5.2.** Plates or other suitable containers of appropriate size. The plates or containers used should be of appropriate durability to withstand the oven temperatures. Cake pans or pie tins are examples of suitable types of containers.

**5.3.** Standard basket meeting the dimensions shown in **Figure 1**. The basket shall be constructed using standard 0.25 in (6.3 mm) sieve cloth as specified in **ASTM E11**.

**FIGURE 1**



**5.4.** Spatulas, trowels, mixer and bowls as needed.

**5.5.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**. The balance shall be accurate to 0.1 gram.

## **6. SAMPLE PREPARATION**

**6.1.** Laboratory Prepared Samples:

**6.1.1** Number of samples for each mixture tested, the draindown characteristics should be determined at two different temperatures. The two temperatures should be the anticipated plant production temperature as well as 27°F (15°C) above.

**NOTE:** When using the test as part of the mixture design procedure, the test should be performed at two temperatures in order to determine the potential effect that plant temperature variation may have on the mixture during production. When the test is used in the field during production, it should be necessary to perform the test at the plant production temperature only.

**6.1.2.** Dry the aggregate to constant mass at 221° to 230°F (105° to 110°C) and separate the aggregates by dry-sieving into the appropriate size fractions. The following size fractions are recommended:

- 1 to 3/4 in (25.0 to 19.0 mm)
- 3/4 to 3/8 in (19.0 to 9.5 mm)
- 3/8 to No. 4 (9.5 to 4.75 mm)
- No. 4 to No. 8 (4.75 to 2.36 mm)
- Passing No. 8 (Passing 2.36 mm)

**6.1.3.** Determine the anticipated plant production temperature or select a mixing temperature which will produce a viscosity of  $170 \pm 20$  cSt upon heating.

**6.1.4.** Place into separate pans for each test sample the amount of each size fraction required to produce completed mixture samples having a mass of  $1200 \pm 200$  grams. The aggregate fractions shall be combined such that the resulting aggregate blend has the same gradation as the job-mix-formula. Place the aggregate samples in an oven and heat to a temperature not to exceed the mixing temperature established in **Section 6.1.3** of this test method by more than approximately 50°F (28°C).

**6.1.5.** Heat the asphalt cement to the temperature established in **Section 6.1.3** of this test method.

**6.1.6.** Place the heated aggregate in the mixing bowl. Add any stabilizers and thoroughly mix the dry components. Form a crater in the aggregate blend and add the required amount of asphalt. The amount of asphalt shall be such that the final sample has the same asphalt content as the job-mix-formula. At this point, the temperature of the aggregate and asphalt cement shall be within the limits for the mixing temperature established in **Section 6.1.3** of this test method. Using a spatula (if mixing by hand) or a mixer, mix the aggregate (and stabilizer, if any) and asphalt cement quickly until the aggregate is thoroughly coated.

**NOTE:** Some types of stabilizers such as fibers or some polymers must be added directly to the aggregate prior to mixing with the asphalt cement. Other types of stabilizers must be added directly to the asphalt cement prior to blending with the aggregate.

## **6.2. Plant Produced Samples:**

**6.2.1.** Number of Samples- For plant produced samples, duplicate samples should be tested at the plant production temperature.

**6.2.2.** Samples may be obtained during plant production by sampling the mixture at any appropriate location such as the trucks prior to the mixture leaving the plant. Samples obtained during actual production should be reduced to the proper test sample size by the quartering method.

**NOTE:** Caution should be exercised when sampling from surge or storage bins because draindown may already have taken place.

## **7. PROCEDURE**

**7.1.** Transfer the hot laboratory produced or plant produced uncompacted mixture sample to a tared wire basket as described in **Section 5.3** of this test method. Place the entire sample in the wire basket. Do not consolidate or otherwise disturb the sample after transfer to the basket. Determine the mass of the sample to the nearest 0.1 g. The sample should not be cooled more than 77°F (25°C) below the test temperature (see **Section 7.1.1** of this test method.)

**7.1.1.** Determine and record the mass of a plate or other suitable container to the nearest 0.1 g. Place the basket on the plate or container and place the assembly into the oven at the temperature as determined in **sections 6.1.1 or 6.2.1** of this test method for 1 hour ± 5 minutes. If the sample has cooled more than 77°F (25°C) below the test temperature, the test should be conducted for 70 ± 5 minutes.

**7.1.2.** After the sample has been in the oven for the time specified in **Section 7.1.1** of this test method, remove the basket and plate or container from the oven. Determine and record the mass of the plate or container plus draindown to the nearest 0.1 g.

## **8. CALCULATIONS**

**8.1.** Calculate the percent of mixture that drained by subtracting the initial plate or container mass from the final plate or container mass and divide this by the initial total sample mass. Multiply the result by 100 to obtain a percentage.

## **9. REPORT**

**9.1.** Report the average percent drainage at each of the test temperatures.



5.9.64 METHOD FOR DETERMINING VOLUME OF VOIDS IN COMPACTED FILLER OR FINES  
(Kansas Test Method KT-64)

## 1. SCOPE

This test procedure describes a method for determining the void volume in a dry-compacted mineral filler or fines (Rigden voids). The test method is based upon the assumption that the densest packing (maximum bulk density) of fines can be obtained by compacting the dry fines in a mold.

This method is from National Asphalt Pavement Association Information Series 127, Evaluation of Baghouse Fines for Hot Mix Asphalt.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. AASHTO T 100: Specific Gravity of Soils

2.3. AASHTO T 133; Density of Hydraulic Cement

2.4. ASTM E11; Woven Wire Test Sieve Cloth and Test Sieves

2.5. AASHTO T 88; Test for Particle Size Analysis of Soils

2.6. National Asphalt Pavement Association Information Series 127, Evaluation of Baghouse Fines for Hot Mix Asphalt

## 3. SIGNIFICANCE AND USE

In this test method, the volume of the voids in a dry-compacted bed of mineral dust (Rigden voids) is determined by compacting the dust in a small mold. The void volume in dry compacted fines (Rigden voids) is sensitive to changes in gradation and other properties of the fines, and therefore, the dry compaction test has been proposed as a test for monitoring the uniformity of the fines collected in HMA facilities. Rigden voids can also be used to estimate the stiffening effect of the fines when mixed with asphalt cement.

## 4. DEFINITIONS

4.1. Maximum packing occurs when the particles are packed together in their minimum volume with a minimum void volume. Maximum packing results in a maximum bulk density.

4.2. The bulk density of the compacted fines is defined as the dry weight of the fines divided by the bulk volume of the compacted fines. The bulk volume includes the sum of the solid volume of the fines particles and the volume of the voids between the particles.

4.3. The density of the fines is defined as the dry weight of the fines divided by the solid volume of the fines particles. This density can be obtained from **AASHTO T 133 or T 100** or another appropriate test method.

## 5. APPARATUS

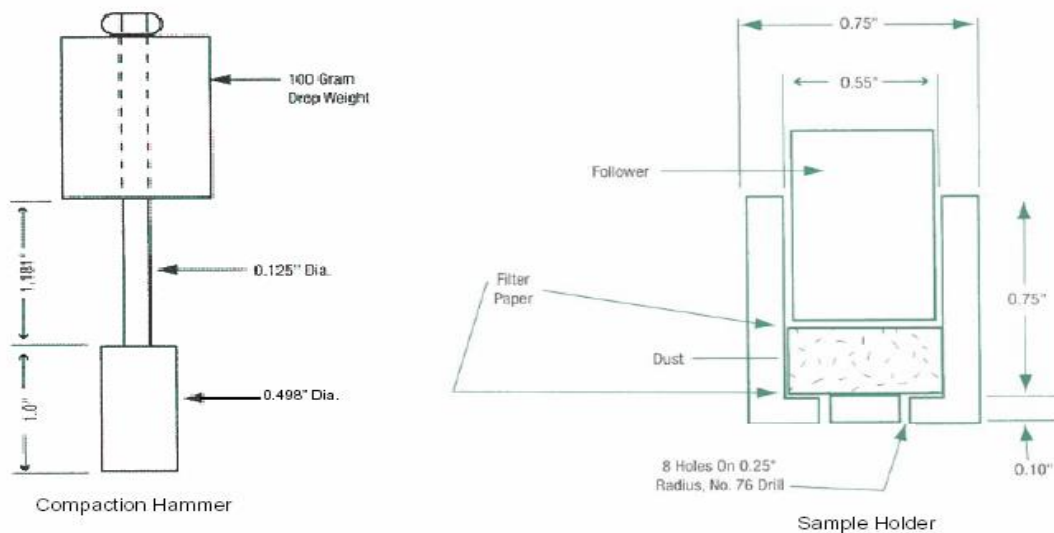
5.1. Compaction hammer, as shown in **Figure 1**, is required to compact the fines into the test mold. The fines are compacted in one layer, using 25 blows of the hammer.

5.2. Test mold or sample holder, as shown in **Figure 1**, is required for measuring the volume of the compacted bed of fines.



- 5.3.** Compaction pedestal, a steel block, 1 in thick x 4 in x 4 in is used as a base for placing the test mold.
- 5.4.** Thickness measuring system, a dial gauge with 0.001 in gradations is required for measuring the thickness of the compacted bed of fines.
- 5.5.** Filter membrane, a small 1/2 in diameter disks must be cut from Millipore No. SCWP0190R, Whatman 41 (Cat No. 1441 110) or Whatman 2 (Cat No 1002 150) filter membrane. A round cutting tool can be used for this purpose.
- 5.6.** Tweezers are needed for handling the filter disks.
- 5.7.** No. 200 sieve (75  $\mu\text{m}$ ) sieve meeting the requirements of **ASTM E11** is needed to remove the particles larger than No. 200 (75  $\mu\text{m}$ ).
- 5.8.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, a balance or scale rated to 200 grams and sensitive to 0.01 gram is required.

**Figure 1**



## 6. SAMPLE PREPARATION

**6.1.** The fines may be obtained from a primary or secondary dust collector, the coarse or fine aggregate, or the aggregate extracted from a mixture. Particles larger than No. 200 (75  $\mu\text{m}$ ) should be removed by sieving. Dry sieving is usually adequate if several sieves coarser than No. 200 (75  $\mu\text{m}$ ) sieve are placed above the No. 200 (75  $\mu\text{m}$ ) sieve during the sieving operation to avoid overloading the No. 200 sieve (75  $\mu\text{m}$ ). Wet sieving should be avoided because the fine particles tend to stick together after they are dried.

## 7. PROCEDURE

**7.1.** Use the cutting tool to cut a number of 1/2 inch diameter filter disks. Place two of these disks in the bottom of the sample cup, place the follower over the top of the disks, and seat the follower on the filter disks using firm finger pressure. Insert the entire assembly under the dial gauge. Record the dial gauge reading as  $t_1$ .

**7.2.** Weigh the empty mold, two filter disks, and the follower, and record the weight as  $W_1$ . Remove the follower and the two filter disks.

**7.3.** Place a filter disk in the bottom of the sample cup, making certain that it is centered and firmly in place at the bottom of the mold. Select a representative sample of minus No. 200 (75  $\mu\text{m}$ ) fines that weighs approximately 1.0-1.3 grams. Carefully place the fines in the sample cup over the top of the filter disk. Place a second filter disk over the top of the fines and use the follower and firm hand pressure to seat the disk on top of the fines. This procedure will result in some initial compaction of the fines and is to be expected.

**7.4.** Remove the follower, place the sample cup on the steel base plate and apply 25 blows with the compaction hammer. Use caution during the compaction process to be certain that the mold is seated firmly on compaction pedestal, the drop weight falls its full height and the drop weight falls freely.

**7.5.** Remove the compaction hammer and insert the follower on top of the compacted fines and filter disk. Insert the entire assembly under the dial gauge and record the dial gauge reading,  $t_2$ . Weigh the entire mold assembly and record as the weight  $W_2$ .

**7.6.** The specific gravity of the fines solids is required to complete the calculations. If the specific gravity of the fines solids is not known, it will be necessary to measure it using **AASHTO T 133 or T 100**. **Caution:** The specific gravity of the fines solids may not be the same as for the other aggregate fractions. Although kerosene has been used as a liquid for determining specific gravity, water can also be used without adversely affecting the accuracy of the results.

## 8. CALCULATIONS

### 8.1. Notation

Where:

- $d$  = Diameter of test mold (inch)
- $G_{fs}$  = Specific gravity of the fines solids
- $t$  = Thickness of compacted sample (inch)
- $t_1$  = Initial dial gauge reading (inch)
- $t_2$  = Final dial gauge reading (inch)
- $V_{fB}$  = Bulk volume of compacted fines sample ( $\text{cm}^3$ )
- $V_{fS}$  = Volume of fines solids ( $\text{cm}^3$ )
- $RV$  = Volume of voids in compacted fines or Rigden voids ( $\text{cm}^3$ )
- $\%RV$  = Volume of voids in compacted fines expressed as percentage of bulk volume
- $W_{fs}$  = Weight of dry fines solids (g)
- $\gamma_w$  = Density (unit weight) of water ( $1.00\text{g}/\text{cm}^3$ )

### 8.2. Compacted Dust

**8.2.1.** Calculate the bulk volume of the compacted fines  $V_{fB}$  as follows:

$$V_{fB} = \frac{15.7 \times \pi \times d^2 \times t}{4} = \text{cm}^3$$

Where:

- $d$  = Diameter of mold (inch)
- $t$  =  $t_2 - t_1$ , sample thickness (inch)

**8.2.2.** Calculate the volume of the fines solids,  $V_{fs}$  as follows:

$$V_{fs} = \frac{W_{fs}}{\gamma_w \times G_{fs}} = cm^3$$

Where:  $W_{fs}$  =  $W_2 - W_1$ , weight of compacted fines (grams)  
 $\gamma_w$  = unit weight of water (1.000 g/cm<sup>3</sup>)  
 $G_{fs}$  = specific gravity of fines solids as determined from the **AASHTO T 133** or **T 100** or other suitable test method.

**8.2.3** Calculate the volume of the voids in the compacted fines,  $RV$  (Rigden voids), as follows:

$$RV = V_{fB} - V_{fs}$$

**8.2.4.** Calculate the percentage of voids in the compacted fines (Rigden voids), as follows:

$$\%RV_{fs} = \frac{V_{fB} - V_{fs}}{V_{fB}} \times 100$$

5.9.65 SAMPLING AND SPLITTING CEMENT TREATED BASE MIXTURES  
(Kansas Test Method KT-65)

**1. SCOPE**

This method covers the procedure for sampling cement treated base mixtures from truck beds, batch plants, and continuous mix plants.

**NOTE:** The total length of time required to sample and split the material shall take no longer than 45 minutes.

**2. APPARTUS**

**2.1.** Square pointed shovel or scoop.

**2.2.** A five-gallon container that will be filled with loose, cement treated base mixture. The container should be equipped with a handle that will permit it to be carried easily. The container should also have a lid to prevent moisture loss during transport.

**3. SAMPLING PROCEDURE**

**3.1.** Truck beds.

**3.1.1.** Divide the truck bed into at least three areas of approximately equal size.

**3.1.2.** Dig a hole about 1 ft (0.3 m) deep at a point that will be representative of each area.

**3.1.3.** Take a sample near the bottom of each hole and place in container, taking care to prevent segregation.

**3.1.4.** Combine the individual samples into a single sample and mix thoroughly<sup>a</sup>.

**3.1.5.** The combined sample size shall be at least four times the amount required for testing.

**3.2.** Conveyor Belt.

**3.2.1.** Stop the conveyor belt while the sample increments are being obtained. Insert two templates, the shape of which conforms to the shape of the belt in the mixture stream on the belt. Space the templates such that the material contained between will yield an increment of the required mass.

**3.2.2.** Obtain at least three approximately equal increments, selected at random, from the unit being sampled.

**3.2.3.** Carefully scoop all material between the templates into the container and collect the fines from the belt with a brush and dust pan and add to the container.

**3.2.4.** Combine the individual samples into a single sample and mix thoroughly.

**3.2.5.** The combined sample size shall be at least four times the amount required for testing.

### **3.3. Sampling from Discharge or Flowing Streams.**

**3.3.1.** The batch mixer or the continuous mixer (pugmill) shall be capable of sampling at the discharge outlet. When a sample is taken from the discharge, use a loader(s) or other heavy equipment capable of intercepting the entire cross section of the discharge stream.

**3.3.2.** Divide the material in the loader bucket into at least three areas of approximately equal size. Obtain a sample from each of the three sections.

**3.3.3.** Combine the individual samples into a single sample and mix thoroughly<sup>a</sup>.

**3.3.4.** The combined sample size shall be at least four times the amount required for testing.

**NOTE a:** After mixing, place the lid securely on the container immediately following sampling to prevent moisture loss in the material. The lid shall not be removed until the splitting procedure begins.

## **4. SPLITTING PROCEDURE**

**4.1.** During mixing and reducing, care must be exercised to prevent moisture loss within the sample.

**4.2.** Reduce sample to the required size by splitting or quartering in the following manner:

**4.2.1.** Spread a sheet of paper (Kraft or similar) on a hard, clean smooth and level surface. Place the sample in a pile near the center of the paper and mix by alternately lifting each corner towards the opposite corner thereby rolling the mixture to the opposite corner. This should be performed in a vigorous manner. Placing the sample on clean sheet metal and mixing thoroughly with a trowel is an acceptable alternative.

**4.2.2.** Divide the pile into four equal quarters with a straightedge (trowel or similar metal blade) and completely remove two pre-selected diagonally opposite quarters.

**4.2.3.** Continue this quartering procedure until the original sample is reduced to the approximately desired size. On the final quartering step, if the sample is too large before quartering, but will be too small after quartering, the sample pile is divided into equal opposite sectors but unequal adjacent sectors. This can be accomplished by varying the dividing angle at the center of the sample pile from the normal 90 degrees. Opposite sections can then be selected to obtain the desired sample size.

5.9.66 SAMPLING EPOXY PAVEMENT MARKING/MULTI-COMPONENT PAVEMENT MARKING (Kansas Test Method KT-66)

**1. SCOPE**

This method covers the procedures for field sampling of epoxy pavement marking and multi-component pavement marking.

**2. APPARATUS**

**2.1.** Supply of clean, 1/2 pint wide mouth friction top metal cans.

**2.2** Duct or packing tape.

**2.3.** Hammer.

**3. SAMPLING PROCEDURES**

**3.1.** Have the contractor load the application equipment and allow the truck to apply the epoxy or multi-component pavement marking for approximately one-half hour prior to collecting samples.

**3.2.** Coordinate the sampling site with the contractor.

**3.3.** Using a clean 1/2 pint wide mouth metal can, take a sample for the resin component prior to mixing. Fill the can completely.

**3.4.** Remove the can. Tap the lid securely on with a hammer. Seal the lid with duct or packing tape.

**3.5.** Using a second clean 1/2 pint wide mouth metal can, take a sample for the hardener component prior to mixing. Fill the can completely.

**3.6.** Remove the can. Tap the lid securely on with a hammer. Seal the lid with duct or packing tape.

**3.7. DO NOT MIX THE RESIN AND THE HARDENER SAMPLES.**

**4. SHIPPING INFORMATION**

**4.1.** Label each 1/2 pint containers with at least the following:

**4.1.1.** Epoxy or Multi-Component producer (Epoxy or Multi-Component Brand Name).

**4.1.2.** Epoxy or Multi-Component Manufacturer Product ID.

**4.1.3.** Epoxy resin or Multi-Component batch number or Epoxy hardener batch number.

**4.1.4.** Project number.

**4.1.5. Sample ID** Number. Each component must have a different Sample ID Number.

**4.1.6.** Pack and ship samples of the resin component and the hardener component to the Materials & Research Center, 2300 SW Van Buren, Topeka, KS 66611.



## 5.9.67 SAMPLING GLASS BEADS (Kansas Test Method KT-67)

### **1. SCOPE**

This method covers the procedures for field sampling of Glass Beads. On double drop systems, a separate sample is required for each type of bead.

### **2. APPARATUS**

**2.1** Supply of clean, one-quart friction top metal cans.

**2.2** Duct or packing tape.

**2.3** Hammer.

**2.4** Pipe thief or similar device

### **3. SAMPLING PROCEDURES**

*\*\* Beads will be submitted by the manufacturer and tested at the MRC lab according to type before use on KDOT projects. \*\**

*\*\* Follow the below directions for sampling of glass beads when a sample is needed due to material issues only. Beads should have been tested and prequalified by the MRC prior to use on projects. \*\**

**3.1** Coordinating with the contractor, fill completely two, clean one-quart wide mouth metal cans, from the drums of glass beads, using a pipe thief or similar device.

**3.2** Place lid on can. Tap the lid securely on with a hammer. Seal the lid with duct or packing tape.

**3.3** Take a second sample following the above procedures **Sections 3.1** and **3.2** of this test method.

### **4. SHIPPING INFORMATION**

**4.1.** Label each quart of beads with at least the following:

**4.1.1.** Bead Producer.

**4.1.2.** Bead batch or lot number.

**4.1.3.** Specification number and/or type.

**4.1.4. Sample ID** number.

**4.1.5.** Pack and ship two (2)- one-quart samples to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.





## 5.9.68 SAMPLING TRAFFIC PAINT (Kansas Test Method KT-68)

### **1. SCOPE**

This method covers the procedures for sampling traffic paint in the field.

### **2. APPARATUS**

**2.1.** Supply of clean, one quart friction top plastic-lined metal cans.

**2.2** Hammer.

### **3. SAMPLING PROCEDURES**

**3.1.** Have the contractor load the application equipment and agitate. Allow the truck to apply paint for approximately one-half hour.

**3.2.** Coordinating with the contractor, fill completely two clean one quart plastic-lined metal cans from the paint tank drain. Always fill the can completely as air in the can could affect the sample.

**3.3.** Remove the can. Tap the lid securely on with a hammer.

**3.4.** Take a second sample following the above procedures **Sections 3.2** and **3.3** of this test method.

### **4. SHIPPING INFORMATION**

**4.1.** Label each quart of paint with at least the following:

**4.1.1.** Paint Producer.

**4.1.2.** Paint batch number.

**4.1.3. Sample ID** number.

**4.1.4.** Pack and ship two (2)- one quart samples to the Materials and Research Center, 2300 SW Van Buren, Topeka, KS 66611.



## 5.9.69 Relative Density (Kansas Test Method KT-69)

### **1. SCOPE.**

These test methods cover the procedure for determination of the maximum–index dry density/unit weight of cohesionless, free draining soils using a vertically vibrating table. These test methods are applicable to soils that may contain up to 15% soil particles passing the No. 200 sieve and 100% passing a 3 inch sieve.

**KT-69** reflects testing procedures found in ASTM D4253.

### **2. REFERENCED DOCUMENTS**

**2.1.** KT-06 Specific Gravity and Absorption of Aggregate

**2.2.** KT-02 Sieve Analysis of Aggregates

**2.3.** KT-03 Material Passing 75  $\mu\text{m}$  (No. 200) Sieve by the Wash Method

**2.4.** KT-11 Moisture Test

**2.5.** ASTM D653 Standard Terminology Relating to Soil, Rock and Contained Fluids

**2.6.** ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft<sup>3</sup>(600 kN-m/m<sup>3</sup>))

**2.7.** ASTM D854 Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

**2.8.** ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56 000 ft-lbf/ft<sup>3</sup>(2700kN-m/m<sup>3</sup>))

**2.9.** ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

**2.10.** ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

**2.11.** ASTM D3740 Standard Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

**2.12.** ASTM D4253 Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

**2.13.** ASTM D4254 Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density

**2.14.** ASTM D4753 Standard Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

**2.15.** ASTM D6026 Standard Practice for Using Significant Digits in Geotechnical Data

**2.16.** ASTM E11 Standard Specification for Woven Wire Test Sieve Cloth and test Sieves

**2.17.** ASTM E177 Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods

**2.18.** ASTM E691 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

### **3. APPARATUS.**

**3.1. Mold Assembly**—An example of a typical mold assembly is shown in Fig. 1. Individual components and accessories shall be as follows:

**3.1.1 Standard Molds**-- Cylindrical metal molds having nominal volumes of 0.100 ft<sup>3</sup> (2 830 cm<sup>3</sup>) and 0.500 ft<sup>3</sup> (14 200 cm<sup>3</sup>). The molds shall conform to the requirements shown in Figure 2. The actual volume of the molds shall be within  $\pm 1.5$  % of the specified nominal volume.

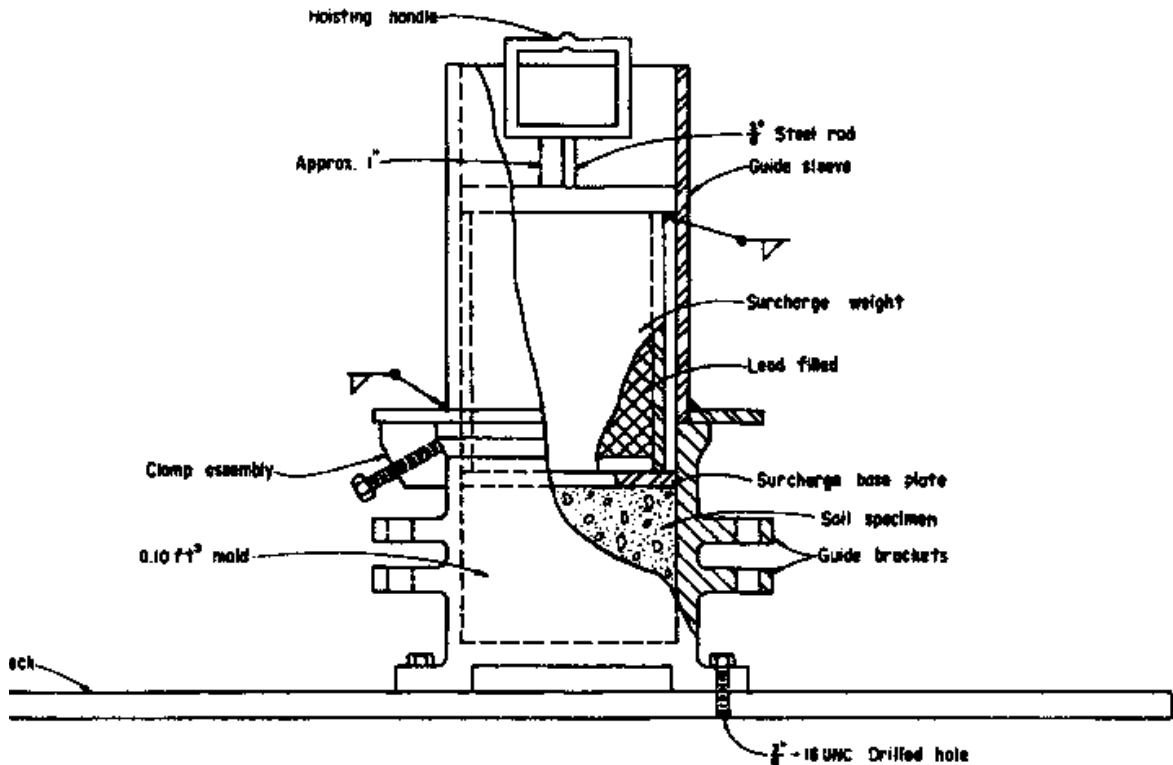
**3.1.2 Special Molds**—Cylindrical metal molds having a capacity less than 0.100 ft<sup>3</sup> (2 830 cm<sup>3</sup>), an inside diameter equal to or greater than 2 ¾ in. (70 mm), but less than 4 in. (100 mm) and conforming to the design methodology presented in Fig. 3. Such molds may only be used when the test results are to be used in conjunction with design or other special studies or both, and there is not enough soil to use the 0.100 ft<sup>3</sup> (2 830 cm<sup>3</sup>) mold.

**3.1.3 Guide Sleeves**—One guide sleeve with clamp assembly, or other suitable attachment devices [see Fig. 4(a)], for each size mold.

**3.1.4 Surcharge Base Plates**—One surcharge base plate for each standard size mold conforming to the requirements of Fig. 4.

**3.1.5 Surcharge Weights**—One surcharge weight for each size mold. See Fig 4 for tolerances related to the 0.100 ft<sup>3</sup> (2 830 cm<sup>3</sup>) and 0.500 ft<sup>3</sup> (14 200 cm<sup>3</sup>) molds. For special molds, similar tolerances should be maintained. The total mass of the surcharge base plate and surcharge weight shall be equivalent to a surcharge stress of  $2.00 \pm 0.02$  lb/in.<sup>2</sup> ( $13.8 \pm 0.1$  kPa) for the mold being used. For special molds, the surcharge weight can be composed of a single solid mass of metal.

**3.1.6 Surcharge Base-Plate Handle**—A device used to initially place and then to remove the surcharge base plate upon completion of densification. An example of such a handle is given in Fig 4(b); however, any convenient hooking device may be used.



**FIG. 1 Schematic Drawing of a Typical Mold Assembly**

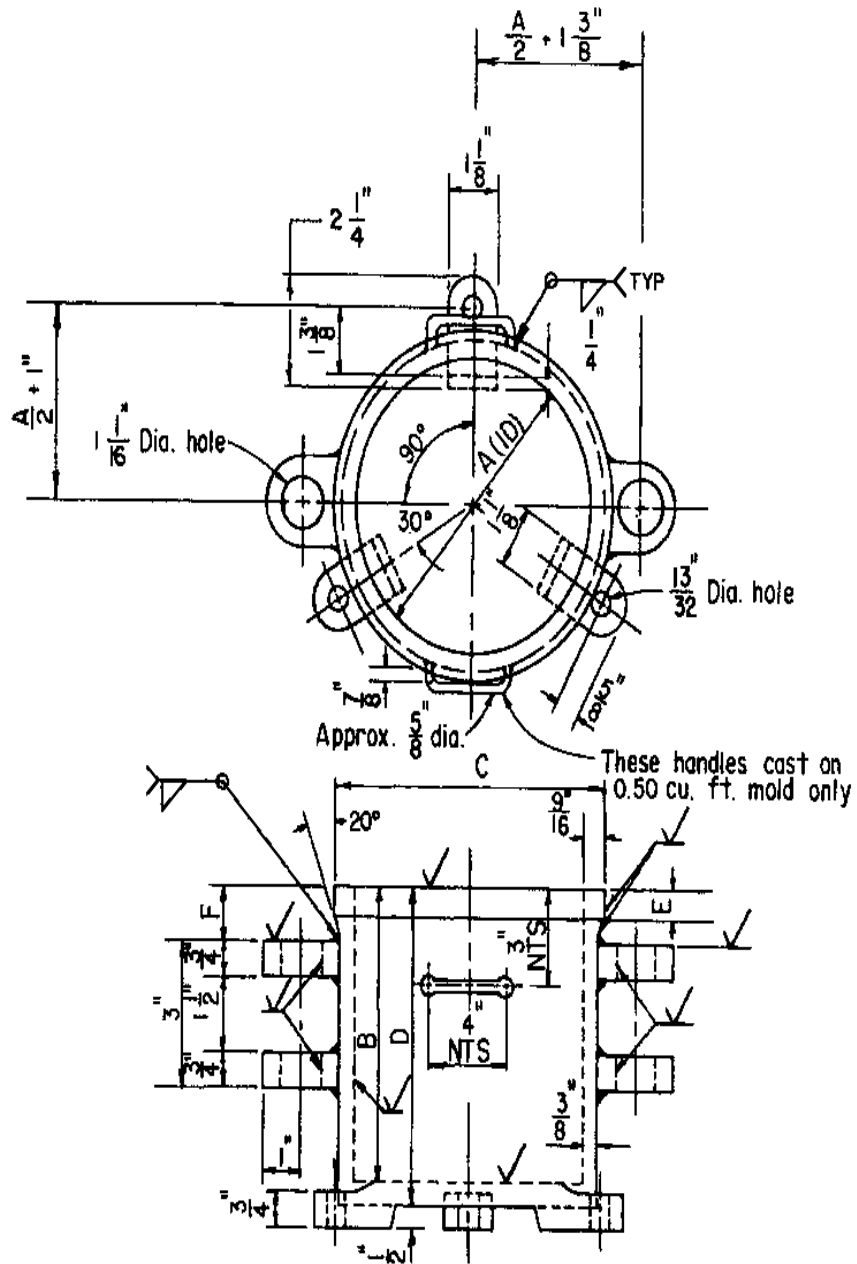
**3.2. Dial-Indicator Gage Holder and Dial Indicator**—A device used, in conjunction with the guide brackets, to measure the difference in elevation between the top surfaces of the mold and surcharge base plate after densification [Fig. 4(c)]. The dial indicator shall have a 2 in. (50 mm) or greater travel with 0.001 in. (0.025 mm) graduations and mounted so that the dial stem is parallel with the vertical axis of the mold. The dial indicator may be of the clockwise-movement type where the dial pointer reads zero when the stem is extended, or of the counterclockwise type where the dial pointer reads zero when the stem is all the way in.

**3.3. Balance** of sufficient capacity to determine the total mass of the specimen and mold, having sufficient accuracy that the mass of the soil is determined to the nearest 0.1%.

**3.4. Hoist** A rope, chain, or cable hoist of at least 300 lb. (140 kg) capacity when either the 0.100 ft<sup>3</sup> (2 830 cm<sup>3</sup>) or 0.500 ft<sup>3</sup> (14 200 cm<sup>3</sup>) size molds are being used.

**3.5. Drying Oven** thermostatically controlled, preferably of the forced-draft type, capable of maintaining a uniform temperature of 230° F throughout the drying chamber.

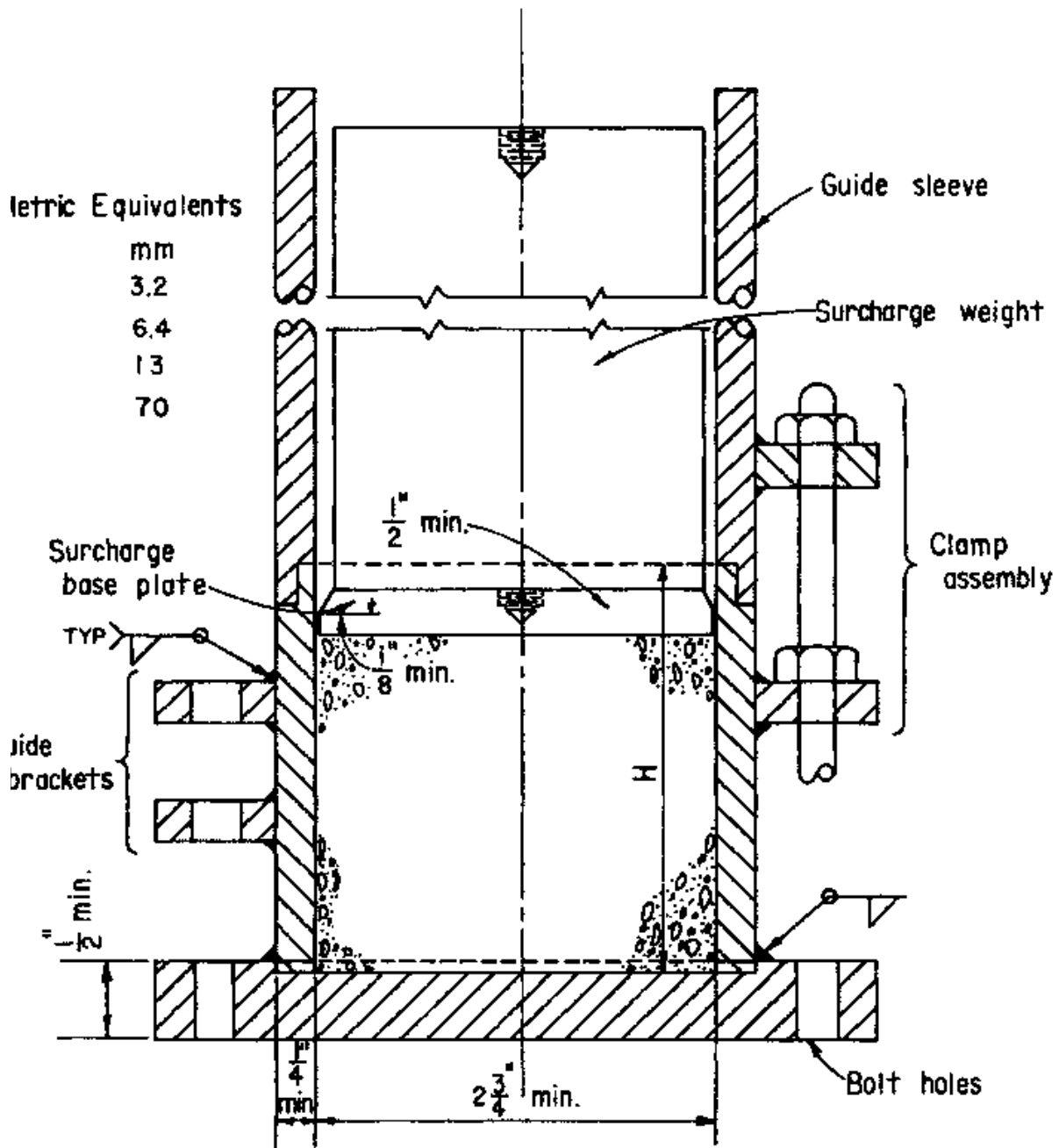
**3.6. Sieves**, 3 in. (75 mm), 1 ½ in. (37.5 mm), ¾ in. (19 mm), ⅜ in. (9.5 mm), No.4 (4.75 mm), and No. 200 (75 µm).



Note 1—Tolerances are  $\pm\frac{1}{64}$ in. ( $\pm 0.4$  mm) unless otherwise noted.

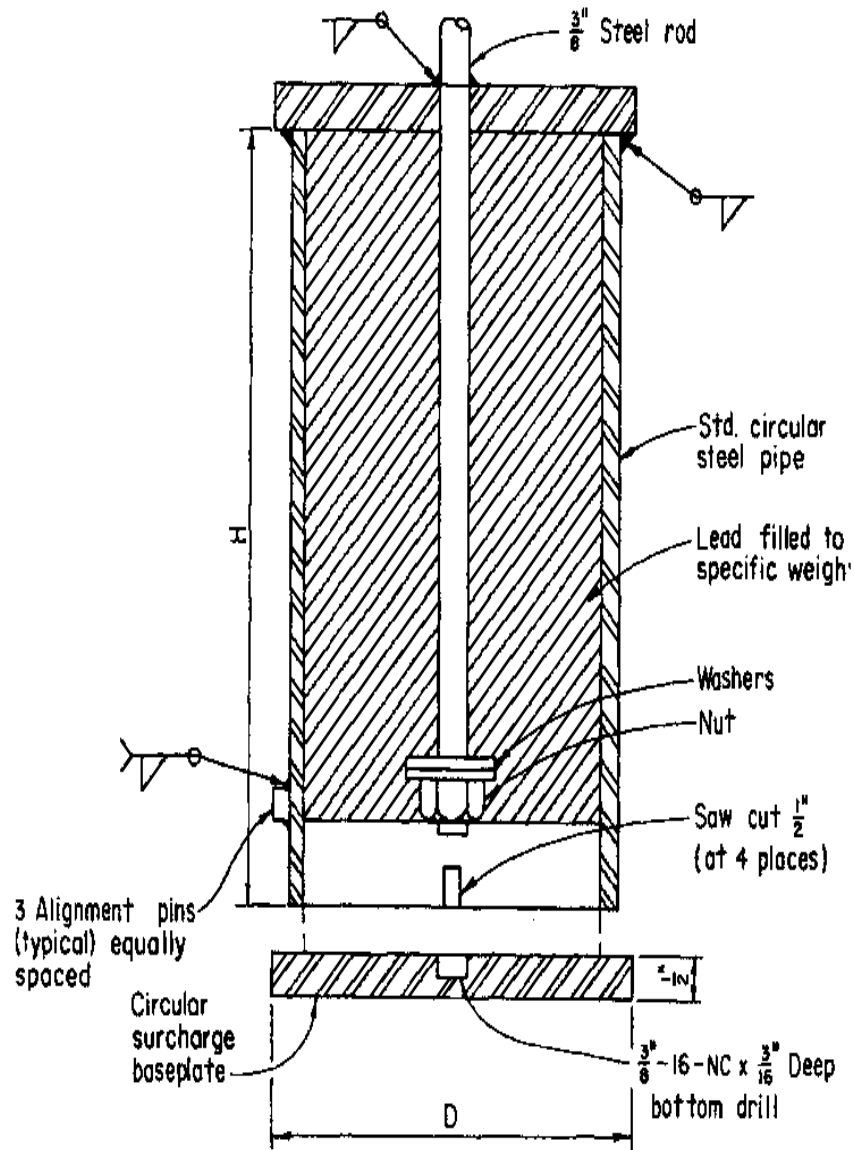
Size Mold ft <sup>3</sup> (cm <sup>3</sup> )	Dimensions, in. (mm)					
	A ( +0.005 in. / -0.000 )	B ( +0.005 in. / -0.000 )	C	D	E	F
0.100 (2830)	6.000 (152.4)	6.112 (155.2)	7 $\frac{1}{16}$ (181.0)	6 $\frac{1}{2}$ (105.1)	$\frac{1}{2}$ (12.7)	1 $\frac{1}{4}$ (28.6)
0.500 (14 200)	11.000 (279.4)	9.092 (230.9)	12 $\frac{1}{16}$ (308.0)	9 $\frac{1}{2}$ (241.3)	$\frac{3}{4}$ (15.9)	2 (50.8)

FIG. 2 Details of Molds



H = (0.7 to 1.3) times diameter  
**FIG. 3 Special Cylindrical Metal Molds**





NOTE 1—All plates shall be 1/2-in. (12.7-mm) thick steel.

NOTE 2—Top plates for weights may be torch-cut, but edges must be ground as smooth as practicable. Surcharge base plates must be machined to the specified diameter.

NOTE 3—Hoisting handles shall have the same shape as the surcharge base plate handle (see Fig. 4 (b)).

Size Mold, ft <sup>3</sup> (cm <sup>3</sup> )	D, in. (mm)	H, in. (mm)	Standard Pipe, in. (mm)	Total Weight Required, lb (kg)
0.100 (2830)	5 1/4 (151)	6.0 (150)	4.0 (100)	56.5 ± 0.5 (25.6 ± 0.2)
0.500 (14 200)	10 3/4 (278)	9.0 (230)	10 (250)	190 ± 2 (86.2 ± 0.9)

FIG. 5 Circular Surcharge Weight and Base Plate

**3.7. Calibration Bar**, metal, about 3 by 12 by ¼ in. (75 by 300 by 6 mm)

**3.8.** Other equipment such as mixing pans, a large metal scoop, a hair-bristled dusting brush, a timing device indicating minutes and seconds, a micrometer with at least a 1 in. (25 mm) travel and with 0.001 in. (0.025 mm) graduations, and a metal straight edge (for trimming excess soil after it has been placed in the mold.

**3.9. Vibrating Table**, shall be mounted to a concrete floor or mass of sufficient size and configuration that excess vibrations are not transmitted to other testing areas. The vertically vibrating deck of the table shall be of sufficient size and rigidity that the mold assembly being used can be attached and rigidly supported during the test. The table shall be capable of vertically vibrating the mold assembly with a sinusoid-like time-vertical displacement relationship at an average double amplitude (peak-to-peak displacement) of  $0.013 \pm 0.002$  in. ( $0.33 \pm 0.05$  mm) at a frequency of 60 Hz or  $0.019 \pm 0.003$  in. ( $0.48 \pm 0.08$  mm) at 50 Hz under test conditions. The table shall have the capability for adjustment of the frequency of vibration (between 0 to 60 Hz) or double amplitude of vibration, or both, between about 0.005 in. (0.15 mm) and 0.013 in. (0.33 mm) at 60 Hz or about 0.007 in. (0.20 mm) and 0.019 in. (0.48 mm) at 50 Hz for use with Methods 1A, 1B, 2A, or 2B (11.2.3). The table shall have the capability for adjustment of the double amplitude of vibration between about 0.008 in. (0.20 mm) and 0.025 in. (0.64 mm) at 60 Hz or about 0.012 in. (0.30 mm) and 0.036 in. (0.91 mm) at 50 Hz for use in conjunction with design or other special studies.

**3.9.1.1. Electromagnetic Vibrating Table** – A steel table conforming to the requirements of **3.9** with a vertically vibrating, cushioned steel deck generally about 30 by 30 in. (760 by 760 mm), actuated by an electromagnetic vibrator of the solid-impact type with a net mass over 45 kg. The table shall be mounted to a concrete floor or slab having a mass of about 450 kg.

**3.9.1.2. Eccentric or Cam-Driven Vibrating Table**, conforming to the requirements of **3.9**. The mass required to support cam driven tables and eliminate vibrations in other areas may be as large as 4500 kg.

## **4. SAMPLE AND TEST SPECIMEN**

**4.1.** Prior to testing, the sample should be stored in a manner to prevent freezing, contamination with other matter, loss of soil, or loss of identification.

**4.2.** The required size (mass) of the test specimen and mold is a function of the maximum particle size contained in the sample and the particle-size distribution (gradation) of the sample (see Table 1).

**4.2.1.** Using a visual method or Test Method KT-02 (depending upon the complexity of the gradation of the sample and operator experience), determine the percentage of particles retained on the 3 in. (75 mm), 1 ½ in. (37.5 mm), ¾ in. (19.0 mm), ¾ in. (9.5 mm), No. 4 (4.75 mm), and No. 200 (75 µm) sieves.

**4.2.2.** The determination of the maximum index density/unit weight should not be performed in accordance with these test methods unless the following requirements are met. Soils that may contain up to 15%, by dry mass, of soil particles passing a No.200 (75 µm) sieve, provided they still have cohesionless, free-draining characteristics. Further, these test methods are applicable to soils in which 100%, by dry mass, of soil particles pass a 3 in. (75 mm) sieve. If these conditions are met, then the mold

size and specimen mass required can be determined according to the maximum particle size as prescribed in Table 1.

**4.2.3.** When it is applicable to use special molds, 100% of the sample shall pass the 3/4 in. (19.0 mm) sieve and have less than 10% retained on the 3/8 in. (9.5 mm) sieve.

**4.2.3.1.** The selected test specimen shall have a mass not less than that determined using the following equation:

$$M_r = 0.0024 \cdot V_m$$

where:

$M_r$  = mass required in kg, and

$V_m$  = volume of mold in  $\text{cm}^3$ .

**4.3.** Select a representative specimen of soil that meets the requirements of **4.2.**, using a splitter, riffle, or other method such as quartering.

**4.4.** If Methods 1A or 2A are being performed, dry the specimen in the drying oven, maintained at  $110 \pm 5^\circ\text{C}$  to a constant mass. It is often desirable to obtain the water content of the field sample. If this is the case, determine the water content in accordance with Test Method KT-11.

**4.4.1.** After drying, thoroughly break up the weakly cemented aggregations; avoiding the reduction of the natural size of the particles.

**TABLE 1 Required Mass of Specimen**

Maximum Particle Size (100% Passing) in. (mm)	Mass of Specimen Required, lb. (kg)	Size of Mold to be Used, $\text{ft}^3$ ( $\text{cm}^3$ )
3 (75)	75 (34)	0.500 (14 200)
1 1/2 (38/1)	75 (34)	0.500 (14 200)
3/4 (19.0)	25 (11)	0.100 (2830)
3/8 (9.5)	25 (11)	0.100 (2830)
No. 4 (4.75) or less	25 (11)	0.100 (2830)

## 5. PROCEDURE

### 5.1. Initial Dial Reading

Insert the dial indicator gage holder in each of the guide brackets with the dial gage stem in contact with the rim of the mold (at its center) on both sides of the guide brackets. Obtain six sets of dial indicator readings, three on each side of each guide bracket. The average of these twelve readings is the initial dial gage reading,  $R_i$ . Record  $R_i$  to the nearest 0.001 in. (0.025 mm).

### 5.2. Dry Method—Methods 1A or 2A:

**5.2.1,** Mix the oven-dried specimen to provide an even distribution of particle sizes; that is, having as little segregation as possible.

**5.2.2.** Fill the mold with soil and level the surface of the soil using methods that minimize segregation. A scoop or pouring device (funnel) should be used to place the soil in the mold. The sides of the mold may be struck a few times using a metal bar, rubber hammer, or similar item to settle the soil so that the surcharge base plate can be easily placed into position and there is no surge of air from the mold when vibration is initiated.

**5.2.3.** Place the appropriate surcharge base plate on the surface of the soil and twist it slightly several times so that it is firmly and uniformly in contact with the surface of the soil. Remove the surcharge base-plate handle.

**5.2.4.** Attach the mold to the vibrating table.

**5.2.5.** Firmly attach the guide sleeve to the mold and lower the appropriate surcharge weight onto the surcharge base plate.

**5.2.6.** Setting for double amplitude of vibration.

**5.2.6.1. Method 1A**—Set the vibrator control (rheostat) at the setting determined in the calibration of the vibration table for the mold assembly being used to obtain a double amplitude of vertical vibration of  $0.013 \pm 0.002$  in. ( $0.33 \pm 0.05$  mm) at 60 Hz or  $0.019 \pm 0.003$  in. ( $0.48 \pm 0.08$  mm) at 50 Hz.

**5.2.6.2. Method 2A**—Set the eccentric or cam at the setting determined in the calibration of the vibration table for the mold assembly being used to obtain a double amplitude of vertical vibration of  $0.013 \pm 0.002$  in. ( $0.33 \pm 0.05$  mm) at 60 Hz or  $0.019 \pm 0.003$  in. ( $0.48 \pm 0.08$  mm) at 50 Hz.

**5.2.6.3.** There is a relationship between density/unit weight and double amplitude of vibration, and the peak density/unit weight occurs at an optimum double amplitude of vibration which may not be the same as the maximum index density/unit weight obtained at the double amplitude of vibration prescribed in **5.2.6.1** and **5.2.6.2**. Therefore, this method allows the use of a double amplitude of vertical vibration other than those prescribed in **5.2.6.1** or **5.2.6.2** if the following conditions are met:

**5.2.6.3.1.** Test results are to be used in conjunction with design or special studies or both, and

**5.2.6.3.2.** The double amplitude of vertical vibration used should be: (A) the optimum double amplitude of vertical vibration (see the Appendix X1 of ASTM D4253 for a recommended method to obtain the optimum double amplitude of vibration), (B) less than 0.025 in. (0.64 mm) at 60 Hz or 0.037 in. (0.94 mm) at 50 Hz, and (C) greater than 0.008 in. (0.20 mm) at 60 Hz or 0.012 in. (0.30 mm) at 50 Hz (except when filling the mold for the wet method, 11.2.3). In terms of nominal peak acceleration, these values are greater than about 1.5 g ( $14 \text{ m/s}^2$ ) and less than about 4.8 g ( $45 \text{ m/s}^2$ ).

**5.2.7.** Vibrate the mold assembly and specimen for  $8 \pm 1/4$  min at  $60 \pm 2$  Hz or for  $12 \pm 1/4$  min at  $50 \pm 2$  Hz. Remove the surcharge weight and guide sleeve from the mold. Check that the surcharge base plate is firmly and uniformly in contact with the surface of the soil; that is, does not wobble when pressed at the edges. If it wobbles, this should be noted on the report form (data sheet).

**5.2.8.** To obtain and record dial indicator gage readings on opposite sides of the surcharge base plate, place the indicator gage holder in each of the guide brackets. Brush aside any fines that might have collected on the surcharge base plate where these readings will be taken.

**5.2.9.** Remove the surcharge base plate from the mold and detach the mold from the vibratory table. During this step, prevent (as much as possible) any fines that have collected on the surfaces of the surcharge base plate and the rim of the mold from entering the mold. If the mass of these fines is greater than about 0.2 % of the total mass of the specimen, determine the mass and note it on the report form (data sheet).

**5.2.10.** Determine and record the mass of the mold and soil using a balance. To calculate and record the mass of the soil filling the mold, subtract the mass of the empty mold from the mass of the mold and soil. Alternately, the contents of the mold may be emptied into a pan and weighed. Calculate the maximum-index density/unit weight,  $\rho_{dmax,n}$ , in accordance with Section f.

**5.2.11.** Steps **5.2.1-5.2.10** should be repeated until consistent values of maximum index density/unit weight (preferably within 2%) are obtained. If excessive degradation (particle breakdown) of the soil is suspected, a sufficient quantity of representative soil sample should be provided (if possible), so that a single test specimen is not repeatedly subjected to step **5.2.7**.

### **5.3. Wet Method—Methods 1B or 2B:**

**5.3.1.** The wet method may be conducted on either oven-dried soil to which sufficient water is added or, if preferred, on wet soil from the field. Mix the sample to provide an even distribution of particle sizes and water content with as little segregation as possible. If water is added to dry soil, allow a minimum soaking period of about 1/2 h. The amount of water added should be sufficient enough that free water does not accumulate in the mixing pan, and the specimen will become basically saturated during the densification process.

**5.3.2.** Attach the mold to the vibrating table.

**5.3.3.** With the vibrating table turned on, slowly fill the mold with wet soil using a scoop or shovel. After each increment of soil is added, inspect to see if a small amount of free water has accumulated on the soil surface. If not, add a sufficient amount of water by squeezing from a sponge, pouring from a small container, or by other means. During this process, which is to take 5 to 6 minutes, the double amplitude or the frequency or both, of vibration must be adjusted to prevent excessive boiling and fluffing of the soil. During and just after the final minute of vibration, any water appearing above the surface of the soil should be removed using means which prevent, as much as possible, the removal of soil.

**5.3.4.** Assemble the surcharge base plate, surcharge weight, and guide sleeve as specified in **5.2.3** and **5.2.5**.

**5.3.5.** Vibrate the mold assembly and specimen as specified in **5.2.6-5.2.7**. After the vibration period, remove the surcharge weight and guide sleeve from the mold. Remove any free water appearing above, on, and around the surcharge base plate.

**5.3.6.** Obtain and record dial indicator-gage readings in accordance with **5.2.8**.

**5.3.7.** Remove the surcharge base plate and detach the mold from the vibratory table in accordance with **5.2.9**. If a determination of the specimen water content is desired, determine and record the mass of the mold and soil. Carefully remove the entire wet specimen from the mold, placing it in a pan of known mass for oven drying. Wash all particles clinging to the inside of the mold and bottom of the base plate into the pan. Dry the specimen in a drying oven, maintained at  $110 \pm 5^\circ\text{C}$  to a constant mass. Determine and record its oven-dried mass, using a balance.

## 6. CALCULATION

**6.1.** Calculate the maximum index density for each trial (see **5.2.11**) as follows:

$$\rho_{dmax,n} = Ms / V$$

where:

$\rho_{dmax,n}$  = maximum index density for given trial, Mg/m<sup>3</sup> or g/cm<sup>3</sup>

$Ms$  = mass of the tested-dry soil, Mg or g, and

$V$  = volume of the tested-dry soil, m<sup>3</sup> or cm<sup>3</sup>, being equal to:

$$V = V_c - (A_c \cdot H \cdot \text{Conversion Factor})$$

with: Conversion Factor given in Table 2; and

$V_c$  = calibrated volume of mold, m<sup>3</sup> or cm<sup>3</sup>,

$A_c$  = calibrated cross sectional area of mold, m<sup>2</sup> or cm<sup>2</sup>,

and

$H$  = positive difference in elevation between top surfaces of mold and tested soil (bottom surface of surcharge base plate), m or cm, being equal to:

$H = R_f - R_i + T_p$  for clockwise-reading dial indicator, or

$H = R_i - R_f + T_p$  for counterclockwise-reading dial indicator.

with:

$R_i$  = initial dial reading (see **5.1**), mm or in.,

$R_f$  = average of final dial gage readings on opposite sides of the surcharge base plate after completion of the vibration period, mm or in., and

$T_p$  = thickness of surcharge base plate, mm or in.

**6.1.1.** Calculate the average maximum-index density/unit weight from the trials of the dry method that agree within 2%, see **5.2.11**. This average value is to be recorded/reported as the maximum-index density,  $\rho_{dmax}$ .

**6.1.1.1.** If it is established that the wet method produces a maximum-index density/unit weight higher than the dry method and this higher value would significantly affect its application, then the result of the wet method should be used.

**6.1.2.** If requested, calculate the maximum-index unit weight of the specimen as follows:

$$\gamma_{dmax} = 9.807 \cdot \rho_{dmax}, \text{ kN/m}^3, \text{ or}$$

$$\gamma_{dmax} = 62.428 \cdot \rho_{dmax}, \text{ lbf/ft}^3$$

where:

$\rho_{dmax}$  = maximum-index unit weight, kN/m<sup>3</sup> or lbf/ft<sup>3</sup>

9.807 = conversion factor, Mg/m<sup>3</sup> or g/cm<sup>3</sup> to kN/m<sup>3</sup>, and

62.428 = conversion factor, Mg/m<sup>3</sup> or g/cm<sup>3</sup> to lbf/ft<sup>3</sup>.

**6.2.** If requested, calculate the minimum-index void ratio,  $e_{min}$ , as follows:

$$e_{min} = [(\rho_w \cdot G_{avg}) / \rho_{dmax}] - 1$$

where:

$e_{\min}$  = minimum-index void ratio,

$\rho_w$  = density of water at 20°C (0.99821) or equal to 1 Mg/m<sup>3</sup> or g/cm<sup>3</sup>,

$\rho_{d\max}$  = maximum-index density, Mg/m<sup>3</sup> or g/cm<sup>3</sup>,

and

$G_{\text{avg}@20^\circ\text{C}}$  = weighted average specific gravity of soil solids composed of particles larger and smaller than the No. 4 (4.75 mm) sieve being equal to:

$$G_{\text{avg}@20^\circ\text{C}} = 1 / [(R / 100G_{1@20^\circ}) + (P / 100G_{2@20^\circ\text{C}})]$$

with:

$G_{1@20^\circ\text{C}}$  = apparent specific gravity of the soil solids retained on the No. 4 sieve as determined by Test Method ASTM C127 and corrected to 20°C (see Test Method ASTM D854),

$G_{2@20^\circ\text{C}}$  = specific gravity of the soil solids passing the No. 4 sieve as determined by Test Method ASTM D854,

$R$  = percentage of soil particles retained on the No. 4 sieve, and

$P$  = percentage of soil particles passing the No. 4 sieve.

**TABLE 2 Dial Reading Conversion Factors for Volume Calculations**

Volume Requirements	Factor	
	Dial Reading Units	
	mm	in.
m <sup>3</sup>	0.001	0.0254
cm <sup>3</sup>	0.1	0.2540

## 7. REPORT

7.1. The report shall include the following information:

7.1.1. Origin of material used in test.

7.1.2. Description of appearance of test specimen, based on **ASTM Practice D2488 (Practice D2487 may be used as an alternative)**.

7.1.3. The Methods (1A, 1B, 2A, or 2B) and size of mold used.

7.1.4. Double amplitude of vertical vibration used if different from that specified in **5.2.6.1** or **5.2.6.2**.

7.1.5. The maximum index density,  $\rho_{d\max}$ , Mg/m<sup>3</sup> or g/cm<sup>3</sup> or maximum-index unit weight,  $\gamma_{d\max}$  in lbf/ft<sup>3</sup> (kN/m<sup>3</sup>), or both, to four significant digits (in accordance with ASTM Practice D6026).

7.1.6. Any abnormalities such as loss of material, segregation, or excessive tilt of base plate.

5.9.70 METHOD FOR TESTING POLYMER OVERLAYS FOR SURFACE PREPARATION AND ADHESION (Kansas Test Method KT-70)

**1. SCOPE**

This method covers the test procedure used to measure the tensile rupture strength between hydraulic cement concrete and polymer concrete overlays. This test procedure may involve hazardous materials, operations, and equipment. Follow all manufacturer suggested safety precautions when performing the test.

**NOTE:** “Polymer Overlay” represents the complete system; polymer adhesive and aggregate bonded to the concrete bridge deck.

**2. REFERENCED DOCUMENTS**

**2.1.** None.

**3. APPARATUS**

**3.1.** A dynamometer with a minimum capacity of 2000 lbf (1000 kg).

**3.2.** A mechanical testing device for pulling a bonded pipe cap in tension as shown in **Figure 1** below.

**3.3.** Core drill with a 2 inch (50 mm) inside diameter diamond tipped core barrel.

**3.4.** A standard 1 1/2 inch (37 mm) diameter pipe cap, where the bottom surface has been machined smooth, flat, and shoulder cut to provide a 2 inch (50 mm) diameter bonding surface. The surface of the pipe cap should be textured to provide good adhesion to the adhesive. This may be achieved by sandblasting, scoring or any method that produces a roughened bonding surface.

**3.5.** A rapid curing adhesive with strength and viscosity properties suitable for bonding the pipe caps to the overlay. A high viscosity, rapid setting epoxy with a pot life of 3 to 25 minutes is recommended.

**3.6.** Calipers or other measuring device.

**3.7.** Small propane torch (optional).

**3.8.** Surface and internal thermometers.

**3.9** Duct tape.

**Note:** Test equipment for this procedure is available in other forms and may be used with the approval of the Engineer.

**4. PREPERATION OF TEST PATCHES**

**4.1.** Select 1 1/2 foot x 3 foot (0.5 m x 1.0 m) areas of the bridge deck for the polymer concrete test patches. The test patches should cover various surface conditions found on the bridge deck. Typical surface conditions tested should include areas in the wheel paths, in the area between wheel paths and in other areas that represent nominal as well as the worst surface conditions.



**4.2.** Clean test patch areas by the same method to be used to prepare the entire deck. Remove all loose disintegrated concrete, dirt, paint, oil, asphalt, laitance carbonation and curing materials from patches and other foreign material from the surface of the deck that can interfere with the curing or adhesion of the overlay. Cleaning is usually indicated by a significant change in the color of the concrete and exposing coarse aggregate particles.

**4.3.** Tape off an area 1 1/2 foot x 3 foot (0.5 m x 1.0 m) using duct tape. Measure and record the temperatures of the air, deck surface, polymer components and aggregate.

**4.4.** Mix the polymer components as prescribed by the manufacturer using the same equipment, timing, and sequence of operation as will be used when placing the overlay on the full deck surface.

**4.5.** Collect a 2 ounce (50 mL) sample of the mixed polymer and measure and record the polymer gel time. The gel time is the time interval between the initial mixing of the polymer and the formation of a gelatinous mass in the center of the sample.

**4.6.** Accurately prepare sufficient quantities of the polymer mixture for each test patch. Place the polymer on each 0.5 square yard (0.5 sq m) prepared test area. Spread the polymer with a notched squeegee in the same manner as on the full deck surface. Apply the polymer uniformly without puddling. Apply the dry overlay aggregate on each test patch at the same rate as specified in Contract Documents.

**4.7.** Allow the polymer to cure as required to allow sweeping or vacuuming without damaging the surface (curing time varies according to temperature). Curing of the first course can be checked by placing thumb on the aggregate and applying pressure. If the aggregate moves, curing has not been sufficient. See **Table 1** for typical minimum cure times.

**4.8.** Remove excess aggregate.

**4.9.** Accurately measure sufficient quantities of the polymer mixture for each test patch. Place the polymer on the first course of each 0.5 square yard (0.5 sq m) test area. Spread the polymer with a notched squeegee in the same manner as on the full deck surface. Apply the polymer uniformly without puddling. Apply the dry overlay aggregate on each test patch at the same rate as specified in Contract Documents.

**4.10.** Allow the polymer to cure as required to prevent damage from traffic. See **TABLE 1** for typical minimum cure times.

**4.11.** Remove excess aggregate

**TABLE 1**

**TYPICAL POLYMER CONCRETE OVERLAY CURE TIMES.**

COURSE	AVERAGE TEMPERATURE OF OVERLAY COMPONENTS, °F (°C)						
	55-59 (13-15)	60-64 (16-18)	65-69 (19-21)	70-74 (22-23)	75-79 (24-26)	80-85 (27-29)	85+ (29+)
	MINIMUM CURE TIME, hrs.						
<b>1</b>	5	4	3	2.5	2	1.5	1
<b>2</b>	8	6.5	5	4	3	3	3

## 5. PROCEDURE

**5.1.** Using a diamond tipped core barrel, drill through the polymer overlay and into the concrete surface to a depth of 1/2 inch (13 mm). The dimensions of the core barrel must be such that the resulting concrete core is 2 inches (50 mm) in diameter. Do not use water for the coring operation.

**5.2.** Vacuum or blow the dust from around the core. Bond a 1 1/2 inch (37 mm) pipe cap that has been machined to have a flat bottom surface of 2 inches (50 mm) in diameter, to the cored overlay disk. The adhesive used to bond the pipe cap to the overlay should be a rapid curing adhesive with a minimum working life of 3 minutes. Apply a small amount of adhesive to both the pipe cap surface and the cored disk. Do not allow any adhesive to flow over the edge of the cored disk or down into the cored area. If this occurs, do not record the test result, core an alternate area and perform another test. To decrease the curing time of the epoxy adhesives, heat may be applied to pipe cap by means of a small propane torch. Do not heat the cored disk directly! Monitor the temperature of the pipe cap. Do not allow the cap temperature to exceed 120°F (49°C).

**5.3.** It is of the utmost importance that the tensile rupture equipment and dynamometer be aligned with the extended axis of the pipe cap to give accurate test results. To ensure the alignment of the apparatus alignment the use of a template is advised.

**5.4.** Screw the lower threaded hook into the cap. Place the testing apparatus over the pipe cap and align with the cored disk.

**5.5.** Attach the dynamometer to the upper and lower hooks. Set the load indicator on the dynamometer to zero. Check the date of calibration on the dynamometer. It must have been calibrated within the last 12 months.

**5.6.** Apply a tensile load at the rate of  $100 \pm 10$  pounds ( $45 \pm 5$  kg), every 5 seconds.

**5.6.1.** Record the load for each test core to the nearest 10 lbf (5 kg).

**5.6.2.** Record the type of failure for each test core and percent failure in the concrete over the test area for *Type 1* and *Type 2* failures.

There are five types of failures:

- *Type 1* - Failure in the concrete at a depth greater than or equal to 1/4 inch (6 mm) over more than 50% of the test area.
- *Type 2* - Failure in the concrete at a depth less than 1/4 inch (6 mm) over more than 50% of test area.
- *Type 3* - Separation of the polymer overlay from the concrete surface.
- *Type 4* - Failure within the polymer overlay.
- *Type 5* - Failure of the test adhesive.

A properly applied polymer overlay on a properly prepared surface typically will result in a failure in the concrete (*Type 1*).

**5.6.3.** Using calipers, take two measurements of the diameter of the specimen to the nearest 0.01 in (0.25 mm). The measurements are taken at right angles to each other.

**5.6.4** The two measurements taken in **Section 5.6.3.** of this test method are averaged for determining the cross-sectional area of the specimen.

**5.7.** Perform a minimum 4 pull-off tests on each 1 1/2 foot x 3 foot (0.5 m x 1.0 m) test patch.

**5.8.** Repair the hole created by the tensile rupture strength test with a mixture of the polymer and aggregate used in the overlay.

## **6. CALCULATIONS**

**6.1.** Use the 3 highest values to calculate the Tensile Rupture Strength for the test patch as noted below.

**6.1.1.** For *Type 1* failures:

- Tensile Rupture Strengths less than 250 psi (1.7 MPa) will not be used in the average tensile rupture calculation.
- Should one pullout fail below 250 psi (1.7 MPa) the test result will be the average of the two remaining pull-off tests.
- Should two pullouts fail below 250 psi (1.7 MPa) the test result will be the Tensile Rupture Strength of the one remaining test.
- A failure *in the concrete* below 250 psi (1.7 MPa) indicates weak concrete, not poor overlay bond.

**6.1.2.** For *Type 2, 3* or *5* failures use the average of the three highest pull-off values to determine the Tensile Rupture Strength.

**6.1.3.** *Type 4* failures will not be accepted or used in calculations.

**6.2.** Determine the Tensile Rupture Strength for each test core using the following equation:

$$TRS_x = \frac{P}{A}$$

$TRS_x$  = Tensile Rupture Strength for one test core.

P = Load (Dynamometer)

A = Area of cored disc, verify the area prior to performing the calculations.

**6.2.1** This value will be recorded as the result for one test core. Record the result to nearest 10 psi (0.1 MPa).

**6.3.** Determine the average Tensile Rupture Strength for each test patch using the following equation.

$$TRS_{avg} = \frac{TRS_1 + TRS_2 + \dots + TRS_n}{n}$$

n = number of test cores

## **7. REPORT**

**7.1** This value will be recorded as the result for one test patch. Report the result to nearest 10 psi (0.1 MPa).



**Figure 1**



## 5.9.71 AIR-VOID ANALYZER (Kansas Test Method KT-71)

### **1. SCOPE**

This method of test covers the determination of characteristics of the air-void system of freshly mixed concrete using a sample of mortar. Spacing factor, specific surface and entrained air content are determined by capturing air bubbles released from a mortar sample.

The sample will only be representative of the depth of the concrete within approximately 2.5 in (60 mm) below the level at which the sampling is begun. This method is applicable to fresh concrete with a minimum slump of 0.4 in (10 mm) and air content between 3.5 and 10% by volume. Only air voids less than 0.1 in (3 mm) in diameter are measured by this method. The test must be performed in sheltered, stable conditions.

### **2. REFERENCED DOCUMENTS**

**2.1.** Part V, 5.9; Sampling and Test Methods Foreword

**2.2.** KT-18; Air Content of Freshly Mixed Concrete by the Pressure Method

**2.3.** KT-19; Air Content of Freshly Mixed Concrete by the Volumetric Method

**2.4.** KT-20; Mass per Cubic Foot (Meter), Yield, and Air Content (Gravimetric) of Freshly Mixed Concrete

**2.5.** KT-21; Slump of Portland Cement Concrete

**2.6.** ASTM C457; Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete

### **3. APPARATUS**

**3.1.** The balance shall conform to the requirements of **Part V, Section 5.9; Sampling and Test Methods Foreword** for the class of general purpose balance required for the principal sample mass of the sample being tested. The balance shall also have an integral arm from which the dish can be suspended.

**3.2.** Analysis and data collection apparatus assembly, the sampling equipment and materials is designed and built to function as an integrated system that is demonstrated by the manufacturer to accurately measure and calculate air-void distribution in fresh air-entrained concrete.

**3.3.** Riser cylinder made of clear plastic with a base and a collar approximately as shown in **Figure 1**. The base shall have an integral heating element capable of maintaining the analysis liquid at  $73 \pm 4^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) and entry holes for the plastic rod and the sample syringe with gaskets to make a watertight seal.

**3.4.** Magnetic stirrer capable of maintaining 300 rpm during mixing.

**3.5.** A cabinet shall house the riser cylinder, magnetic stirrer and balance as shown in **Figure 2**.

**3.6.** A ferromagnetic steel rod approximately 0.2 in (5 mm) in diameter and 2.5 in (62 mm) in length.

**3.7.** A temperature sensor capable of detecting the temperature of the analysis liquid at the bottom of the cylinder. The temperature sensor should be capable of measuring the temperature to within  $1.0^\circ\text{F}$  ( $0.5^\circ\text{C}$ )

in the range of 59 to 86°F (15 to 30°C) and of transmitting such measurements to the computer through an appropriate interface.

**3.8.** 20 ml plastic syringes, with the tapered end removed, calibrated and marked for collecting the specified sample volume as shown in **Figure 3**.

**3.9.** Plastic rod at least 1.5 in (35 mm) longer than the width of the base. The outside diameter of the body of the rod is the same as the syringes used in the test. A 0.04 in (1 mm) length at the end of the rod shall have a reduced diameter that fits tightly within the inside diameter of the syringe as shown in **Figure 3**.

**3.10.** Clear, shallow dish that is large enough to cover the entire area of the cylinder, retain the rising bubbles and fit within the collar. The dish shall have an opening on the side to allow entrapped air to be removed.

**NOTE:** An inverted Petri dish with an appropriate slot, as shown in **Figure 3**, can fulfill these requirements.

**3.11.** A device to suspend the dish from a balance arm by a single wire as shown in **Figure 3**.

**3.12.** Control System. A computer, software and interface system capable of controlling the test, recording data, and displaying data at least once per minute during the test. It shall also calculate, display and record the air content(s), air-void spacing factor, and specific surface of the air-void system.

**3.13.** Sampling assembly to hold the syringe and a wire cage and vibrate at approximately 50 Hz with an amplitude that allows the mortar to flow into the wire cage.

**NOTE:** A drill operating at 3000 rpm with an eccentrically weighted, forked assembly as shown in **Figure 4** can fulfill these requirements. The hammering function of the drill can be used as needed in stiffer concrete mixes.

**3.14.** A wire cage that is of sufficient size to obtain a sample of fresh concrete mortar, similar to **Figure 4**. The cage wires shall have a clear spacing of 0.24 in (6 mm).

**3.15.** Rigid, clear plastic plate approximately 10 x 10 x 1/8 in. (250 x 250 x 3 mm) with a center hole of a diameter approximately 1/8 in (3 mm) greater than that of the wire cage.

**3.16.** A calibrated funnel marked for measuring a specified amount of analysis liquid similar to that shown in **Figure 4**. The funnel is capable of introducing the analysis liquid into the bottom of the water-filled riser cylinder with a minimum of mixing.

**3.17.** A spatula to trim the mortar sample flush with the end of the syringe.

**3.18.** A water container with a 2 gallon (4 liter) minimum capacity.

**NOTE:** A 5 gallon (19 liter) portable insulated drinking water cooler is useful for repeated testing.

**3.19.** An immersible heating element capable of maintaining the water in the container at approximately 73 ± 4°F (23 ± 2°C).

**3.20.** Thermometer accurate to ± 1.0°F (± 0.5°C) over the range of 50 to 86°F (10 to 30°C).

**3.21.** Brush with a handle longer than the riser cylinder is tall and an angled head.

**3.22.** An insulated “cooler-type” lunchbox is useful.

**3.23.** Sealable plastic bags, commercially available in pint and quart sizes.

#### **4. MATERIALS**

**4.1.** Analysis Liquid. The analysis liquid shall have physical and chemical properties such that the air-void bubbles remain discrete. The viscosity of the analysis liquid must remain constant over the range of temperatures found in the test and be compatible with the apparatus and the control system. The viscosity of the analysis liquid used shall provide a measurable separation in time between the arrivals of bubbles of different sizes at the top of the water column. The analysis liquid and its viscosity shall be specified by the equipment manufacturer.

**NOTE:** A commercially-available solution of glycerol in water can fulfill these requirements. A mixture of 4 parts glycerol to 1 part distilled water has been known to work well.

**4.2.** De-Ionized water from the Materials and Research Chemistry Lab. The water shall be de-aerated and maintained at atmospheric pressure and approximately  $73 \pm 4^{\circ}\text{F}$  ( $23 \pm 2^{\circ}\text{C}$ ) for a minimum of 12 hours before use.

**NOTE:** Properly de-aerated water is crucial to this test. The solubility of air in water increases as pressure increases and temperature decreases. The change in dissolved air content due to temperature occurs slowly; thus, the water must be maintained at constant temperature for a minimum of 12 hours before use. De-aerated water also reabsorbs air when cooled. If the water is not de-aerated correctly or if it is used shortly after reheating, air may be liberated in the riser cylinder. Air bubbles may form in the riser cylinder and on the dish, and may have a considerable effect on the specific surface and spacing factor results.

**4.3.** Ice as needed in cubes or chips or frozen, re-freezable ice packs or cubes.

#### **5. SAMPLING**

**5.1.** Take samples as soon as possible after the concrete is in the desired state. The sampling location depends on the purpose of the test. Samples can be extracted from concrete in place (pavements, structural members, decks, etc.), from concrete sampling containers such as unit weight buckets, beam molds, or cylinder molds, or from other locations.

**5.2.** Insert a syringe into the sampling assembly and mount the wire cage onto the sampling assembly. Fully collapse the syringe.

**5.3.** Place the plastic plate in good contact with the surface of the concrete to be sampled. Begin the vibration of the sampling assembly. Lower the wire cage through the hole in the plastic plate into the concrete. The vibration will cause the mortar fraction of the concrete to flow into the wire cage. Advance the wire cage into the concrete at a rate such that the concrete surface under the plate and the surface of the mortar within the cage remain at approximately the same level at all times. Avoid filling the cage with surface mortar by pressing the plastic plate against the fresh concrete. The pressure is adequate when the air bubbles under the plastic plate do not move towards the hole while sampling.



**5.4.** Advance the wire cage into the concrete until the end of the syringe plunger is in full contact with the surface of the mortar. While maintaining the vibration, push the syringe cylinder smoothly into the mortar at such a rate that the wire cage remains full of mortar until the syringe is fully extended. Stop the vibration and withdraw the wire cage and syringe from the concrete.

**5.5.** Remove the wire cage and the syringe from the sampling assembly saving the excess mortar from the wire cage. Pack this excess mortar around the end of the syringe to be used to displace any large air bubbles from the syringe.

**5.6.** Immediately place the sample in a plastic bag on ice or freezer packs in the insulated box to retard the onset of initial set. Testing must begin before the initial set of the concrete.

**5.7.** If large air bubbles are present at the base of the syringe, remove the plunger and pack enough excess mortar through the opposite end of the syringe to remove the air bubble. Replace the plunger to contact the mortar. Remove the excess mortar from the outside of the syringe and clean the outside of the syringe with a damp cloth. Advance the plunger to the mark corresponding to the specified sample volume and trim the mortar flush with the end of the syringe cylinder using the spatula. Retract the plunger approximately 0.04 in (1 mm) to allow room for the recessed end of the plastic rod. This step may be performed at any time before **Section 7.9** of this test method, seating the syringe on the plastic rod.

## **6. PREPARATION OF APPARATUS**

**6.1.** Bring the analysis liquid and at least 0.5 gallon (2 liters) of de-aerated water to a temperature of  $73 \pm 4^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ) without altering other characteristics of the liquids.

**NOTE:** Using ice in sealed plastic bags, or freezer packs to cool the liquids is acceptable.

**6.2.** Select a test location protected from any wind, vibration or movement that may affect the balance readings. Place the cabinet on a stable and level surface. Allow the balance to stabilize so that it does not drift more than 0.01 g in four minutes. If the balance has auto-zeroing capability, place a small load on the balance to obtain a non-zero reading in order to observe the variation of the reading.

**6.3.** Connect the control system.

**NOTE:** Place the control system so that if the plastic rod is accidentally removed from the base of the riser cylinder the contents of the riser cylinder will not spill onto the control system.

**6.4.** See **Section 11** of this test method for additional hints on preparation of apparatus.

## **7. PROCEDURE**

**7.1.** Enter all required data into the control system.

**7.2.** Place the stirrer rod flat on the bottom of the riser cylinder. Insert the plastic rod through the hole on the wider side of the base of the riser cylinder so that the full diameter of the plastic rod protrudes through the hole on the opposite (narrower) side of the base.

**NOTE:** Using a light coat of waterproof grease on the rubber o-rings will improve the seal between the plastic rod and the base of the riser cylinder.

**NOTE:** When testing low-viscosity materials such as self-consolidating concrete, it is permissible to tilt the riser column to seat the syringe on the plastic rod before the liquids are added to the riser column.

**7.3.** Fill the riser cylinder with de-aerated water to about 0.5 in (15 mm) above the bottom of the top collar. Use the brush to remove all bubbles from the stirrer rod, the plastic rod and the riser cylinder.

**NOTE:** Rotating the plastic rod can be helpful in assuring that all bubbles are removed.

**7.4.** Mount the riser cylinder in position on the cabinet. It is permissible to fill the riser cylinder with the water after positioning the riser cylinder on the cabinet.

**7.5.** Fill the funnel with the manufacture's specified amount of the analysis liquid.

**7.6.** Insert the analysis liquid into the bottom of the riser cylinder using the funnel to minimize the mixing of the analysis liquid with the de-aerated water. Replace the stopper once the specified amount of analysis liquid has been discharged. Remove the funnel from the riser cylinder and discard any remaining liquid in the funnel.

**7.7.** Connect the integral heating element of the riser cylinder and the temperature sensor to the control system.

**7.8.** Insert the dish into the riser cylinder collar. Submerge the dish in the de-aerated water and tilt to allow all entrapped air to escape through the opening. Suspend the dish from the balance arm in such a way that it is approximately centered and does not touch the walls of the riser cylinder collar. Only a single wire of the suspension device may break the surface of the water. Add more de-aerated water if necessary.

**7.9.** Seat the syringe containing the sample on the reduced end of the plastic rod. Move the syringe and plastic rod together through the riser cylinder base until the junction of the syringe and plastic rod is at the nearest inside edge of the riser cylinder. Leaving the syringe in position, continue withdrawing the plastic rod until the reduced end is flush with the opposite inside edge of the riser cylinder.

**NOTE:** To make positioning the plastic rod and syringe with respect to the riser cylinder easier, mark the correct position on the plastic rod and note the position of the syringe before starting the test. If moving the plastic rod and syringe is difficult, use a small amount of waterproof grease or analysis fluid on the gaskets and use a twisting motion.

**7.10.** Remove enough of the air that may have risen during the separation of the syringe and the plastic rod from under the dish so that the dish is neither touching nor close to the wall of the riser cylinder collar.

**7.11.** When the temperature of the analysis liquid as measured by the temperature sensor is  $73 \pm 4^{\circ}\text{F}$  ( $23 \pm 2^{\circ}\text{C}$ ), inject the mortar from the syringe into the riser cylinder. Immediately start the mixing and data collection.

**7.12.** If any of the recorded temperature readings are outside the range of  $73 \pm 4^{\circ}\text{F}$  ( $23 \pm 2^{\circ}\text{C}$ ), discard the test.

**7.13.** If unusual variations that may be due to vibration or disturbance are noted in the data, discard the test.

**7.14.** Analyze samples as soon as possible. However, samples may be used whenever they can be completely dispersed in the analysis liquid by the stirring action.

## **8. REPORT**

**8.1.** The report shall include the following information:

**8.2.** Project identification

**8.3.** Test identification number

**8.4.** Date of test

**8.5.** Sampling location

**8.6.** Slump by **KT-21** (if known)

**8.7.** Air content by **KT-18** or **KT-19** (if known)

**8.8.** Unit weight by **KT-20** (if known)

**8.9.** Mortar (material less than 6 mm) volume, percent, as calculated from the mix design

**8.10.** Paste volume, percent, as calculated from the mix design

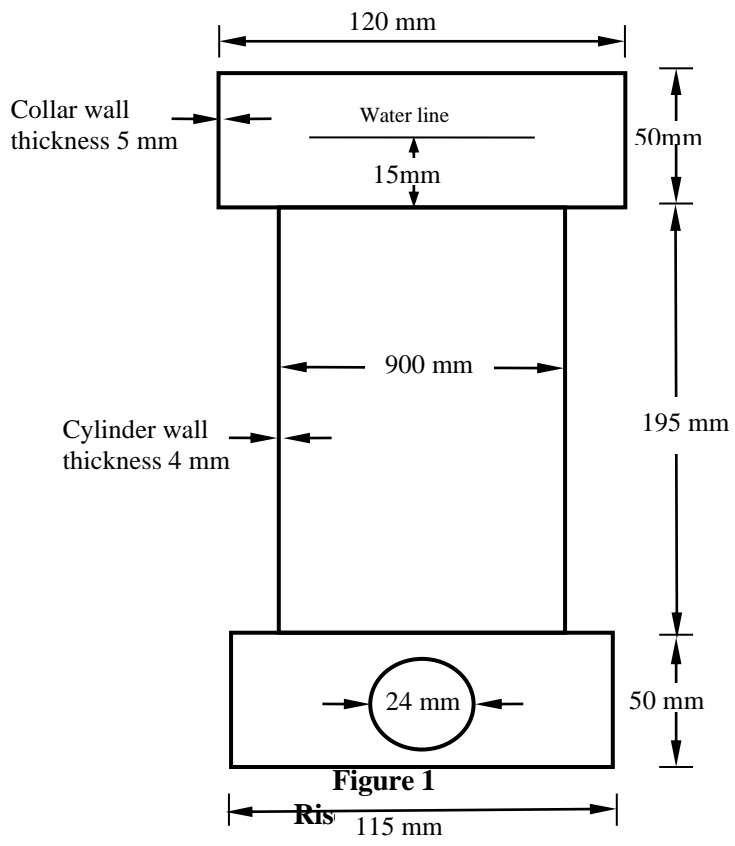
**8.11.** Sample volume, ml

**8.12.** Test temperature range, °F (°C)

**8.13.** Air content(s), percent

**8.14.** Spacing factor, in (mm)

**8.15.** Specific Surface, in<sup>2</sup>/in<sup>3</sup> (mm<sup>2</sup>/mm<sup>3</sup>)

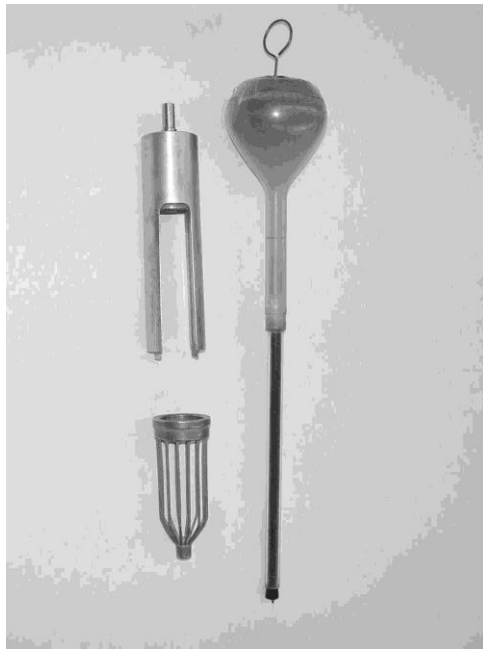




**Figure 2**  
**Typical Apparatus with Riser Cylinder, Cabinet,**  
**and Computer**



**Figure 3**  
**Petri dish, 20 ml syringe,**  
**and temperature sensor**



**Figure 4**  
**Wire cage and funnel**

## 9. VERIFICATION

**9.1** To correlate the air-void characteristics (spacing factor, entrained air content or specific surface) as determined by the buoyancy-change method from fresh concrete with those obtained by **ASTM C457** from hardened concrete, compare a minimum of five pairs of samples. Each pair of samples of the fresh and hardened concrete should be from the same batch of concrete, placed and consolidated uniformly, of comparable depth and located as close together as possible without including any of the area disturbed during sampling the fresh concrete in the hardened sample. Calculate the percent difference of the buoyancy test results from the **ASTM C457** results for each pair, and then average these percent differences. The average of the percent differences of the five pairs of should be 20% or less for the results to be considered equivalent. Average percent differences greater than 20% may arise from **ASTM C457** testing errors such as mistaking fly ash spheres or voids left by sand grains plucked from the polished surface of the specimen during sample preparation for air voids in the concrete paste. Sampling errors, testing errors in the buoyancy change method, admixtures that affect the viscosity or the miscibility of fresh concrete, or other factors may also cause some variation. The buoyancy change method is less likely than **ASTM C457** to overestimate the quantity and quality of the air voids in any given concrete. In the buoyancy change method, bubbles may coalesce after release into the fluid, and the portion of entrained air associated with the coarse aggregate is excluded from the sample. Thus the buoyancy change method will tend to give a lower specific surface and higher spacing factor than **ASTM C457**.

## **10. REPEATABILITY**

**10.1** Although each buoyancy test requires a unique sample and therefore cannot be duplicated exactly, researchers at the Kansas Department of Transportation have found that pairs of samples obtained within 1.5 feet of each other in the field vary 10% from each other on average.

## **11. SET UP HINTS**

**11.1** Several steps can be taken to reduce the amount of time necessary to set up the buoyancy testing equipment. Preparing the de-aerated water and the bottle of analysis liquid in an insulated water container at least one day before testing occurs will save time. If the water container will be stored in an area that is cooler than the specified temperature, set the immersible heater to the correct temperature and put it into the covered water container. If the room temperature is slightly higher than the specified temperature, uncovering the container will allow the water to cool approximately 5°F (3°C). If the room temperature is much higher than the specified temperature, a sealed bag of ice or freezer packs placed in the covered water container the night before testing will generally result in the correct water and analysis fluid temperature.

**11.2** After the water has been brought to the proper temperature, care should be taken to keep the temperature as constant as possible. Protect the water container from temperature extremes, such as may be encountered in an enclosed vehicle.

**11.3** Obtaining a constant balance reading at the beginning of the test may also take a significant amount of time if the equipment is set up in an unstable location. Mobile work trailers that are resting on their tires are generally not stable enough. Any movement by people in the trailer can move the trailer enough to disturb the apparatus and render the test unusable. Generally, only trailers that have been put up on blocks so they are not sitting on their tires are at all acceptable, and only as a last alternative.

**11.4** Isolating the test equipment from vibration will reduce the time necessary to obtain a constant balance reading at the beginning of the test. One or two anti-vibration pads may be used under each corner of the cabinet to attenuate shock and vibration.

## 5.9.72 MEASURING FLOWING CONCRETE (Kansas Test Method KT-72)

### **1. SCOPE.**

These test methods cover the procedure for determination of static segregation of self consolidating concrete by measuring the coarse aggregate content in the top and bottom portions of a cylindrical specimen and slump flow of the same self consolidating concrete. **KT-72** reflects testing procedures found in **ASTM C1610** and **ASTM C1611**.

### **2. REFERENCED DOCUMENTS**

**2.1.** KDOT Construction Manual, Part V, Section 5.6.

**2.2.** KT-17; Sampling Freshly Mixed Concrete

**2.3.** ASTM C1610; Static Segregation of Self-Consolidating Concrete Using Column Technique

**2.4.** ASTM C1611; Slump Flow of Self-Consolidating Concrete

**2.5.** ASTM D1785; Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

### **3. APPARATUS.**

**3.1.** A Balance conforming to the requirements of **Part V, Section 5.9; Sampling and Test Methods Foreword** for the class of general purpose required for the principal sample mass of the sample being tested.

**3.2.** Column Mold; the column portion of the mold shall be poly(vinyl chloride) (PVC) plastic pipe Schedule 40 meeting the requirements of **ASTM D1785**. The column shall be 8 in (200 mm) in diameter by 26 in (660 mm) in height and separated into 3 sections. The top section shall be 6.5 in (165 mm) in height, the middle section 13 in (330 mm) in height, and the bottom section 6.5 in (165 mm) in height, as shown in **Figure 1**. Each section shall have its ends flat and plane and be marked as “Top”, “Middle”, or “Bottom” relative to its location in the column. Couplers, brackets, clamps, or other equivalent fastening systems shall be used for securing the column sections together to form a mortar-tight joint and to secure the column to the base plate. The column mold shall be securely attached to a non-absorbent, rigid base plate measuring at least 12 in (300 mm) by 12 in (300 mm) square.

**3.3.** Collector plate, used to obtain concrete from the top section of the column, shall be made of any nonabsorbent, rigid material measuring at least 20 in (510 mm) by 20 in (510 mm) square. The plate shall contain a cut out section in the center measuring 8.5 in (215 mm) across and it shall contain a rigid lip that is at least 2 in (50 mm) high running around three sides of the perimeter of the plate, as shown in **Figure 2**.

**3.4.** Strike-off bar; a flat, straight steel bar at least 1/8 by 3/4 by 12 in (3 by 20 by 300 mm) or a flat, straight bar at least 0.23 by 0.75 by 12 in (6 by 20 by 300 mm) high density polyethylene or other plastic of equal or greater abrasion resistance.

**3.5.** A No. 4 (4.75 mm) rectangular sieve with minimum dimensions of 13 in (330 mm) by 25 in (630 mm).



3.6. Sample Receptacle – The receptacle shall be a heavy-gauge metal pan, wheelbarrow, or flat, clean nonabsorbent board of sufficient capacity to allow easy remixing of the entire sample with a shovel, trowel, or scoop.

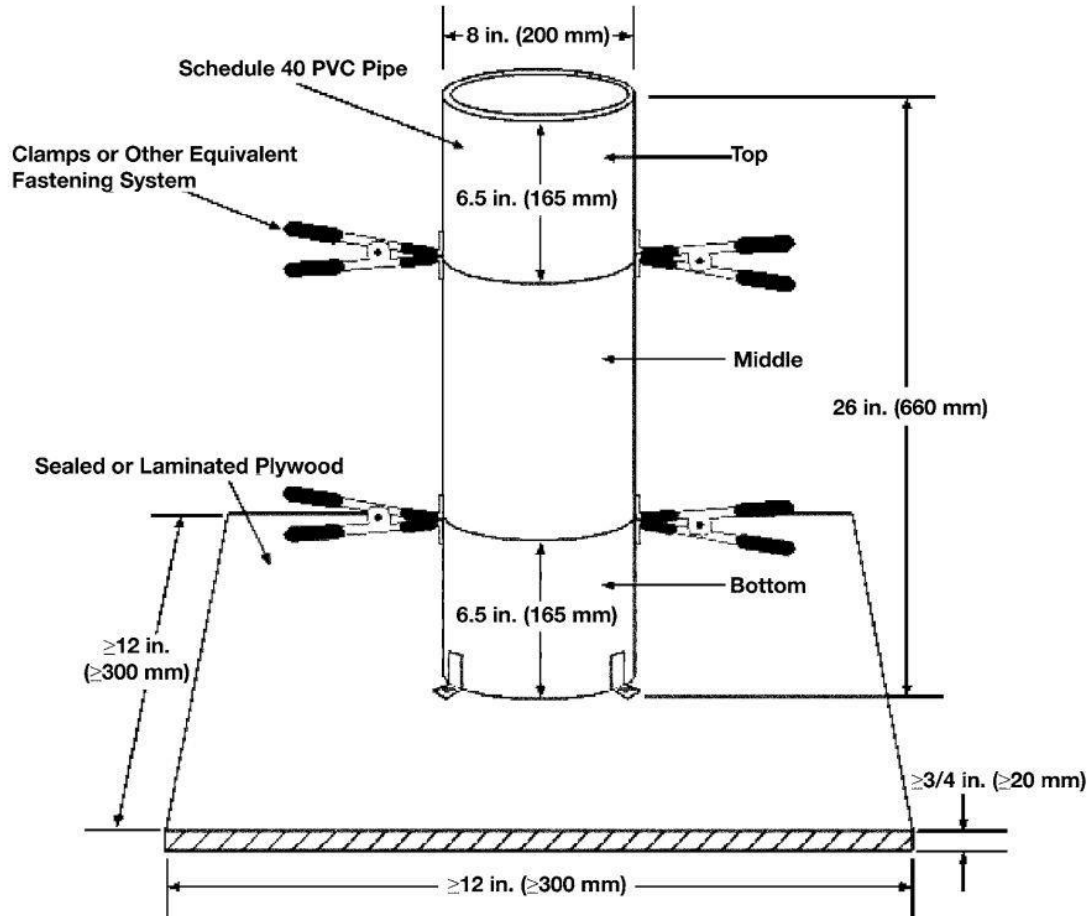
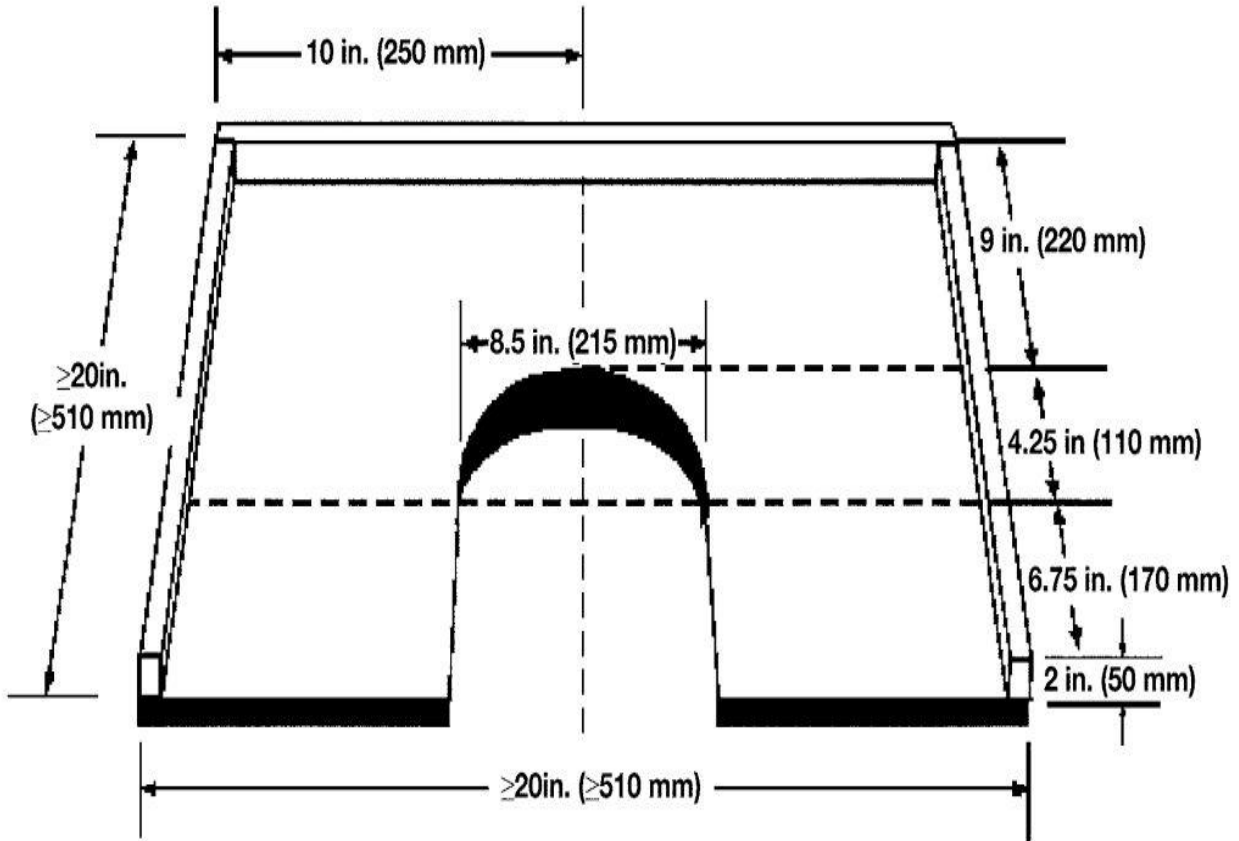


FIGURE 1



**Figure 2**

**3.7.** Tools and items such as shovels, plastic pails, trowels, scoops and rubber gloves shall be provided.

**3.8.** Mold or slump cone fabricated from metal not readily attacked by cement paste. The metal shall not be thinner than 0.060 in (1.5 mm) or if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 in (1.15 mm). The mold shall have the shape of a frustum of a right circular cone and be equipped with handles and foot plates. The dimensions shall meet requirements in **Table 1**:

**Table 1**  
**Mold or Slump Cone Dimensions**

Inside diameter at top	Inside diameter at bottom	Height
4 ± 1/8 in (102 ± 3.2 mm)	8 ± 1/8 in (205 ± 3.2 mm)	12 ± 1/8 in (305 ± 3.2 mm)

**3.9.** Slump Base Plate—The base plate on which the slump mold rests shall be nonabsorbent, smooth, rigid, and have a minimum diameter of 36 in (915 mm).

#### **4. SAMPLE AND TEST SPECIMEN**

**4.1.** Obtain a sample of freshly-mixed self-consolidating concrete in accordance with **KT-17**.

#### **5. PROCEDURE FOR STATIC SEGREGATION TEST**

**5.1.** Perform the column segregation test on a flat, level surface. Do not subject the testing surface and the column mold to any vibration or disturbance.

**5.2.** Remix the sample obtained in accordance with **Section 4** of this test method in the sample receptacle using a shovel or scoop so that the concrete is homogeneous.

**5.3.** Using a shovel, scoop, or plastic pail, immediately fill the column mold with concrete completely and above the rim, within 2 minutes.

**5.4.** After filling the mold, strike off the top surface by sliding the strike-off bar across the top rim of the mold with a sawing motion until the concrete surface is level with the top of the mold.

**5.5.** Allow the concrete to stand undisturbed in the column mold for 15 ± 1 min.

**5.6.** Immediately following the standing period, securely hold the top section of the mold and remove the fastening system. Complete steps in **Sections 5.7-5.14** of this test method within 20 minutes thereafter.

**5.7.** Place the cut out section of the collector plate around the column just below the joint between the “Top” and “Middle” section to catch and collect concrete.

**5.8.** Grasp the upper section of the column mold and, using a horizontal rotating motion, screed the concrete from the top section of the column on to the collector plate and then deposit it into a plastic pail.

**5.9.** Repeat steps in **Sections 5.6-5.8** of this test method to remove the concrete from the middle section of the column mold and discard the concrete.

**5.10.** Place the concrete sample collected from the upper section of the column onto the No. 4 (4.75 mm) sieve.

**5.11.** Wash the concrete on the No. 4 (4.75 mm) sieve so that only coarse aggregate remains on the sieve and then deposit the coarse aggregate into a clean plastic pail.

**5.12.** Repeat steps in **Sections 5.10-5.11** of this test method for the concrete retained in the bottom section of the mold.

**5.13.** Bring the coarse aggregate obtained from both the top and bottom sections of the column to a surface-dry condition by rolling it in a large absorbent cloth until all visible film of water are removed.

**5.14.** Determine the mass of coarse aggregate from the top and bottom sections of the column to the nearest 0.1 lb (50 g).

## **6. PROCEDURE FOR THE SLUMP-FLOW TEST**

**6.1.** The slump-flow test shall be performed on a flat, level, nonabsorbent surface such as a pre-moistened concrete floor or a base plate. The base plate shall be used in conditions where a flat, level surface is not available, such as on a construction job site. When the base plate is used, position and shim the base plate so that it is fully supported, flat, and level. When performing the slump flow test-for a given study or project, do not change the base plate surface type for the duration of the study or project.

**6.2.** The user has the option of filling the mold by following either Procedure A or Procedure B.

**6.2.1 Filling Procedure A (Upright Mold):** Dampen and place the mold, with the larger opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface. Firmly hold the mold in place during filling by the operator standing on the two foot pieces. From the sample of concrete obtained in accordance with **Section 4.** of this test method, immediately fill the mold in one lift. Slightly overfill the concrete above the top of the mold.

**6.2.2. Filling Procedure B (Inverted Mold):** Dampen and place the mold, with the smaller opening of the mold facing down, in the center of a flat, moistened base plate or concrete surface. From the sample of concrete obtained in accordance with **Section 4.** of this test method, immediately fill the mold in one lift. Slightly overfill the concrete above the top of the mold.

**6.3.** Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of  $9 \pm 3$  in ( $225 \pm 75$  mm) in  $3 \pm 1$  second by a steady upward lift with no lateral or torsional motion. Complete the entire test from start of the filling through removal of the mold, without interruption, within an elapsed time of 2.5 minutes.

**6.4.** Wait for the concrete to stop flowing and then measure the largest diameter of the resulting circular spread of concrete to the nearest 1/4 in (5 mm). When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter of the circular spread at an angle approximately perpendicular to the original measured diameter.

**6.5.** If the measurement of the two diameters differs by more than 2 in (50 mm), the test is invalid and shall be repeated.

## 7. CALCULATION

7.1. Calculate the slump flow using the following equation:

$$\text{Slump Flow} = \frac{(d_1 + d_2)}{2}$$

where:

$d_1$  = the largest diameter of the circular spread of the concrete

$d_2$  = the circular spread of the concrete at an angle approximately perpendicular to  $d_1$

7.1.1. Record the average of the two diameters to the nearest ½ in. (10 mm).

7.2. Calculate the percent static segregation using the following equation:

$$S = 2 * \frac{(CA_B - CA_T)}{(CA_B + CA_T)} * 100, \text{ if } CA_B > CA_T$$

$$S = 0, \text{ if } CA_B \leq CA_T$$

where:

$S$  = static segregation, percent

$CA_T$  = mass of coarse aggregate in the top section of the column

$CA_B$  = mass of coarse aggregate in the bottom section of the column

## 8. REPORT

8.1. Mixture designation.

8.2. The mass of coarse aggregate obtained from the top and bottom sections of the column separately to the nearest 0.1 lb (50 g).

8.3. The static segregation to the nearest 0.1%.

8.4. Report the use of filling procedure A or B for the slump flow test.

8.5. Report the slump flow to the nearest 1/2 in (10 mm).

5.9.73 DENSITY, ABSORPTION AND VOLUME OF PERMEABLE VOIDS IN HARDENED CONCRETE (Kansas Test Method KT-73)

## 1. SCOPE

This method covers the determinations of density, percent absorption and percent volume of permeable voids in hardened concrete. **KT-73** reflects testing procedures found in **ASTM C642**.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.3. KT-49; Method for Obtaining and Testing Drilled Cores

2.4. ASTM C642; Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

## 3. APPARATUS

3.1. The balance shall conform to the requirements of **Part V, 5.9.3; Sampling and Test Methods Foreword**, Class G5. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of weighing platform or pan of the balance into a bucket with an overflow device to maintain a constant water level.

3.2. Forced draft oven capable of maintaining a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ).

3.3. Container suitable for boiling the immersed specimens with a rack suitable for supporting the specimens a minimum of  $\frac{1}{4}$ " above the bottom of the container. The container must be large enough to keep the specimens covered with boiling water for a period of 5 hours.

3.4. Hot plate, stove or other heat source capable of maintaining the water at boiling for 5 hours.

## 4. TEST SPECIMENS

4.1. Prepare 3 specimens per sample, each to be tested separately. Each specimen shall consist of a 2" thick by 4" diameter piece taken from the top portion of a cast concrete cylinder or core. Remove not more than  $\frac{3}{8}$ " from the top of the cylinder or core and obtain the specimen from the next 2". Each specimen shall be free from observable cracks, fissures, or shattered edges. Cylinders molded and cured in accordance with **KT-22** of this manual shall be used for mix design approval and most verification samples. Cores obtained in accordance with **KT-49** of this manual may be used for verifications on PCCP.

## 5. PROCEDURE

5.1. Determine the mass of each specimen. Place each specimen on its edge in a forced draft oven directly on the oven rack and dry the specimens at a temperature of  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ ) for not less than 24 hours. Do not place the specimens inside a pan or any other container. Do not place the specimens on the flat surface of the cylinder. Allow enough room between specimens for complete airflow around each specimen. After removing each specimen from the oven, allow it to cool in dry air (preferably in a desiccator) to a temperature of  $72 \pm 5^{\circ}\text{F}$  ( $22 \pm 3^{\circ}\text{C}$ ) and determine the mass. If the specimen was comparatively dry when its mass was first determined, and the second mass agrees with the first within

0.5%, consider it dry. If the specimen was wet when its mass was first determined, place it in the oven for a second drying treatment of 24 hours and again determine the mass. In case of any doubt, redry the specimen for 24 hour periods until check values of mass are obtained. If the difference between values obtained from two successive values of mass exceeds 0.5% of the lesser value, return the specimens to the oven for an additional 24 hour drying period. Repeat this procedure until the difference between any two successive values is less than 0.5 % of the lowest value obtained. Designate this final mass value **A**.

**5.2.** Immerse the specimen on its edge in water at  $72 \pm 5^{\circ}\text{F}$  ( $22 \pm 3^{\circ}\text{C}$ ). Do not place the specimen on the flat surface of the cylinder. Continue soaking the specimen in water for not less than 48 hours and until two successive values of mass of the surface-dried sample at intervals of 24 hours show an increase in mass of less than 0.5% of the larger value. Surface-dry the specimen by removing surface moisture with a towel, and determine the mass. Designate the final surface-dry mass after immersion **B**.

**5.3.** Begin boiling tap water in a suitable container. Verify that the water is rapidly boiling prior to placing the specimens in the water for testing. Place the specimen on its edge on a rack in the boiling water a minimum of 1/4" from the bottom of the container. The water must return to boiling in less than 1 hour. Boil the specimens completely submersed for a minimum of 5 hours. Do not add additional water during boiling. Allow the specimens and water to cool by natural loss of heat for not less than 14 hours to a final temperature of  $72 \pm 5^{\circ}\text{F}$  ( $22 \pm 3^{\circ}\text{C}$ ). Continue to store the specimens on their edges in the boiled water until the final two steps are completed.

**5.4.** Suspend the specimen in the bucket at a constant water level by the suitable apparatus and determine the apparent mass of the specimen in water at  $77 \pm 2^{\circ}\text{F}$  ( $25 \pm 1^{\circ}\text{C}$ ). Designate this apparent mass **D**.

**5.5.** Remove the specimen from the water. Quickly damp-dry the specimen with a damp absorbent cloth and determine the mass of the specimen. Designate the boiled surface-dried mass **C**.

## 6. CALCULATION

**6.1.** Using the values for mass determined in accordance with the procedures described in **Section 5** of this test method make the following calculations:

$$\text{Absorption after immersion, \%} = [(B-A)/A] \times 100$$

$$\text{Absorption after immersion and boiling, \%} = [(C-A)/A] \times 100$$

$$\text{Bulk density, dry} = [A/(C-D)] = g_1$$

$$\text{Bulk density after immersion,} = [B/(C-D)]$$

$$\text{Bulk density after immersion and boiling} = [C/(C-D)]$$

$$\text{Apparent density} = [A/(A-D)] = g_2$$

$$\text{Volume of permeable voids (pore space), \%} = [(C-A)/(C-D)] \times 100$$

Where:

- A = Mass of oven dried specimen in air
- B = Mass of surface-dry specimen in air after immersion
- C = Mass of surface-dry specimen in air after immersion and boiling
- D = Apparent mass of specimen in water after immersion and boiling
- $g_1$  = Bulk density, dry

$g_2 =$  Apparent density

## **7. REPORT**

**7.1.** Record absorption to the nearest 0.01 %.

**7.2.** Record densities to the nearest 0.1 lb/ ft<sup>3</sup> (1 kg/m<sup>3</sup>).

**7.3.** Record the volume of permeable voids (pore space) to the nearest 0.01 % and report to the nearest 0.1%.



## 5.9.76 METHOD FOR TESTING THE COMPRESSIVE STRENGTH OF MOLDED CYLINDRICAL CONCRETE SPECIMENS (Kansas Test Method KT-76)

### **1. SCOPE**

**1.1.** This test method provides standardized procedures for determining the compressive strength of molded cylindrical concrete specimens. This method is not used for testing drilled cores. See **KT-49** of this manual for testing of drilled cores. This method only applies to concrete having a unit weight greater than 50 lb/ft<sup>3</sup> (800 kg/m<sup>3</sup>).

### **2. REFERENCED DOCUMENTS**

**2.1.** KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

**2.2.** KT-49; Method for Obtaining and Testing Drilled Cores From PCCP and Precast Girders

**2.3.** KT-77; Method for Capping Cylindrical Concrete Specimens

**2.4.** AASHTO T 22; Compressive Strength of Cylindrical Concrete Specimens

**2.5.** AASHTO T 231; Capping Cylindrical Concrete Specimens

### **3. SIGNIFICANCE AND USE**

**3.1.** This method may be used to determine the compressive strength of molded cylindrical concrete specimens prepared and cured in accordance with **KT-22** of this manual.

### **4. APPARATUS**

**4.1.** Testing Machine- The testing machine shall comply with requirements set forth in **AASHTO T 22**. The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading corresponding to a stress rate on the specimen of  $35 \pm 7$  psi/s ( $0.25 \pm 0.05$  MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase. The testing machine shall be capable of testing specimens up to and including 12 in (300 mm) in length.

**4.1.1.** Verify that the faces of the bearing blocks are plane every 12 months.

Except for the concentric circles described in AASHTO T 22, Section 5.2., the bearing block faces shall not depart from a plane by more than 0.001 in (0.02 mm) along any 6 in (150mm) length for bearing blocks with a diameter of 6 in (150mm) or larger, or by more than 0.001 in (0.02 mm) in any direction for smaller bearing blocks. New bearing blocks shall be manufactured within one half of this tolerance.

**4.1.2.** Clean and lubricate the curved surfaces of the socket and spherical portion of the upper bearing block every six months. Check for any visible wear on the spherical portion of the upper bearing block during the cleaning and lubrication. Any noticeable wear is cause for replacement of the upper bearing block. The lubricant shall be conventional motor oil.

**4.2.** Caliper and a 12 in (300 mm) steel rule graduated in 0.01 in (0.25 mm).

**4.3.** Metal square to determine the perpendicularity of the ends to the side.

## 5. DETERMINING THE DIAMETER OF SPECIMENS

### 5.1 Determining the Diameter of Specimens.

**5.1.1** Using calipers, take two measurements of the diameter to the nearest 0.01 in (0.25 mm). The measurements are taken at right angles to each other at about mid-height of the specimen.

**5.1.2** The two measurements taken in **Section 5.1.1** of this test method are averaged for determining the cross-sectional area of the specimen.

**5.1.3** Specimens shall not be tested if any individual diameter of a cylinder varies from any other diameter of the same specimen by more than 2%.

## 6. END PREPARATION

**6.1.** End Preparation Prior to Capping - The ends of specimens to be tested in compression shall be essentially smooth, perpendicular to the longitudinal axis, and of the same diameter as the body of the specimen. No point on either end of compressive test specimens shall protrude by more than 0.125 inches (3 mm) from a plane perpendicular to the axis of the specimen at the lowest point of the surface *prior to capping*. If the end exceeds this limit, saw or grind the end of the specimen no more than the amount that is required to correct the condition.

**NOTE:** Prior to capping, the density of a specimen may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

## 7. CAPPING

**7.1** Cap the specimen according to the procedures contained in **KT-77**. Maintain free moisture on the surface of the specimen after capping. The specimen may be returned to standard curing as soon as the cap has hardened. Maintain the specimen in a moist condition at all times until testing.

**7.2.** Measurement - Prior to testing, measure the length of the capped specimen to the nearest 0.01 inch (0.25 mm) and use this length to compute the length-diameter ratio. Take three caliper measurements at 120 degree intervals along the circumference of the circle to determine the average length.

## 8. TESTING

**8.1** Test the specimens for the compression strength at a given age within the time tolerances shown in **Table 1**.

**Table 1 Permissible Time Tolerances**

Test Age	Permissible Tolerance
12 h	± 0.25 h
24 h	± 0.5 h
3 days	± 2 h
7 days	± 6 h
28 days	± 20 h
56 days	± 40 h
90 days	± 2 days

**8.2. Placing the Specimen** - Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically-seated (upper) bearing block. Wipe clean the bearing faces of the upper- and lower-bearing blocks and of the test specimen and place the test specimen on the lower bearing block.

**8.3. Zero Verification and Block Seating** - Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator. As the spherically-seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

**NOTE:** The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

**8.4. Rate of Loading** - Apply the load continuously and without shock.

**8.4.1.** The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of  $35 \pm 7$  psi/s ( $0.25 \pm 0.05$  MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

**NOTE:** For a screw driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

**8.4.2.** During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. Apply the higher loading rate in a controlled manner so that the specimen is not subjected to shock loading.

**8.4.3.** Do not adjust the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

**8.4.4.** Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (See **Figure 1**. For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95% of the peak load. A setting of 60% of peak is recommended. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained and a clear fracture pattern is discernible. Record the maximum load carried by the specimen during the test and note the type of fracture pattern according to **Figure 1**. If the fracture pattern is not one of the typical patterns shown in **Figure 1**, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with **Section 7** of this test method.

## 9. CALCULATIONS

9.1. Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen as follows:

Compressive strength=peak load/area

$$Area = \pi r^2$$

9.2. Determine the length to diameter ratio (L/D), and round the result to the nearest hundredth using the following formula:

$$LD = \text{Length} / \text{Diameter}$$

9.3. If the specimen length to diameter ratio is 1.75 or less, correct compressive strength obtained in Section 9.1 by multiplying by the correction factor shown in Table 2. Interpolate to determine correction factors between the L/D ratios shown.

L/D Ratio:	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87

## 10. REPORT

10.1. Report the results as required by the Contract Documents with the addition of the following information:

10.1.1. Identification number.

10.1.2. Diameter and length, inch (mm).

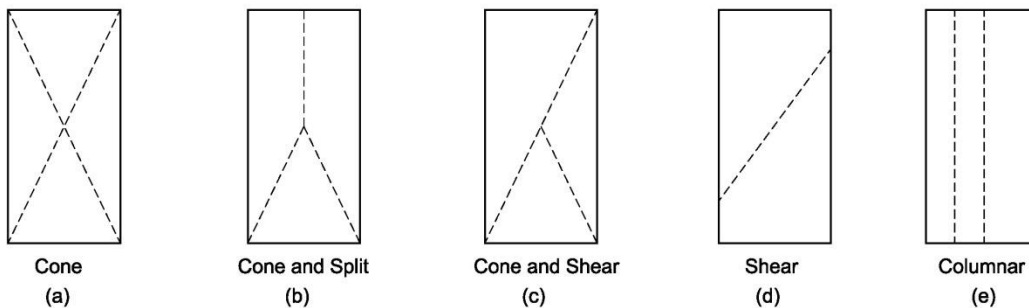
10.1.3. Cross-sectional area, in<sup>2</sup> (cm<sup>2</sup>).

10.1.4. Maximum load, lbf (kN).

10.1.5. Compressive strength (corrected) calculated to the nearest 10 psi (0.1 MPa).

10.1.6. Type of fracture, if other than the usual cone. (See **Figure 1**)

**Figure 1 - Sketches of Types of Fracture**



**10.1.7.** Defects in either specimen or caps.

**10.1.8.** Age of specimen.

**10.1.9.** The moisture conditioning history.

**10.1.10.** The date and time when tested.

**10.1.11.** If determined, the density to the nearest 1 lb/ ft<sup>3</sup> (10 kg/m<sup>3</sup>).

**10.1.12.** If any deviation from this test method was required, describe the deviation and explain why it was necessary.

## **11. PRECISION AND BIAS**

### **11.1. Precision**

**11.1.1.** Within-Test Precision- The acceptable range of individual cylinder strengths between two cylinders under laboratory conditions is 9.0% and 6.6% for 4x8 inch and 6x12 inch cylinders respectively. The acceptable range of individual cylinder strengths between three cylinders under laboratory conditions is 10.6% and 7.8% for 4x8 inch and 6x12 inch cylinders respectively.

**11.1.2.** Multilaboratory Precision- The difference between properly conducted compressive strength tests between two laboratories on 6x12 inch cylinders is not expected to exceed 14% of the average. This does not include variations associated with different operators preparing specimens from split samples. These variations are expected to increase the multilaboratory coefficient of variation.

**11.1.3.** See **AASHTO T-22** for further information on precision.

**11.2.** Bias- Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.



5.9.77 METHOD FOR CAPPING CYLINDRICAL CONCRETE SPECIMENS  
(Kansas Test Method KT-77)

**1. SCOPE**

**1.1.** This test method provides standardized procedures for the capping of cylindrical concrete specimens prior to test for compressive strength. It is intended that capping procedures comply with the applicable sections of **AASHTO T 231**.

**2. REFERENCED DOCUMENTS**

**2.1.** KT-49; Method for Obtaining and Testing Drilled Cores From PCCP and Precast Girders

**2.2.** KT-76; Method For Testing The Compressive Strength of Molded Cylindrical Concrete Specimens

**2.3.** AASHTO T 231; Capping Cylindrical Concrete Specimens

**2.4.** ANSI/ASME B46.1; Surface Texture (Surface Roughness, Waviness and Lay)

**3. SIGNIFICANCE AND USE**

**3.1.** This method describes procedures for providing plane surfaces on the end surfaces of molded concrete cylinders or drilled cores when the end surfaces do not conform to the planeness and perpendicularity requirements of the applicable standards.

**4. APPARATUS**

**4.1.** Metal square to determine the perpendicularity of the ends to the side.

**4.2.** Straight edge and feeler gauges for determining planeness.

**4.3.** Metal Thermometer.

**4.4.** Capping Plates- Sulfur mortar caps shall be formed against a machined metal plate at least 0.45 in (11 mm) thick or a polished plate of granite or diabase at least 3 in (76 mm) thick. In all cases, plates shall be at least 1 in. (25 mm) greater in diameter than the test specimen and the working surfaces shall not depart from a plane by more than 0.002 in (0.05 mm). The surface roughness of newly finished metal plates shall not exceed that set forth in **Table 4 of ANSI B46.1**, or 125  $\mu$  in (0.003 mm) for any type of surface and direction of lay. The surface, when new, shall be free of gouges, grooves, or indentations beyond those caused by the finishing operation. Metal plates that have been in use shall be free of gouges, grooves, and indentations greater than 0.010 in (0.25 mm) deep or greater than 0.05 in<sup>2</sup> (32 mm<sup>2</sup>) in surface area. If a recess is machined into the metal plate, the thickness of the plate beneath the recessed area shall be at least 0.5 in (13 mm). In no case shall the recess in the plate be deeper than 0.5 in (13 mm).

**4.5.** Alignment Devices- Suitable alignment devices, such as guide bars or bull's-eye levels, shall be used in conjunction with capping plates to ensure that no single cap will depart from perpendicularity to the axis of a cylindrical specimen by more than 0.5 degrees (approximately equivalent to 0.125 inches in 12 in. (3.2 mm in 305 mm)). The same requirement is applicable to the relationship between the axis of the alignment device and the surface of a capping plate when guide bars are used. In addition, the location

of each bar with respect to its plate must be such that no cap will be off-centered on a test specimen by more than 0.06 in (1.6 mm).

**4.6. Melting Pots for Sulfur Mortars**-Pots used for melting sulfur mortars shall be equipped with automatic temperature controls and shall be made of metal or lined with a material that is nonreactive with molten sulfur.

## **5. END PREPARATION**

**5.1. End Preparation Prior to Capping** – Prepare the ends of the specimen according to the requirements stated in applicable test method, **KT-49** for drilled cores or **KT-76** for molded cylinders.

**NOTE:** Prior to capping, the density of a specimen may be determined by weighing it and dividing it by the volume calculated from the average diameter and length, or by any other standard method for determining density.

## **6. CAPPING MATERIAL**

**6.1** The capping material shall be a sulfur mortar that has been tested for compressive strength in accordance with **AASHTO T 231 Section 5.4.2**.

**6.2** Capping material shall have a minimum compressive strength of at least 5000 psi (35 MPa) and not less than the compressive strength of the concrete being tested except as allowed in **AASHTO T 231, Section 5.1.1** for concrete strengths greater than 7000 psi when comparison tests of capped and ground specimens have been made.

## **7. CAPPING**

Maintain free moisture on the surface of cylinders after capping. The specimen may be returned to standard curing as soon as the cap has hardened. Cylinders may be wrapped with a moist towel if testing is to occur in 2 hours.

Return cores to the plastic container and reseal until testing.

**7.1** Prepare sulfur mortar for use by heating to about 265°F (130°C). Determine the temperature of the material periodically by inserting a metal thermometer inserted near the center of the mass. Empty the pot and recharge with fresh material at frequent enough intervals to ensure that the oldest material has not been heated more than five times.

**7.2** The ends of the specimen shall be free of oil, wax or other contaminants prior to capping. The ends shall be dry enough to preclude the formation of steam or foam pockets under the cap larger than 0.25 in (6 mm). Moist cured specimens shall be maintained in a moist condition between the completion of capping and the time of testing by returning them to moist storage consistent with the requirements for the type of specimen, cylinders or cores.

**7.3** The capping plate or device should be warmed slightly before use to slow the rate of hardening and permit the production of thin caps. Oil the capping plate lightly and stir the molten sulfur mortar immediately prior to capping. Pour the mortar onto the surface of the capping plate. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies. Lift the cylinder above the plate and contact the cylinder sides with the guides. While keeping the cylinder sides in constant contact with the



guides, slide the cylinder down the guides onto the capping plate. The cylinder end should continue to rest on the capping plate while maintaining positive contact with guides until the mortar has hardened.

**7.4** The capped surfaces of the specimens shall not depart from perpendicular to the axis of the specimen by more than 0.5 degrees; i.e. 0.125 inches in 12 inches (3.2 mm in 305 mm), 0.070 inches in 8 inches (1.8 mm in 200 mm). Perpendicularity may be checked by placing one leg of a notched square on the cap and checking for any clearance between the other leg and side of the cylinder. The surface of the cap shall not depart from plane by more than .002 in (0.05 mm). Caps should be about 0.125 in (3 mm) thick. For specimens with compressive strengths up to 7000 psi (50 MPa), caps shall be no more than 0.31 in (8 mm) thick at any point. For specimens with compressive strengths over 7000 psi (50 MPa), caps shall be no more than 0.20 in (5 mm) thick at any point. Tap the cap with a metal implement after hardening to check for hollow areas under the cap. Remove and replace any cap not meeting these requirements.

**NOTE:** Very high compressive strengths may require caps to be less than 0.080 in (2 mm) to produce accurate test results. Test results may not be valid when using sulfur capping compound on specimens with compressive strengths above 19,000 psi (130 MPa).<sup>1</sup>

**7.5.** Compressive strengths above 7000 psi (50 MPa) require testing of the capping compound as specified in **AASHTO T 231, Section 5.1.1** or grinding so that each end surface is perpendicular to the axis of the specimen within 0.5 degrees or 0.125 inches in 12 inches (3.2 mm in 305 mm) and that the surface does not depart from plane by more than .002 in (0.05 mm). *Testing of the capping compound according to AASHTO T 231 Section 5.1.1, is not required if routine testing of the capping compound indicates that the compound has as high or higher compressive strength than the concrete being tested.*

For specimens with compressive strengths of less than 5000 psi (35 MPa), allow the caps to cure a minimum of two hours prior to testing. For specimens with compressive strengths of greater than 5000 psi (35 MPa), allow the caps to cure for a minimum of 16 hours.

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<sup>1</sup> Acitcin, P.-C., High-Performance Concrete (1998)



5.9.78 METHOD FOR DETERMINING THE TENSILE ADHESIVE STRENGTH OF ASPHALT PAVEMENT TACK COAT (Kansas Test Method KT-78)

## 1. SCOPE

This method covers the test procedure used to measure the tensile adhesive strength of asphalt pavement tack coat. This test procedure may involve hazardous materials, operations, and equipment. Follow all safety precautions when performing the test.

## 2. REFERENCED DOCUMENTS

2.1. Part V, Section 5.2.2.2., Random Sampling.

## 3. APPARATUS

3.1. Grinder or sander.

3.2. Core drill with a 2 inch (50 mm) inside diameter diamond tipped core barrel and a 6 inch (150 mm) nominal diameter diamond tipped core barrel.

3.3. Ice.

3.4. Markers suitable for marking asphalt samples.

3.5. Standard 1 1/2 inch (37 mm) diameter pipe caps, where the bottom surface has been machined flat and the shoulder has been cut to provide a 2 inch (50 mm) diameter bonding surface. See **Figure 1** below. The surface of the pipe cap should be textured to provide good adhesion to the adhesive. This may be achieved by sandblasting, scoring or any method that produces a roughened bonding surface. The surface of the cap must be clean and free of any rust or oil prior to use. Cleaning with acetone prior to each use is recommended.

3.6. A rapid curing adhesive with strength and viscosity properties suitable for bonding the pipe caps to the overlay. A high viscosity, rapid setting epoxy with a pot life of 3 to 25 minutes is recommended.

3.7. Mixing utensils for adhesive. Small plastic cups and tongue depressors are suitable for mixing.

3.8. Electric fan.

3.9. A mechanical testing device for pulling a bonded pipe cap in tension similar to that shown in **Figure 2** below. The device used for this test shall have a feature that eliminates torque being applied to the test specimen.

3.10. A tension link scale, crane scale or dynamometer with a capacity of 500 lbf (200 kg) with resolution and accuracy to 1 lbf (0.5 kg) or better and an ability to retain and display the peak load. The scale must have been calibrated or normalized to a NIST traceable standard within the previous 12 months.

3.11. A table-like fixture with an adjustable shelf below the top surface and with a 3 inch hole in the top surface. See **Figure 3**.

3.12. A digital thermometer with probe, readable to 0.1°F (0.1°C).

**3.13.** Ruler or measuring device.

**3.14.** An oven or propane torch.

**3.15.** A stiff putty knife or scraper.

**3.16.** Calipers.

**3.17.** Framing square.

**3.18.** Wire brush.

**3.19.** Wire rack.

**3.20.** 8x8" pan with fine aggregate.

**Note:** Test equipment for this procedure may be available in various forms and may be used with the approval of the Engineer.

#### **4. OBTAINING SAMPLES**

**4.1.** Select the station at which the samples will taken by method described in **Part V, Section 5.2.2.2., Random Sampling**. Record the time at which the pavement is placed at the selected station. Record the surface condition on which the overlay is placed, i.e. milled surface, existing surface, new pavement.

**4.2.** Sand, grind or wire brush at the coring locations to provide a finish suitable for the adhesive to bond to the surface. The use of right angle grinder with a 36 grit sanding disk to remove surface asphalt and expose the aggregate has proved to be suitable.

**4.3.** Using the 2 inch core barrel, core to a depth  $\frac{1}{4}$  to  $\frac{3}{4}$  inch deeper than the expected overlay depth. The core drill must be oriented perpendicular to the pavement surface to within  $\frac{1}{4}$  inch in 12 inches. Use a framing square to check the perpendicularity at two points 90 degrees apart around the circumference of the core barrel. Core three times in a triangular pattern so the set of two inch cores may be circumscribed by a six inch circle. It is necessary to core to a depth slightly below the overlay but not so deep as to penetrate the layer of pavement on which the overlay is placed. It may be necessary to use ice placed on the sample location for a period of time prior to coring to prevent damage to the sample. The core should remain attached to the pavement. **DO NOT** remove the cores from the pavement.

Coring should be done at slow pace with little downward pressure to avoid damage to the specimen.

**4.3.1.** If the overlay separates from the base during coring, examine the surface of the base layer. Note the location and presence or absence of visible tack. Repeat the steps in **Sections 4.2** through **4.3** at a point 3 feet away in the direction of paving. If the overlay separates at the new location the test result is considered a failure and both locations, presence or absence of tack, and the separation during coring should be recorded.

**4.3.2.** If one of the cores separate in the base layer during coring, note the location and repeat the steps in **Sections 4.2** through **4.3** at a point 3 feet away in the direction of paving. If the cores separate at the new location, the base layer is not strong enough for this test method or the coring technique needs to be evaluated. Both locations and the separation during coring in the base layer should be recorded.

**4.3.3.** If one or two of the cores separate as noted in **Section 4.3.1** or **4.3.2** but a total of three intact cores are obtained, note the separations in the test report and continue with the remainder of the test procedure.

**4.4.** Using the 6 inch core barrel, center the drill over the set of 2 inch cores and core to a depth of nine inches or to the depth of the pavement, whichever is less. Any length of six inch core removed from the hole that includes the substrate on which the overlay was placed and the intact 2 inch cores is acceptable for testing.

**4.5.** Remove the 6 inch core from the pavement using the minimum amount of lateral force necessary to break the core loose.

**4.6.** Gently turn the core over to drain water from the 2 inch cores.

**4.7.** Verify that the 2 inch core barrel reached a depth below the overlay interface by inserting a thin steel ruler or wire witness between the 2 inch cores and the remainder of the 6 inch core. Note that waste material may be present at the bottom of the core in the form of mud or particles that must be gently pushed aside to reach the full depth of the core. Use care not to apply any lateral force to the 2 inch core.

**4.8.** Transport the samples to the field laboratory in an upright manner taking care to avoid any shock that might loosen or dislodge the 2 inch cores.

## **5. TEST PROCEDURE**

**5.1.** In a field laboratory with a controlled air temperature maintained less than 77°F (25°C) place the sample on an elevated wire rack in front of a fan so that air can circulate around the entire sample. Acclimate the sample to room temperature until the temperature at the bottom of the 2 inch core is less than 77°F (25°C). If the sample is cold and damp allow extra time for temperature acclimation.

**5.2.** Bond a 1 1/2 inch (37 mm) pipe cap to the cored overlay disk. The adhesive used to bond the pipe cap to the overlay should be a rapid curing adhesive with a minimum working life of approximately 3 minutes. Apply a thin layer of adhesive to both the pipe cap surface and the cored disk. Attempt to evenly cover the overlay surface and cap filling in all voids. Do not allow any adhesive to flow over the edge of the cored disk down into the cored area. If adhesive reaches the interface of the overlay and the substrate or bonds the cored disk to the remainder of the overlay, do not record the test result.

If samples are to be tested from more than a single location it will save time to bond one cap to each sample at the same time.

The cap may be bonded during the temperature acclimation period in **Section 5.1**.

**5.3.** Determine the temperature by allowing a probe type thermometer to stabilize at room temperature, recording the temperature and then carefully placing the probe in contact with bottom of the 2 inch core. The temperature of the probe must be stable to 0.2°F (0.1°C) for a period of 3 minutes before either reading is taken. Do not apply any lateral pressure to the 2 inch core when inserting the probe.

The use of infrared thermometers is specifically prohibited.

**5.4.** Perform the tensile adhesion test at the time required by the relevant specification.

**5.5.** Place the test specimen on the fixture shelf so that the cap is centered under the hole in the table. If the bottom of the core is not flat a shallow pan filled with fine aggregate may be used to help keep the specimen in an upright position.

Raise the shelf until the top of the core is seated flat against the bottom of the table and the pipe cap is centered in the hole.

**5.6.** Gently screw the eyebolt loosely into the pipe cap. Do not over tighten or apply torque to the sample. Place the apparatus on top of the table centered over the specimen and attach the scale to the apparatus and to the eyebolt in the pipe cap. Set the scale to peak load mode. Without tension on the specimen, zero the scale.

**5.7.** Apply a preload of approximately 10 lbf (5 kg). Position yourself so that a  $\frac{3}{4}$  turn of the handle can be made in a smooth continuous motion. Apply a load with a travel rate of  $0.8 \pm 0.1$  inches per minute. With a thread pitch of 11 threads per inch this corresponds to a rotation rate of the handle of one turn in 6 to 8 seconds or 3 to 4 seconds per half turn.

DO NOT exceed the capacity of the scale.

**5.7.1.** Record the peak load for each test core to the nearest 1 lbf (0.5 kg). If the load exceeds the scale capacity, record the load as 500+ lbf with a note that the capacity of the scale was exceeded.

**5.7.2.** Record the location of failure for each test core and percent failure in the asphalt layer that failed.

Various types of failures:

- Failure at the interface of the top layer and substrate.
- Failure in the top layer.
- Failure in the substrate.
- Failure in the top layer and substrate, record a percentage of top layer vs. substrate.
- Failure in the top layer or substrate and the interface, record a percentage of top layer or substrate vs. interface.
- Failure of the adhesive

**5.7.3** Measure and record the diameter of the core at the failure location. Take two measurements to the nearest 0.001 inch (0.025 mm) at right angles with the calipers.

**5.8.** Repeat **Sections 5.2.** through **5.7.3.** for all three specimens.

**5.9.** Clean the pipe caps by heating in an oven set to 350°F for one hour or by heating with a propane torch until the adhesive degrades to the point that it can scraped from the cap with a putty knife or scraper. Thoroughly clean the cap surface with a wire brush or sandpaper to remove the remainder of the adhesive.

**5.10.** Motorized test equipment may be used with the Engineer's approval.

## **6. CALCULATIONS**

**6.1.** Calculate average diameter for each specimen to the nearest 0.001 inch (0.025 mm).

**6.2.** Calculate cross sectional area to the nearest 0.01 inch<sup>2</sup> (0.25 mm<sup>2</sup>) for each 2 inch specimen.

**6.3.** Calculate the stress at failure to the nearest 0.1 psi (0.7 kPa) for each specimen.

**6.3.1.** If a specimen fails at more than 50% in the surface layer or the substrate and with a value less than required by the specification do not use that sample to calculate the average stress at failure.

**6.3.2.** If the adhesive fails with a value less than required by the specification do not use the test result to calculate the average stress at failure. If the adhesive fails with a value less than required by the specification in all three specimens, the test is inconclusive.

**6.3.3.** If all specimens fail at more than 50% in the surface layer or the substrate and with a value less than required by the specification the test result is inconclusive. This does not indicate a tack coat failure.

**6.4.** Calculate the average stress at failure for the three specimens.

## **7. RECORD AND REPORT**

**7.1.** Record the average stress at failure to the nearest 0.1 psi (0.7 kPa).

**7.2.** Report the average stress at failure to the nearest 1 psi (7 kPa).

**7.3.** Record all test data required on the report form in this method.

**Figure 1.**



**Figure 2.**



**Figure 3.**





**REPORT FORM**  
**KT-78 METHOD FOR DETERMINING THE TENSILE ADHESIVE STRENGTH OF ASPHALT**  
**PAVEMENT TACK COAT**

<b>Project Number:</b>	<b>Station:</b>
<b>Date Placed:</b>	<b>Time Placed:</b>
<b>Time Cored:</b>	<b>Surface:</b>

Sample Id	Location In/Between Wheel Paths	Notes

<b>Sample Id:</b>		<b>Date Tested:</b>		<b>Time Tested:</b>	
<b>Core Temp F:</b>	<b>a</b>	<b>Load lbf:</b>	<b>b</b>	<b>Dia. 1 in.:</b>	
<b>Failure Type:</b>	<b>e</b>	$\pi * (\frac{1}{2}d)^2$	<b>Area:</b>	<b>c</b>	<b>Dia. 2 in.:</b>
	<b>f</b>	<b>a/e</b>	<b>Stress PSI:</b>	<b>d</b>	$\frac{b+c}{2}$

<b>Sample Id:</b>		<b>Date Tested:</b>		<b>Time Tested:</b>	
<b>Core Temp F:</b>	<b>a</b>	<b>Load lbf:</b>	<b>b</b>	<b>Dia. 1 in.:</b>	
<b>Failure Type:</b>	<b>e</b>	$\pi * (\frac{1}{2}d)^2$	<b>Area:</b>	<b>c</b>	<b>Dia. 2 in.:</b>
	<b>f</b>	<b>a/e</b>	<b>Stress PSI:</b>	<b>d</b>	$\frac{b+c}{2}$

<b>Sample Id:</b>		<b>Date Tested:</b>		<b>Time Tested:</b>	
<b>Core Temp F:</b>	<b>a</b>	<b>Load lbf:</b>	<b>b</b>	<b>Dia. 1 in.:</b>	
<b>Failure Type:</b>	<b>e</b>	$\pi * (\frac{1}{2}d)^2$	<b>Area:</b>	<b>c</b>	<b>Dia. 2 in.:</b>
	<b>f</b>	<b>a/e</b>	<b>Stress PSI:</b>	<b>d</b>	$\frac{b+c}{2}$

Average Stress: \_\_\_\_\_ PSI

$$\frac{\sum f_1 \dots f_n}{n}$$



## 5.9.79 SURFACE RESISTIVITY INDICATION OF CONCRETE'S ABILITY TO RESIST CHLORIDE ION PENETRATION (Kansas Test Method KT-79)

### 1. SCOPE

This test method covers the determination of the electrical resistivity of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is based on procedures found in AASHTO T 358.

### 2. REFERENCED DOCUMENTS

- 2.1. KDOT Construction Manual, Part V, Section, 5.9; Sampling and Test Methods Forward
- 2.2. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field
- 2.3. AASHTO T 358; Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

### 3. TERMINOLOGY

- 3.1. Sample: Set of three cylinders taken from the same concrete batch at the same time.
- 3.2. Specimen: One cylinder of the set of cylinders to be tested.

### 4. APPARATUS

**4.1. Proceq Resipod is the only currently approved meter to measure surface resistivity. Results from any other meter will not be accepted.**

4.2. Surface Resistivity meter with a Wenner linear four-probe array. The meter should have a range of 0 to 100 k $\Omega$ -cm, with a resolution of 0.1 k $\Omega$ -cm and an accuracy of  $\pm 2\%$  of reading. The Wenner probe array spacing should be set at 1.5 inches (38.1 mm). The meter should be a single, self-contained handheld unit. The Proceq Resipod meets these requirements.

4.3. Specimen holder. Specimen holder to prevent specimen rotation during testing. Holder should be non-conductive.

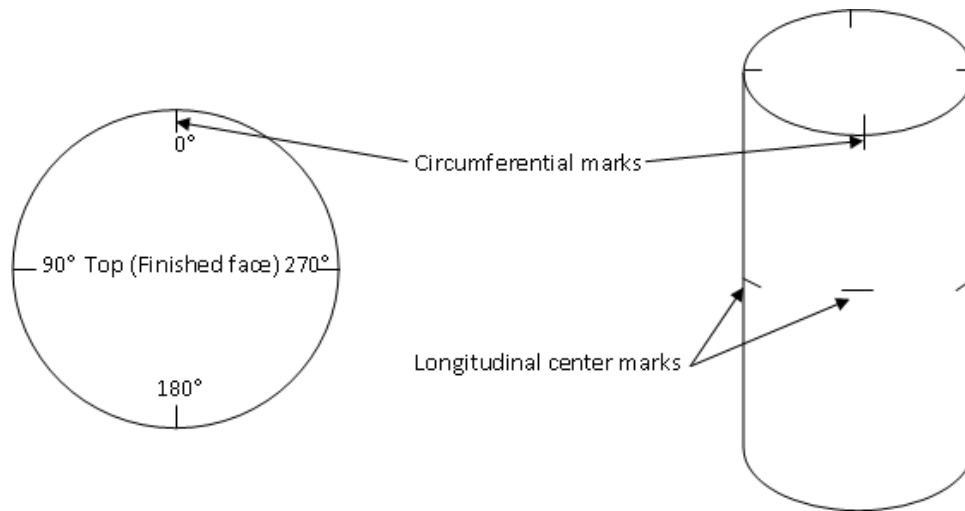
### 5. TEST SPECIMEN

5.1. Prepare 3 specimens per sample per mix design. Each specimen is to be tested separately. The specimens shall be 4" x 8" (100 mm x 200 mm) cylinders cast at time of mixing. Cylinders shall be molded in accordance with **KT-22** of this manual.

### 6. CURING AND CONDITIONING

6.1. Initial curing of cast samples: Cast samples must undergo initial curing procedures according to **KT-22** with the requirement that samples are to be submitted to the testing facility within 48 hours of casting. Therefore, the samples must be demolded at  $24 \pm 8$  hours. See **6.4.** for transportation requirements.

**6.2.** Make four indelible marks on the top (finished) circular face of the specimen marking the 0, 90, 180, and 270 degree points of the circumference of the circle. Randomly assign one of the marks as 0°, then rotate either clockwise or counterclockwise and assign the next mark 90°, and so on. Extend the marks into the longitudinal sides of the specimens. On the longitudinal sides mark the center of the longitudinal length of the specimen in order to use as a visual reference during testing. (Figure 1)



**Figure 1:** Specimen Marking

**6.3.** Standard Curing: Samples will undergo standard curing according to **KT-22**. Samples are to remain in the curing environment until specified in section **7.3**. of this test method.

**6.4.** Transporting samples: Whenever samples are to be transported at any time after demolding, they are to be wrapped in saturated towels, placed in sealed plastic bags and delivered to their destination. Upon arrival at destination, samples are to be removed from bags and placed back in suitable curing environment within 30 minutes of arrival. Alternatively to saturated towels and plastic bags, samples may be fully submerged in water in a suitable water-tight container during transport.

If samples are demolded at a location other than the testing facility, samples must be demolded and transported to the testing facility and placed back in the curing environment within 48 hours of casting. If samples are to be moved a second time after 28 day testing has occurred, samples must be transported within 72 hours from when they were removed from the curing environment.

NOTE: If these procedures are not followed and samples are allowed to dry out at any point during the curing process, this can result in an invalid test.

## 7. PROCEDURE

**NOTE:** Testing is typically scheduled at 28 days. However, as this is a nondestructive test and is likely to be run on samples cast for other testing purposes, resistivity testing shall occur as close to the specified test date as possible before the sample is altered in any way for a different test; i.e., resistivity testing will occur on day 27 or 28 before the samples are tested for strength, **KT-76**. The samples are to be tested no earlier than 1 day before, or no later than 4 days after the specified test date. Therefore, samples tested for **KT-73** cannot be used for surface resistivity testing.

**7.1.** At the beginning of each day of testing, calibrate the unit using the test strip provided by the manufacturer. Foam pads located on each probe tip must be saturated before and during calibration and testing. If unit does not display correct values during calibration check the following: ensure foam pads are saturated (over-saturation can occur), turn off and restart the unit. If issues persist, contact KDOT Research personnel for further assistance.

**7.2.** During the test, the air temperature around the specimens shall be maintained in the range of 68 to 77°F (20 to 25°C). As the unit is portable, testing the specimens in the room they are stored in is ideal.

**7.3.** Remove the specimens from curing environment, blot off excess water with damp towel/sponge to SSD condition, and transfer specimen to specimen holder. If specimens are stored in lime-saturated water storage tanks, clean off excess lime residue from specimens prior to testing. If several samples are to be tested, be sure that the specimens are not allowed to dry out excessively before completion of the testing. It is recommended that only one set of three specimens are removed from the curing environment at any given time.

**7.4.** Place the meter longitudinally on the side of the specimen at the 0 degree mark. Center the meter longitudinally on the specimen by making sure the longitudinal center mark on the specimen is equidistant between the two inner probes (Figure 2). Make sure all the points of the array probe are in contact with the concrete. Contact with the specimen will automatically induce a reading on the display screen. Wait until a stable reading is obtained (usually 3 to 5 seconds), and record the resistivity measurement on the testing form to the nearest 0.1 kΩ-cm. A reading is considered unstable if it drifts by more than 1 kΩ-cm. Negative, unstable or obviously erroneous readings are indicative of problems with the instrument, the probe array, or specimen, and need to be addressed before proceeding.



**Figure 2:** Location of unit during testing

**7.5.** Repeat step 7.4 for the 90, 180, and 270 degree marks.

**7.6.** Repeat steps 7.4 and 7.5 for the same specimen for a total of eight readings.

7.7. Repeat steps 7.4 to 7.6 for the remaining two specimens in the sample set.

## 8. CALCULATION

8.1. Calculate an average resistivity for each specimen. Calculate the coefficient of variation (COV) for each specimen. If the COV is above 7.5%, fully immerse the specimen in a water bath 68 to 77°F (20 to 25°C) for two (2) hours, then repeat the test. If the COV on second test is below 7.5%, use second test to calculate specimen average and complete 8.2 and 8.3. If the COV on second test is greater than 7.5%, use all 16 readings for the specimens to calculate specimen average.

8.2. Calculate an average resistivity for the sample by averaging the average resistivity (8.1) of the three specimens tested.

8.3. If specimens were cured in lime-saturated water, multiply set average by 1.1. Report the final resistivity to the nearest 0.1 kΩ-cm.

8.4. Factors which are known to affect chloride ion penetration include: water-cement ratio, pozzolans, the presence of polymeric admixtures, sample age, air-void system, aggregate type, degree of consolidation, and type of curing.

## 9. REPORT

9.1. Report the results as required by the Contract Documents with the addition of the following information:

9.1.1. Source of cylinder, in terms of the particular station the cylinder represents.

9.1.2. AWP or equivalent identification number of cylinder.

9.1.3. AWP or equivalent mix design number.

9.1.4. Date cast.

9.1.5. Date samples were demolded.

9.1.6. Min/Max temperature during first 24 hrs (if known).

9.1.7. Date of surface resistivity testing.

9.1.8. Description of specimen, including presence and location of reinforcing steel, presence and thickness of overlay, and presence and thickness of surface treatment.

9.1.9. Curing history of specimen.

9.1.10. Unusual specimen preparation, for example, removal of surface treatment or sulfur capping.

9.1.11. Test results, reported as the surface resistivity measured from 8.2 or 8.3 if a correction factor is applied.

5.9.80 UNCOMPACTED VOID CONTENT OF COARSE AGGREGATE (As Influenced by Particle Shape, Surface Texture, and Grading) (Kansas Test Method KT-80)

## 1. SCOPE

This method describes the determination of the loose uncompact void content of a sample of coarse aggregate. When measured on any aggregate of a known grading, void content provides an indication of the aggregate's angularity, sphericity, and surface texture compared with other coarse aggregates tested in the same grading. **KT-80** reflects testing procedures found in **AASHTO T 326**.

## 2. REFERENCED DOCUMENTS

2.1. Part V, 5.9; Sampling and Test Methods Foreword

2.2. KT-01; Sampling and Splitting of Aggregates

2.3. KT-02; Sieve Analysis of Aggregate

2.4. KT-03; Material Passing No. 200 (75  $\mu$ m) Sieve by the Wash Method

2.5. KT-05; Unit Weight of Aggregate

2.6. KT-06; Specific Gravity and Absorption of Aggregate

2.7. KT-15; Bulk Specific Gravity and Unit Weight of Compacted Asphalt Mixtures

2.8. AASHTO T 326; Standard Method of Test for Uncompact Void Content Of Coarse Aggregate (As Influenced by Particle Shape, Surface Texture, and Grading)

## 3. APPARATUS

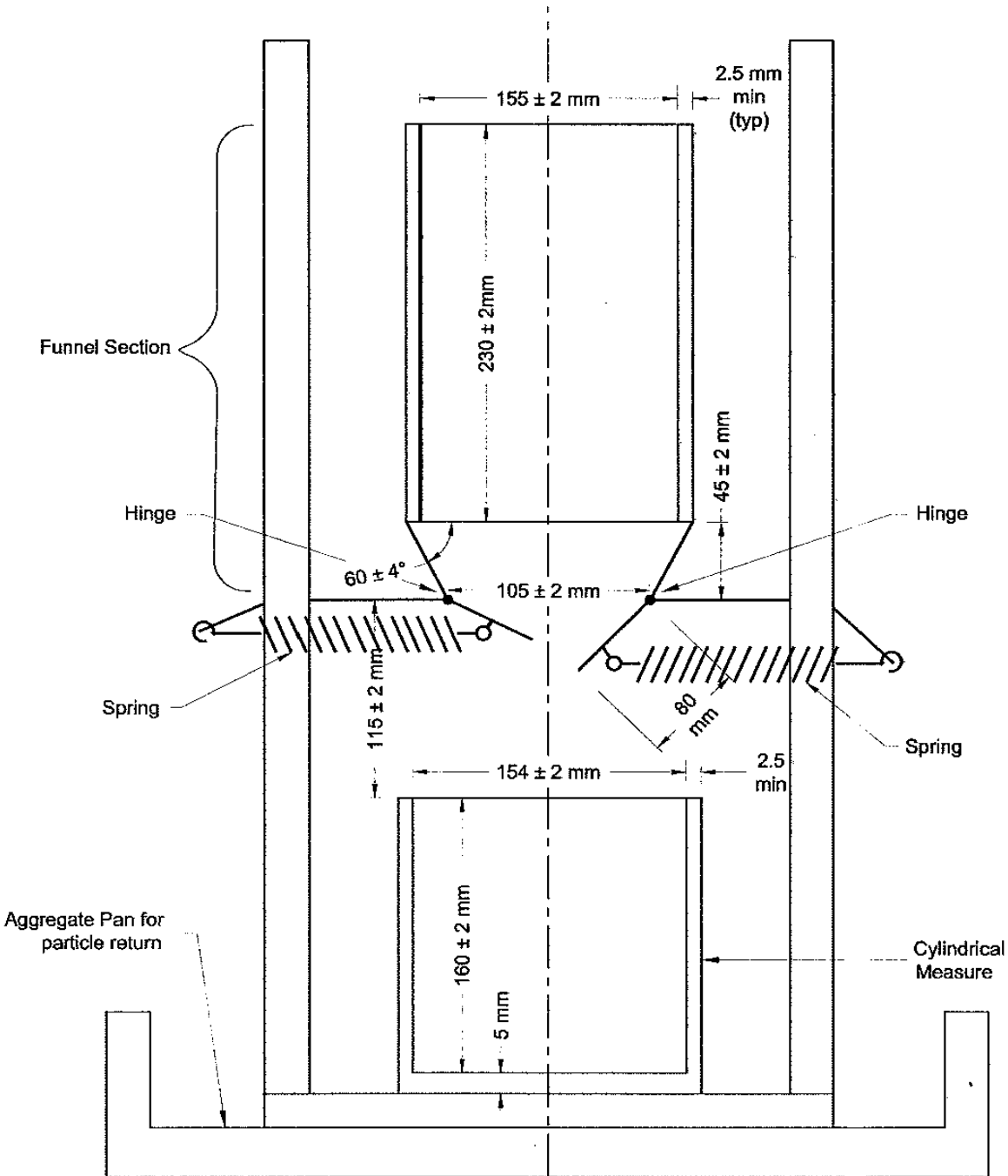
3.1. Drying oven capable of maintaining a uniform temperature of  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).

3.2. A cylindrical metal measure shall be watertight, with the top and bottom true and even, preferably machined to accurate dimensions on the inside and sufficiently rigid to retain its form under rough usage. The top rim shall be smooth and plane within .01 in (0.25 mm) and shall be parallel to the bottom within 0.5 degrees. The inside diameter shall be  $6.0 \pm 0.1$  in ( $154 \pm 2$  mm) and the inside height shall be  $6.3 \pm 0.1$  in ( $160 \pm 2$ ) mm. **Figure 1**.

3.3. The lateral surface of the right frustum of a cone sloped  $60 \pm 4$  degrees from the horizontal with an opening of  $4.13 \pm 0.1$  in ( $105 \pm 2$ -mm) diameter. The funnel section shall be a piece of metal, smooth on the inside. It shall have a volume of at least two times the volume of the cylindrical measure or shall be provided with a supplemental metal container to provide the required volume. **Figure 1**.

3.4. A support capable of holding the funnel firmly in position with the axis of the funnel colinear [within a four degree angle and a displacement of 0.1 in (2 mm)] with the axis of the cylindrical measure. The funnel opening shall be  $4.53 \pm 0.1$  in ( $115 \pm 2$  mm) above the top of the cylinder. **Figure 1**.

Figure 1 Test Apparatus





**3.5.** A square glass plate approximately 6.75 in by 6.75 in (170 mm by 170 mm) with a minimum thickness of 0.16 in (4 mm) used to calibrate the cylindrical measure.

**3.6.** A metal or glass pan of sufficient size to contain the funnel stand and to prevent loss of material. The purpose of the pan is to catch and retain aggregate particles that overflow the measure during filling and strike off.

**3.7.** A flat metal straightedge approximately 12 in (300 mm) length, 1.5 in (40 mm) in width and 0.12 in (3 mm) thickness is used to strike off the top of the container.

**3.8.** The balance shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Foreword**, for the class of general purpose balance required for the principal sample mass of the sample being tested.

#### **4. DETERMINATION OF THE VOLUME OF CYLINDRICAL MEASURE**

**4.1.** Determine the following weights to the nearest 0.1 g.

Apply a light coat of grease to the top edge of the dry, empty cylindrical measure. Weigh the measure, grease, and glass plate. Fill the measure with distilled/deionized water at a temperature of  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ). Record the temperature of the water. Place the glass plate on the measure, being sure that no air bubbles remain. Dry the outer surfaces of the measure and determine the combined mass of measure, glass plate, grease, and water by weighing. Following the final weighing, remove the grease, and determine the mass of the clean, dry, empty measure for subsequent tests. This procedure should be done at least once a year.

Calculate the volume of the measure as follows:

$$V_c = \frac{W}{0.99704}$$

Where:  $V_c$  = volume of cylinder, mL

$W$  =  $d - c$  = net mass of water, g

$c$  = cylinder + glass + grease, g

$d$  = cylinder + glass + grease + water, g

Determine the volume to the nearest 0.1 mL.

**NOTE:** Density of water varies based on temperature. Since the water bath temperature is fixed at  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ), use the specified value of 0.99704 g/mL. For tests not restrained by the  $77 \pm 2^\circ\text{F}$  ( $25 \pm 1^\circ\text{C}$ ) requirement, select the proper density for water from **KT-15, Table 1**. Divide the value given in the table by 1000 for g/mL.

#### **5. SAMPLE PREPARATION**

**5.1.** Wash the sample over the No. 200 (75  $\mu\text{m}$ ) sieve using the equipment and procedures listed in **KT-03, section 3 and section 5**. Dry the plus No. 200 (75  $\mu\text{m}$ ) material to a constant mass. Sieve the dry aggregate over the 3/4 in. (19 mm), 1/2 in. (12.5 mm), 3/8 in. (9.5 mm), No.4 (4.75 mm).

**5.2.** Weigh out and combine the following quantities of dry aggregate from each of the sizes:

Maximum Size of Aggregate	Individual Size Fraction	Mass, g
3/4 in. (19 mm)	3/4 in. (19 mm) to 1/2 in. (12.5 mm)	1740
	1/2 in. (12.5 mm) to 3/8 in. (9.5 mm)	1090
	3/8 in. (9.5 mm) to No. 4 (4.75 mm)	2170
1/2 in. (12.5 mm)	1/2 in. (12.5 mm) to 3/8 in. (9.5 mm)	1970
	3/8 in. (9.5 mm) to No. 4 (4.75 mm)	3030

The total sample weight should be 5000 g  $\pm$  10 g.

**5.3.** If the bulk dry specific gravity of coarse aggregate from the source is unknown, determine it on the plus No. 4 (4.75 mm) sample according to **KT-06**.

## **6. TEST PROCEDURE<sup>1</sup>**

**6.1.** Record the mass of the empty measure. Also, for each run, record the mass of the measure and coarse aggregate.

**6.2.** Mix the test sample until it is homogenous. Center the cylindrical measure under the funnel section as shown in **Figure 1**. Close the doors at the bottom of the funnel section and latch them shut. Pour the test sample into the funnel section. Hold the doors shut with one finger and open the latch on the doors. Remove the finger from the doors, allowing the doors to swing open and the aggregate to fall freely into the cylindrical measure.

**NOTE:** A latch may be placed on the doors for the convenience of the operator or the operator may hold the doors closed with a finger during the filling of the funnel section, in which case the latch on the doors would not be necessary.

**6.3.** After the funnel empties, strike off excess heaped aggregate from the cylindrical measure. Strike off the surplus aggregate in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure. Until this operation is complete, exercise care to avoid vibration or any disturbance that could cause compaction of the coarse aggregate in the cylindrical measure. Remove any aggregate that may have fallen on the outside of the container and determine the mass of the cylindrical measure and contents to the nearest 0.1 g. Retain all aggregate particles for a second test run.

**6.4.** Recombine the sample from the retaining pan and cylindrical measure and repeat the procedure. The results of two runs are averaged.

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<sup>1</sup> **AASHTO 326** Allows Methods A, B and C. KDOT allows only Method A to be run.

## 7. CALCULATIONS

7.1. Calculate the uncompacted void content, ( $U_k$ ), by this method:

$$U_k = \frac{U_1 + U_2}{2}$$

Where:  $U_1$  and  $U_2$  are the uncompacted void content for Trial No. 1 and Trial No.2 respectively, and are determined by:

Calculate the uncompacted voids for each determination as follows:

$$U_{1,2} = \frac{V_c - (F/G)}{V_c} \times 100$$

where:

$V_c$  = volume of cylindrical measure, mL;

$F$  = net mass, g, of coarse aggregate in measure (gross mass minus the mass of the empty measure);

$G$  = bulk dry specific gravity of coarse aggregate; and

$U$  = uncompacted voids, percent, in the material.

## 8. REPORT

8.1. Record uncompacted voids to the nearest 0.1%. Report uncompacted voids to the nearest 1%.

8.2. The specific gravity value used in calculation.



5.9.81 SAMPLING COLD PLASTIC PAVEMENT MARKING MATERIALS, PATTERNED COLD PLASTIC PAVEMENT MARKING MATERIALS AND HIGH DURABILITY PAVEMENT MARKING TAPE (KANSAS TEST METHOD KT-81)

**1. SCOPE**

This method covers the procedures for field sampling Cold Plastic Pavement Marking Material, Patterned Cold Plastic Pavement Marking Material and High Durability Pavement Marking Tape.

**2. APPARATUS**

**2.1.** Utility Knife

**2.2** Packing material, box, tape, etc.

**3. SAMPLING PROCEDURES**

**3.1.** Select points at which to sample each color and lot from the entire length of material supplied to the project using procedures described in **Section 5.2.2.2.** of this manual. Do not sample from symbols.

**3.2.** Coordinate the sampling site with the contractor

**3.3.** Using a sharp instrument such as a utility knife, cut a sample from the entire width of the product to the length shown in **3.4.** below.

**3.4.** When the material being sampled is less than 12 inches (300 mm) in width, provide a sample that is a minimum of 36 inches (900 mm) in length in a single piece. When the material being sampled is 12 (300 mm) inches and wider, provide a sample that is a minimum of 24 inches (600 mm) in length in a single piece.

**3.5.** Keep the adhesive side of the material clean during sampling and packaging.

**3.6.** Roll the material so that the adhesive side is on the inside of the roll. Do not include any paper inside the roll. Place a rubber band around the roll and any paperwork. Place the sample inside a box and seal with packing tape.

**4. SHIPPING INFORMATION**

**4.1.** Label each sample container with at least the following:

**4.1.1.** Producer.

**4.1.2.** Producer product ID.

**4.1.3.** Lot number and color.

**4.1.4.** Project number.

**4.1.5.** Sample ID Number. Each sample must have a different Sample ID Number.

**4.1.6.** Ship samples to the Materials & Research Center, 2300 SW Van Buren, Topeka, KS 66611.



5.9.82 DETERMINATION OF EXCESSIVE MOISTURE IN CONCRETE SURFACES  
(Kansas Test Method KT-82)

**1. SCOPE**

This method covers the determination of the presence of moisture in hardened concrete that may be detrimental to coating adhesion. **KT-82** reflects testing procedures found in **ASTM D4263**.

**2. REFERENCED DOCUMENTS**

**2.1.** ASTM D4263; Indicating Moisture in Concrete by the Plastic Sheet Method

**3. APPARATUS**

**3.1. Method A**

**3.1.1.** Transparent plastic sheeting approximately 4 mils (0.1 mm) thick.

**3.1.2.** Adhesive tape that will adhere to the surface. 2 inch (50 mm) wide duct tape is suggested.

**3.2. Method B**

**3.2.1.** Electrical impedance type moisture meter with a mode specific for testing concrete. Calibrate the meter within 12 months prior to use or calibrate onsite at the time of use according to the manufacturer's recommendations. Make the calibration certificate or field calibration materials and the operating manual available to the Engineer prior to use.

**4. PROCEDURE**

**4.1.** Method B may only be used with the Engineers approval. Method A shall be the referee method. Results from Method A take precedence in the case of discrepancies between methods or if concerns exist regarding the accuracy of the meter.

**4.2. Method A**

**4.2.1.** Avoid testing in areas with direct sunlight. Shade the test area if necessary. Use an approximately 18 by 18 inch sheet of plastic. Tightly seal the edges to the surface being tested with tape. Leave the plastic sheet in place for a minimum of 2 hours.

**4.2.2.** Remove the plastic sheet and visually check the underside of the sheet and the concrete surface for the presence of moisture.

**4.3. Method B**

**4.3.1.** Using the moisture meter in accordance with the manufacturer's procedures stated in the operating manual test the concrete surface in three locations and record the moisture to the nearest 0.1%.

**5. Report**

**5.1.** Method A: Report the presence or absence of moisture. Method B: Report all moisture content readings to the nearest 0.1%. Do not average the readings.





## 5.9.83 STRAND BOND IN PRESTRESSED CONCRETE MEMBERS (Kansas Test Method KT-83)

### **1. SCOPE**

This method covers the procedures for verifying the bond of pre-tensioned prestressing strand in prestressed concrete members. **KT-83** reflects testing procedures found in the **Spring 2009 (revised May 2009) PCI Journal**.

### **2. REFERENCED DOCUMENTS**

- 2.1.** Part V, 5.9; Sampling and Testing Methods Forward
- 2.2.** KT-22; Making and Curing Compression and Flexural Test Specimens in the Field
- 2.3.** KT-76; Compressive Strength of Molded Cylindrical Concrete Specimens
- 2.4.** PCI Journal, Spring 2009 (Revised May 2009), “A Simple Quality Assurance Test for Strand Bond”

### **3. APPARATUS**

- 3.1.** Fork Lift:
- 3.2.** One 12 inch long, 4 inch wide by 0.5 inch thick simple elastomeric bearing pad.
- 3.3.** One 12 inch long, 4 inch wide by 0.375 inch thick Teflon coated elastomeric bearing pad.
- 3.4.** One 14 inch long, 6 inch wide by 0.125 inch thick stainless steel plate.
- 3.5.** Load blocks of various weights.
- 3.6.** Nylon straps to suspend the load block(s) from the test beam.

**NOTE:** Proper results require the use of a stainless steel plate and Teflon coated elastomeric bearing pad at one end of the test beam. Do not use a simple elastomeric pad at each end.

### **4. LOAD BLOCKS**

- 4.1.** Determine the mass of the various load blocks using a calibrated scale. The scale shall conform to the requirements of **Part V, 5.9; Sampling and Test Methods Forward**.

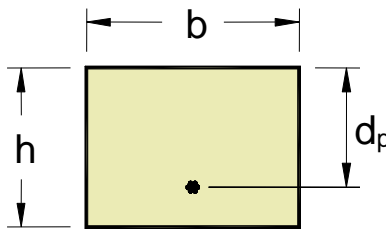
### **5. SAMPLE PREPARATION**

**5.1.** Cast a concrete test beam of rectangular cross section with a single pre-tensioned, prestressing strand and having the dimensions shown in **Table 1**, and **Figures 1 and 2**. Place the strand at a depth specified in **Table 1**. Test beams must not contain shear reinforcement. Use standard tensioning, batching, placement, consolidation, curing, and detensioning methods.

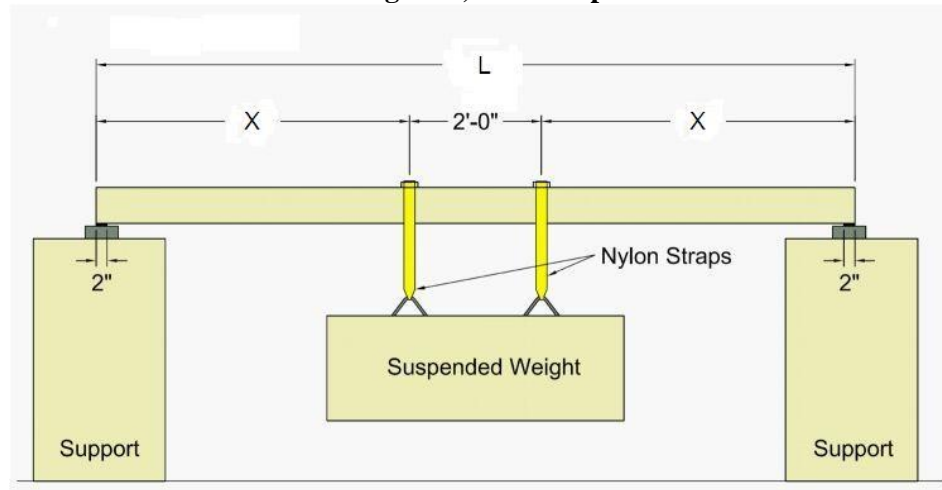
**Table 1, Critical Dimensions**

Nominal Diameter of Strand	b	h	d <sub>p</sub>	L	X
0.500	8 in	6 in	4-1/2 in	11 ft 6 in	4 ft 9 in
0.600	10 in	6-1/2 in	4-3/4 in	13 ft 4 in	5 ft 8 in

**Figure 1, Test Beam Cross Section**



**Figure 2, Test Setup**



**5.2.** When casting test beams, make a minimum of two sets of three cylinders each to determine when release and 28-day strengths have been attained. Make cylinders according to **KT-22**. Cure cylinders under the same conditions as the test beams they represent.

**5.3.** Cap and test cylinder sets according to **KT-76**. De-Tension strand only after cylinders indicate that release strength has been attained. Testing can only take place after cylinders indicate that the specified 28-day strength has been attained.

**5.4.** Verify and record the “as-built” dimensions of the finished test beams. If, in the center 2 ft of its length, the test beam width (b) and depth to strand ( $d_p$ ) deviate from **Table 1** values by more than 0.125 in, calculate the required applied load (see **section 5.6.**) using “as-built” values rather than the nominal values from **Table 1**.

**5.5.** Grind the ends of the strand flush with the concrete at the ends of the beam.

**5.6.** Using the equations on **pages 156 through 160 of the Spring 2009 (revised May 2009) PCI Journal**, or using approved programs, calculate in pounds:

- The total applied load ( $P_{85\%}$ ) required to produce a moment in the test beam equal to 85% of the nominal moment capacity of the test beam.
- The total applied load ( $P_{100\%}$ ) required to produce a moment in the test beam equal to the nominal moment capacity of the test beam.

For calculation purposes, span length is 4 inches less than beam length (X).

## **6. PROCEDURE**

**6.1.** Support the beam and suspend the load for testing as shown in **Figure 2**.

**NOTE:** The L and X dimensions shown in **Table 1** and **Figure 2** have been chosen to establish a development length of approximately 80% of the calculated development length of the member. Therefore, overall beam and span length, and location of the load straps are critical.

**6.2.** Place the ends of the beam 2 inches from the inside edge of the bearing pads. Establish span length (inside-to-inside face of bearings) to within  $\pm 0.25$  inch. Place the plain elastomeric bearing pad under one end of the beam and a Teflon coated bearing pad under the other end. Place the Teflon coated surface face down onto a clean stainless steel plate.

**6.3.** Gradually load the beam up to  $P_{85\%}$  by slowly hanging load block(s) from the straps or by slowly lowering load blocks uniformly onto the beam between the straps.

**6.3.1.** Inspect the beam and document cracks and strand end slip if present. With the ends of strand ground flush prior to testing, any draw-in will be visually detected.

**6.4.** Sustain the  $P_{85\%}$  load for a minimum of 24 hours.

**6.4.1.** Inspect the beam for increased signs of distress such as increased strand slipping, increased cracking, concrete crushing, etc.

**6.5.** Load the beam to  $P_{100\%}$  and hold for a minimum of 10 minutes. If the beam has not collapsed during this period, it passes the test. **Collapse of the beam constitutes a failed test.**

## **7. RECORD AND REPORT**

**7.1** Record  $P_{85\%}$  and  $P_{100\%}$  to the nearest pound. Report both to the nearest 10 pounds. Record and report all dimensions to the nearest 0.125 inch.



## 5.9.84 SAMPLING NUTS, BOLTS AND WASHERS (Kansas Test Method KT-84)

### **1. SCOPE**

This method covers the procedure for sampling steel nuts, bolts and washers from the supplier's plant or warehouse.

Note: Contact Engineer of Tests if sampling is performed at a different location.

### **2. APPARTUS**

**2.1.** Plastic sample bags.

**2.2.** Sample tags.

**2.3.** Shipping container. A sturdy cardboard box is acceptable.

**2.4** Ties, tie wire or packing tape to seal the bags.

### **3. SAMPLING PROCEDURE**

**3.1.** Samples are taken by Department personnel or an agent of the Department.

**3.1.1.** Provide samples in the quantities shown in **Section 5.5 of Part V of the Construction Manual**.

**3.1.2.** Provide samples that are taken randomly and are representative of the entire heat or lot.

**3.2.** Place samples into bags individually representing each heat or lot number.

**3.2.1.** Include related nuts and washers with each bolt if required.

**3.2.2.** Mark or tag each bag with the heat/lot numbers for the bolts, nuts and washers and with the related Sample ID number.

**3.3.** Package the samples in a sturdy container for shipping or transport.

**3.3.1.** Include manufacturer's certifications for all heat/lot numbers in the package along with a cover sheet identifying the heat/lot numbers and the quantities represented by the samples and the related Sample ID.

**3.3.2.** Ship or transport the package to the Engineer of Tests: Materials and Research Center, 2300 SW Van Buren, Topeka Kansas, 66611.

## 5.9.85 PROCEDURES FOR EVALUATING THE MOVEMENT, ROTATION, AND SOUND GENERATION OF PORTABLE TEMPORARY RUMBLE STRIPS (Kansas Test Method KT-85)

### **1. SCOPE**

This method covers the procedures for evaluating the movement (longitudinal and lateral), rotation, and sound generation of portable temporary rumble strips. This appendix reflects testing procedures found in the KDOT sponsored research report KU-14-6.

### **2. REFERENCED DOCUMENTS**

**2.1.** KU-14-6, August 2015, “Development of Temporary Rumble Strip Specifications”

### **3. DEFINITIONS**

**3.1.** Downstream – the direction of test vehicle travel as it traverses the rumble strips.

**3.2.** Upstream – the direction opposite of test vehicle travel as it traverses the rumble strips.

**3.3.** Left/Right – as when looking in the downstream direction.

### **4. APPARATUS**

**4.1.** Front wheel drive, full-size passenger car.

**4.2.** Tandem-axle dump truck with axle loads (front to rear) of 18 kips, 20 kips, and 20 kips.

**4.3.** Paved closed course having sufficient length to permit test truck (see **section 4.2**) to safely attain a constant speed of 67.5 mph and then safely decelerate after traversing the rumble strips.

**4.4.** A minimum of 120 feet of 4” wide white or yellow temporary pavement marking tape.

**4.5.** Sound level meter capable of measuring frequency-weighted sound pressure levels with output in decibels (dB). The meter must have a range of 20 to 140 dB and an accuracy of  $\pm 0.1$  dB.

**4.6.** A 12 megapixel (MP),  $f/1.8$  digital camera.

**4.7.** A thermometer to determine ambient temperature at the test site.

### **5. SET-UP**

**5.1.** Make certain the pavement in the test area is clean and dry, without the presence of dust, sand or gravel.

**5.2.** Place temporary pavement marking tape in two parallel straight lines 12 feet apart. The tape will delineate a minimum 60-foot long test lane.

**5.3.** Locate three individual rumble strips so that they are perpendicular to the edge lines, centered within the 12-foot test lane and spaced as per the manufacturer’s recommendations. Do not use an adhesive to secure the strips to the pavement.

**5.4.** Mark the pavement at the four corners of each of the three undisturbed rumble strips so the rumble strips can be returned to their initial location after completing all passes at a test speed.

**5.5.** Position a sound meter 6 feet from a lane line, centered on and facing the middle rumble strip.

**5.6.** Movement and sound generation testing may proceed only when the ambient temperature is 55 to 75 degrees F.

**5.7.** Record all movement related measurements to the nearest tenth of an inch.

## **6. TEST PROCEDURE – MOVEMENT (TRUCK & PASSENGER CAR)**

**6.1.** Using the test truck, traverse the rumble strips 40 times at 67.5 mph in the same direction. Proceed to **steps 6.2 through 6.6** only after completion of the 40<sup>th</sup> pass.

**6.2.** Photograph the displaced strips so that relative locations to one another and to the lane line are apparent for all three strips. Take close-up photos of strips that are damaged or if adjacent strip sections become detached.

**6.3.** Using the upstream or downstream side of each strip as a zero-reference line, measure and record the longitudinal displacement of the corresponding left corner, panel length midpoint, and right corner of each strip in inches. Each strip is treated separately. Therefore, a point on a displaced strip is measured along a line parallel to a lane line from the displaced point back to the “zero” reference line for the same strip. All measurements are taken parallel to a lane line. Downstream movements from the reference line are positive (+), upstream movements are negative (-).

**6.4.** Measure and record the final longitudinal clear spacing between the left sides (x1, x2), midpoints (y1, y2), and right sides (z1, z2) of adjacent strips in inches. See **Figure 1** below. All measurements are parallel to a lane line so one point will need to be “projected” along a line perpendicular to a lane line and passing through the point before a longitudinal clear spacing value can be correctly determined.

**6.5.** For lateral displacement, record whether either end of any of the three strips overlaps a lane line.

**6.6.** Return the three rumble strips to their initial (undisturbed) location.

**6.7.** Repeat **steps 6.1 through 6.6** using the same truck to make 40 passes at 57.5 mph, then 37.5 mph, and finally 22.5 mph.

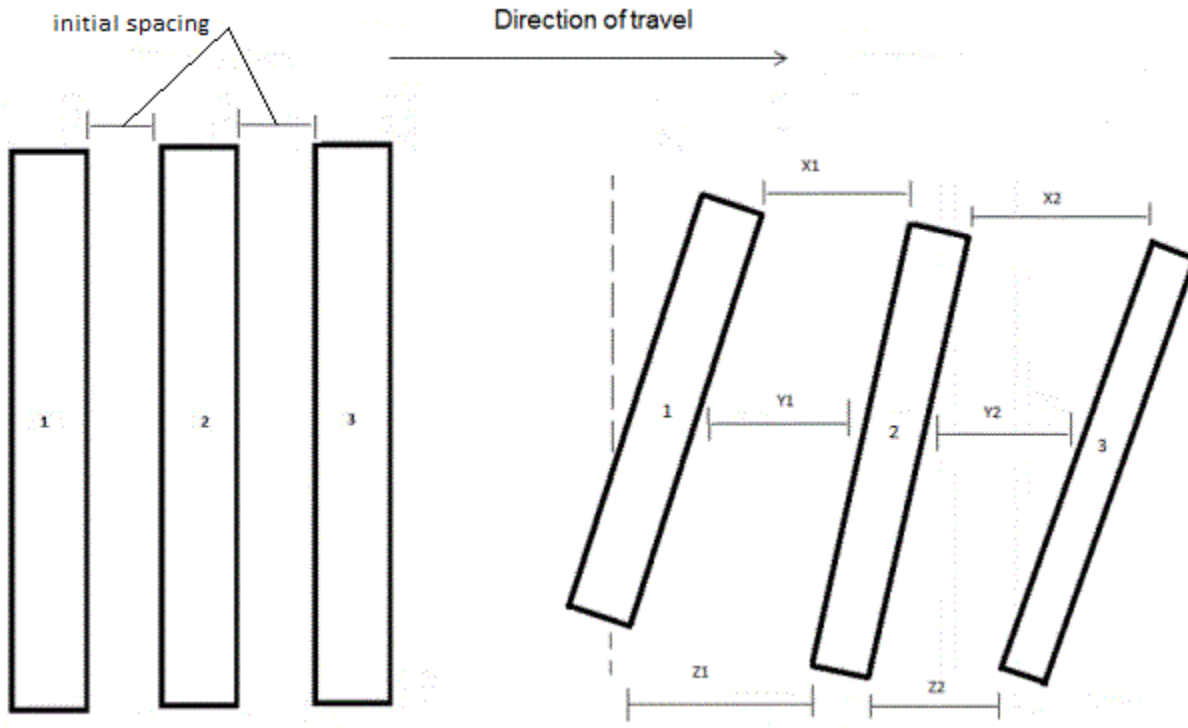
**6.8.** Once all 160 passes of the truck are complete, repeat **steps 6.1 through 6.6** using the test car to make 40 passes each at 67.5 mph, 57.5 mph, 37.5 mph, and finally 22.5 mph.

**Note:** At each traverse speed of the test car, peak sound will be measured during ten of the 40 passes. See **Section 7**.

## **7. TEST PROCEDURE – SOUND (PASSENGER CAR ONLY)**

**7.1.** Before testing begins with the test car, determine which ten of the 40 passes at each traverse speed will be used in the measurement of peak sound. It is recommended that these 10 passes be distributed roughly equally throughout the total of 40 passes. Only the peak sound values recorded during these predetermined passes will be used during ensuing calculations.

7.2. Record peak sound for 10 passes at each traverse speed using the sound level meter positioned as described in **subsection 5.5**.



**Figure 1**

## 8. CALCULATIONS

**8.1. Average Relative Longitudinal Movement (ARLM).** Calculate an ARLM for the left side, midpoint, and right side of the strip group for each traverse speed and test vehicle.

$$ARLM_{y,s,m} = [(m1_f - m1_i) + (m2_f - m2_i)] / 2 \text{ where,}$$

y = test vehicle = t (truck), p (passenger car)

s = traverse speed (mph)

m1<sub>f</sub>, m1<sub>i</sub>, m2<sub>f</sub>, m2<sub>i</sub> = clear spacing values determined in **step 6.4** (inches)

m = x (left side), y (midpoint), z (right side) as shown in **Figure 1**

i = initial (undisturbed) spacing between panels (as per manufacturer's recommendations)

f = final (disturbed) spacing between panels after 40 passes

1 = 1<sup>st</sup> bay between strip 1 and 2, see **Figure 1**

2 = 2<sup>nd</sup> bay between strip 2 and 3, see **Figure 1**

Note: Resultant ARLM values can be either (+) or (-).

**8.2. Average Rotation (AROT).** Calculate AROT using the left and right corner longitudinal displacement data for each strip collected in **step 6.3**, the length of the rumble strips (inches), and trigonometry. With respect to the left edge of the strip, counterclockwise rotations are positive (+), clockwise rotations are negative (-).



$AROT_{y,s} = (ROT_1 + ROT_2 + ROT_3) / 3$  where,

y = test vehicle = t (truck), p (passenger car)

s = traverse speed (mph)

$ROT_1, ROT_2, ROT_3$  = rotation of strip 1, 2, & 3 ( $\pm$  degrees)

Note: Pay attention to sign in the above calculation

**8.3. Average Peak Sound.** Calculate Average Peak Sound (APS) using data collected in **step 7.2** for each traverse speed of the passenger vehicle.

$APS_s = \sum PS_{1-10} / 10$  where,

s = traverse speed (mph)

$\sum PS_{1-10}$  = sum of the peak sounds for the 1<sup>st</sup> thru the 10<sup>th</sup> recorded pass (dB)

## **9. REPORT**

**9.1.** Provide the following:

**9.1.1.** Product data.

**9.1.2.** Photographs and descriptions of test vehicles, including axle loads for test truck.

**9.1.3.** Product and performance data of sound level meter.

**9.1.4.** Photographs and a description of the fully set-up test area.

After 40 passes of each test vehicle and each traverse speed, provide:

**9.1.5.** Photographs described in **subsection 6.2**.

**9.1.6.** Longitudinal displacement data from **subsection 6.3**.

**9.1.7.** Longitudinal clear spacing data from **subsection 6.4**.

**9.1.8.** A description of lateral displacement in relation to lane lines (**subsection 6.5**).

**9.1.9.** Peak sound values (passenger car only) from **subsection 7.2**.

**9.1.10.** Tabulations of calculated values for ARLM, AROT and APS for each applicable test vehicle and traverse speed, as defined in **subsections 8.1, 8.2 and 8.3**.

5.9.86 CHARACTERIZATION OF THE AIR-VOID SYSTEM OF FRESHLY MIXED CONCRETE BY THE SEQUENTIAL PRESSURE METHOD (Super Air Meter) (Kansas Test Method KT-86)

## 1. SCOPE

**1.1.** This method covers the procedure for determining the air content and system air metric (SAM) number of freshly mixed concrete from observation of the change in volume of concrete with a sequential change in test pressure. **KT-86** reflects testing procedures found in **AASHTO TP 118**.

**1.2.** This method is intended for use with concretes and mortars made with aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in Section 4. It is not applicable to concretes made with light-weight aggregates, air-cooled blast furnace slag, or other aggregates with high porosity. This test method is also not applicable to non-plastic fresh concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

**1.3.** The values stated in inch-pound units are to be regarded as the standard.

**1.4.** This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. REFERENCED DOCUMENTS

**2.1.** KT-17; Sampling Freshly Mixed Concrete

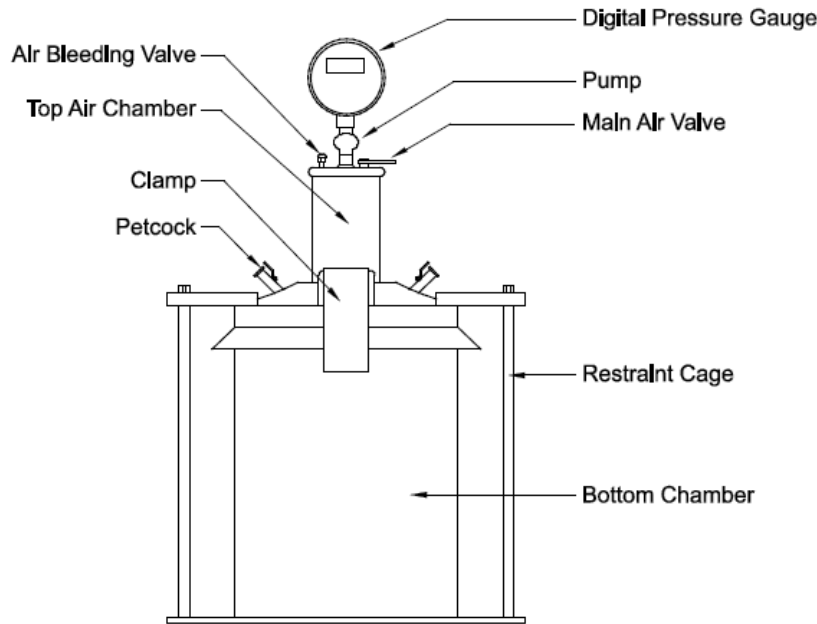
**2.2.** KT-19; Air Content of Freshly Mixed Concrete by the Volumetric Method

**2.3.** KT-20; Mass Per Cubic Foot (Meter), Yield and Air Content (Gravimetric) of Freshly Mixed Concrete

**2.4.** AASHTO TP 118; Characterization of the Air-Void System of Freshly Mixed Concrete by the Sequential Pressure Method

## 3. APPARATUS

**3.1.** An air meter consisting of a measuring bowl and cover assembly as shown in **Figure 1** conforming to the requirements of **Sections 3.2** and **3.3**. The operational principle of this meter consists of sequentially equalizing known volumes of air in a sealed air chamber, at a series of known pressures, with the unknown volume of air in the concrete sample placed in the measuring bowl. A digital pressure gauge with 0.01 psi (0.07 kPa) accuracy shall be used. Digital gauges with maximum pressures of 50.0 psi (344.7 kPa) have been used satisfactorily. The digital gauge shall be able to compute and report the air content within 0.1% and the SAM number to 0.01 psi (0.07 kPa). The cover assembly shall be fixed to the measuring bowl with the same uniform pressure that was used during the calibration of the meter.



**Figure 1**—Schematic of the Assembled Meter

**3.2.** The measuring bowl shall be essentially cylindrical in shape, made of steel, hard metal, or other hard material not readily attacked by the cement paste, having a minimum diameter equal to 0.75 to 1.25 times the height, and a capacity of at least 0.20 ft<sup>3</sup> (0.006 m<sup>3</sup>). It shall be flanged or otherwise constructed to provide for a pressure-tight fit between the bowl and cover assembly. The interior surfaces of the bowl and surfaces of rims, flanges, and other component fitted parts shall be machined smooth. The measuring bowl and cover assembly shall be sufficiently rigid to limit the expansion of the apparatus assembly to not more than 0.1% of air content on the indicator scale as described in **Section 10**.

**3.3. Cover Assembly:**

**3.3.1.** The cover assembly shall be made of steel, hard metal, or other hard material not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly and shall have machined-smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover shall be sufficiently rigid to limit the expansion as prescribed in **Section 3.2**.

**3.3.2.** The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary for the particular meter design. Suitable means for clamping the cover to the bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and bowl. The clamping method should provide a uniform pressure along the seal that can be verified by the user. A suitable hand pump shall be provided with the cover, either as an attachment or as an accessory.

**3.4.** The calibration vessel is a measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent of air in the concrete to be tested; or, if smaller, it shall be possible to check calibration of the meter indicator at the approximate percent of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape and of an inside depth 0.5 in. (13 mm) less than that of the bowl. A satisfactory calibration vessel to

place within the measure bowl may be machined from No. 16 gauge brass tubing, of a diameter to provide the volume desired, to which a brass disk 0.5 in. (13 mm) thick is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled bowl and cover assembly to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above described cylinder.

**3.5.** Tamping rod shall be a round, straight steel rod, with a  $0.625 \pm 0.0625$  in. ( $16 \pm 2$  mm) diameter and not less than approximately 16 in. (400 mm) in length. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

**3.6.** A mallet (with a rubber or rawhide head) weighing approximately  $1.25 \pm 0.50$  lb. ( $0.57 \pm 0.23$  kg) for use with measures of  $0.5 \text{ ft}^3$  ( $0.014 \text{ m}^3$ ) or smaller, and a mallet weighing approximately  $2.25 \pm 0.50$  lb. ( $1.02 \pm 0.23$  kg) for use with measures larger than  $0.5 \text{ ft}^3$  ( $0.14 \text{ m}^3$ ).

**3.7.** The strike-off bar is a flat, straight bar of steel or other suitable metal at least 0.125 in. (3 mm) thick and 0.75 in. (20 mm) wide by 12 in. (300 mm) long.

**3.8.** The strike-off plate is a flat, rectangular metal plate at least 0.75 in. (6 mm) thick or a glass or acrylic plate at least 0.5 in. (12 mm) thick with a length and width at least 2 in. (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 0.0625 in. (1.5 mm).

**3.9.** Funnel, with the spout fitting into a spray tube.

**3.10.** Vibrators, internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 per minute or greater while in use. The outside diameter or side dimension of the vibrating elements shall be at least 0.75 in (19 mm) and not greater than 1.50 in (38 mm). The combined length of the shaft and vibrating element shall exceed the maximum depth of the section being vibrated by at least 3 in (76 mm). External vibrators may be of two types: table or plank. The frequency for external vibrators shall not be less than 3,600 per minute, and preferably higher. For both table and plank vibrators, provision shall be made for clamping the mold securely to the apparatus. A vibrating-reed tachometer should be used to check the frequency of vibration.

**3.11.** Scoop of a size large enough so that each amount of concrete obtained from the sampling receptacle is representative and small enough that it is not spilled during placement in the measuring bowl.

## **4. DETERMINATION OF AGGREGATE CORRECTION FACTOR**

### **4.1. Procedure:**

**4.1.1.** Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in **Sections 4.2 to 4.4**. It is determined by applying  $14.5 \pm 0.05$  psi ( $100 \pm 0.3$  kPa) to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount, and proportions occurring in the concrete sample under test.

## 4.2. Aggregate Sample Size:

4.2.1. Calculate the weights of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$$(1) F_S = \frac{(S)(F_b)}{B}$$

$$(2) C_S = \frac{(S)(C_b)}{B}$$

Where:  $F_s$  = Mass of fine aggregate in concrete sample under test, lb (kg);  
 $S$  = Volume of concrete sample (same as volume of measuring bowl), ft<sup>3</sup> (m<sup>3</sup>);  
 $B$  = Volume of concrete produced per batch, ft<sup>3</sup> (m<sup>3</sup>);  
 $F_b$  = Total mass of fine aggregate in the moisture condition used in batch, lb (kg);  
 $C_s$  = Mass of coarse aggregate in concrete sample under test, lb (kg); and  
 $C_b$  = total weight of coarse aggregate in the moisture condition used in batch, lb (kg).

**NOTE:** The volume of concrete produced per batch can be determined in accordance with applicable provisions of **KT-20**.

## 4.3. Placement of Aggregate in Measuring Bowl:

4.3.1. Mix representative samples of fine aggregate,  $F_s$ , and coarse aggregate,  $C_s$ . Place a calibration vessel approximately equivalent to the volume of air that would be contained in a typical concrete sample in the measuring bowl. Fill the measuring bowl one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water so as to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible, remove accumulations of foam promptly, and lightly rod the upper 1 in. (25 mm) of the aggregate about 8–12 times and tap the sides of the measuring bowl. Stir after each addition of aggregate to eliminate entrapped air. Do not allow water in the calibration vessel.

## 4.4. Aggregate Correction Factor Determination:

### 4.4.1. Initial Procedure:

4.4.1.1. When all of the aggregate has been placed in the measuring bowl, remove foam at the surface and keep the aggregate inundated for a period of time approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in Section 4.4.2.

4.4.2. Perform the procedures as described in Sections 6.5.1 and 6.5.2. Complete the test as described in Section 6.5.3.1 and 6.5.3.1.4. The aggregate correction factor,  $G$ , is equal to the air-content reading minus the volume provided by the calibration vessel,  $R$ .

**NOTE:** The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be easily made and must not be ignored. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

**NOTE:** The aggregate correction factor applies only to apparent air content ( $A_a$ ) as determined in 6.5.3.1.1 and calculated in 7.1. The aggregate correction does not apply to the SAM Number.

## 5. PREPARATION OF CONCRETE TEST SAMPLE

5.1. Obtain a sample of freshly mixed concrete in accordance with **KT-17**.

## 6. PROCEDURE FOR DETERMINING AIR CONTENT AND SAM NUMBER

### 6.1. Placement and Consolidation of Sample:

6.1.1. Prepare the concrete sample as described in **Section 5.1**. Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Using the scoop, place the concrete in the measuring bowl in equal layers. Concrete at different slump levels require different methods of consolidation to prepare satisfactory test specimens. The methods listed below should be used as a guide in determining the type of consolidation to use:

Slump of Concrete	Type of Consolidation
More than 3 in (75 mm)	Rodding
1 to 3 in (25 to 75 mm)	Rodding or Vibration
Less than 1 in (25 mm)	Vibration

### 6.2. Rodding Procedure:

6.2.1. Place the concrete in the measuring bowl in three layers of approximately equal volume.

6.2.2. Consolidate each layer of concrete by 25 strokes of the tamping rod evenly distributed over the cross section. Rod the bottom layer throughout its depth, but the rod shall not forcibly strike the bottom of the measure. In rodding the second and final layers, use only enough force to cause the rod to penetrate the surface of the previous layer about 1 in. (25 mm). Add the final layer of concrete in a manner to avoid excessive overfilling (**Section 6.4.1**).

6.2.3. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.

### 6.3. Vibration Procedure:

6.3.1. Place the concrete in the measuring bowl in two layers of approximately equal volume. Place all of the concrete for each layer before starting vibration of that layer.

6.3.2. Consolidate each layer by three insertions of the vibrator evenly distributed over the cross section. Add the final layer in a manner to avoid excessive overfilling (**Section 6.4.1**).

6.3.2.1. In consolidating each layer, do not allow the vibrator to rest on or touch the measuring bowl.

6.3.2.2. Take care in withdrawing the vibrator to ensure that no air pockets are left in the specimen.

6.3.2.3. Observe a standard duration of vibration for the particular kind of concrete, vibrator, and measuring bowl involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Continue vibration only long enough to achieve proper

consolidation of the concrete. Over-vibration may cause segregation and loss of intentionally entrained air. Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and has a glazed appearance. Never continue vibration long enough to cause escape of froth from the sample.

#### 6.4. Strike Off

**6.4.1.** After consolidation of the concrete, strike off the top surface by sliding the strike-off bar or plate across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just full. On completion of consolidation, the bowl must not contain an excess or deficiency of concrete. Removal of approximately 1/8 in. (3 mm) during strike off is optimum. A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off.

#### 6.5. Procedure:

**6.5.1.** Thoroughly clean the flanges or rims of the bowl and the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus.

**6.5.2.** Close the air valve between the air chamber and the measuring bowl and open both petcocks on the holes through the cover. Using a rubber syringe, inject water through one petcock until water emerges from the opposite petcock. Incline the apparatus and rock back and forth while continuing to add water to remove any air bubbles above the concrete sample. Continue adding water with the rubber syringe until water emerges air-free from the opposite petcock.

#### 6.5.3. Test Procedure:

##### 6.5.3.1. First Sequential Pressure:

**6.5.3.1.1.** Close the air bleeder valve on the air chamber and pump air into the air chamber until the gauge reads  $14.5 \pm 0.05$  psi ( $100 \pm 0.3$  kPa). For all pressure readings these values can be reached by pumping or bleeding off air as necessary. Allow a few seconds for the pressure reading to stabilize (this occurs as the compressed air cools to normal temperature). Close both petcocks on the holes through the cover. Open the air valve between the air chamber and the measuring bowl. Continue to hold this air valve open for ten seconds while tapping the sides of the measuring bowl smartly with the mallet.

**NOTE:** The meter may display apparent air content ( $A_a$ ) after this step. If the apparent air content ( $A_a$ ) is the only value desired, the test may be aborted after completing this step and recording the apparent air content ( $A_a$ ).

**6.5.3.1.2. Without releasing the petcocks,** pump air into the air chamber until the gauge reads  $30 \pm 0.05$  psi ( $207 \pm 0.3$  kPa). Open the air valve between the air chamber and the measuring bowl. Continue to hold this air valve open for ten seconds while tapping the sides of the measuring bowl smartly with the mallet.

**6.5.3.1.3.** Repeat the step in Section **6.5.3.1.2** with an air chamber pressure of  $45 \pm 0.05$  psi ( $310 \pm 0.3$  kPa).

**6.5.3.1.4.** Release the pressure by opening both petcocks and releasing air from the air chamber (**Figure 1**). Failure to close the main air valve before releasing the pressure from either the container or the air

chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be removed and cleaned.

#### **6.5.3.2. Second Sequential Pressure:**

**6.5.3.2.1.** Repeat the steps in Section **6.5.2** to refill the water in the bottom chamber while still leaving the cover clamped to the bottom chamber.

**6.5.3.2.1.** Repeat the steps in Sections **6.5.3.1.1** through **6.5.3.1.4**.

**6.5.3.3.** The meter will then display the apparent air content ( $A_a$ ) and the SAM number.

## **7. CALCULATION**

**7.1. Air Content of Sample Tested:** Calculate the air content of the concrete in the measuring bowl as follows:

$$(3) A_s = A_a - G$$

Where:  $A_s$  = air content of sample tested, percent;  
 $A_a$  = apparent air content of the sample tested, percent (Section 6.5.3.3); and  
 $G$  = aggregate correction factor, percent (Section 4).

## **8. REPORT**

**8.1.** Report the following information:

**8.1.1.** The air content of the concrete sample to the nearest 0.1 percent after subtracting the aggregate correction factor ( $A_s$  per Equation 3).

**8.1.2.** The SAM number to 0.01 psi.

**8.1.3.** The date and time of the test.

## **9. PRECISION AND BIAS**

**9.1.** Precision:

**9.1.1. Single-Operator Precision:** The single operator standard deviation cannot be established because the sample requirements for this test do not allow a single operator time to conduct more than one test on a sample.

**9.1.2. Multilaboratory Precision:** The multilaboratory standard deviation has not been established.

**9.1.3. Multioperator Precision:** The multioperator standard deviation of a single test has been found to be 0.06 percent air by volume of concrete and SAM number of 0.05 psi (0.3 kPa) for SAM numbers less than 0.30 psi (2.1 kPa).



**NOTE:** The precision statement is based on the variation in tests on 95 different concretes.

**NOTE:** When the tests were used to investigate calibration vessels in water for 40 different tests the standard deviation for the air content was similar to the measurement in concrete, but the SAM number was 0.02 psi (0.14 kPa). This suggests that the variability of the SAM number measurement has a strong dependence on the concrete sample being measured.

**9.2. Bias:** This test method has no bias because the air content and void size distribution of freshly mixed concrete can only be defined in terms of the test methods.

## **10. CALIBRATION OF APPARATUS**

**NOTE:** Rough handling, change in volume, or adjustment of the clamp arms will affect the calibration of the meter. The steps described in **Section 10**, as applicable to the meter type under consideration, are prerequisites for the final calibration test to ensure the meter is reading accurately. Calibration shall be made as frequently as necessary to ensure the correct air content is being indicated on the air content scale. The pressure gauge shall be calibrated annually in accordance with AASHTO TP 118 to ensure that it is reading correctly.

### **10.1. Calibration of the Calibration Vessel:**

**10.1.1.** Determine accurately the mass of water required to fill the calibration vessel,  $w$ , using a scale accurate to 0.1% of the mass of the vessel filled with water.

### **10.2. Calibration of the Assembled Apparatus:**

**10.2.1.** Determine the mass of water required to fill the assembled Apparatus,  $W$ , using a scale accurate to 0.1% of the mass of the apparatus filled with water. This is done by nearly filling the measuring bowl with water, assembling the lid while ensuring a tight seal to the measuring bowl, and then adding water through the petcocks to fill the chamber. This should be done while making certain that all entrapped air has been removed.

### **10.3. Effective volume of the Calibration Vessel, $R$ :**

**10.3.1.** The constant  $R$  represents the effective volume of the calibration vessel expressed as a percentage of the volume of the assembled apparatus.

$$(4) R = w/W$$

Where:  $w$  = weight of water required to fill the calibration vessel, and  
 $W$  = weight of water required to fill the apparatus.

#### 10.4. Calibration Test to Check the Air Content Measured by the Pressure Gauge:

**10.4.1.** Place the calibration vessel within the bottom chamber. Fill the assembled apparatus as described in **Section 10.2**. Be sure to not allow water inside the calibration vessel during the filling or the removal of the entrapped air from the assembly.

Pressurize the air chamber until it reaches  $14.5 \pm 0.05$  psi ( $100 \pm 0.3$  kPa), close both petcocks in the cover assembly, and then open the valve between the air chamber and the measuring bowl. The indicated air content on the pressure gauge should correspond to  $R$  as defined in **Section 10.3.1**. If two or more determinations show the same variation from the correct air content, the gauge should be adjusted to provide the correct air content and the test repeated until the gauge reading corresponds to  $R$ .

If difficulty is encountered in obtaining consistent readings, check for leaks; for the presence of water inside the air chamber or the calibration vessel; or for the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool, aerated water. In this latter instance, use deaerated water, which can be obtained by cooling hot water to room temperature.

#### 10.5. Calibration Test to Determine Consistent Chamber Volume

**10.5.1.** Fill the assembled apparatus with water as outlined in **Section 10.2**. Follow the procedure as outlined in **Section 6.5.3** but do not tap the container with a mallet. Record the values at the three points of pressure equalization. Compare these values to those provided by the manufacturer. If the difference between the measured values and those provided are greater than 0.25 psi (1.7 kPa), then the air chamber, measuring bowl, and underside of the lid should be checked for material build up and obstructions. The meter should also be checked for leaks. The meter should not be used until the manufacturer-provided values can be obtained.

**NOTE:** Calibration records shall include size of the calibration vessel used and the reading of the meter at the calibration test point(s).

**NOTE:** Unless otherwise stated, follow manufacturer's recommended calibration frequency.

### 11. PARAMETER CALCULATIONS

**11.1.** Apparent Air Content: Determination of the apparent air content,  $A_a$ , varies with the manufacturer of the air pressure meter.

**11.2.** SAM Number: Calculate the SAM number as follows:

$$(5) \text{ SAM number} = P45-2 - P45-1 \text{ (A2.1)}$$

Where:

SAM number = A parameter that corresponds to the air-void size distribution in the fresh concrete,  
P45-2 = Equilibrium pressure between the air chamber and bottom chamber from the second 45 psi (310 kPa) pressure step, and  
P45-1 = Equilibrium pressure between the air chamber and bottom chamber from the first 45 psi (310 kPa) pressure step.



## 5.10. CALCULATIONS

### 5.10.1. ABSOLUTE VOLUME AND PERCENT OF VOIDS IN A UNIT VOLUME OF AGGREGATE

#### 1. Scope.

This method covers the procedure for calculating the volume of space occupied by the aggregate particles and the voids in a unit volume of aggregate.

#### 2. Procedure.

**2.1.** The unit weight of the aggregate shall be determined by **KT-05**. The specific gravity of the aggregate shall be determined by **KT-06**.

**2.2.** Volume of Aggregate Particles: Calculate the absolute volume of space occupied by the aggregate particles by the following formula:

$$\begin{array}{ll} \text{SI Formula:} & \text{English Formula:} \\ A_s = \frac{W_{sm}}{\text{Sp. Gr.}(997)} & A_s = \frac{W_s}{\text{Sp. G.}(62.24)} \end{array}$$

Where:

$A_s$  = Absolute volume of the aggregate.  
 $W_s$  = Weight of the unit volume of aggregate in pounds.  
 $W_{sm}$  = Weight of the volume of aggregate in kilograms (kg)  
 $\text{Sp.G.}$  = Specific Gravity of the aggregate. (Saturated-Surface Dry condition, unless otherwise specified)

Example: Unit weight of aggregate is normally expressed in kilograms per cubic meter (pounds per cubic foot). Therefore, one cubic meter (cubic foot) is used in this example.

$W_{sm}$  = Wt. of 1 cu. meter of aggregate = 1762 kg.  
 $W_s$  = Wt. of 1 cu. ft. of aggregate = 110 lb.  
 $\text{Sp.G.}$  = 2.65

$$\begin{array}{ll} \text{SI Example:} & \text{English Example:} \\ A_s = \frac{1762}{2.65(997)} = 0.667 \text{ cu. meter} & A_s = \frac{110}{2.65(62.24)} = 0.667 \text{ cu. ft.} \end{array}$$

or  $0.667 \times 100 = 66.7$  percent of the total volume is occupied by the aggregate.

**2.3.** Volume of Voids: Since the aggregate occupies 0.667 cu. meter (cu. ft.) the volume of voids is:

$1.000 - 0.667 = 0.333$  cu. meter (cu. ft.) or:  
 $0.333 \times 100 = 33.3$  percent of the total volume is voids.



## 5.10.2. THEORETICAL SPECIFIC GRAVITY OF A COMBINATION OF AGGREGATES

### 1. SCOPE

This method covers the procedure for calculating the theoretical specific gravity of a mixture of aggregates that have been combined on a weight basis.

### 2. PROCEDURE

The specific gravity of the individual aggregates shall be determined using **KT-06**. Calculate the specific gravity of the mixture by use of the following formula.

$$G = \frac{100}{\left(\frac{P_1}{G_1}\right) + \left(\frac{P_2}{G_2}\right) + \left(\frac{P_3}{G_3}\right) + \dots}$$

Where:  $G$  = Specific gravity of the combined aggregate.

$P_1, P_2, P_3$ , etc. = Percentage by weight of aggregates No. 1, 2, 3, etc. in the mixture.

$G_1, G_2, G_3$ , etc. = Specific gravity (Bulk-Saturated Surface Dry) of aggregates No. 1, 2, 3, etc.

Example:

<u>Aggregate</u>	<u>% in Mix by Weight</u>	<u>Specific Gravity</u>
Crushed Stone	45	2.58
Sand	40	2.61
Mineral Filler	15	2.52

$$G = \frac{100}{\left(\frac{45}{2.58}\right) + \left(\frac{40}{2.61}\right) + \left(\frac{15}{2.52}\right)} = 2.58$$



## 5.10.03. VOLUME OF ASPHALT MATERIALS

### 1. SCOPE

This method covers the procedures for correcting the volume of asphalt cement or cutback asphalt at a temperature other than 60°F or 15°C to the volume it would occupy at 60°F or 15°C. For emulsions, the volume is corrected to 60°F (15.6°C).

### 2. PROCEDURE FOR ASPHALT CEMENTS AND CUTBACK ASPHALTS:

SI Procedures:

**Table 1** from the Asphalt Institute Manual Series No. 6 (MS-6) shows the factors to be used in calculating the volume of asphalt material at 15°C. The factors are divided into two groups: A and B in **Table 1** depending on the density. The specific gravity test results for asphalt are reported by the refinery or Department chemists. The specific gravity may be converted to density values by use of the following formula:

$$\text{Density} = 1000G$$

Where: G = The specific gravity of the material

SI Examples for conversion of volume to 15°C.

SI Example No. 1:

Given: 5.678 m<sup>3</sup> of MC-70 at 65.5°C  
Specific Gravity = 0.9600

To calculate the volume at 15°C:  
Density = 1000G = 1000 (0.9600) = 960 kg/m<sup>3</sup>

A density of 960 kg/m<sup>3</sup> places the material in Group B of **Table 1**. In this table, the volume correction factor at 65.5°C is 0.9644. The volume at 15°C is determined as follows:

$$5.678 \text{ m}^3(0.9644) = 5.476 \text{ m}^3 \text{ at } 15^\circ\text{C}$$

SI Example No. 2:

Given: 5.678 m<sup>3</sup> of AC-5 at 150°C  
Specific gravity = 1.0093

To calculate the volume at 15°C  
Density = 1000G = 1000(1.0093) = 1009.3 kg/m<sup>3</sup>

A density of 1009.3 kg/m<sup>3</sup> places the material in Group A of **Table 1**. In this table, the volume correction factor at 150°C is 0.9177. The volume at 15°C is determined as follows:

$$5.678 \text{ m}^3(0.9177) = 5.211 \text{ m}^3 \text{ at } 15^\circ\text{C}$$



English Procedures:

**Table 2**, shows the factors to be used in calculating the volume of asphalt material at 60°F. The factors are divided into three groups: 0, 1, and 2 depending upon the API gravity degrees of the material in question. Specific gravity test results for asphalts are reported by the refinery or Department chemists. These specific gravities may be converted to API values by use of the following formula:

$$API\ Gravity\ (degrees) = \frac{141.5 - 131.5(G)}{G}$$

Where: G = The specific gravity of the material.

For convenience in using **Table 2**, the following relationships between specific gravity and API gravity have been computed:

<u>Group</u> (See <b>Table 2</b> )	<u>API</u> <u>Gravity</u>	<u>Specific</u> <u>Gravity</u>
0	0-14.9	1.0760 to 0.9665
1	15.0-34.9	0.9659 to 0.8504
2	35.0-50.9	0.8498 to 0.7758

English Example No. 1:

Given: 1500 gal. of MC-70 at 150°F.  
Specific Gravity = 0.9600

To calculate volume at 60°F:

From the above tabulation, a specific gravity of 0.9600 places the material in Group 1 of **Table 2**. In this table, the factor for Group 1 at 150°F is 0.9647.

Then: 1500 gal. x 0.9647 = 1447 gal. at 60°F.

English Example No. 2:

Given: 1500 Gal. of AC-5 at 300°F  
Specific Gravity = 1.0093.

To calculate the volume at 60°F

This material is in Group 0 in **Table 2**. In this table, the factor for Group 0 at 300°F. is 0.9187.

Then: 1500 gal. x 0.9187 = 1378 gal. at 60°F.

### 3. PROCEDURE FOR EMULSIFIED ASPHALTS:

**Table 3** has been taken from the Asphalt Institute Manual Series No. 19(MS-19) and is to be used to correct the volume of hot emulsified asphalt to its volume at (15.6°C) 60°F.

Example No. 1:

Given:

5.678 m<sup>3</sup> (1500 gal.) of emulsion at 54.4°C (130°F)

From the table, at 54.4°C (130°F) the factor is 0.98250.

SI Example:

$$5.678 \text{ m}^3 \text{ at } 54.4^\circ\text{C} = 5.678 (0.98250) = 5.579 \text{ m}^3 \text{ at } 15.6^\circ\text{C}$$

English Example:

$$1500 \text{ gal. at } 130^\circ\text{F} = 1500 (0.98250) = 1474 \text{ gal. at } 60^\circ\text{F}$$

Example No. 2:

Given:

3.854 cubic meters (1018 gal.) of diluted emulsified asphalt at 54°C (130°F)

[1.893 cubic meters (500 gal.) of water and 1.893 cubic meters (500 gal.) of emulsified asphalt at ambient temp.]

From the table, at 54°C (130°F) the factor is 0.98250

SI Example:

$$\frac{3.854}{2} \text{ m}^3 = 1.927 \text{ m}^3 \text{ emulsified asphalt at } 54^\circ\text{C}$$

$$1.927(0.98250) = 1.893 \text{ m}^3 \text{ emulsified asphalt at } 15.5^\circ\text{C}$$

English Example:

$$\frac{1018}{2} = 509 \text{ gal. of emulsified asphalt at } 130^\circ\text{F}$$

$$509(0.98250) = 500 \text{ gal. of emulsified asphalt at } 60^\circ\text{F}$$

**TABLE 1**

Temperature - Volume Corrections for Asphalt Materials  
(Degrees Celsius)  
(From Asphalt Institute Manual Series No. 6 (MS-6))

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>-25.0</b>	1.0254	1.0290	<b>-12.5</b>	1.0174	1.0199	<b>0</b>	1.0095	1.0108
<b>-24.5</b>	1.0251	1.0286	<b>-12.0</b>	1.0171	1.0195	<b>0.5</b>	1.0092	1.0104
<b>-24.0</b>	1.0248	1.0283	<b>-11.5</b>	1.0168	1.0192	<b>1.0</b>	1.0089	1.0101
<b>-23.5</b>	1.0244	1.0279	<b>-11.0</b>	1.0164	1.0188	<b>1.5</b>	1.0085	1.0097
<b>-23.0</b>	1.0241	1.0276	<b>-10.5</b>	1.0161	1.0185	<b>2.0</b>	1.0082	1.0094
<b>-22.5</b>	1.0238	1.0272	<b>-10.0</b>	1.0158	1.0181	<b>2.5</b>	1.0079	1.0090
<b>-22.0</b>	1.0235	1.0268	<b>-9.5</b>	1.0155	1.0177	<b>3.0</b>	1.0076	1.0086
<b>-21.5</b>	1.0232	1.0265	<b>-9.0</b>	1.0152	1.0174	<b>3.5</b>	1.0073	1.0083
<b>-21.0</b>	1.0228	1.0261	<b>-8.5</b>	1.0148	1.0170	<b>4.0</b>	1.0069	1.0079
<b>-20.5</b>	1.0225	1.0258	<b>-8.0</b>	1.0145	1.0166	<b>4.5</b>	1.0066	1.0076
<b>-20.0</b>	1.0222	1.0254	<b>-7.5</b>	1.0142	1.0163	<b>5.0</b>	1.0063	1.0072
<b>-19.5</b>	1.0219	1.0250	<b>-7.0</b>	1.0139	1.0159	<b>5.5</b>	1.0060	1.0068
<b>-19.0</b>	1.0216	1.0247	<b>-6.5</b>	1.0136	1.0155	<b>6.0</b>	1.0057	1.0065
<b>-18.5</b>	1.0212	1.0243	<b>-6.0</b>	1.0132	1.0151	<b>6.5</b>	1.0053	1.0061
<b>-18.0</b>	1.0209	1.0239	<b>-5.5</b>	1.0129	1.0148	<b>7.0</b>	1.0050	1.0058
<b>-17.5</b>	1.0206	1.0236	<b>-5.0</b>	1.0126	1.0144	<b>7.5</b>	1.0047	1.0054
<b>-17.0</b>	1.0203	1.0232	<b>-4.5</b>	1.0123	1.0140	<b>8.0</b>	1.0044	1.0050
<b>-16.5</b>	1.0200	1.0228	<b>-4.0</b>	1.0120	1.0137	<b>8.5</b>	1.0041	1.0047
<b>-16.0</b>	1.0196	1.0224	<b>-3.5</b>	1.0117	1.0133	<b>9.0</b>	1.0037	1.0043
<b>-15.5</b>	1.0193	1.0221	<b>-3.0</b>	1.0114	1.0130	<b>9.5</b>	1.0034	1.0040
<b>-15.0</b>	1.0190	1.0217	<b>-2.5</b>	1.0111	1.0126	<b>10.0</b>	1.0031	1.0036
<b>-14.5</b>	1.0187	1.0213	<b>-2.0</b>	1.0107	1.0122	<b>10.5</b>	1.0028	1.0032
<b>-14.0</b>	1.0184	1.0210	<b>-1.5</b>	1.0104	1.0119	<b>11.0</b>	1.0025	1.0029
<b>-13.5</b>	1.0180	1.0206	<b>-1.0</b>	1.0101	1.0115	<b>11.5</b>	1.0022	1.0025
<b>-13.0</b>	1.0177	1.0203	<b>-0.5</b>	1.0098	1.0112	<b>12.0</b>	1.0019	1.0022

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.

**TABLE 1 - continued**

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>12.5</b>	1.0016	1.0018	<b>27.5</b>	0.9922	0.9911	<b>42.5</b>	0.9829	0.9805
<b>13.0</b>	1.0012	1.0014	<b>28.0</b>	0.9918	0.9907	<b>43.0</b>	0.9825	0.9801
<b>13.5</b>	1.0009	1.0011	<b>28.5</b>	0.9915	0.9904	<b>43.5</b>	0.9822	0.9798
<b>14.0</b>	1.0006	1.0007	<b>29.0</b>	0.9912	0.9900	<b>44.0</b>	0.9819	0.9794
<b>14.5</b>	1.0003	1.0004	<b>29.5</b>	0.9909	0.9897	<b>44.5</b>	0.9816	0.9791
<b>15.0</b>	1.0000	1.0000	<b>30.0</b>	0.9906	0.9893	<b>45.0</b>	0.9813	0.9787
<b>15.5</b>	0.9997	0.9998	<b>30.5</b>	0.9903	0.9889	<b>45.5</b>	0.9810	0.9784
<b>16.0</b>	0.9994	0.9993	<b>31.0</b>	0.9900	0.9886	<b>46.0</b>	0.9807	0.9780
<b>16.5</b>	0.9991	0.9989	<b>31.5</b>	0.9897	0.9882	<b>46.5</b>	0.9804	0.9777
<b>17.0</b>	0.9988	0.9986	<b>32.0</b>	0.9894	0.9879	<b>47.0</b>	0.9801	0.9773
<b>17.5</b>	0.9985	0.9982	<b>32.5</b>	0.9891	0.9875	<b>47.5</b>	0.9798	0.9770
<b>18.0</b>	0.9981	0.9978	<b>33.0</b>	0.9887	0.9871	<b>48.0</b>	0.9794	0.9766
<b>18.5</b>	0.9978	0.9975	<b>33.5</b>	0.9984	0.9868	<b>48.5</b>	0.9791	0.9763
<b>19.0</b>	0.9975	0.9971	<b>34.0</b>	0.9881	0.9864	<b>49.0</b>	0.9788	0.9759
<b>19.5</b>	0.9972	0.9968	<b>34.5</b>	0.9878	0.9861	<b>49.5</b>	0.9785	0.9756
<b>20.0</b>	0.9969	0.9964	<b>35.0</b>	0.9875	0.9857	<b>50.0</b>	0.9782	0.9752
<b>20.5</b>	0.9966	0.9961	<b>35.5</b>	0.9872	0.9854	<b>50.5</b>	0.9779	0.9749
<b>21.0</b>	0.9963	0.9957	<b>36.0</b>	0.9869	0.9850	<b>51.0</b>	0.9776	0.9745
<b>21.5</b>	0.9959	0.9954	<b>36.5</b>	0.9866	0.9847	<b>51.5</b>	0.9773	0.9742
<b>22.0</b>	0.9956	0.9950	<b>37.0</b>	0.9863	0.9843	<b>52.0</b>	0.9770	0.9738
<b>22.5</b>	0.9953	0.9947	<b>37.5</b>	0.9860	0.9840	<b>52.5</b>	0.9767	0.9735
<b>23.0</b>	0.9950	0.9943	<b>38.0</b>	0.9856	0.9836	<b>53.0</b>	0.9763	0.9731
<b>23.5</b>	0.9947	0.9940	<b>38.5</b>	0.9853	0.9833	<b>53.5</b>	0.9760	0.9728
<b>24.0</b>	0.9943	0.9936	<b>39.0</b>	0.9850	0.9829	<b>54.0</b>	0.9757	0.9724
<b>24.5</b>	0.9940	0.9933	<b>39.5</b>	0.9847	0.9826	<b>54.5</b>	0.9754	0.9721
<b>25.0</b>	0.9937	0.9929	<b>40.0</b>	0.9844	0.9822	<b>55.0</b>	0.9751	0.9717
<b>25.5</b>	0.9934	0.9925	<b>40.5</b>	0.9841	0.9819	<b>55.5</b>	0.9748	0.9714
<b>26.0</b>	0.9931	0.9922	<b>41.0</b>	0.9838	0.9815	<b>56.0</b>	0.9745	0.9710
<b>26.5</b>	0.9928	0.9918	<b>41.5</b>	0.9835	0.9812	<b>56.5</b>	0.9742	0.9707
<b>27.0</b>	0.9925	0.9915	<b>42.0</b>	0.9832	0.9808	<b>57.0</b>	0.9739	0.9703

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.

**TABLE 1 - continued**

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>57.5</b>	0.9736	0.9700	<b>72.5</b>	0.9643	0.9595	<b>87.5</b>	0.9552	0.9492
<b>58.0</b>	0.9732	0.9696	<b>73.0</b>	0.9640	0.9592	<b>88.0</b>	0.9548	0.9489
<b>58.5</b>	0.9729	0.9693	<b>73.5</b>	0.9637	0.9588	<b>88.5</b>	0.9545	0.9485
<b>59.0</b>	0.9726	0.9689	<b>74.0</b>	0.9634	0.9585	<b>89.0</b>	0.9542	0.9482
<b>59.5</b>	0.9723	0.9686	<b>74.5</b>	0.9631	0.9581	<b>89.5</b>	0.9539	0.9478
<b>60.0</b>	0.9720	0.9682	<b>75.0</b>	0.9628	0.9578	<b>90.0</b>	0.9536	0.9475
<b>60.5</b>	0.9717	0.9679	<b>75.5</b>	0.9625	0.9575	<b>90.5</b>	0.9533	0.9472
<b>61.0</b>	0.9714	0.9675	<b>76.0</b>	0.9622	0.9571	<b>91.0</b>	0.9530	0.9468
<b>61.5</b>	0.9711	0.9672	<b>76.5</b>	0.9619	0.9568	<b>91.5</b>	0.9527	0.9465
<b>62.0</b>	0.9708	0.9668	<b>77.0</b>	0.9616	0.9564	<b>92.0</b>	0.9524	0.9461
<b>62.5</b>	0.9705	0.9665	<b>77.5</b>	0.9613	0.9561	<b>92.5</b>	0.9521	0.9458
<b>63.0</b>	0.9701	0.9661	<b>78.0</b>	0.9609	0.9557	<b>93.0</b>	0.9518	0.9455
<b>63.5</b>	0.9698	0.9658	<b>78.5</b>	0.9606	0.9554	<b>93.5</b>	0.9515	0.9451
<b>64.0</b>	0.9695	0.9654	<b>79.0</b>	0.9603	0.9550	<b>94.0</b>	0.9512	0.9448
<b>64.5</b>	0.9692	0.9651	<b>79.5</b>	0.9600	0.9547	<b>94.5</b>	0.9509	0.9444
<b>65.0</b>	0.9689	0.9647	<b>80.0</b>	0.9597	0.9543	<b>95.0</b>	0.9506	0.9441
<b>65.5</b>	0.9686	0.9644	<b>80.5</b>	0.9594	0.9540	<b>95.5</b>	0.9503	0.9438
<b>66.0</b>	0.9683	0.9640	<b>81.0</b>	0.9591	0.9536	<b>96.0</b>	0.9500	0.9434
<b>66.5</b>	0.9680	0.9637	<b>81.5</b>	0.9588	0.9533	<b>96.5</b>	0.9497	0.9431
<b>67.0</b>	0.9677	0.9633	<b>82.0</b>	0.9585	0.9529	<b>97.0</b>	0.9494	0.9427
<b>67.5</b>	0.9674	0.9630	<b>82.5</b>	0.9582	0.9526	<b>97.5</b>	0.9491	0.9424
<b>68.0</b>	0.9670	0.9626	<b>83.0</b>	0.9578	0.9523	<b>98.0</b>	0.9488	0.9421
<b>68.5</b>	0.9667	0.9623	<b>83.5</b>	0.9576	0.9519	<b>98.5</b>	0.9485	0.9417
<b>69.0</b>	0.9664	0.9619	<b>84.0</b>	0.9573	0.9516	<b>99.0</b>	0.9482	0.9414
<b>69.5</b>	0.9661	0.9616	<b>84.5</b>	0.9570	0.9512	<b>99.5</b>	0.9479	0.9410
<b>70.0</b>	0.9658	0.9612	<b>85.0</b>	0.9567	0.9509	<b>100.0</b>	0.9476	0.9407
<b>70.5</b>	0.9655	0.9609	<b>85.5</b>	0.9564	0.9506	<b>100.5</b>	0.9473	0.9404
<b>71.0</b>	0.9652	0.9605	<b>86.0</b>	0.9561	0.9502	<b>101.0</b>	0.9470	0.9400
<b>71.5</b>	0.9649	0.9602	<b>86.5</b>	0.9558	0.9499	<b>101.5</b>	0.9467	0.9397
<b>72.0</b>	0.9646	0.9598	<b>87.0</b>	0.9555	0.9495	<b>102.0</b>	0.9464	0.9393

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.

**TABLE 1 - continued**

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>102.5</b>	0.9461	0.9390	<b>117.5</b>	0.9371	0.9289	<b>132.5</b>	0.9281	0.9188
<b>103.0</b>	0.9458	0.9387	<b>118.0</b>	0.9368	0.9285	<b>133.0</b>	0.9278	0.9185
<b>103.5</b>	0.9455	0.9383	<b>118.5</b>	0.9365	0.9282	<b>133.5</b>	0.9275	0.9181
<b>104.0</b>	0.9452	0.9380	<b>119.0</b>	0.9362	0.9279	<b>134.0</b>	0.9272	0.9178
<b>104.5</b>	0.9449	0.9376	<b>119.5</b>	0.9359	0.9275	<b>134.5</b>	0.9269	0.9174
<b>105.0</b>	0.9446	0.9373	<b>120.0</b>	0.9356	0.9272	<b>135.0</b>	0.9266	0.9171
<b>105.5</b>	0.9443	0.9370	<b>120.5</b>	0.9353	0.9269	<b>135.5</b>	0.9263	0.9168
<b>106.0</b>	0.9440	0.9366	<b>121.0</b>	0.9350	0.9265	<b>136.0</b>	0.9260	0.9164
<b>106.5</b>	0.9437	0.9363	<b>121.5</b>	0.9347	0.9262	<b>136.5</b>	0.9257	0.9161
<b>107.0</b>	0.9434	0.9359	<b>122.0</b>	0.9344	0.9258	<b>137.0</b>	0.9254	0.9158
<b>107.5</b>	0.9431	0.9356	<b>122.5</b>	0.9341	0.9255	<b>137.5</b>	0.9251	0.9155
<b>108.0</b>	0.9428	0.9353	<b>123.0</b>	0.9338	0.9252	<b>138.0</b>	0.9248	0.9151
<b>108.5</b>	0.9425	0.9349	<b>123.5</b>	0.9335	0.9248	<b>138.5</b>	0.9246	0.9148
<b>109.0</b>	0.9422	0.9346	<b>124.0</b>	0.9332	0.9245	<b>139.0</b>	0.9242	0.9145
<b>109.5</b>	0.9419	0.9342	<b>124.5</b>	0.9329	0.9241	<b>139.5</b>	0.9239	0.9141
<b>110.0</b>	0.9416	0.9339	<b>125.0</b>	0.9326	0.9238	<b>140.0</b>	0.9236	0.9138
<b>110.5</b>	0.9413	0.9336	<b>125.5</b>	0.9323	0.9235	<b>140.5</b>	0.9233	0.9135
<b>111.0</b>	0.9410	0.9332	<b>126.0</b>	0.9320	0.9231	<b>141.0</b>	0.9230	0.9131
<b>111.5</b>	0.9407	0.9329	<b>126.5</b>	0.9317	0.9228	<b>141.5</b>	0.9227	0.9128
<b>112.0</b>	0.9404	0.9325	<b>127.0</b>	0.9314	0.9225	<b>142.0</b>	0.9224	0.9125
<b>112.5</b>	0.9401	0.9322	<b>127.5</b>	0.9311	0.9222	<b>142.5</b>	0.9222	0.9122
<b>113.0</b>	0.9397	0.9319	<b>128.0</b>	0.9308	0.9218	<b>143.0</b>	0.9219	0.9118
<b>113.5</b>	0.9394	0.9315	<b>128.5</b>	0.9305	0.9215	<b>143.5</b>	0.9216	0.9115
<b>114.0</b>	0.9391	0.9312	<b>129.0</b>	0.9302	0.9212	<b>144.0</b>	0.9213	0.9112
<b>114.5</b>	0.9388	0.9308	<b>129.5</b>	0.9299	0.9208	<b>144.5</b>	0.9210	0.9108
<b>115.0</b>	0.9385	0.9305	<b>130.0</b>	0.9296	0.9205	<b>145.0</b>	0.9207	0.9105
<b>115.5</b>	0.9382	0.9302	<b>130.5</b>	0.9293	0.9202	<b>145.5</b>	0.9204	0.9102
<b>116.0</b>	0.9379	0.9298	<b>131.0</b>	0.9290	0.9198	<b>146.0</b>	0.9201	0.9098
<b>116.5</b>	0.9376	0.9295	<b>131.5</b>	0.9287	0.9195	<b>146.5</b>	0.9198	0.9095
<b>117.0</b>	0.9373	0.9292	<b>132.0</b>	0.9284	0.9191	<b>147.0</b>	0.9195	0.9092

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.

**TABLE 1 - continued**

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>147.5</b>	0.9192	0.9089	<b>162.5</b>	0.9104	0.8991	<b>177.5</b>	0.9017	0.8893
<b>148.0</b>	0.9189	0.9085	<b>163.0</b>	0.9101	0.8987	<b>178.0</b>	0.9014	0.8890
<b>148.5</b>	0.9186	0.9082	<b>163.5</b>	0.9098	0.8984	<b>178.5</b>	0.9011	0.8887
<b>149.0</b>	0.9183	0.9079	<b>164.0</b>	0.9095	0.8981	<b>179.0</b>	0.9008	0.8883
<b>149.5</b>	0.9180	0.9075	<b>164.5</b>	0.9092	0.8977	<b>179.5</b>	0.9005	0.8880
<b>150.0</b>	0.9177	0.9072	<b>165.0</b>	0.9089	0.8974	<b>180.0</b>	0.9002	0.8877
<b>150.5</b>	0.9174	0.9069	<b>165.5</b>	0.9086	0.8971	<b>180.5</b>	0.8999	0.8874
<b>151.0</b>	0.9171	0.9065	<b>166.0</b>	0.9083	0.8968	<b>181.0</b>	0.8996	0.8871
<b>151.5</b>	0.9168	0.9062	<b>166.5</b>	0.9080	0.8964	<b>181.5</b>	0.8993	0.8867
<b>152.0</b>	0.9165	0.9059	<b>167.0</b>	0.9077	0.8961	<b>182.0</b>	0.8990	0.8864
<b>152.5</b>	0.9163	0.9056	<b>167.5</b>	0.9075	0.8958	<b>182.5</b>	0.8988	0.8861
<b>153.0</b>	0.9160	0.9052	<b>168.0</b>	0.9072	0.8955	<b>183.0</b>	0.8985	0.8858
<b>153.5</b>	0.9157	0.9049	<b>168.5</b>	0.9069	0.8952	<b>183.5</b>	0.8982	0.8855
<b>154.0</b>	0.9154	0.9046	<b>169.0</b>	0.9066	0.8948	<b>184.0</b>	0.8979	0.8851
<b>154.5</b>	0.9151	0.9042	<b>169.5</b>	0.9063	0.8945	<b>184.5</b>	0.8976	0.8848
<b>155.0</b>	0.9148	0.9039	<b>170.0</b>	0.9060	0.8942	<b>185.0</b>	0.8973	0.8845
<b>155.5</b>	0.9145	0.9036	<b>170.5</b>	0.9057	0.8939	<b>185.5</b>	0.8970	0.8842
<b>156.0</b>	0.9142	0.9033	<b>171.0</b>	0.9054	0.8935	<b>186.0</b>	0.8967	0.8839
<b>156.5</b>	0.9139	0.9029	<b>171.5</b>	0.9051	0.8932	<b>186.5</b>	0.8964	0.8835
<b>157.0</b>	0.9136	0.9026	<b>172.0</b>	0.9048	0.8929	<b>187.0</b>	0.8961	0.8832
<b>157.5</b>	0.9133	0.9023	<b>172.5</b>	0.9046	0.8926	<b>187.5</b>	0.8959	0.8829
<b>158.0</b>	0.9130	0.9020	<b>173.0</b>	0.9043	0.8922	<b>188.0</b>	0.8956	0.8826
<b>158.5</b>	0.9127	0.9017	<b>173.5</b>	0.9040	0.8919	<b>188.5</b>	0.8953	0.8823
<b>159.0</b>	0.9124	0.9013	<b>174.0</b>	0.9037	0.8916	<b>189.0</b>	0.8950	0.8819
<b>159.5</b>	0.9121	0.9010	<b>174.5</b>	0.9034	0.8912	<b>189.5</b>	0.8947	0.8816
<b>160.0</b>	0.9118	0.9007	<b>175.0</b>	0.9031	0.8909	<b>190.0</b>	0.8944	0.8813
<b>160.5</b>	0.9115	0.9004	<b>175.5</b>	0.9028	0.8906	<b>190.5</b>	0.8941	0.8810
<b>161.0</b>	0.9112	0.9000	<b>176.0</b>	0.9025	0.8903	<b>191.0</b>	0.8938	0.8807
<b>161.5</b>	0.9109	0.8997	<b>176.5</b>	0.9022	0.8899	<b>191.5</b>	0.8935	0.8803
<b>162.0</b>	0.9106	0.8994	<b>177.0</b>	0.9019	0.8896	<b>192.0</b>	0.8932	0.8800

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.

**TABLE 1 - continued**

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>192.5</b>	0.8930	0.8797	<b>207.5</b>	0.8843	0.8702	<b>222.5</b>	0.8758	0.8608
<b>193.0</b>	0.8927	0.8794	<b>208.0</b>	0.8840	0.8698	<b>223.0</b>	0.8755	0.8604
<b>193.5</b>	0.8924	0.8791	<b>208.5</b>	0.8837	0.8695	<b>223.5</b>	0.8752	0.8601
<b>194.0</b>	0.8921	0.8787	<b>209.0</b>	0.8835	0.8692	<b>224.0</b>	0.8749	0.8598
<b>194.5</b>	0.8918	0.8784	<b>209.5</b>	0.8832	0.8689	<b>224.5</b>	0.8746	0.8595
<b>195.0</b>	0.8915	0.8781	<b>210.0</b>	0.8829	0.8686	<b>225.0</b>	0.8743	0.8592
<b>195.5</b>	0.8912	0.8778	<b>210.5</b>	0.8826	0.8683	<b>225.5</b>	0.8740	0.8589
<b>196.0</b>	0.8909	0.8775	<b>211.0</b>	0.8823	0.8680	<b>226.0</b>	0.8737	0.8586
<b>196.5</b>	0.8906	0.8771	<b>211.5</b>	0.8820	0.8676	<b>226.5</b>	0.8735	0.8582
<b>197.0</b>	0.8903	0.8768	<b>212.0</b>	0.8817	0.8673	<b>227.0</b>	0.8732	0.8579
<b>197.5</b>	0.8901	0.8765	<b>212.5</b>	0.8815	0.8670	<b>227.5</b>	0.8729	0.8576
<b>198.0</b>	0.8898	0.8762	<b>213.0</b>	0.8812	0.8667	<b>228.0</b>	0.8726	0.8573
<b>198.5</b>	0.8895	0.8759	<b>213.5</b>	0.8809	0.8664	<b>228.5</b>	0.8723	0.8570
<b>199.0</b>	0.8892	0.8755	<b>214.0</b>	0.8806	0.8660	<b>229.0</b>	0.8721	0.8566
<b>199.5</b>	0.8889	0.8752	<b>214.5</b>	0.8803	0.8657	<b>229.5</b>	0.8718	0.8563
<b>200.0</b>	0.8886	0.8749	<b>215.0</b>	0.8800	0.8654	<b>230.0</b>	0.8715	0.8560
<b>200.5</b>	0.8883	0.8746	<b>215.5</b>	0.8797	0.8651	<b>230.5</b>	0.8712	0.8557
<b>201.0</b>	0.8880	0.8743	<b>216.0</b>	0.8794	0.8648	<b>231.0</b>	0.8709	0.8554
<b>201.5</b>	0.8877	0.8739	<b>216.5</b>	0.8792	0.8645	<b>231.5</b>	0.8707	0.8551
<b>202.0</b>	0.8874	0.8736	<b>217.0</b>	0.8789	0.8642	<b>232.0</b>	0.8704	0.8548
<b>202.5</b>	0.8872	0.8733	<b>217.5</b>	0.8786	0.8639	<b>232.5</b>	0.8701	0.8545
<b>203.0</b>	0.8869	0.8730	<b>218.0</b>	0.8783	0.8635	<b>233.0</b>	0.8698	0.8541
<b>203.5</b>	0.8866	0.8727	<b>218.5</b>	0.8780	0.8632	<b>233.5</b>	0.8695	0.8538
<b>204.0</b>	0.8863	0.8723	<b>219.0</b>	0.8778	0.8629	<b>234.0</b>	0.8693	0.8535
<b>204.5</b>	0.8860	0.8720	<b>219.5</b>	0.8775	0.8626	<b>234.5</b>	0.8690	0.8532
<b>205.0</b>	0.8857	0.8717	<b>220.0</b>	0.8772	0.8623	<b>235.0</b>	0.8687	0.8529
<b>205.5</b>	0.8854	0.8714	<b>220.5</b>	0.8769	0.8620	<b>235.5</b>	0.8684	0.8526
<b>206.0</b>	0.8851	0.8711	<b>221.0</b>	0.8766	0.8617	<b>236.0</b>	0.8681	0.8523
<b>206.5</b>	0.8849	0.8708	<b>221.5</b>	0.8763	0.8614	<b>236.5</b>	0.8678	0.8520
<b>207.0</b>	0.8846	0.8705	<b>222.0</b>	0.8760	0.8611	<b>237.0</b>	0.8675	0.8517

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.



**TABLE 1 - continued**

Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C		Observed Temperature, °C	Vol. Correction <sup>C,D</sup> Factors to 15°C	
	A	B		A	B		A	B
<b>237.5</b>	0.8673	0.8514	<b>252.5</b>	0.8588	0.8422	<b>267.5</b>	0.8504	0.8330
<b>238.0</b>	0.8670	0.8510	<b>253.0</b>	0.8585	0.8418	<b>268.0</b>	0.8501	0.8326
<b>238.5</b>	0.8667	0.8507	<b>253.5</b>	0.8582	0.8415	<b>268.5</b>	0.8498	0.8323
<b>239.0</b>	0.8664	0.8504	<b>254.0</b>	0.8580	0.8412	<b>269.0</b>	0.8496	0.8320
<b>239.5</b>	0.8661	0.8501	<b>254.5</b>	0.8577	0.8409	<b>269.5</b>	0.8493	0.8317
<b>240.0</b>	0.8658	0.8498	<b>255.0</b>	0.8574	0.8406	<b>270.0</b>	0.8490	0.8314
<b>240.5</b>	0.8655	0.8495	<b>255.5</b>	0.8571	0.8403	<b>270.5</b>	0.8487	0.8311
<b>241.0</b>	0.8652	0.8492	<b>256.0</b>	0.8568	0.8400	<b>271.0</b>	0.8484	0.8308
<b>241.5</b>	0.8650	0.8489	<b>256.5</b>	0.8566	0.8397	<b>271.5</b>	0.8482	0.8305
<b>242.0</b>	0.8647	0.8486	<b>257.0</b>	0.8563	0.8394	<b>272.0</b>	0.8479	0.8302
<b>242.5</b>	0.8644	0.8483	<b>257.5</b>	0.8560	0.8391	<b>272.5</b>	0.8476	0.8299
<b>243.0</b>	0.8641	0.8480	<b>258.0</b>	0.8557	0.8388	<b>273.0</b>	0.8473	0.8296
<b>243.5</b>	0.8638	0.8477	<b>258.5</b>	0.8554	0.8385	<b>273.5</b>	0.8470	0.8293
<b>244.0</b>	0.8636	0.8474	<b>259.0</b>	0.8552	0.8382	<b>274.0</b>	0.8468	0.8290
<b>244.5</b>	0.8633	0.8471	<b>259.5</b>	0.8549	0.8379	<b>274.5</b>	0.8465	0.8287
<b>245.0</b>	0.8630	0.8468	<b>260.0</b>	0.8546	0.8376			
<b>245.5</b>	0.8627	0.8465	<b>260.5</b>	0.8543	0.8373			
<b>246.0</b>	0.8624	0.8462	<b>261.0</b>	0.8540	0.8370			
<b>246.5</b>	0.8622	0.8459	<b>261.5</b>	0.8538	0.8367			
<b>247.0</b>	0.8619	0.8456	<b>262.0</b>	0.8535	0.8364			
<b>247.5</b>	0.8616	0.8453	<b>262.5</b>	0.8532	0.8361			
<b>248.0</b>	0.8613	0.8449	<b>263.0</b>	0.8529	0.8357			
<b>248.5</b>	0.8610	0.8446	<b>263.5</b>	0.8526	0.8354			
<b>249.0</b>	0.8608	0.8443	<b>264.0</b>	0.8524	0.8351			
<b>249.5</b>	0.8605	0.8440	<b>264.5</b>	0.8521	0.8348			
<b>250.0</b>	0.8602	0.8437	<b>265.0</b>	0.8518	0.8345			
<b>250.5</b>	0.8599	0.8434	<b>265.5</b>	0.8515	0.8342			
<b>251.0</b>	0.8596	0.8431	<b>266.0</b>	0.8512	0.8339			
<b>251.5</b>	0.8594	0.8428	<b>266.5</b>	0.8510	0.8336			
<b>252.0</b>	0.8591	0.8425	<b>267.0</b>	0.8507	0.8333			

<sup>C</sup>Use column A factors for asphalts with density at 15°C of 966 kg/m<sup>3</sup> or higher.

<sup>D</sup>Use column B factors for asphalts with density at 15°C of 850 to 965 kg/m<sup>3</sup>.

**TABLE 2**  
**Standard Abridged Volume Correction Table for Petroleum Oils**  
**A. S. T. M. Serial Designation D1250 (Table 7)**

Observed temperature, °F.	Group No. and API gravity range at 60°F			Observed temperature °F.	Group No and API gravity range at 60°F		
	Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API		Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API
Factor for reducing volume to 60°F.				Factor for reducing volume to 60°F.			
50.....	1.0035	1.0040	1.0050	100.....	0.9861	0.9842	0.9801
51.....	1.0031	1.0036	1.0045	101.....	0.9857	0.9838	0.9796
52.....	1.0028	1.0032	1.0040	102.....	0.9854	0.9834	0.9791
53.....	1.0024	1.0028	1.0035	103.....	0.9851	0.9830	0.9786
54.....	1.0021	1.0024	1.0030	104.....	0.9847	0.9826	0.9781
55.....	1.0017	1.0020	1.0025	105.....	0.9844	0.9822	0.9776
56.....	1.0014	1.0016	1.0020	106.....	0.9840	0.9818	0.9771
57.....	1.0010	1.0012	1.0015	107.....	0.9837	0.9814	0.9766
58.....	1.0007	1.0008	1.0010	108.....	0.9833	0.9810	0.9761
59.....	1.0003	1.0004	1.0005	109.....	0.9830	0.9806	0.9756
60.....	1.0000	1.0000	1.0000	110.....	0.9826	0.9803	0.9751
61.....	0.9997	0.9996	0.9995	111.....	0.9823	0.9799	0.9746
62.....	0.9993	0.9992	0.9990	112.....	0.9819	0.9795	0.9741
63.....	0.9990	0.9988	0.9985	113.....	0.9816	0.9791	0.9736
64.....	0.9986	0.9984	0.9980	114.....	0.9813	0.9787	0.9731
65.....	0.9983	0.9980	0.9975	115.....	0.9809	0.9783	0.9726
66.....	0.9979	0.9976	0.9970	116.....	0.9806	0.9779	0.9721
67.....	0.9976	0.9972	0.9965	117.....	0.9802	0.9775	0.9717
68.....	0.9972	0.9968	0.9960	118.....	0.9799	0.9771	0.9712
69.....	0.9969	0.9964	0.9955	119.....	0.9795	0.9767	0.9707
70.....	0.9965	0.9960	0.9950	120.....	0.9792	0.9763	0.9702
71.....	0.9962	0.9956	0.9945	121.....	0.9788	0.9760	0.9697
72.....	0.9958	0.9952	0.9940	122.....	0.9785	0.9756	0.9692
73.....	0.9955	0.9948	0.9935	123.....	0.9782	0.9752	0.9687
74.....	0.9951	0.9944	0.9930	124.....	0.9778	0.9748	0.9682
75.....	0.9948	0.9940	0.9925	125.....	0.9775	0.9744	0.9677
76.....	0.9944	0.9936	0.9920	126.....	0.9771	0.9740	0.9672
77.....	0.9941	0.9932	0.9916	127.....	0.9768	0.9736	0.9667
78.....	0.9937	0.9929	0.9911	128.....	0.9764	0.9732	0.9662
79.....	0.9934	0.9925	0.9906	129.....	0.9761	0.9728	0.9657
80.....	0.9930	0.9921	0.9901	130.....	0.9758	0.9725	0.9652
81.....	0.9927	0.9917	0.9896	131.....	0.9754	0.9721	0.9647
82.....	0.9923	0.9913	0.9891	132.....	0.9751	0.9717	0.9642
83.....	0.9920	0.9909	0.9886	133.....	0.9747	0.9713	0.9637
84.....	0.9916	0.9905	0.9881	134.....	0.9744	0.9709	0.9632
85.....	0.9913	0.9901	0.9876	135.....	0.9740	0.9705	0.9627
86.....	0.9909	0.9897	0.9871	136.....	0.9737	0.9701	0.9622
87.....	0.9906	0.9893	0.9866	137.....	0.9734	0.9697	0.9617
88.....	0.9902	0.9889	0.9861	138.....	0.9730	0.9693	0.9612
89.....	0.9899	0.9885	0.9856	139.....	0.9727	0.9690	0.9607
90.....	0.9896	0.9881	0.9851	140.....	0.9723	0.9686	0.9602
91.....	0.9892	0.9877	0.9846	141.....	0.9720	0.9682	0.9597
92.....	0.9889	0.9873	0.9841	142.....	0.9716	0.9678	0.9592
93.....	0.9885	0.9869	0.9836	143.....	0.9713	0.9674	0.9587
94.....	0.9882	0.9865	0.9831	144.....	0.9710	0.9670	0.9582
95.....	0.9878	0.9861	0.9826	145.....	0.9706	0.9666	0.9577
96.....	0.9875	0.9857	0.9821	146.....	0.9703	0.9662	0.9572
97.....	0.9871	0.9854	0.9816	147.....	0.9699	0.9659	0.9567
98.....	0.9868	0.9850	0.9811	148.....	0.9696	0.9655	0.9562
99.....	0.9864	0.9846	0.9806	149.....	0.9693	0.9651	0.9557

**TABLE.2 Continued**

Observed temperature, °F.	Group No. and API gravity range at 60°F			Observed temperature °F.	Group No and API gravity range at 60°F		
	Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API		Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API
	Factor for reducing volume to 60°F.				Factor for reducing volume to 60°F.		
150.....	0.9689	0.9647	0.9552	200.....	0.9520	0.9456	0.9303
151.....	0.9686	0.9643	0.9547	201.....	0.9516	0.9452	0.9298
152.....	0.9682	0.9639	0.9542	202.....	0.9513	0.9448	0.9293
153.....	0.9679	0.9635	0.9537	203.....	0.9510	0.9444	0.9288
154.....	0.9675	0.9632	0.9532	204.....	0.9506	0.9441	0.9283
155.....	0.9672	0.9628	0.9527	205.....	0.9503	0.9437	0.9278
156.....	0.9669	0.9624	0.9522	206.....	0.9499	0.9433	0.9273
157.....	0.9665	0.9620	0.9517	207.....	0.9496	0.9429	0.9268
158.....	0.9662	0.9616	0.9512	208.....	0.9493	0.9425	0.9263
159.....	0.9658	0.9612	0.9507	209.....	0.9489	0.9422	0.9258
160.....	0.9655	0.9609	0.9502	210.....	0.9486	0.9418	0.9253
161.....	0.9652	0.9605	0.9497	211.....	0.9483	0.9414	0.9248
162.....	0.9648	0.9601	0.9492	212.....	0.9479	0.9410	0.9243
163.....	0.9645	0.9597	0.9487	213.....	0.9476	0.9407	0.9238
164.....	0.9641	0.9593	0.9482	214.....	0.9472	0.9403	0.9233
165.....	0.9638	0.9589	0.9477	215.....	0.9469	0.9399	0.9228
166.....	0.9635	0.9585	0.9472	216.....	0.9466	0.9395	0.9223
167.....	0.9631	0.9582	0.9467	217.....	0.9462	0.9391	0.9218
168.....	0.9628	0.9578	0.9462	218.....	0.9459	0.9388	0.9213
169.....	0.9624	0.9574	0.9457	219.....	0.9456	0.9384	0.9208
170.....	0.9621	0.9570	0.9452	220.....	0.9452	0.9380	0.9203
171.....	0.9618	0.9566	0.9447	221.....	0.9449	0.9376	0.9198
172.....	0.9614	0.9562	0.9442	222.....	0.9446	0.9373	0.9193
173.....	0.9611	0.9559	0.9437	223.....	0.9442	0.9369	0.9188
174.....	0.9607	0.9555	0.9432	224.....	0.9439	0.9365	0.9183
175.....	0.9604	0.9551	0.9428	225.....	0.9436	0.9361	0.9178
176.....	0.9601	0.9547	0.9423	226.....	0.9432	0.9358	0.9173
177.....	0.9597	0.9543	0.9418	227.....	0.9429	0.9354	0.9168
178.....	0.9594	0.9539	0.9413	228.....	0.9426	0.9350	0.9163
179.....	0.9590	0.9536	0.9408	229.....	0.9422	0.9346	0.9158
180.....	0.9587	0.9532	0.9403	230.....	0.9419	0.9343	0.9153
181.....	0.9584	0.9528	0.9398	231.....	0.9416	0.9339	0.9148
182.....	0.9580	0.9524	0.9393	232.....	0.9412	0.9335	0.9143
183.....	0.9577	0.9520	0.9388	233.....	0.9409	0.9331	0.9138
184.....	0.9574	0.9517	0.9383	234.....	0.9405	0.9328	0.9133
185.....	0.9570	0.9513	0.9378	235.....	0.9402	0.9324	0.9128
186.....	0.9567	0.9509	0.9373	236.....	0.9399	0.9320	0.9123
187.....	0.9563	0.9505	0.9368	237.....	0.9395	0.9316	0.9118
188.....	0.9560	0.9501	0.9363	238.....	0.9392	0.9313	0.9113
189.....	0.9557	0.9498	0.9358	239.....	0.9389	0.9309	0.9108
190.....	0.9553	0.9494	0.9353	240.....	0.9385	0.9305	0.9103
191.....	0.9550	0.9490	0.9348	241.....	0.9382	0.9301	0.9098
192.....	0.9547	0.9486	0.9343	242.....	0.9379	0.9298	0.9093
193.....	0.9543	0.9482	0.9338	243.....	0.9375	0.9294	0.9088
194.....	0.9540	0.9478	0.9333	244.....	0.9372	0.9290	0.9083
195.....	0.9536	0.9475	0.9328	245.....	0.9369	0.9286	0.9078
196.....	0.9533	0.9471	0.9323	246.....	0.9365	0.9283	0.9073
197.....	0.9530	0.9467	0.9318	247.....	0.9362	0.9279	0.9068
198.....	0.9526	0.9463	0.9313	248.....	0.9359	0.9275	0.9063
199.....	0.9523	0.9460	0.9308	249.....	0.9356	0.9272	0.9058

**TABLE 2 Continued**

Observed temperature, °F.	Group No. and API gravity range at 60°F			Observed temperature °F.	Group No. and API gravity range at 60°F		
	Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API		Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API
Factor for reducing volume to 60°F.				Factor for reducing volume to 60°F.			
250.....	0.9352	0.9268	0.9053	300.....	0.9187	0.9083	.....
251.....	0.9349	0.9264	.....	301.....	0.9184	0.9080	.....
252.....	0.9346	0.9260	.....	302.....	0.9181	0.9076	.....
253.....	0.9342	0.9257	.....	303.....	0.9177	0.9072	.....
254.....	0.9339	0.9253	.....	304.....	0.9174	0.9069	.....
255.....	0.9336	0.9249	.....	305.....	0.9171	0.9065	.....
256.....	0.9332	0.9245	.....	306.....	0.9167	0.9061	.....
257.....	0.9329	0.9242	.....	307.....	0.9164	0.9058	.....
258.....	0.9326	0.9238	.....	308.....	0.9161	0.9054	.....
259.....	0.9322	0.9234	.....	309.....	0.9158	0.9050	.....
260.....	0.9319	0.9231	.....	310.....	0.9154	0.9047	.....
261.....	0.9316	0.9227	.....	311.....	0.9151	0.9043	.....
262.....	0.9312	0.9223	.....	312.....	0.9148	0.9039	.....
263.....	0.9309	0.9219	.....	313.....	0.9145	0.9036	.....
264.....	0.9306	0.9216	.....	314.....	0.9141	0.9032	.....
265.....	0.9302	0.9212	.....	315.....	0.9138	0.9029	.....
266.....	0.9299	0.9208	.....	316.....	0.9135	0.9025	.....
267.....	0.9296	0.9205	.....	317.....	0.9132	0.9021	.....
268.....	0.9293	0.9201	.....	318.....	0.9128	0.9018	.....
269.....	0.9289	0.9197	.....	319.....	0.9125	0.9014	.....
270.....	0.9286	0.9194	.....	320.....	0.9122	0.9010	.....
271.....	0.9283	0.9190	.....	321.....	0.9118	0.9007	.....
272.....	0.9279	0.9186	.....	322.....	0.9115	0.9003	.....
273.....	0.9276	0.9182	.....	323.....	0.9112	0.9000	.....
274.....	0.9273	0.9179	.....	324.....	0.9109	0.8996	.....
275.....	0.9269	0.9175	.....	325.....	0.9105	0.8992	.....
276.....	0.9266	0.9171	.....	326.....	0.9102	0.8989	.....
277.....	0.9263	0.9168	.....	327.....	0.9099	0.8985	.....
278.....	0.9259	0.9164	.....	328.....	0.9096	0.8981	.....
279.....	0.9256	0.9160	.....	329.....	0.9092	0.8978	.....
280.....	0.9253	0.9157	.....	330.....	0.9089	0.8974	.....
281.....	0.9250	0.9153	.....	331.....	0.9086	0.8971	.....
282.....	0.9246	0.9149	.....	332.....	0.9083	0.8967	.....
283.....	0.9243	0.9146	.....	333.....	0.9079	0.8963	.....
284.....	0.9240	0.9142	.....	334.....	0.9076	0.8960	.....
285.....	0.9236	0.9138	.....	335.....	0.9073	0.8956	.....
286.....	0.9233	0.9135	.....	336.....	0.9070	0.8952	.....
287.....	0.9230	0.9131	.....	337.....	0.9066	0.8949	.....
288.....	0.9227	0.9127	.....	338.....	0.9063	0.8945	.....
289.....	0.9223	0.9124	.....	339.....	0.9060	0.8942	.....
290.....	0.9220	0.9120	.....	340.....	0.9057	0.8938	.....
291.....	0.9217	0.9116	.....	341.....	0.9053	0.8934	.....
292.....	0.9213	0.9113	.....	342.....	0.9050	0.8931	.....
293.....	0.9210	0.9109	.....	343.....	0.9047	0.8927	.....
294.....	0.9207	0.9105	.....	344.....	0.9044	0.8924	.....
295.....	0.9204	0.9102	.....	345.....	0.9040	0.8920	.....
296.....	0.9200	0.9098	.....	346.....	0.9037	0.8916	.....
297.....	0.9197	0.9094	.....	347.....	0.9034	0.8913	.....
298.....	0.9194	0.9091	.....	348.....	0.9031	0.8909	.....
299.....	0.9190	0.9087	.....	349.....	0.9028	0.8906	.....

**TABLE 2 Continued**

Observed temperature, °F.	Group No. and API gravity range at 60°F			Observed temperature °F.	Group No and API gravity range at 60°F		
	Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API		Group 0 0-14.9° API	Group 1 15.0-34.9° API	Group 2 35.0-50.9° API
Factor for reducing volume to 60°F.				Factor for reducing volume to 60°F.			
350.....	0.9024	0.8902	.....	375.....	0.8944	0.8813	.....
351.....	0.9021	0.8899	.....	376.....	0.8941	0.8809	.....
352.....	0.9018	0.8895	.....	377.....	0.8937	0.8806	.....
353.....	0.9015	0.8891	.....	378.....	0.8934	0.8802	.....
354.....	0.9011	0.8888	.....	379.....	0.8931	0.8799	.....
355.....	0.9008	0.8884	.....	380.....	0.8928	0.8795	.....
356.....	0.9005	0.8881	.....	381.....	0.8924	0.8792	.....
357.....	0.9002	0.8877	.....	382.....	0.8921	0.8788	.....
358.....	0.8998	0.8873	.....	383.....	0.8918	0.8784	.....
359.....	0.8995	0.8870	.....	384.....	0.8915	0.8781	.....
360.....	0.8992	0.8866	.....	385.....	0.8912	0.8777	.....
361.....	0.8989	0.8863	.....	386.....	0.8908	0.8774	.....
362.....	0.8986	0.8859	.....	387.....	0.8905	0.8770	.....
363.....	0.8982	0.8856	.....	388.....	0.8902	0.8767	.....
364.....	0.8979	0.8852	.....	389.....	0.8899	0.8763	.....
365.....	0.8976	0.8848	.....	390.....	0.8896	0.8760	.....
366.....	0.8973	0.8845	.....	391.....	0.8892	0.8756	.....
367.....	0.8969	0.8841	.....	392.....	0.8889	0.8753	.....
368.....	0.8966	0.8838	.....	393.....	0.8886	0.8749	.....
369.....	0.8963	0.8834	.....	394.....	0.8883	0.8746	.....
370.....	0.8960	0.8831	.....	395.....	0.8880	0.8742	.....
371.....	0.8957	0.8827	.....	396.....	0.8876	0.8738	.....
372.....	0.8953	0.8823	.....	397.....	0.8873	0.8735	.....
373.....	0.8950	0.8820	.....	398.....	0.8870	0.8731	.....
374.....	0.8947	0.8816	.....	399.....	0.8867	0.8728	.....
			.....	400.....	0.8864	0.8724	.....

**TABLE 3**

Temperature--Volume Corrections for Emulsified Asphalts

Legend: °C = Observed temperature in Celsius  
 °F = Observed temperature in Fahrenheit  
 M = Multiplier for correcting volumes to the basis of 15.6°C (60°F)

°C	°F	M	°C	°F	M	°C	°F	M	°C	°F	M
10.0	50	1.00250	32.2	90	0.99250	54.4	130	0.98250	76.7	170	0.97250
10.6	51	1.00225	32.8	91	0.99225	55.0	131	0.98225	77.2	171	0.97225
11.1	52	1.00200	33.3	92	0.99200	55.6	132	0.98200	77.8	172	0.97200
11.7	53	1.00175	33.9	93	0.99175	56.1	133	0.98175	78.3	173	0.97175
12.2	54	1.00150	34.4	94	0.99150	56.7	134	0.98150	78.9	174	0.97150
12.8	55	1.00125	35.0	95	0.99125	57.2	135	0.98125	79.4	175	0.97125
13.3	56	1.00100	35.6	96	0.99100	57.8	136	0.98100	80.0	176	0.97100
13.9	57	1.00075	36.1	97	0.99075	58.3	137	0.98075	80.6	177	0.97075
14.4	58	1.00050	36.7	98	0.99050	58.9	138	0.98050	81.1	178	0.97050
15.0	59	1.00025	37.2	99	0.99025	59.4	139	0.98025	81.7	179	0.97025
15.6	60	1.00000	37.8	100	0.99000	60.0	140	0.98000	82.2	180	0.97000
16.1	61	0.99975	38.3	101	0.98975	60.6	141	0.97975	82.8	181	0.96975
16.7	62	0.99950	38.9	102	0.98950	61.1	142	0.97950	83.3	182	0.96950
17.2	63	0.99925	39.4	103	0.98925	61.7	143	0.97925	83.9	183	0.96925
17.8	64	0.99900	40.0	104	0.98900	62.2	144	0.97900	84.4	184	0.96900
18.3	65	0.99875	40.6	105	0.98875	62.8	145	0.97875	85.0	185	0.96875
18.9	66	0.99850	41.1	106	0.98850	63.3	146	0.97850	85.6	186	0.96850
19.4	67	0.99825	41.7	107	0.98825	63.9	147	0.97825	86.1	187	0.96825
20.0	68	0.99800	42.2	108	0.98800	64.4	148	0.97800	86.7	188	0.96800
20.6	69	0.99775	42.8	109	0.98775	65.0	149	0.97775	87.2	189	0.96775
21.1	70	0.99750	43.3	110	0.98750	65.6	150	0.97750	87.8	190	0.96750
21.7	71	0.99725	43.9	111	0.98725	66.1	151	0.97725	88.3	191	0.96725
22.2	72	0.99700	44.4	112	0.98700	66.7	152	0.97700	88.9	192	0.96700
22.8	73	0.99675	45.0	113	0.98675	67.2	153	0.97675	89.4	193	0.96675
23.3	74	0.99650	45.6	114	0.98650	67.8	154	0.97650	90.0	194	0.96650
23.9	75	0.99625	46.1	115	0.98625	68.3	155	0.97625	90.6	195	0.96625
24.4	76	0.99600	46.7	116	0.98600	68.9	156	0.97600	91.1	196	0.96600
25.0	77	0.99575	47.2	117	0.98575	69.4	157	0.97575	91.7	197	0.96575
25.6	78	0.99550	47.8	118	0.98550	70.0	158	0.97550	92.2	198	0.96550
26.1	79	0.99525	48.3	119	0.98525	70.6	159	0.97525	92.8	199	0.96525
26.7	80	0.99500	48.9	120	0.98500	71.1	160	0.97500	93.3	200	0.96500
27.2	81	0.99475	49.4	121	0.98475	71.7	161	0.97475			
27.8	82	0.99450	50.0	122	0.98450	72.2	162	0.97450			
28.3	83	0.99425	50.6	123	0.98425	72.8	163	0.97425			
28.9	84	0.99400	51.1	124	0.98400	73.3	164	0.97400			
29.4	85	0.99375	51.7	125	0.98375	73.9	165	0.97375			
30.0	86	0.99350	52.2	126	0.98350	74.4	166	0.97350			
30.6	87	0.99325	52.8	127	0.98325	75.0	167	0.97325			
31.1	88	0.99300	53.3	128	0.98300	75.6	168	0.97300			
31.7	89	0.99275	53.9	129	0.98275	76.1	169	0.97275			



## 5.10.4. CALCULATIONS FOR THE MARSHALL MIX DESIGN OF BITUMINOUS MIXTURES

### 1. SCOPE

This method covers the formulas used to compute the various values used in the Marshall Mix Design of 100% virgin aggregate mixtures or reclaimed material and virgin aggregate mixtures.

### 2. PROCEDURE

#### 2.1. Aggregate Specific Gravity.

**2.1.1. Virgin Aggregate:** Measure the Bulk (Dry) Specific Gravity of the coarse and fine aggregate fractions (**KT-06**, Procedure I & II).

**2.1.2. Reclaimed Material:** **KT-06**, as indicated above can be used on extracted aggregate if a sufficient quantity is available. If sufficient extracted aggregate is not available, conduct **KT-39** on the reclaimed material. Obtain the specific gravity of the extracted asphalt and calculate the specific gravity of the combined aggregate in the reclaimed material.

**2.2.** Determine the specific gravity of the asphalt cement.

**2.3.** Calculate the Bulk Specific Gravity of the aggregate combination in the paving mixture. ( $G_{sb}$ )

**2.4.** Measure the Maximum Specific Gravity of the loose paving mixture. (**KT-39**) ( $G_{mm}$ )

**2.5.** Measure the Bulk Specific Gravity of the compacted paving mixture. (**KT-15**) ( $G_{mb}$ )

**2.6.** Calculate the Effective Specific Gravity of the aggregate. ( $G_{se}$ )

**2.7.** Calculate asphalt absorption of the aggregate. ( $P_{ba}$ )

**2.8.** Calculate the effective asphalt content of the mixture. ( $P_{be}$ )

**2.9.** Calculate the percent voids in the mineral aggregate in the compacted paving mixture. (VMA)

**2.10.** Calculate the percent air voids in the compacted mixture. ( $P_a$ )

**2.11.** Calculate the percent voids filled with asphalt in the compacted mixture. (VFA)

**2.12.** Calculate the limiting asphalt content at the tentative design asphalt content. ( $R'_{max}$ )

**2.13.** Calculate the Bearing Capacity for each asphalt content.

### 3. EQUATIONS

Equations for the above calculations follow in this text and their application may be expedited by use of the appropriate worksheet (**Figure 1**). Also, there is a computer program available which will complete these calculations. For purposes of illustration, the following data is presumed "known" for a bituminous mixture under evaluation.



**3.1.**

BASIC DATA FOR SAMPLE OF PAVING MIXTURE

**3.1.1. Constituents:**

Material	Specific Gravity		Test Method	Mixture Composition Percent by wt. of	
	Apparent	Bulk Dry		Total Mix	Dry Aggr.
Asph. Cement	G <sub>b</sub> 1.010		T-228	P <sub>b</sub> 6.96	P' <sub>b</sub> 7.48
Coarse Aggr.	2.759	G <sub>1</sub> 2.606	KT-06-I	P <sub>1</sub> 51.45	P' <sub>1</sub> 55.30
Fine Aggr.	2.905	G <sub>2</sub> 2.711	KT-06-II	P <sub>2</sub> 41.59	P' <sub>2</sub> 44.70

**Table 1**

**3.1.2. Paving Mixture:** Bulk specific gravity of compacted paving mixture sample. G<sub>mb</sub> (KT-15) = 2.344

Maximum specific gravity of paving mixture sample. G<sub>mm</sub> (KT-39) = 2.438

NOTE: The calculations are simplified by converting from percent by dry weight of aggregates to percent by total weight of mixture. This is accomplished by use of the following formulas:

$$P_b = \frac{(P_{b'} \times 100)}{(100 + P_{b'})}$$

$$P_1 = \frac{(P_{1'} \times 100)}{(100 + P_{1'})}$$

Where: P<sub>b</sub> = Percent asphalt, total mixture basis.  
P'<sub>b</sub> = Percent asphalt, dry weight basis.  
P<sub>1</sub> = Percent Coarse Aggr., total mixture basis.  
P'<sub>1</sub> = Percent Coarse Aggr., dry weight basis.

Example:  $P_b = \frac{(7.48 \times 100)}{(100 + 7.48)} = 6.96\%$  (asphalt)

$$P_1 = \frac{(55.30 \times 100)}{(100 + 7.48)} = 51.45\%$$
 (coarse aggr.)

P<sub>2</sub> and P<sub>3</sub> are calculated in the same manner as P<sub>1</sub>.

**3.2. Bulk Specific Gravity of Aggregate:** When the total aggregate consists of separate fractions of coarse aggregate, fine aggregate, and mineral filler, all having different specific gravities, the bulk and apparent specific gravities for the total aggregate are calculated as follows:

### 3.2.1. Bulk Specific Gravity, $G_{sb}$ .

$$G_{sb} = \frac{P_1 + P_2 + \dots + P_n}{\left(\frac{P_1}{G_1}\right) + \left(\frac{P_2}{G_2}\right) + \dots + \left(\frac{P_n}{G_n}\right)} \quad (\text{Eq. 1, Figure 1})$$

Where:

- $G_{sb}$  = Bulk dry specific gravity of the total aggregate  
 $P_1, P_2, P_n$  = Percentages by weight of aggregates, 1,2,n;  
 $G_1, G_2, G_n$  = Bulk specific gravities of aggregates 1,2,n.

The bulk specific gravity of mineral filler is difficult to determine accurately at the present time. However, if the apparent specific gravity of the filler is used instead, the error is usually negligible.

Calculation using the data from **Table 1**.

$$G_{sb} = \frac{51.450 + 41.590}{\left(\frac{51.450}{2.606}\right) + \left(\frac{41.590}{2.711}\right)} = \frac{93.040}{19.743 + 15.341} = 2.652$$

**3.3. Effective Specific Gravity of Aggregate:** When based on the maximum specific gravity of a paving mixture,  $G_{mm}$ , the effective specific gravity of the aggregate,  $G_{se}$ , includes all void spaces in the aggregate particles except those that absorb asphalt. It is determined as follows:

$$G_{se} = \frac{P_{mm} - P_b}{\left(\frac{P_{mm}}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)} \quad (\text{Eq. 2, Figure 1})$$

Where:

- $G_{se}$  = Effective specific gravity of aggregate  
 $P_{mm}$  = total loose mixture = 100%  
 $P_b$  = asphalt, percent by total weight of mixture  
 $G_{mm}$  = maximum specific gravity of paving mixture (no air voids), **(KT-39)**  
 $G_b$  = specific gravity of asphalt

Calculation using the data from **Table 1**.

$$G_{se} = \frac{100 - 6.960}{\left(\frac{100}{2.438}\right) - \left(\frac{6.960}{1.010}\right)} = \frac{93.040}{34.126} = 2.726$$

NOTE: The volume of asphalt binder absorbed by an aggregate is almost invariably less than the volume of water absorbed. Consequently, the value for the effective specific gravity of an aggregate ( $G_{se}$ ) should

be between its bulk ( $G_{sb}$ ) and apparent specific gravities ( $G_{sa}$ ). When the effective specific gravity falls outside these limits, its value must be assumed to be incorrect. If this occurs; the calculations, the maximum specific gravity of the total mix (**KT-39**) and the composition of the mix should then be rechecked for the source of the error.

If the apparent specific gravity of the coarse aggregate is 2.759 and the apparent specific gravity of the fine aggregate is 2.905 (see **Table 1.**), the apparent specific gravity,  $G_{sa}$ , of the total aggregate can be calculated by the same formula as the bulk specific gravity by using the apparent specific gravity of each aggregate constituent. For this example, then, the calculated apparent specific gravity,  $G_{sa}$ , is;

$$G_{sa} = \frac{51.450 + 41.590}{\left(\frac{51.450}{2.759}\right) + \left(\frac{41.590}{2.905}\right)} = \frac{93.040}{32.965} = 2.822$$

In the example, the three specific gravities are as follows:

Bulk Specific Gravity	$G_{sb} = 2.652$
Effective Specific Gravity	$G_{se} = 2.726$
Apparent Specific Gravity	$G_{sa} = 2.822$

**3.4. Maximum Specific Gravities of Mixtures with Different Asphalt Contents:** In designing a paving mixture with a given aggregate, the maximum specific gravities,  $G_{mm}$ , at different asphalt contents are needed to calculate the percentage of air voids for each asphalt content. While the same maximum specific gravity can be determined for each asphalt content by **KT-39**, the precision of the test is best when the mixture has close to the optimum asphalt content. Also, it is preferable to measure the maximum specific gravity in duplicate or triplicate.

After averaging the results from these tests and calculating the effective specific gravity of the aggregate, the maximum specific gravity for any other asphalt content can be obtained. For all practical purposes, the effective specific gravity of the aggregate is constant because the asphalt absorption does not vary appreciably with variations in asphalt content.

$$G_{mm} = \frac{P_{mm}}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}} \quad (\text{Eq. 3, Figure 1})$$

Where:

$G_{mm}$	=	maximum specific gravity of paving mixture (no air voids)
$P_{mm}$	=	total loose mixture = 100%
$P_s$	=	aggregate, percent by total weight of mixture ( $P_1 + P_2 + P_3 + P_n$ )
$P_b$	=	asphalt, percent by total weight of mixture.
$G_{se}$	=	effective specific gravity of aggregate.
$G_b$	=	specific gravity of asphalt.

Calculation using specific gravity data from **Table 1.**, effective specific gravity,  $G_{se}$ , determined in **section 3.3.** and an asphalt content,  $P_b$  of 6.96.%

$$G_{mm} = \frac{100}{\frac{93.04}{2.726} + \frac{6.960}{1.010}} = \frac{100}{41.022} = 2.438$$

**3.5. Asphalt Absorption:** Absorption is expressed as a percentage by weight of aggregate rather than as a percentage by total weight of mixture. Asphalt,  $P_{ba}$ , absorption is determined as follows:

$$P_{ba} = 100 \frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})} G_b \quad (\text{Eq. 4, Figure 1})$$

Where:

- $P_{ba}$  = absorbed asphalt, percent by weight of aggregate.
- $G_{se}$  = effective specific gravity of aggregate.
- $G_{sb}$  = bulk specific gravity of aggregate.
- $G_b$  = specific gravity of asphalt.

Calculation using bulk and effective gravities determined in **sections 3.2. and 3.3.** and asphalt specific gravity from **Table 1.**

$$P_{ba} = 100 \times \frac{(2.726 - 2.652)}{(2.652 \times 2.726)} \times 1.010 = 100 \times \frac{0.074}{7.229} \times 1.010 = 1.03$$

**3.6. Effective Asphalt Content of a Paving Mixture:** The effective asphalt content,  $P_{be}$ , of a paving mixture is the total asphalt content minus the quantity of asphalt lost by absorption into the aggregate particles. It is the portion of the total asphalt content that remains as a coating on the outside of the aggregate particles, and is the asphalt content on which service performance of an asphalt paving mixture depends. The formula is:

$$P_{be} = P_b - \left(\frac{P_{ba}}{100}\right) P_s \quad (\text{Eq. 5, Figure 1})$$

Where:

- $P_{be}$  = effective asphalt content, percent by total weight of mixture.
- $P_b$  = asphalt, percent by total weight of mixture.
- $P_{ba}$  = absorbed asphalt, percent by weight of aggregate.
- $P_s$  = aggregate, percent by total weight of mixture.

Calculation using data from **Table 1** and **section 3.5.**

$$P_{be} = 6.96 - \left(\frac{1.03}{100}\right) \times 93.04 = 6.96 - 0.96 = 6.00$$

**3.7. Percent VMA in Compacted Paving Mixture:** The voids in the mineral aggregate, VMA, are defined as the intergranular void space between the aggregate particles in a compacted paving mixture, that includes the air voids and the effective asphalt content, expressed as a percent of the total volume. The VMA is calculated on the basis of the bulk specific gravity of the aggregate and is expressed as a percentage of the bulk volume of the compacted paving mixture. Therefore, the VMA can be calculated by subtracting the volume of the aggregate determined by its bulk specific gravity from the bulk volume of the compacted paving mixture. The method of calculation is illustrated as follows:

If mix composition is determined as percent by weight of the total mixture:

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}} \quad (\text{Eq. 6, Figure 1})$$

Where:

- VMA = voids in mineral aggregate (percent of bulk vol.)
- $G_{sb}$  = bulk specific gravity of aggregate.
- $G_{mb}$  = bulk specific gravity of compacted mixture. (**KT-15**)
- $P_s$  = aggregate, percent by total dry weight of mixture.

Calculation using data from **Table 1** and **section 3.2**.

$$VMA = 100 - \frac{(2.344 \times 93.04)}{2.652} = 100 - 82.23 = 17.77$$

Calculation using data from **Table 1** and **section 3.2**.

$$P_s = \left[ \frac{100}{100 + P_b'} \right] \times 100$$

Where:

$P_b'$  = asphalt, percent by dry weight of aggregate.

$$VMA = 100 - \left[ \frac{2.344}{2.651} \times \frac{100}{100 + 7.48} (100) \right] = 100 - 82.27 = 17.73$$

**3.8. Calculation of Percent Air Voids in Compacted Mixture:** The air voids,  $P_a$ , in a compacted paving mixture consist of the small air spaces between the coated aggregate particles. The percentage of air voids in a compacted mixture can be determined by the following equation:

$$P_a = 100 \left[ \frac{G_{mm} - G_{mb}}{G_{mm}} \right] \quad (\text{Eq. 7, Figure 1})$$

Where:

- $P_a$  = air voids in compacted mixture, percent of total volume.
- $G_{mm}$  = maximum specific gravity of paving mixture (as determined in **section 3.4**. or as determined directly for a paving mixture by **KT-39**)
- $G_{mb}$  = bulk specific gravity of compacted mixture.

Calculation using data from **Table 1**.

$$P_a = 100 \left( \frac{2.438 - 2.344}{2.438} \right) = \frac{9.400}{2.438} = 3.85$$

**3.9. Calculation of Percent Voids Filled with Asphalt:** The voids filled with asphalt, VFA, in a compacted paving mixture consists of that portion of the initial voids in the aggregate, VMA, which has been filled with the non-absorbed, or effective asphalt. The percentage of voids filled with asphalt in a compacted specimen can be determined by the following equation:

$$VFA = \frac{\left(\frac{P_{be}}{G_b}\right)}{\left(\frac{VMA}{G_{mb}}\right)} \times 100$$

or

(Eq. 8, Figure 1)

$$VFA = \left(\frac{VMA - P_a}{VMA}\right) 100$$

Where:

- VMA = voids in mineral aggregate, percent of bulk vol.
- P<sub>be</sub> = effective asphalt content.
- G<sub>b</sub> = specific gravity of asphalt.
- G<sub>mb</sub> = bulk specific gravity of compacted mixture.

$$VFA = 100 \times \frac{\left(\frac{5.98}{1.01}\right)}{\left(\frac{17.73}{2.344}\right)} = 100 \times \frac{5.921}{7.564} = 78.3\%$$

or

$$VFA = \left(\frac{17.73 - 3.85}{17.73}\right) 100 = \left(\frac{13.88}{17.73}\right) 100 = 78.3\%$$

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE

Contract #:  
Project Number:

Date:  
Lab No.:

% AC by Wt. Aggr. 7.48  
AC by Wt. Mix 6.96  
% Aggr. by Wt. Mix 93.04  
S. G. of Asphalt 1.010  
S. G. of Aggr. (bulk) 2.652  
Max. S. G. Mix (KT-39) 2.438  
(computed)  
Theo. Max. KG/M<sup>3</sup>  
Eff. S. G. of Aggr. 2.726  
% Abs. Asphalt 1.05  
Eff. Asph. Content 5.98  
% V. M. A. 17.73  
S. G. of plugs (KT-15) 2.344  
Lab Plugs KG/M<sup>3</sup>  
% Air Voids 3.85  
% Voids Filled 78.3  
P'b Max  
Eff. Film Thickness  
Filler/Binder Ratio

Eq.  
P<sub>b</sub>' %  
P<sub>b</sub>=A  
P<sub>s</sub>=B  
G<sub>b</sub>=C  
1 G<sub>sb</sub>=D  
3 G<sub>mm</sub>  
E  
F (SI)=F  
2 G<sub>sc</sub>=G  
4 P<sub>ba</sub>=H  
5 P<sub>be</sub>=I  
6 VMA=J  
G<sub>mb</sub>=K  
L (SI)=L  
7 P<sub>a</sub>=M  
8 VFA=N  
O  
P  
Q

$$P_b = A = \frac{P_b' * 100}{100 + P_b'}$$

$$P_s = B = 100 - A$$

$$F = 1000E$$

$$G_{sc} = G = \frac{B}{\frac{100}{E} - \frac{A}{C}}$$

$$P_{ba} = H = 100 * \frac{G - D}{D * G} * C$$

$$P_{be} = I = A - \frac{H}{100} * B$$

$$VMA = J = 100 - \frac{K * B}{D}$$

COMBINED AGGREGATE SP. GR.

	APPARENT	BULK	%
+4.75 mm	2.759	2.606	55.30
-4.75 mm	2.905	2.711	44.70
Theo. Comb.	2.822		

$$L = 1000K$$

$$P = M = 100 * \frac{E - K}{E}$$

$$VFA = N = \frac{100 * \frac{I}{C}}{\frac{J}{K}}$$

Figure 1. SI Example

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE

Contract #:  
Project Number:

Date:  
Lab No.:

% AC by Wt. Aggr. 7.48  
 AC by Wt. Mix 6.96  
 % Aggr. by Wt. Mix 93.04  
 S. G. of Asphalt 1.010  
 S. G. of Aggr. (bulk) 2.652  
 Max. S. G. Mix (KT-39) 2.438  
 (computed)  
 Theo. Max. KG/M<sup>3</sup>  
 Eff. S. G. of Aggr. 2.726  
 % Abs. Asphalt 1.05  
 Eff. Asph. Content 5.98  
 % V. M. A. 17.73  
 S. G. of plugs (KT-15) 2.344  
 Lab Plugs KG/M<sup>3</sup>  
 % Air Voids 3.85  
 % Voids Filled 78.3  
 P'b Max  
 Eff. Film Thickness  
 Filler/Binder Ratio

Eq.  
 P<sub>b</sub>' %  
 P<sub>b</sub>=A  
 P<sub>s</sub>=B  
 G<sub>b</sub>=C  
 1 G<sub>sb</sub>=D  
 3 G<sub>mm</sub>  
 E  
 F (SI)=F  
 2 G<sub>sc</sub>=G  
 4 P<sub>ba</sub>=H  
 5 P<sub>be</sub>=I  
 6 VMA=J  
 G<sub>mb</sub>=K  
 L (SI)=L  
 7 P<sub>a</sub>=M  
 8 VFA=N  
 O  
 P  
 Q

$$P_b = A = \frac{P_b' \cdot 100}{100 + P_b'}$$

$$P_s = B = 100 - A$$

$$F = E \cdot 62.4$$

$$G_{sc} = G = \frac{B}{\frac{100}{E} - \frac{A}{C}}$$

$$P_{ba} = H = 100 \cdot \frac{G - D}{D \cdot G} \cdot C$$

$$P_{be} = I = A - \frac{H}{100} \cdot B$$

$$VMA = J = 100 - \frac{K \cdot B}{D}$$

COMBINED AGGREGATE SP. GR.

	APPARENT	BULK	%
+4	2.759	2.606	55.30
-4	2.905	2.711	44.70
Theo. Comb.	2.822		

$$L = K \cdot 62.4$$

$$P = M = 100 \cdot \frac{E - K}{E}$$

$$VFA = N = \frac{100 \cdot \frac{I}{C}}{J - K}$$

Figure 1. English Example



#### 4. PRELIMINARY CALCUATIONS FOR RECYCLED MIXTURES:

When designing recycled mixtures, certain calculations must be made to obtain the correct values for  $P_b'$ ,  $G_b$  and  $G_{sb}$  prior to entering the "Worksheet for Analysis of Compacted Paving Mixtures" (Figure 1). The following sequence of equations may be followed to obtain the needed values.

##### 4.1. Reclaimed Roadway (RAP).

Given:

$P_{BRAP}$  = Percent asphalt in RAP from extractions = 6.2

$P_{BN}$  = Percent added asphalt or recycling agent.

$G_{AC-RAP}$  = Specific gravity of reclaimed asphalt = 1.025

$G_{BN}$  = Specific gravity of added asphalt or recycling agent = 1.008

$G_{RAG}$  = Specific gravity of reclaimed agg. = 2.522

$G_{SBN}$  = Specific gravity of new aggregates = 2.651

$P_{RAP}$  = Percent reclaimed in aggregate blend = 40%

$P_{VA}$  = Percent new aggregate in blend = 60%

##### 4.1.1. % asphalt in RAP (Wet Weight Basis)

$$\frac{P_{BRAP}}{\left(1 + \frac{P_{BRAP}}{100}\right)} = \frac{6.2}{1 + \left(\frac{6.2}{100}\right)} = 5.84$$

##### 4.1.2. % aggregate in RAP (Wet Weight Basis)

$$100 - a. = 100 - 5.84 = 94.16$$

##### 4.1.3. Weight of asphalt in RAP portion/100 g of aggregate blend

$$\frac{(a.)(P_{RAP})}{100} = \frac{(5.84)(40)}{100} = 2.34$$

##### 4.1.4. Weight of aggregate in RAP portion/100 g of aggregate blend

$$\frac{(b.)(P_{RAP})}{100} = \frac{(94.16)(40)}{100} = 37.66$$

##### 4.1.5. Weight of reclaimed material/100 g of aggregate blend

$$c. + d. = 2.34 + 37.66 = 40.00$$

##### 4.1.6. Weight of new aggregate/100 g of aggregate blend

$$100 - e. = 100 - 40.00 = 60.00$$

COMBINED MATERIALS

	%	%	%	%
g. % additive - Dry wt. basis	2.0	2.5	3.0	3.5
h. Additive wt./100 g sample = (P <sub>BN</sub> )	2.0	2.5	3.0	3.5
c. Asphalt wt. in RAP/100 g sample	2.34	2.34	2.34	2.34
i. Revised wt of bitumen (c. + h.)	4.34	4.84	5.34	5.84
d. Aggr. wt. in RAP/100 g sample	37.66	37.66	37.66	37.66
f. New aggr. wt./100 g sample	60.00	60.00	60.00	60.00
j. Revised wt. of aggr. = (d + f)	97.66	97.66	97.66	97.66
k. Total weight = (i + j)	102.0	102.5	103.0	103.5
l. % asphalt dry wt of aggr (i/j)(100) Enter as P <sub>b</sub> ' on Fig. 1 worksheet	4.44	4.96	5.47	5.98
m. Specific gravity - combined bituminous material $\frac{i}{\frac{h}{G_{BN}} + \frac{c}{G_{AC-RAP}}}$ Enter as G <sub>b</sub> on Fig. 1 worksheet	1.017	1.016	1.015	1.015
n. Specific gravity - Combined aggregates (Bulk Dry) $\frac{j}{\frac{d}{G_{RAG}} + \frac{f}{G_{SBN}}}$ Enter as G <sub>SB</sub> on Fig. 1 worksheet	2.600	2.600	2.600	2.600

**5. SUPPLEMENTAL CALCULATIONS (DRY AGGREGATE BASIS):**

**5.1. Calculation of Film Thickness:** The film thickness is a calculated or theoretical value and does not denote a measurable property of the mix. It is, however, useful in the analysis of bituminous mixtures when evaluating the effect of gradation changes. Higher film thickness is generally desirable (within practical considerations) since thicker films are better able to withstand asphalt hardening. Film thickness is calculated for other purposes such as slurry seal design.

Convert the gradation (percent retained) to percent passing and enter into a worksheet (similar to the table below). Then complete the calculations for Surface Area (S.A.).

### DETERMINATION OF SURFACE AREA

Sieve Size	Percent x S.A. Factor # = Surface Area		
	Passing	m <sup>2</sup> /kg (ft <sup>2</sup> /lb)	m <sup>2</sup> /kg (ft <sup>2</sup> /lb)
19.0 mm (3/4 in.)	100 *	0.0041(0.02)	0.410(2.0)
12.5 mm (1/2 in.)	93 *		
9.5 mm (3/8 in.)	81 *		
4.75 mm (No. 4)	65	0.0041(0.02)	0.266(1.30)
2.36 mm (No. 8)	48	0.0082(0.04)	0.393(1.92)
1.18 mm (No. 16)	38	0.0164(0.08)	0.623(3.04)
600 μm (No. 30)	27	0.0287(0.14)	0.774(3.78)
300 μm (No. 50)	13	0.0614(0.30)	0.799(3.90)
150 μm (No. 100)	8	0.1229(0.60)	0.983(4.80)
75 μm (No. 200)	6.8	0.3277(1.60)	<u>2.228(10.88)</u>
Total Surface Area = 6.476 m <sup>2</sup> /kg (31.62 ft <sup>2</sup> /lb)			

#Surface area factors shown are applicable only when all the above-listed sieves are used in the sieve analysis.

\*Surface area factor is 0.41 m<sup>2</sup>/kg (2 ft<sup>2</sup>/lb) for any material retained above the 4.75 mm (No. 4) sieve. Thus, the surface area equals 0.410 (2.0) for all material above the 4.75 mm (No. 4) sieve.

**5.2. Calculation of Bitumen Index:** The bitumen index is the ratio of effective asphalt content to the aggregate surface area.

$$\text{SI: Bitumen Index} = \frac{P_{be}(2.048)}{\text{S.A.}} \quad \text{English: Bitumen Index} = \frac{P_{be}(10)}{\text{S.A.}}$$

$$\text{SI Example : Bitumen Index} = \frac{5.98(2.048)}{6.476} = 1.891$$

$$\text{English Example : Bitumen Index} = \frac{5.98(10)}{31.62} = 1.891$$

Where: P<sub>be</sub> = effective asphalt content, see **section 3.6**.

**5.3. Conversion of Bitumen Index to Film Thickness (Microns):**

$$\text{Film Thickness (FT)} = \text{Bitumen Index} \times 4.87 = 1.891 \times 4.87 = 9.2 \text{ Microns}$$

## **6. MAXIMUM PERCENT OF ASPHALT:**

Determine the maximum percentage of asphalt (P<sub>b</sub>' max) which can be placed in a mix and still maintain a safe level of air voids under conditions of post-construction traffic and elevated mat temperature.

**6.1.** The maximum volume of asphalt which a mix can contain is the volume of the voids in mineral aggregate (VMA) plus the volume of asphalt absorbed into the aggregate. The volume of the absorbed asphalt (VP<sub>ba</sub>) may be determined by the following formula:

$$VP_{ba} = \frac{P_{ba} \times G_{sb}}{G_b}$$

$$= \frac{1.05 \times 2.651}{1.01} = 2.76$$

Where:  $P_{ba}$  = absorbed asphalt, **section 3.5.**

$G_{sb}$  = bulk dry specific gravity of the total aggregate, **section 3.2.1.**

$G_b$  = apparent specific gravity of asphalt, **section 3.1.1.**

**6.2.** Total Safe Volume at 74°C (165°F.) represents the available volume minus 2% to allow for plant fluctuation. The Total Safe Volume (TSV) is determined by the following equation:

$$TSV = VMA + VP_{ba} - 2.0$$

$$= 17.73 + 2.76 - 2.0 = 18.49$$

Where: VMA = voids in mineral aggregates, **section 3.7.**

**6.3.** Conversion of TSV to percentage of asphalt, ( $P_b'$ ), is accomplished in the following steps:

$$P_b \text{ max} = \frac{TSV(G_b)(0.9638)}{G_{sb}}$$

$$= \frac{18.49 \times 1.01 \times 0.9638}{2.651} = 6.79\%$$

$$P_b' \text{ max} = \frac{P_b \text{ max}(100 + P_b \text{ max})}{100}$$

$$= \frac{6.79(106.79)}{100} = 7.25\%$$

Where:  $P_b \text{ max}$  = maximum percent asphalt by weight of total mix

$P_b' \text{ max}$  = maximum percent asphalt by weight of dry aggregate

**7. COMPUTE BEARING CAPACITY, kPa(psi), AS FOLLOW:**

*SI:*

$$\text{Bearing Capacity, kPa} = \frac{1.55 \text{ Stability}}{\text{Flow}} \left( \frac{120 - \text{Flow}}{100} \right)$$

*Where: Stability in Newtons(N)*

*Flow in 0.25mm*

*SI Example:*

$$\text{Bearing Capacity, kPa} = \frac{1.55(7784)}{12} \left[ \frac{120 - 12}{100} \right] = 1086 \text{ kPa}$$

*English Example:*

$$\begin{aligned} \text{Bearing Capacity, psi} &= \frac{\text{Stability}}{\text{Flow}} \times \frac{120 - \text{Flow}}{100} \\ &= \frac{1750}{12} \times \frac{120 - 12}{100} = 157 \text{ psi} \end{aligned}$$

**8. Compute Filler - Binder Ratio as follows :**

$$\begin{aligned} F / B &= \frac{\text{Percent of } -75 \mu\text{m} \text{ (-No.200) fraction (see subsection (f)(1))}}{\text{Percent of asphalt (dry weight basis)(see subsection (c)(1))}} \\ &= \frac{6.8}{7.48} = 0.91 \end{aligned}$$

## 5.10.5. FINENESS MODULUS OF AGGREGATES (GRADATION FACTOR)

### 1. SCOPE

This method covers the procedure for calculating the fineness modulus (also known as the gradation factor) of aggregates.

This abstract, but useful figure indicates the relative fineness or coarseness of an aggregate gradation and indicates to some extent, the distribution of sizes of the aggregate if the maximum size is known.

### 2. PROCEDURE

The fineness modulus is determined by adding the percentages by mass retained on the following sieves meeting ASTM designation E11, and dividing by 100

3" (75mm), 1 1/2" (3.75 mm), 3/4" (19 mm), 3/8" (9.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (600 μm), No. 50 (300 μm) and No. 100 (150 μm).

Example:

For the following gradation.

<u>Sieve Size</u>		<u>Percent Retained</u>
(English)	(SI)	
3/8"	9.5 mm	0
No. 4	4.75 mm	2
No. 8	2.36 mm	16
No. 16	1.18 mm	27
No. 30	600 μm	62
No. 50	300 μm	88
No. 100	150 μm	96

The fineness modulus (gradation factor) is:

$$\frac{2 + 16 + 27 + 62 + 88 + 96}{100} = 2.91$$

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 200</b>							
<b>COMPACTION OF EARTHWORK</b> Sec. 204, 205 & 208							
<b>Compaction Type B</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	INF			a	4 per day per <u>lift</u> when visual determination is not possible.
<b>Moisture Content (MR-90)</b>	Moisture Tests (0.1 g or 0.01% of mass)	KT-13 or KT-51	INF			a	4 per day per <u>lift</u> when visual determination is not possible.
<b>Backfill Type B</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	INF				1 per structure minimum (each side).
<b>Backfill Moisture Content (MR-90)</b>	Moisture Tests (0.1 g or 0.01% of mass)	KT-13 or KT-51	INF				1 per structure minimum (each side).
<b>Compaction Types AAA, AA, or A</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	ACC			a b	1 per every 1000 CY of compacted earthwork
<b>Moisture Content Requirements for MR-0, MR-3, MR-3-3 or MR-5</b>	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	ACC			e	1 per every 1000 CY of compacted earthwork
<b>SPECIAL FILL</b> Sec. 209	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	INF				1 per <u>lift</u> per 300 feet of wall or once daily
<b>MECHANICALLY STABILIZED EARTH FILL</b> Sec. 214	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	INF				1 per <u>lift</u> per 300 feet of wall or once daily

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 300</b> (See also Division 1100 regarding aggregates)							
<b>SUBGRADE MODIFICATION</b> Sec. 301, 1110 & 1112							
<b>Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	Once in the AM and once in the PM or every 500 TONS whichever is less frequent.
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07				e	
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08				e	
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	ACC			b c	Once in the AM and once in the PM or every 500 TONS whichever is less frequent.
	Sticks in Aggregate (0.01% of mass)	KT-35				e	
<b>CALCIUM CHLORIDE</b> Sec. 301, 305 & 1702			VER		Sample first container received on project.		
<b>LIME TREATED SUBGRADE</b> Sec. 302, 2000 & 2400	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			e	
	Sieve Analysis for Acceptance of Lime or Cement Treated Subgrade (1% of mass)	KT-42	INF			e	
	Percent Solids of Lime Slurry (WPG 0.01 g, Slurry Solids 0.1%)	KT-62	INF				1 per day or batch, whichever is greater.



**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 300 (continued)</b>							
<b>LIME TREATED SUBGRADE</b> Sec. 302, 2000 & 2400 (continued)	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	ACC				1 per 1500 SY
<b>HYDRATED LIME AND PEBBLE QUICKLIME</b> Sec. 302, 1103, 2002 & 2003		KT-29	VER	a	1 sample for each 10 loads.		See Standard Specifications.
<b>CEMENT OR FLY ASH TREATED SUBGRADE</b> Sec. 303, 2000, & 2400	Sieve Analysis for Acceptance of Lime or Cement Treated Subgrade (1% of mass)	KT-42	INF			e	
	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-51	ACC				1 per 1500 SY
<b>FLY ASH FOR STABILIZATION AND COLD RECYCLE</b> Sec. 303, 604, & 2005		KT-29	VER	a	2 samples per month per source per district.		See Standard Specifications.
<b>CRUSHED STONE SUBGRADE</b> Sec. 304, 1100, & 2400	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-41	INF			e	
	Relative Density	KT-69	INF				Submit samples to MRC as required.
<b>CRUSHED STONE FOR BACKFILL</b> Sec. 304 & 1107	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	Once in the AM and once in the PM or every 500 TONS whichever is less frequent.

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 300 (continued)</b>							
<b>AGGREGATE BASE COURSE</b> Sec. 305 and 1104							
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e			
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	VER	e			
<b>Binder Material</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e			
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	VER	e			
<b>Combined Aggregate</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	1 per 500 Tons
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	ACC			a c	1 per 1000 Tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			e	
<b>Completed Base</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-41	ACC			a	1 per 500 tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11 or KT-41	INF			b	

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 300 (continued)</b>							
<b>AGGREGATE SHOULDERS</b> Aggregate, Non-HMA Sec. 305 and 1113							
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e			
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	VER	e			
<b>Binder Material</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e			
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	VER	e			
<b>Combined Aggregate</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	1 per 500 tons
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	ACC			a c	1 per 1000 Tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			e	
<b>Completed Shoulder</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-41	ACC			b	1 per 500 tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11 or KT-41	INF			b	

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 300 (continued)</b>							
<b>CEMENT TREATED BASE (CTB)</b> Sec. 306 & 1105							
	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	INF			a	1 in A.M. and 1 in P.M. or each 500 Tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11 or KT-41	INF			e	Minimum 1 per day.
	Density (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-37 or KT-20*	VER	e	Minimum of 1 per day		
<b>Completed Base (CTB)</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-41	ACC			a	1 per 2500 SY or 1 per 500 Tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11 or KT-41	ACC			a	1 per 5000 SY or 1 per 1000 Tons
<b>GRANULAR BASE</b> Sec. 307 and 1106							
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e			
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	VER	e			
<b>Binder Material</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e			
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	VER	e			

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 300 (continued)</b>							
<b>GRANULAR BASE</b> Sec. 307 and 1106 (Continued)							
<b>Pulverization</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER			e	Minimum 1 per day.
<b>Combined Aggregate</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	1 per 500 Tons
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	ACC			a	1 per 1000 Tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			e	
<b>Completed Work</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-41	ACC			a	1 per 500 Tons
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	ACC			a	1 per 1000 Tons
<b>DIVISION 400</b> (See also Division 1100 regarding aggregates)							
<b>PORTLAND CEMENT CONCRETE STRUCTURES AND MISCELLANEOUS CONSTRUCTION</b> Sec. 401, 402, 703, 710 and 717	Slump (0.25 in)	KT-21	ACC			h	As needed to control product, min. 1 set of tests every 50 yd <sup>3</sup> . Select initial sample from first 2 or 3 loads and then on a random basis or as conditions indicate.
	Temperature (1 °F)	KT-17	ACC				
	Mass per cubic foot (0.1 lb/ft <sup>3</sup> )	KT-20	ACC				
	Air Content (0.25%)	KT-18 or KT-19	ACC				

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 400 (continued)</b>							
<b>PORTLAND CEMENT CONCRETE STRUCTURES AND MISCELLANEOUS CONSTRUCTION</b> Sec. 401, 402, 703, 710 and 717 (continued)	Moisture in Aggregate (0.1 g or 0.01% of mass)	KT-24	VER		Minimum of 1 in AM and 1 in PM during concrete mixing operations.		
	Density of Fresh Concrete (0.1 lb/ft <sup>3</sup> )	KT-36	VER			a b	1 per 150 yd <sup>2</sup> for thin overlays and bridge deck wearing surfaces.
	Permeability (0.01%, KT-73 or 10 coulomb, AASHTO T 277 or nearest 0.1 kΩ-cm. KT-79)	KT-73 or AASHTO T 277 or KT-79	VER	l	1 per mix design per project.		Acceptance of contractor's mix design by KDOT.
	Cylinders (1 lbf, 0.1 in, 1 psi)	KT-22 and KT-76	VER	k	<u>Bridge Deck Only</u> (all classes except thin overlay) Min. of 2 sets of 3 per pour or major mix design change and 1 set of 3 per 100 yds <sup>3</sup> .		
		KT-22 and KT-76	VER	k	<u>Thin Overlays and Bridge Deck Surfacing</u> Min. of 1 set of 3 per 150 yd <sup>2</sup> per placement or major mix design change.		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 400 (continued)</b>							
<b>PORTLAND CEMENT CONCRETE STRUCTURES AND MISCELLANEOUS CONSTRUCTION</b> Sec. 401, 402, 703, 710 and 717 (continued)	Cylinders (1 lbf, 0.1 in, 1 psi) (continued)	KT-22 and KT-76	VER		Drilled Shafts 1 set of 3 per shaft minimum and 1 set of 3 per 100 yd <sup>3</sup> . <u>Other Construction</u> (all classes) Min. of 2 sets of 3 per pour or major mix design change and one set of 3 per 100 yd <sup>3</sup> . Waive the 2 sets of 3 minimum for pours of less than 20 yd <sup>3</sup> that are non-critical elements. (This includes all structural concrete not classified as bridge deck wearing surface - i.e. culverts, wash checks, ditch lining, bridge substructure, hubguards, handrails, etc.)		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 500</b> (See also Division 1100 regarding aggregates)							
<b>PORTLAND CEMENT CONCRETE PAVEMENT</b> Sec. 401, 403, 502 and 503	Mass per cubic foot (0.1 lb/ft <sup>3</sup> )	KT-20	ACC				As often as needed to control product. Min. of 1 set of tests per each half day and/or per 4000 yd <sup>2</sup> .
	Temperature (1 °F)	KT-17	ACC				
	Slump (0.25 in)	KT-21	ACC				
	Air Content (0.25%)	KT-18 or KT-19	ACC		Determine the air loss due to paving operations once in the AM and once in the PM. Determine the difference between the air content from concrete sampled before the paver, and concrete sampled behind the paver.		Refer to SS 2015 403.4. For all mainline paving, test the concrete at the beginning of the day's operation and approximately every 2 hours thereafter for air content. For all other slipformed pavement, test for air content at the beginning of a day's operation and approximately every 4 hours thereafter. Test hand placements for air content at least once daily.
	Beams (1 psi)	KT-22 & KT-23	VER	a			1 set of 3 as required for opening to traffic. See SS 2015 502.3i.(3)



**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 500 (continued)</b>							
<b>PORTLAND CEMENT CONCRETE PAVEMENT</b> Sec. 401, 403, 502 and 503 (continued)	Profilograph	KT-46	VER	e		b	Testing by contractor. Results reviewed by KDOT.
	Moisture in Aggregate (0.1 g or 0.01% of mass)	KT-24	VER	a	Minimum of 1 in AM and 1 in PM during concrete mixing operations.		
	Thickness - Cored by District or Contractor (0.01 in)	KT-49	INF				See SS 2015 section 502.3m.
	Density of Fresh Concrete (0.1 lb/ft <sup>3</sup> )	KT-38	VER			a b	Initially, 1 complete transverse profile. Thereafter, 5 per day.
	Air Void Analyzer (0.0001 in)	KT-71			1 test randomly during every 4 weeks of production.		Prequalification of mix required as per SS 2015 sec. 403.4.
	Permeability (0.01%, KT-73; 10 coulomb, AASHTO T 277; nearest 0.1 kΩ-cm, KT-79 )	KT-73 or AASHTO T 277 or KT-79	VER	l	1 per mix design per project.		Acceptance of contractor's mix design by KDOT.
	Vibrator Frequency Per Standard Specification 154.2e	SS 154.2e			Daily by KDOT		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 600</b> (See also Division 1100 regarding aggregates)							
<b>HMA (Plant Mix)</b> Sec. 603, 611, 1103 & 15-06001							
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	INF	e		b h i	1 per lot.
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07		e			
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08		e			
	Percent Crushed Particles in Crushed Gravel (0.1%)	KT-31	VER	b h	500 TONS.		
	Sticks in Aggregate (0.01% of mass)	KT-35		e			
	Uncompacted Void Content of Fine Aggregate (0.1%)	KT-50	VER	e			
<b>Mineral Filler Supplement</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER			a	250 TONS.
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	INF			c h	250 TONS.
<b>Combined Aggregate</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	INF				1 per subplot.

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 600 (continued)</b>							
<b>HMA (Plant Mix) (continued)</b> Sec. 603, 611, 1103 & 15-06001							
<b>Combined Aggregate (continued)</b>	Sand Equivalent Test (1%)	KT-55	INF			h	1 per subplot. (District tested)
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	VER	a	Minimum of 1 per day.		
<b>HMA Mixtures (Field Lab)</b>	Density (0.1 lb/ft <sup>3</sup> or 0.01% of optimum density)	KT-15 and KT-58	VER	a	Minimum of 1 set per day.		
	Voids (0.01%)						
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			a	Minimum of 1 per day.
<b>Asphalt Binder</b>	Binder Sampling	KT-26	VER	e b	1 sample per 3 loads.		1 per project.
<b>HMA Mixtures (District Lab)</b>	Density (0.1 lb/ft <sup>3</sup> or 0.01% of optimum density)	KT-15 and KT-58	VER	a	Minimum of 1 set per project. (District molded)		
	Voids (0.01%)						
	Stability (1 lbf)						
	Flow (0.01 in)						
	Gradation (1%, 0.1% for the No. 200 sieve, of mass)	KT-34					
	Asphalt Content (0.1 g or 0.01%)	KT-57					

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 600 (continued)</b>							
<b>HMA (Plant Mix) (continued)</b> Sec. 603, 611, 1103 & 15-06001							
<b>BM-Mixes (Field Lab)</b>	Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures ( $G_{mm} = 0.001$ )	KT-39	VER		1 per lot with a minimum of 1 per day.		
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			a	Minimum of 1 per day.
<b>BM-Mixes (District Lab)</b>	Air Voids ( $V_a = 0.01\%$ ; $G_{mb} = 0.001$ )	KT-15 and KT-58	VER	j	Minimum of 1 set per project. (District molded)		
	Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures ( $G_{mm} = 0.001$ )	KT-39					
	Gradation (1%, 0.1% for the No. 200 sieve, of mass)	KT-34					
	Asphalt Content (0.1 g or 0.01%)	KT-57					
<b>Federal Aid Projects (Field or District Labs)</b>	Asphalt Content (0.1 g or 0.01%)	KT-57	VER		Minimum of 1 in AM and 1 in PM, or 1 per 1000 TONS.		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	AWP	CODE	VERIFICATION SAMPLES & TESTS (Note f)	CODE	ACCEPTANCE SAMPLES & TESTS
<b>DIVISION 600 (continued)</b>							
<b>HMA (Plant Mix) (continued)</b> Sec. 603, 611, 1103 & 15-06001							
<b>Completed Road Work</b>  <u>Field Density Tests</u> (Use Cores, Nuclear Density, or the Approved Rolling Procedure method on all HMA roadway or shoulder construction)	Field Density - Cores ( $G_{mb} = 0.001$ ; 0.1 lb/ft <sup>3</sup> or 0.01% of optimum density)  Note: If specified [plan] lift thickness is less than 1.5", none required.	KT-15	INF			a b	<u>Shoulders</u> 1 set per shoulder per mile per lift.  <u>Surf. &amp; Base Courses</u> 1 set per lane per mile per lift.  Min. of 1 per day.
<b>Completed Road Work (continued)</b>  <u>Field Density Tests</u> (Use Cores, Nuclear Density, or the Approved Rolling Procedure method on all HMA roadway or shoulder construction)	Field Density - Nuclear Density (0.1 lb/ft <sup>3</sup> or 0.01% of optimum density)  Note: If specified [plan] lift thickness is 1.5" or less, none required.	KT-32	INF			a b	<u>Shoulders</u> 3 locations per shoulder per mile per lift.  <u>Surf. &amp; Base Courses</u> 3 locations per lane per mile per lift.  Min. of 1 per day.
	Field Density - Approved Rolling Procedure (0.1 lb/ft <sup>3</sup> or 0.01% of optimum density)  Note: If specified [plan] lift thickness is 1.5" or less.	SS 2015 602.4e.	INF			a b	1 in AM and 1 in PM.
	Profilograph	KT-46	INF	e		b	Testing by contractor. Results reviewed by KDOT.

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 600 (continued)</b>							
<b>HMA (Plant Mix) (continued)</b> Sec. 603, 611, 1103 & 15-06001							
<b>Commercial Grade</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC				1 test for each 500 ton lot or fraction thereof. Also see SS 2015 section 611.2d.
<b>SURFACE RECYCLE</b> Section 605	Asphalt Rejuvenating Agent	KT-26	VER		See section 5.7.1.5.2. of this manual.		
	Depth of Recycling (0.01 ft)	KT-47	INF			a	1 per hour of operation.
<u>Field Density Tests</u>	Field Density - Approved Rolling Procedure (0.1 lb/ft <sup>3</sup> or 0.01% of optimum density)	SS 2015 605.3e.(1)(b)	INF			a	1 in AM and 1 in PM.
<b>COVER MATERIAL FOR ASPHALT SEAL</b> Sec. 608, 609, 610, & 1108	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	250 TONS or 250 yd <sup>3</sup> .
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07				e	
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08				e	
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF			e	
	Sticks in Aggregate (0.01% of mass)	KT-35				e	

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 700</b> (See also Division 1100 regarding aggregates)							
<b>REINFORCING STEEL BARS</b> Sec. 711, 1601 & 1602			VER		1 per month per plant.		
<b>PAINT</b> Sec. 712, 1800		KT-28	VER		1 per source per project.		See Standard Specifications.
<b>POST-TENSIONING (Haunched Slab Bridges)</b> Sec. 716, 1731	Cylinders for grout (1 lbf, 0.1 in, 1 psi)	KT-22	VER				3 cylinders per truck load.
	Infrared Spectroscopy		VER		Sample 1 quart and send to MRC.		
<b>SLIPFORMING CONCRETE BARRIER FOR BRIDGES</b> Sec. 720							
<b>Combined Aggregate</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	INF				1 per bridge.
<b>Concrete</b>	Air Content (0.25%)	KT-19	ACC				As needed to control product, minimum 1 set of tests every 50 yd <sup>3</sup> .
	Slump (0.25 in)	KT-21	ACC				As needed to control product.

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 700 (continued)</b>							
<b>MULTI-LAYER POLYMER CONCRETE OVERLAY</b>							
<b>SLURRY POLYMER CONCRETE OVERLAY</b>							
<b>REPAIR OF EXISTING POLYMER CONCRETE BRIDGE DECK OVERLAY</b>							
Sec. 729, 739, 740 and 1730							
<b>Polymer Resins</b>	Infrared Spectroscopy		VER		Sample 1/2 pint of each lot of each component and send to MRC 1 week prior to placement.		
<b>Aggregate</b>	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF				
<b>Prepared Bridge Deck Surface</b>	Moisture in Deck	KT-82					Prior to application of overlay.
<b>Overlaid Bridge Deck</b>	Surface Preparation and Adhesion (10 lbf or 10 psi)	KT-70					Test by contractor, KDOT to witness. Once every span or every 300 yd <sup>2</sup> of prepared deck surface, whichever is smaller.
<b>DIVISION 800</b>							
(See also Division 1100 regarding aggregates)							
<b>STONE FOR RIPRAP WASH CHECKS &amp; OTHER MISC. USES</b> Sec. 815, 816, 829, & 1114	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 [75 µm] sieve, of mass)	KT-02	ACC			a	500 TONS or 500 yd <sup>3</sup> . Tests to be done at production site. Type III Stone for Filter Course may be accepted visually.
<b>UNDERDRAIN AGGREGATE</b> Sec. 822 and 1107	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	500 TONS.



**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 800</b> Continued							
<b>UNDERDRAIN AGGREGATE</b> Continued	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07				e	
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08				e	
	Sticks in Aggregate (0.01% of mass)	KT-35				e	
<b>DIVISION 1100</b>							
<b>INDIVIDUAL AGGREGATE QUALITY (Applies to all aggregates)</b>			OFQ VER		Aggregate quality only - One sample per source per year per district.		Prior approval required.
<b>ON-GRADE CONCRETE (OGCA) Sec. 1116</b>			QPS		See 5.6 Sect. 5.4.4 of this manual.		
<b>AGGREGATE FOR CONCRETE</b> Sec. 1102, 1116	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	VER	e	As needed to control aggregate used in accepted stockpiles.	a	1 per 350 CY of concrete.
	Unit Weight – lightweight aggregates only (0.1 lb or 0.1% of mass)	KT-05	VER			e	
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07				e	
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08				e	
	Sticks in Aggregate (0.01% of mass)	KT-35				e	

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 1100 (continued)</b>							
<b>AGGREGATE FOR CONCRETE (continued)</b> Sec. 1102, 1116	Coal	AASHTO T 113				e	
	Organic Impurities	AASHTO T 21				e	
<b>AGGREGATE FOR STRUCTURE AND PIPE BACKFILL</b> Sec. 204, 817, 1107	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	500 TONS.
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07				e	
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08				e	
	Sticks in Aggregate (0.01% of mass)	KT-35				e	
<b>BACKFILL FOR MSE WALLS</b> Sec. 1107	Sampling Aggregates	KT-01					Send representative samples to the MRC (Attn: Geot. Eng.) for acceptance prior to placement of material on project.
<b>SURFACE OR RESURFACING AGGREGATE</b> Sec. 1111 & 1112	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	ACC			a	Once in the AM and once in the PM or every 500 TONS whichever is less frequent.

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 1100 (continued)</b>							
<b>SURFACE OR RESURFACING AGGREGATE</b> Sec. 1111 & 1112 (continued)	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07				e	
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11	INF				
	Sticks in Aggregate (0.01% of mass)	KT-35				e	
<b>DRAINABLE BASE</b> Special Provisions	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	INF			a	Minimum of 1 in AM and 1 in PM, or 1 per 500 TONS.
<b>DIVISION 1200</b>							
<b>PERFORMANCE GRADED ASPHALT BINDER, CUTBACK ASPHALT, EMULSIFIED ASPHALT, AND REJUVENATING AGENTS</b> Sec. 1201, 1202, 1203, 1204, & 1205		KT-26	VER	a	See section 5.7.1.4. and 5.7.1.5.2 of this manual, and the Standard Specifications.		
<b>DIVISION 1400</b>							
<b>LIQUID MEMBRANE FORMING COMPOUND</b> Sec. 1404	Infrared Spectroscopy		VER		2 per product per year per district.		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 1500</b>							
<b>MATERIALS FOR FILLING AND SEALING JOINTS IN PIPE</b> Sec. 1505	Sampling Joint Compound Material	KT-27					Each lot.
<b>SAND FOR BRIDGE JOINT GAP REPAIR SYSTEM</b>	Sieve Analysis of Aggregate (1% of mass)	KT-02					Test prior to use.
<b>DIVISION 1600</b>							
<b>REINFORCING STEEL BARS</b> Sec. 1601 & 1602			VER		1 per month per plant.		
<b>WIRE FABRIC</b> Sec. 1603			VER		1 plant per district per year.		
<b>DIVISION 1700</b>							
<b>ABUTMENT STRIP DRAIN</b> Sec. 1706			VER		2 per source, per District per year		
<b>ANTI-GRAFFITI COATING</b> Sect. 1729	Infrared Spectroscopy		VER		1 per project, per manufacturer, per District		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 2000</b>							
<b>PORTLAND CEMENT, BLENDED HYDRAULIC CEMENT, FLY ASH FOR USE IN CONCRETE</b> Sec. 2001, 2004, & 2005		KT-29	VER		<u>Cement</u> : See section 5.7.9 of Part V, and the Standard Specifications.  <u>Fly Ash</u> : Minimum of 1 semi-annual sample per source per concrete project.		See section 5.7.9 of this manual, and Standard Specifications.
<b>DIVISION 2200</b>							
<b>PAVEMENT MARKING</b>							
<b>Cold Plastic</b> Sec. 2207			VER ACC		Except for symbols, 1 per lot per color.		
<b>Patterned Cold Plastic</b> Sec. 2208			VER ACC		Except for symbols, 1 per lot per color.		
<b>High Durability</b> Sec. 2209			VER ACC		Except for symbols, 1 per lot per color.		
<b>Thermoplastic</b> Sec. 2211	Field Sampling of Thermoplastic Pavement Marking Material	KT-30	VER ACC		1 from 1 lot per color per project.		
<b>Preformed Thermoplastic</b> Sec. 2212			VER ACC		Except for symbols, 1 on each lot.		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>AWP</b>	<b>CODE</b>	<b>VERIFICATION SAMPLES &amp; TESTS (Note f)</b>	<b>CODE</b>	<b>ACCEPTANCE SAMPLES &amp; TESTS</b>
<b>DIVISION 2200 (continued)</b>							
<b>PAVEMENT MARKING (continued)</b>							
<b>Sprayed Thermoplastic</b> Sec. 2213	Field Sampling of Thermoplastic Pavement Marking Material	KT-30	VER ACC		1 from 1 lot per color per project.		
<b>Epoxy</b> Sec. 2214			VER ACC		1/2 pint per each component lot per color per project. <b>DO NOT MIX!</b>		
<b>Pavement Marking Paint</b> Sec. 2215			VER ACC		2 samples per color per project.		
<b>Multi-component</b> Sec. 2216			VER ACC		1/2 pint per each component lot per color per project.		

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CODE

INSTRUCTION

- a Normal operation. Minimum frequency for exceptional conditions may be reduced by the District Materials Engineer on a project basis. Written justification shall be made to the Chief of the Bureau of Construction & Materials and placed in the project documents. (Multi-Level Frequency Chart [This appendix, page 27] or other.)
- b Applicable only when specifications contain those requirements.
- c If, for a given project, no Plastic Index results of ten (10) consecutive tests are closer than 1 Plastic Index to the specifications limit, the specified testing frequency may be reduced by fifty percent (50%). When operating at a reduced testing frequency, should any two (2) consecutive Plastic Index results exceed the test limit results required for reduced testing frequency, testing shall be resumed at the original specified frequency. The original specified testing frequency shall be resumed should any one test result exceed the specification limits. Following a return to the original specified testing frequency, the reduced frequency may be resumed provided the original criteria for reduced frequency is met.
- d “Sample Type” must = “ACC” when assignment of a pay quantity is being made. “INF” or “VER” when recording test values for additional acceptance information.
- e Engineer’s discretion. Frequency of tests shall be agreed upon by the Field Engineer and the District Materials Engineer. Frequency will be governed by field conditions. Written documentation of the agreed upon testing frequency shall be included in the project records.
- f Verification sampling and testing are conducted by Department personnel to monitor reliability of certified test results or certifications of specification conformity or to check adequacy of mix design.
- g For determining moisture content of a material KT-43, “Moisture Content of Asphalt Mixtures or Mineral Aggregates – Microwave Oven Method”, can be used in conjunction with KT-02, KT-03, KT-04, KT-08, KT-12, KT-13, KT-14, KT-34, and KT-48.
- h Initial frequency. Frequency may be reduced on a project basis, by authority of the District Materials Engineer, upon continued satisfactory and uniform production. Authorization for reductions in testing frequency shall be documented in the project records.
- i On those mix designations which contain a natural sand requirement and/or an uncrushed minus #200 (75 µm) mineral filler requirement, individual aggregates and mineral filler supplements shall be sampled from the cold feed and tested.
- j The District Laboratory will perform additional testing, as needed, to determine the recommended asphalt content for the asphalt mix.
- k Standard 28 day compressive strength.
- l Verification method must be the same test method as used for mix design approval.

**SAMPLING AND TESTING FREQUENCY CHART**  
**NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

GENERAL NOTES

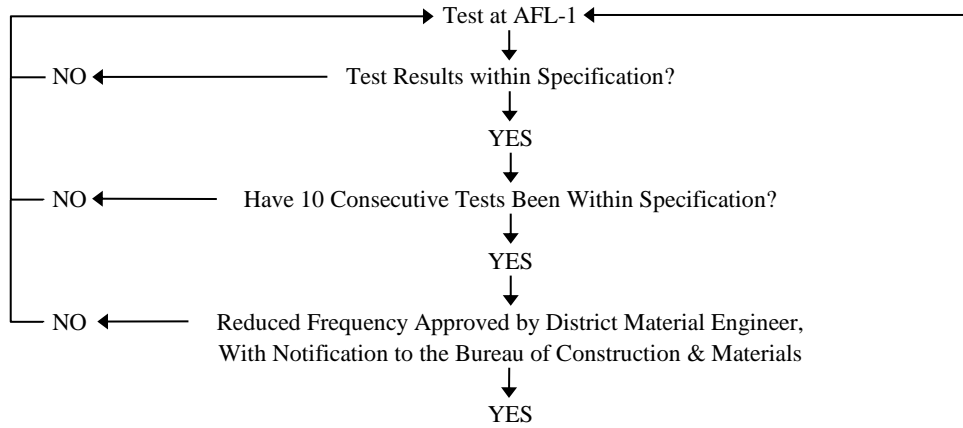
- All sampling and testing frequencies listed are minimums. Additional or other tests will be conducted, as required, to control the work.
- Frequencies are based on two lane roadways. For four or more lane roadway construction, double the frequencies shown per unit length.
- All aggregate acceptance tests are to be conducted at the point of usage except for Stone for Riprap, Wash Checks, and Other Miscellaneous Uses in Division 800.
- For the AASHTOWare Project (AWP), Acceptance Sampling and Tests have been divided into two sections. Items called “ACC” will be Acceptance Tests and will have a quantity assigned. Items called “INF” and "VER" will be Additional Information Tests and they will normally have a quantity assigned, but not for payment. “ACC” tests make the assignment of tested materials to the contract or mix plant.
- For a better explanation of metric (SI) units, see section 5.9, “Sampling and Test Methods Forward”, of this manual.



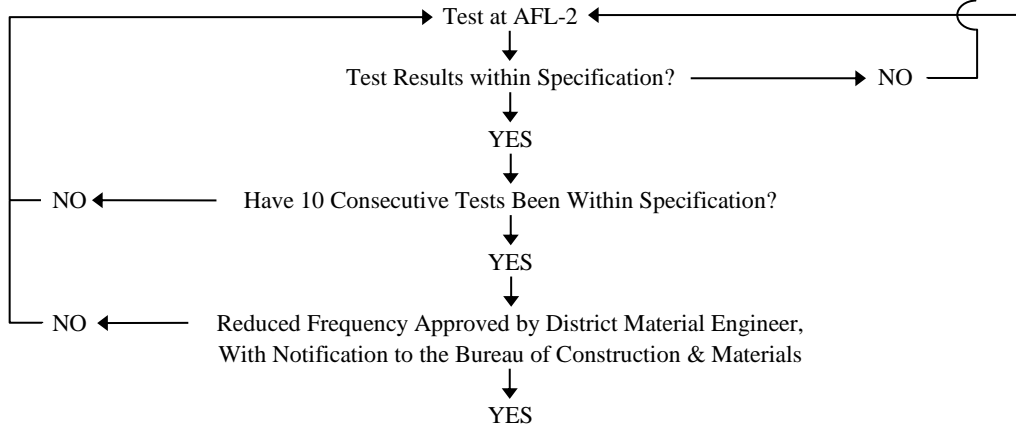
**SAMPLING AND TESTING FREQUENCY CHART  
NON QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

MULTI-LEVEL SAMPLING FREQUENCY CHART

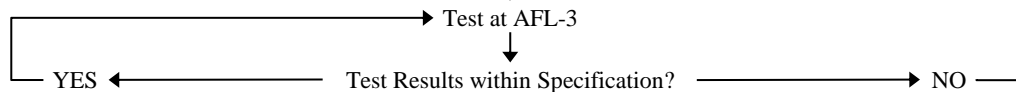
ACCEPTANCE FREQUENCY LEVEL 1 (AFL-1)



ACCEPTANCE FREQUENCY LEVEL 2 (AFL-2)



ACCEPTANCE FREQUENCY LEVEL 3 (AFL-3)



Lot size Definitions –

Acceptance Frequency Level 1 (AFL-1) – Maximum Lot Size as Specified in Sampling and Testing Frequency Chart (This appendix, pages 1 through 22).

Acceptance Frequency Level 2 (AFL-2) – Two times AFL-1.

Acceptance Frequency Level 3 (AFL-3) – Four times AFL-1.

Note: AFL-2 and AFL-3 must be approved by the Bureau of Construction & Materials. See Code “a” on page 23 of this appendix.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 300</b>						
<b>CEMENT TREATED BASE (CTB)</b> Sec. 306 & 1105	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c h	1 per day.		1 per week.
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11 or KT-41		4 per day per design.		1 per week.
	Density (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-37 or KT-20*		1 per day per design (* KT-20 option is only permitted in conjunction with a fluid mix.)		1 per project per design.
	Compressive Strength (1 psi)	KT-37		1 specimen per subplot		1 specimen per lot.
<b>Completed Base</b>	Field Density Tests (0.1 lb/ft <sup>3</sup> or 0.1% of optimum density)	KT-13 or KT-41		4 per day per design.		1 per week per design.
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11 or KT-41		4 per day per design.		1 per week per design.
<b>DIVISION 500</b>						
<b>PORTLAND CEMENT CONCRETE PAVEMENT</b> Sec. 501 & 503	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c m	1 per 350 CY of concrete.		1 per project.
	<b>Individual Aggregates</b> Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07	c h			As required.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 500 (continued)</b>						
<b>PORTLAND CEMENT CONCRETE PAVEMENT</b> Sec. 501 & 503 (continued)  <b>Individual Aggregates (continued)</b>	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08	c h			As required.
	Sticks in Aggregate (0.01% of mass)	KT-35	c h			As required.
	Unit Weight – lightweight aggregates only (0.1 lb or 0.1% of mass)	KT-05	c k			As required.
	Moisture in Aggregate (0.1 g or 0.01% of mass)	KT-24	p	1 per 1/2 day.		1 per week.
	Coal	AASHTO T 113				As required.
	Organic Impurities	AASHTO T 21				As required.
<b>Concrete</b>	Mass per cubic foot (0.1 lb/ft <sup>3</sup> )	KT-20	a	1 per 500 yd <sup>3</sup> .		1 per day.
	Slump (0.25 in)	KT-21	a	1 per 500 yd <sup>3</sup> .		1 per day.
	Temperature (1 °F)	KT-17	a	1 per 500 yd <sup>3</sup> .		1 per day.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 500 (continued)</b>						
<b>PORTLAND CEMENT CONCRETE PAVEMENT</b> Sec. 501 & 503 (continued) <b>Concrete (continued)</b>	Air Content (0.25%)	KT-18 or KT-19	a	1 per 500 yd <sup>3</sup> or every 2 hours (mainline), every 4 hours (other slipformed pvmt), whichever is more frequent. Determine the air loss due to paving operations once in the AM and once in the PM. Determine the difference between the air content from concrete sampled before the paver, and concrete sampled behind the paver.		1 per day.
	Density of Fresh Concrete (0.1 lb/ft <sup>3</sup> )	KT-38		Initially, 1 complete transverse profile, then 1 density per ½ day.		1 density per week.
	Beams (1 psi)	KT-22 & KT-23		1 set of 3 as required for opening to traffic.		1 set of 3 per week as required for opening to traffic.
	Cores (1 lbf, 0.01 in, 1 psi)	KT-49		As required in SS 2015 section 501.5g.		Thickness measurement and compression test – 1 per lot.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 500 (continued)</b>						
<b>PORTLAND CEMENT CONCRETE PAVEMENT</b> Sec. 501 & 503 (continued)  <b>Concrete (continued)</b>	Air Void Analyzer (0.0001 in)	KT-71		Prequalification of mix required as per SS 2015 sec. 403.4.		1 test randomly during every 4 weeks of production.
	Permeability (0.01%, KT-73; 10 coulomb, AASHTO T 277; nearest 0.1 kΩ-cm, KT-79	KT-73 or AASHTO T 277 or KT-79	o			1 per mix design per project.
	Profilograph	KT-46		2 tracks per 12 ft of width for the full length of the project.		At the Engineer's discretion.
	Vibrator Frequency Per Standard Specification 154.2e	SS 154.2e		Every 4 hours		Daily
<b>ON-GRADE CONCRETE (OGCA)</b>						See 5.6 Section 5.4.4 of this manual.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 600</b>						
<b>HMA (Plant Mix)</b> Sec. 602, 603, 611 & 1103						
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c	1 per 1000 TONS for each individual aggregate.		1 during the first 5000 TONS of HMA produced for each individual aggregate.
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07	c h			As required.
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08	c h			As required.
	Sticks in Aggregate (0.01% of mass)	KT-35	c h			As required.
	Uncompacted Void Content of Fine Aggregate (0.1%)	KT-50	l	1 on the first lot then 1 per 10,000 TONS of crushed gravel.		1 during the first 5000 TONS of HMA produced.
	Uncompacted Void Content of Coarse Aggregate (0.01%)	KT-80	l	1 on the first lot then 1 per 10,000 TONS of crushed gravel.		1 during the first 5000 TONS of HMA produced.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	CODE	QUALITY CONTROL BY CONTRACTOR	CODE	VERIFICATION BY KDOT
<b>DIVISION 600 (continued)</b>						
<b>HMA (Plant Mix) continued</b> Sec. 602, 603, 611 & 1103						
<b>Mineral Filler Supplement</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c h	1 per 250 TONS.		1 during the first 5000 TONS of HMA produced.
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	c h	1 per 250 TONS.		
<b>Combined Aggregate</b>	Coarse Aggregate Angularity (Determination of Crushed Particles in Crushed Gravel) (0.1% of mass)	KT-31	c g	1 per lot		1 per week or 1 per 10,000 TONS.
	Uncompacted Void Content of Fine Aggregate (0.1%)	KT-50		1 on the first lot then 1 per 10,000 TONS of combined aggregate.		1 during the first 5000 TONS of HMA produced.
	Sand Equivalent Test (1%)	KT-55	f	1 per lot.		
	Flat or Elongated Particles (1%)	KT-59		1 on the first lot.		
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11		1 per lot.		
<b>Asphalt Material</b>	Sampling	KT-26	b e	Sample per sampling frequency level chart		
<b>HMA Mixtures</b>	Percent Moisture in Mixture (0.1 g or 0.01% of mass)	KT-11		1 per lot.		1 during the first 5000 TONS of HMA produced.
	Air Voids ( $V_a = 0.01\%$ ; $G_{mm}$ & $G_{mb} = 0.001$ )	KT-15, KT-39, KT-58, & SF Manual	q	1 per subplot. (See code n for $G_{mm}$ )	j	1 per lot. [Compact split sample on KDOT Gyrotory – 1 per week or every 15,000 TONS]

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 600 (continued)</b>						
<b>HMA (Plant Mix continued)</b> Sec. 602, 603, 611 & 1103						
<b>HMA Mixtures (continued)</b>	Binder Content (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 per subplot.	j	1 per lot.
	Mix Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per subplot.		1 per lot.
	Moisture Damage to Mix (Modified Lottman) (0.1%)	KT-56	d	1 on first lot then 1 per week or every 10,000 TONS.		1 during the first 5000 TONS of HMA produced. Performed by the District Lab.
<b>Reclaimed Asphalt Pavement (RAP)</b>	Binder Content in RAP (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 during the first lot then 1 per 1000 TONS of RAP.	j	1 during the first lot then 1 per 4000 TONS of RAP.
	RAP Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per 1000 TONS of RAP.		1 during the first 5000 TONS of HMA produced.
	Percent Moisture in RAP (0.1 g or 0.01% of mass)	KT-11		1 per lot.		
<b>Recycled Asphalt Shingles (RAS)</b>	Binder Content in RAS (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 during the first lot then 1 per 1000 TONS of RAP + RAS.	j	1 during the first lot then 1 per 4000 TONS of RAP + RAS.
	RAS Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per 1000 TONS of RAP + RAS.		1 during the first 5000 TONS of HMA produced.
	Percent Moisture in RAS (0.1 g or 0.01% of mass)	KT-11		1 per lot.		



**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)	TESTS REQUIRED (RECORDED TO)	TEST METHOD	CODE	QUALITY CONTROL BY CONTRACTOR	CODE	VERIFICATION BY KDOT
<b>DIVISION 600 (continued)</b>						
<b>HMA (Plant Mix continued)</b> Sec. 602, 603, 611 & 1103						
<b>Completed Road Work</b>  <u>Field Density Tests</u> (Use Cores or Nuclear Density Gauge on all HMA roadway or shoulder construction greater than or equal to 1.5 inches)  (Use approved rolling procedure and Nuclear Density Gauge on all HMA roadway or shoulder construction less than 1.5 inches)	Field Density - Cores or Nuclear Density Gauge ( $G_{mb} = 0.001$ ; 0.1 lb/ft <sup>3</sup> or 0.01% of $G_{mm}$ )	KT-15 or KT-32	i	10 tests per lot.	i	5 companion tests per lot.
	Field Density -Nuclear Density Gauge ( $G_{mb} = 0.001$ ; 0.1 lb/ft <sup>3</sup> or 0.01% of $G_{mm}$ )	KT-32	i	10 Nuclear Gauge readings per lot  Verify Approved Rolling Procedure every 2 hours		
	Profilograph	KT-46		2 tracks per 12 ft of width for the full length of the project.		At the Engineer's discretion.
<b>Cold In-Place Recycle (CIR)</b> Sec. 604	Sampling Aggregate	KT-01		2 per mile. (Sieve according to specification.)	k	1 per day.
	Percent Retained on the #200 Sieve by Dry Screen	KT-04		2 per day.		
	Field Moisture Tests (0.1 g or 0.01% of mass)	KT-32				Minimum 1 per day. Use nuclear gauge w/o correction. (Test before overlay or seal.)
	Field Density ( $G_{mb} = 0.001$ ; 0.1 lb/ft <sup>3</sup> or 0.01% of $G_{mm}$ )	KT-32				3 locations per width laid per mile per lift. Minimum of 1 per day.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE 2015 Std. Spec. (SS 2015)</b>	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 600 (continued)</b>						
<b>Asphalt Material (Emulsion)</b>	Sampling	KT-26	b	1 sample for every 3 loads.	b	
<b>Lime Slurry</b>	Percent Solids of Lime Slurry	KT-62		1 at beginning of project then 1 at each mix design change.	k	
<b>MICROSURFACING</b> Sec. 606 & 1109	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c	1 per 250 TONS for each individual aggregate.		1 per day.
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11		3 per day.		1 per day.
	Emulsified Asphalt	KT-26		1 per project.	k	
	Sampling Cement	KT-29		1 per project.	k	
	Percent Crushed Particles in Crushed Gravel (0.1%)	KT-31		1 per project.	k	
	Uncompacted Void Content of Fine Aggregate (0.1%)	KT-50		1 per project.	k	
	Sand Equivalent Test (1%)	KT-55		1 per project.	k	
<b>ULTRATHIN BONDED ASPHALT SURFACE (UBAS)</b> Sec. 613 & 1103						
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c h	1 per 1000 TONS for each individual aggregate.		1 per project per individual aggregate.
	Uncompacted Void Content of Fine Aggregate (0.1%)	KT-50	l	1 on the first lot then 1 per 10,000 TONS of crushed gravel.		1 per project.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 600 (continued)</b>						
<b>ULTRATHIN BONDED ASPHALT SURFACE (UBAS)</b> Sec. 613 & 1103 (continued)						
<b>Mineral Filler Supplement</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c h	1 per 250 TONS.		1 per project.
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	c h	1 per 250 TONS.		1 per project.
<b>Combined Aggregate</b>	Coarse Aggregate Angularity (0.1% of mass)	KT-31	c g h	1 per lot of combined aggregate		1 per week or 1 per 10,000 TONS.
	Uncompacted Void Content of Fine Aggregate (0.1%)	KT-50	f	1 on the first lot then 1 per 10,000 TONS of combined aggregate.		1 per project.
	Sand Equivalent Test (1%)	KT-55	f	1 per lot.		1 per project.
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11		1 per 2000 TONS of combined mix.		1 per project.
<b>Asphalt Material</b>	Sampling	KT-26	b e	Sample per sampling frequency level chart		
<b>HMA Mixtures</b>	Percent Moisture in Mixture (0.1 g or 0.01% of mass)	KT-11		1 per 2000 TONS of combined mix.		1 per project.
	Theoretical Maximum Specific Gravity (Rice) ( $G_{mm} = 0.001$ )	KT-39	n	1 per subplot.		1 per lot.
	Binder Content (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 per subplot.	j	1 per lot.
	Mix Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per subplot.		1 per lot.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 600 (continued)</b>						
<b>HMA Base [Reflective Crack Interlayer (RCI)]</b> Sec. 614						
<b>Individual Aggregates</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c	1 per 1000 TONS for each individual aggregate.		1 during the first 5000 TONS of HMA produced for each individual aggregate.
	Clay Lumps and Friable Particles in Aggregate (0.1 g or 0.01% of mass)	KT-07	c h			As required.
	Shale or Shale-Like Materials in Aggregate (0.1 g or 0.01% of mass)	KT-08	c h			As required.
	Sticks in Aggregate (0.01% of mass)	KT-35	c h			As required.
<b>Mineral Filler Supplement</b>	Sieve Analysis of Aggregate (1%, 0.1% for No. 200 sieve, of mass)	KT-02	c h	1 per 250 TONS.		1 during the first 5000 TONS of HMA produced.
	Plasticity Tests (0.01 g or 0.1% of mass)	KT-10	c h	1 per 250 TONS.		
<b>Combined Aggregate</b>	Sand Equivalent Test (1%)	KT-55	f	1 per lot.		
	Flat or Elongated Particles (1%)	KT-59		1 on the first lot.		
	Moisture Tests (0.1 g or 0.01% of mass)	KT-11		1 per lot.		
<b>Asphalt Material</b>	Sampling	KT-26	b e	Sample per sampling frequency level chart		
<b>HMA Mixtures</b>	Percent Moisture in Mixture (0.1 g or 0.01% of mass)	KT-11		1 per lot.		1 during the first 5000 TONS of HMA produced.

**SAMPLING AND TESTING FREQUENCY CHART  
CONTRACTOR QUALITY CONTROL TESTING**

<b>CONSTRUCTION OR MATERIAL TYPE</b> 2015 Std. Spec. (SS 2015)	<b>TESTS REQUIRED (RECORDED TO)</b>	<b>TEST METHOD</b>	<b>CODE</b>	<b>QUALITY CONTROL BY CONTRACTOR</b>	<b>CODE</b>	<b>VERIFICATION BY KDOT</b>
<b>DIVISION 600 (continued)</b>						
<b>HMA Base [Reflective Crack Interlayer RCI] Sec. 614 (continued)</b>						
<b>HMA Mixtures (continued)</b>	Air Voids ( $V_a = 0.01\%$ ; $G_{mm}$ & $G_{mb} = 0.001$ )	KT-15, KT-39, KT-58, & SF Manual	q	1 per subplot. (See code n for $G_{mm}$ )	j	1 per lot. [Compact split sample on KDOT Gyrotory – 1 per week or every 15,000 TONS]
	Binder Content (by ignition) (0.1 g or 0.01% of mass)	KT-57		1 per subplot.	j	1 per lot.
	Mix Gradation (after ignition) (0.1 g or 0.01% of mass)	KT-34		1 per subplot.		1 per lot.
<b>Completed Road Work</b>	Field Density Approved Rolling Procedure Nuclear Gauge ( $G_{mb} = 0.001$ ; 0.1 lb/ft <sup>3</sup> or 0.01% of $G_{mm}$ )	KT-32		Verify Approved Rolling Procedure every 2 hours  10 Nuclear Gauge readings per day		

**SAMPLING AND TESTING FREQUENCY CHART**  
**QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

<u>CODE</u>	<u>INSTRUCTION</u>
a	The contractor may reduce the sampling and testing frequency to one test per 1,000 yd <sup>3</sup> provided the first two tests each day show compliance with the specification requirements.
b	Sampled by the district field personnel, or contractor and tested at KDOT Central Materials Laboratory (Materials and Research Center).
c	The aggregate producer's tests may be used for quality control purposes if the tests were performed by an appropriately certified technician. In such cases, the contractor shall perform testing as necessary to determine the degrading effects of hauling and stockpiling on the individual aggregates. For CTB, the minimum testing frequency shall be every 4,000 Tons.
d	At least one Modified Lottman test is required weekly. When more than 10,000 Tons of production occurs in a week, then run additional tests to meet the requirement of 1 test per 10,000 Tons.
e	Specification compliance will be determined on a producer basis not on a project basis. Producer and product testing frequency is maintained in AWP. Start with one in three loads, then generally, the sampling frequency will be reduced to one sample per six loads and then per twelve loads if test results determined by the Department show satisfactory compliance of the material with the specifications.
f	Determine the Sand Equivalent (SE) value on the combined virgin aggregates on the first lot of production and then frequency may be reduced to one test per week provided the SE value exceeds the minimum specified value by five (5) percentage points. The frequency may be reduced to one test per two weeks provided the SE value exceeds the minimum specified value by 25 percentage points. When any test (including verification and assurance) shows the SE value to be less than five (5) percentage points above the specified minimum value then the testing frequency will revert to one per lot until two consecutive tests exceed the minimum specified value by five (5) percentage points.
g	All aggregate types except siliceous gravels and steel slag will be considered to have at least two crushed faces on 100% of the aggregate particles. For mixes containing crushed or uncrushed siliceous gravels or steel slag, determine the Coarse Aggregate Angularity (CAA) value of the combined virgin aggregate of the first lot of production. After three consecutive passing tests, the frequency may be reduced to one per three lots or one per week. If any of the quality control or verification tests fail, the frequency will revert to one per lot until the above criteria for reduced frequency is met.
h	If during the determination of individual aggregate gradation, clay lumps and soft or friable particles, shale or shale-like particles, or sticks are found then perform KT-07, KT-08, and KT-35, respectively, at such frequencies as jointly deemed necessary by the Contractor and the District
i	For small lots [lots with less than 1,000 tons], the number of tests may be reduced (see special provision).
j	Provide access to Contractor owned forced air ignition furnace, ovens, and Superpave Gyratory compactor, as required, for the State Inspector to perform verification tests.

**SAMPLING AND TESTING FREQUENCY CHART**  
**QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATIONS**

CODE

INSTRUCTION

- k Engineer's discretion. Frequency of tests shall be agreed upon by the Field Engineer and the District Materials Engineer. Frequency will be governed by field conditions. Written documentation of the agreed upon testing frequency shall be included in the project records.
- l This testing of crushed gravel is only needed to confirm that 35% or less natural sand is used in the traveled way mixes. If 95% or more of crushed gravel is retained on the #8 sieve, then the material must have a minimum Uncompacted Void Content of Coarse Aggregate (UVA) value of 45 when tested in accordance with KT-80. Test at the same frequency as KT-50. Do not use material with a UVA value less than 45.
- m The contractor may reduce the sampling and testing frequency to one test per 1,500 CY provided the first ten tests show compliance with the specification requirements.
- n If more than one test is performed on the sample, use the average value.
- o Verification method must be the same test method as used for mix design approval.
- p Frequency may be reduced to 1 pre-production verification test per day provided the following are met: 1) Handheld moisture meter is used at least once per every 50 cubic yards of production. 2) The meter has an accuracy of  $\pm 0.5\%$  of the pre-production verification test. 3) Moistures obtained from the meter are used to adjust batch-to-batch moisture corrections.
- q KT-58 test requires the average of two (2) gyratory plugs

GENERAL NOTES

- All sampling and testing frequencies listed are minimums. Additional quality control, verification, and assurance tests will be performed, when necessary, to provide effective control the work. When any quality control test result fails to comply with the specification requirements then the next subplot of production after obtaining the failing test results will be sampled and tested, regardless of any lesser frequency specified in this appendix.
- For the AASHTOWare Project (AWP), Acceptance Sampling and Tests have been divided into three sections. Items called "ACC" will be Acceptance Tests and will have a quantity assigned. Items called "INF" and "VER" will be additional tests and they will not be for payment. "ACC" tests make the assignment of tested materials to the contract or mix plant. "Sample Type" must = "ACC" when assignment of a pay quantity is being made. "INF" and "VER" when recording test values for additional acceptance information.
- For QUALITY CONTROL BY CONTRACTOR, AWP uses INF or ACC unless otherwise noted. For VERIFICATION BY KDOT, AWP uses ACC or INF or VER unless otherwise noted. For INDEPENDENT ASSURANCE BY KDOT, AWP uses ASW (Assurance Witness), ASR (Assurance Replicate), and ASP (Assurance Split) unless otherwise noted (see section 5.4.2 of this manual).
- For a better explanation of metric (SI) units, see section 5.9, "Sampling and Test Methods Forward", of this manual.
- All samples will be taken from the place of incorporation into the project unless otherwise noted.

**APPENDIX C**  
**TEST PROCEDURE CRITERIA FOR THE INDEPENDENT ASSURANCE (IA) PROGRAM**

**1. SCOPE**

Within each table listed below, there are critical core tests to be witnessed. These are designated by double asterisks (\*\*). **As a minimum requirement, each certified technician performing a critical core test must be witnessed on the core tests and participate in replicate tests annually to comply with the Independent Assurance program.**

A district representative may witness more than one technician for each test during a project visit. A minimum of 1 replicate test is required per set of test equipment per witness visit. All technicians witnessed that set of equipment will satisfy their replicate requirements. ***This does not apply to tests that influence pay factors. Each test must be demonstrated and replicates checked to meet requirements.*** Replicates are not required in locations where N/A is entered in the Assurance Replicate Allowable Limits column. Within IA context, replicate sampling includes split sampling. Split sampling is to be performed whenever a splitting procedure exists for the material being tested.

The current groups are classified as follows: Soils Field, Aggregate Field, Aggregate Lab, Concrete Field, Hardened Concrete Properties, Asphalt Mix (Marshall), Asphalt Mix (QC/QA), Density by Nuclear Gauge and Cement Treated Base.

Assurance replicate allowable limits are established using D2S (Difference of 2 standard deviations) as outlined in **ASTM E177**. When directed to a test procedure, compare IA vs. technician results with multilaboratory D2S results. This comparison assumes the test is conducted with different operators and different equipment using comparable material such as split samples.



**Table 01  
Soils Field Testing Group**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-01	Sampling			N/A	
KT-10	Plasticity test	Scales	12	LL-13% PL-18%	**
		Liquid Limit Device	12		
		Grooving Tool	12		
KT-11	Oven Dry Moisture Test (NOTE)	Oven	12	N/A	**
		Scales	12		
KT-12	Standard Compaction Test	Mech. Compactor Incl. Molds	12	Moisture-2.46% Density-4.8 lb/ft <sup>3</sup>	(QC/QA only)
KT-13	Field Density Tests of Soils	Sand Cone		5.0 lb/ft <sup>3</sup> Or 5%	KT-51

**NOTE:** Witness a single **KT-11** test procedure per certified technician per year, regardless of the type of material being tested. (% moisture in aggregate, % moisture in mixture, % moisture in RAP, etc.)

**Table 02.A  
Aggregate Field Testing Group**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-01	Sampling & Splitting			N/A	
KT-02	Sieve Analysis	Sieves	12	See <b>KT-02 Section 9.</b>	**
		Scales	12		
		Mech. Shaker	12		
KT-03	Material Passing No. 200 (75 µm) sieve by the Wash Method	Sieves	12	See <b>KT-03 Section 9.</b>	**
		Scales	12		
		Mech. Shaker	12		
KT-11	Oven Dry Moisture Test (NOTE)	Oven	12	N/A	**
		Scales	12		
KT-50	Uncompacted Void Content of fine Aggregate	Cylindrical Measure	12		
KT-80	Uncompacted Void Content Of Coarse Aggregate	Oven	12	N/A	
		Scales	12		
		Cylindrical Measure	12		

**NOTE:** Witness a single **KT-11** test procedure per certified technician per year, regardless of the type of material being tested. (% moisture in aggregate, % moisture in mixture, % moisture in RAP, etc.)

**Table 02.B  
Aggregate Lab Testing Group**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-06 Proc. I and II	Specific Gravity & Absorption of Aggregate	Scales	12	See <b>KT-06 Section 6.</b>	
		Volumetric Flask	12		
		Oven	12		
		Sieves	12		
KT-31	Percentage of Crushed Particles in Crushed Gravel	Scales	12	N/A	**
		Oven	12		
		Sieves	12		
KT-55	Plastic Fines by use of the Sand Equivalent	Oven	12	N/A	
KT-59	Flat or Elongated Particles			N/A	

**Table 03**  
**Concrete Field Testing Group (ACI Concrete Field Inspector Accepted)**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-17	Sampling Freshly Mixed Concrete			N/A	
KT-18	Air Content (Pressure)	Pressure Meter	3	1.05%	** or KT-19
KT-19	Air Content(Volumetric)	Volumetric Meter	12	1.05%	** Or KT-18
KT-20	Mass	Scales	12	4.2 lb/ft <sup>3</sup> (70 kg/m <sup>3</sup> )	**
		Measures	12		
KT-21	Slump	Cone	12	0.83 in (21 mm)	**
KT-22	Making and Curing Specimens	Molds	Note	N/A	**

**NOTE:** Calibration or verification intervals are dependent on the type of mold used.

		Interval
Cylinders:	Single use molds	Check dimensions of each shipment
	Reusable molds	12 month
Beams:	Reusable molds	12 month

**Table 04  
Hardened Concrete Properties Testing Group**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-23	Breaking Beams Note	Comp. Machine, Molds	12 (see Note, Table 3)	N/A	
KT-44	Maturity Meter	Maturity Meter	Once per month		
KT-49	Obtaining and Testing Drilled Cores				**
	Strength			13.0% of KDOT Value	
	Length			0.20 in (5 mm)	
KT-73	Density, Absorption, Air Voids	Scales	12		
		Thermometers	12		
KT-76	Breaking Cylindrical Concrete Specimen (see Note below)	Comp. Machine, Molds	12 (see Note, Table 3)	8.0% of KDOT Value	** QC/QA only
KT-77	Capping Cylindrical Specimens	Capping Material check Strength	3	N/A	
KT-79	Surface Resistivity	Meter	Daily		

**NOTE:** If IA witnessing and sampling will be conducted by the district, then IA testing on cores and cylinders must be performed by the M & R Center. If the M & R Center performed the verification testing, then IA is not required.

**Table 05**  
**Asphalt Mix Field Testing Group**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-11	Oven Dry Moisture Test (NOTE)	Oven	12	N/A	
		Scales	12		
KT-15	Bulk S.G.	Scales	12	0.031	**
		Thermometers	12		
KT-25	Sampling and Splitting Plant Mix			N/A	
KT-26	Sampling Bit. Material			N/A	
KT-34	Sieve Analysis	Sieves	12	See <b>KT-34 Section 8.</b>	**
		Scales	12		
		Mech. Shaker	12		
KT-39	Theor. Max. S.G.	Vacuum Gauge	12	See <b>KT-39 Section 8.</b>	**
		Thermometers	12		
KT-57	Asphalt Content by Ignition	Scales (if app.)	12	0.50%	**

**NOTE:** Witness a single **KT-11** test procedure per certified technician per year, regardless of the type of material being tested. (% moisture in aggregate, % moisture in mixture, % moisture in RAP, etc.)

**Table 06**  
**Asphalt Mix Testing Group (QC/QA) (SF Training Accepted)**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-11	Oven Dry Moisture Test (NOTE)	Oven	12	N/A	
		Scales	12		
KT-15	Bulk S.G.	Scales	12	0.031	**
		Thermometers	12		
KT-25	Sampling and Splitting Plant Mix			N/A	
KT-26	Sampling Bit. Material			N/A	
KT-34	Sieve Analysis	Sieves	12	See <b>KT-34 Section 8.</b>	**
		Scales	12		
		Mech. Shaker	12		
KT-39	Theor. Max. S.G.	Vacuum Gauge	12	See <b>KT-39 Section 8.</b>	**
		Thermometers	12		
KT-56	Moisture Induced Damage	Stability Machine	12	5%	
		Freezer	12		
KT-57	Asphalt Content by Ignition	Scales (if app.)	12	0.50%	**
KT-58	Superpave Gyratory Compactor	Gyratory	12	N/A	**
		Thermometers	12		

**NOTE:** Witness a single **KT-11** test procedure per certified technician per year, regardless of the type of material being tested. (% moisture in aggregate, moisture in mixture, % moisture in RAP, etc.)

**Table 07  
Density by Nuclear Gauge**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-32	Density by Nuclear Gauge	Nuclear Gauge	12	2.0 % of established density	NOTE below
KT-36	Density by Nuclear Gauge on Bridge Deck Overlays	Nuclear Gauge	12	2.0 % of established density	NOTE below
KT-38	Density by Nuclear Gauge on Pavements	Nuclear Gauge	12	2.0 % of established density	NOTE below
KT-41	Density of Bases or Shoulders by Nuclear Gauge	Nuclear Gauge	12	2.0 % of established density	NOTE below
KT-51	Field Density and Moisture Tests of Soils by Nuclear Gauge	Nuclear Gauge	12	2.0 % of established density	NOTE below

**NOTE:** One test procedure is required to be annually witnessed to ensure that the nuclear gauge is operating properly. Perform **Section 5.8.2.** (Independent Assurance Replicate (ASR) Check for Nuclear Density Gauges) for all nuclear gauges and gauge operators.

**Special Note:** Profilographs require an annual certification performed by the Bureau of Construction and Materials



**Table 08  
Cement Treated Base**

Test Method	Test Method Topic	Equipment Requiring Calibration or Verification	Cal./Ver. Interval (Months)	Assurance Replicate Allowable Limits	Critical Core Tests
KT-02	Sieve Analysis	Sieves	12	See <b>KT-02 Section 9.</b>	**
		Scales	12		
		Mech. Shaker	12		
KT-03	Material Passing No. 200 (75 µm) sieve by the Wash Method	Sieves	12	See <b>KT-03 Section 9.</b>	**
KT-11	Oven Dry Moisture Test (NOTE)	Oven	12	N/A	
		Scales	12		
KT-13	Field Density Tests of Soils	Sand Cone		5.0 lb/ft <sup>3</sup> Or 5%	
KT-37	Making, Curing, and Testing Specimens	Oven	12		**
		Scales	12		
		Mech. Compactor	12		
		Comp. Machine	12		
KT-41	Density of Bases or Shoulders by Nuclear Gauge	Nuclear Gauge	12	2.0% of established density	NOTE below
KT-65	Sampling and Splitting Cement Treated Base Mixtures			N/A	

**NOTE:** One test procedure is required to be annually witnessed to ensure that the nuclear gauge is operating properly. Perform **Section 5.8.2.** (Independent Assurance Replicate (ASR) Check for Nuclear Density Gauges) for all nuclear gauges and gauge operators.

## **APPENDIX D**

### **POLICY AND PROCEDURE MANUAL FOR THE INSPECTION OF KANSAS DEPARTMENT OF TRANSPORTATION DISTRICT LABORATORIES**

#### **1. PURPOSE OF THIS DOCUMENT**

**1.1.** This document is intended to provide a guide for the inspection of the Kansas Department of Transportation District Laboratories and for the witnessing of laboratory and field personnel demonstrating proficiency in performance of test procedures during inspections.

**1.2.** Guidance is provided for arranging, conducting and reporting of inspections. Responsibilities for scheduling and availability of test materials are also outlined.

**1.3.** This Guidance is for KDOT's benefit to meet KDOT's statutory obligations. This Guidance does not ensure the Contractor's quality control results or act as a substitute for the Contractor's obligation to provide acceptable quality.

#### **2. PURPOSE OF LABORATORY INSPECTIONS**

**2.1.** All laboratories accredited by the AASHTO resource and Cement and Concrete Reference Laboratories (CCRL) are required to undergo an AASHTO inspection on a regular basis. All other laboratories involved in highway construction in the state must be inspected by an AASHTO accredited laboratory. The KDOT Materials and Research Center is an accredited AASHTO resource CCRL laboratory.

**2.2.** Personnel from the Bureau of Construction and Materials inspect KDOT District laboratories on an annual basis to comply with this requirement.

**2.3.** District Laboratories are inspected for compliance with KDOT test procedures, equipment calibrations and maintenance of records. This will help KDOT achieve consistent, accurate and comparable test results across the state.

**2.3.1.** During laboratory inspections, District personnel are witnessed to demonstrate proficiency in KDOT test procedures and to help meet the witness requirements for Superpave recertification.

#### **3. WITNESS OF PERSONNEL**

**3.1.** All personnel who either perform tests or witness for tests will be eligible to be witnessed during laboratory inspections. Personnel will only be witnessed on test methods that they perform or witness or on test methods that they need to be eligible to perform or witness.

**3.2.** Personnel will be randomly selected from the list submitted by the District Materials Engineer during scheduling to perform test methods by the inspectors. Each test method that personnel may perform or witness or that may need to perform or witness in the future will be presented. Each test method will usually be demonstrated by only one person during the inspection. Witness for Superpave certification may require several people to demonstrate multiple test methods.

**3.3.** Standard check sheets based on the appropriate test method shall be used. KT test methods will be witnessed using check sheets based on the KT method, not the ASTM method or others. Personnel may

refer to the written test method, use notes, charts, calculators or computers during the test, unless being witnessed for recertification for a CIT<sup>2</sup> Course. The inspector may ask questions during the test but should limit disrupting the procedure.

**3.4.** If a person selected to demonstrate a test method is unavailable at the time of the District inspection, that person shall demonstrate the test procedures at a later date at the Materials and Research Center.

#### **4. EQUIPMENT INSPECTION**

**4.1.** All equipment used in materials testing shall be inspected. Measurements for wear may be taken and the equipment shall be in good working order. All equipment that is to have routine verification and calibration shall have the appropriate records in order. These records should be kept in the Laboratory Quality Manual or the location of these records should be stated in the Quality Manual.

**4.2.** Laboratory thermometers shall be checked during use with a calibrated thermometer at the time of inspection but will not be calibrated by the inspector. Records of calibration using a certified thermometer shall be kept by the Laboratory.

**4.3.** Water baths and freezer temperatures will be checked during inspection. Records of oven calibrations shall be kept by the Laboratory.

**4.4.** Scales, compression testers, gyratory compactors and other equipment requiring calibration by personnel from outside the Laboratory will not be checked for accuracy during inspections but records of calibration shall be maintained and will be examined by KDOT.

#### **5. TEST PROCEDURES TO BE WITNESSED**

**5.1.** Test procedures to be witnessed are stated in the list below. This list shall be examined annually and updated as needed. All or part of a test method may be required to be given verbally. One test method involving the nuclear meter shall be sufficient for the inspection. Gradation methods 02, 03, 34 and 57; and moisture related methods 10 and 11, may be demonstrated by the same person.

##### **Test Procedures**

KT-01	Sampling and Splitting of Aggregates
KT-02	Sieve Analysis of Aggregates
KT-03	Material Passing 75 µm (No. 200) Sieve by the Wash Method
KT-05	Unit Weight of Aggregate
KT-06	Specific Gravity and Absorption of Aggregate
KT-07	Clay Lumps and Friable Particles in Aggregate
KT-08	Shale or "Shalelike" Materials in Aggregate
KT-10	Plasticity Test
KT-11	Moisture Tests
KT-12	Standard Compaction Test
KT-13	Field Density Tests of Soils, Treated Base Courses, and Water Bound Base Courses
KT-15	Bulk Specific Gravity and Unit Weight of Compacted Hot Mix Asphalt (HMA)
KT-18	Air Content of Freshly Mixed Concrete by the Pressure Method
KT-19	Air Content of Freshly Mixed Concrete by the Volumetric Method
KT-20	Mass per Cubic Foot (Meter), Yield Cement Factor and Air Content (Gravimetric) of Freshly Mixed Concrete
KT-21	Slump of Portland Cement Concrete
KT-22	Making and Curing Compression and Flexural Test Specimens in the Field

KT-23	Flexural Strength of Concrete (Third Point Loading Method)
KT-25	Sampling and Splitting Plant Mixed Asphalt Mixtures
KT-26	Sampling Asphalt Materials
KT-32	Method of Test for Density of Compacted Asphalt Mixtures by Nuclear Method
KT-34	Sieve Analysis of Extracted Aggregate
KT-35	Sticks in Aggregate
KT-36	Density of Freshly Mixed Concrete in Bridge Deck Overlays by Nuclear Gauge
KT-37	Making, Curing and Testing Cement Treated and Unbound Bases in the Laboratory
KT-38	Density of Freshly Mixed Concrete in Pavement by Nuclear Gauge
KT-39	Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures
KT-41	Determination of Density and Moisture Content of Portland Cement Treated Bases by Nuclear Method
KT-49	Method for Obtaining and Testing Drilled Cores
KT-50	Uncompacted Void Content of Fine Aggregate
KT-51	Field Density and Moisture Tests of Soils by Nuclear Gauge
KT-55	Plastic Fines in Combined Aggregates by use of the Sand Equivalent Test
KT-56	Resistance of Compacted Asphalt Mixture to Moisture Induced Damage
KT-57	Determination of Asphalt Content and Gradation of Hot Mix Asphalt Concrete by the Ignition Method
KT-58	Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
KT-59	Flat or Elongated Particles in Coarse Material Test
KT-76	Method for Testing the Compressive Strength of Molded Cylindrical Concrete Specimens
KT-77	Method for Capping Cylindrical Concrete Specimens

## **6. LABORATORY QUALITY MANUAL**

**6.1.** A Quality Manual shall be kept by each Laboratory and will be reviewed during inspections. This manual shall provide information pertaining to equipment calibrations and verifications including calibration interval and the date of the last calibration. Equipment shall be uniquely identified by serial number or some type of marking. The date the equipment was put into service and calibration history is useful to the Department.

**6.2.** An example of a Quality Manual is given in **section 5.2.7** of this manual.

## **7. RESPONSIBILITY FOR TEST EQUIPMENT AND MATERIALS**

**7.1.** It shall be the responsibility of each Laboratory to provide the necessary equipment and materials to demonstrate the required test methods. Material may have to be saved to be available when the inspection occurs. Test material may be stockpiled or gathered from a project and may have undergone the normal course of testing. This includes, but is not limited to concrete cylinders and beams, hot mix asphalt, aggregate and soil samples. The Bureau of Construction and Materials may, at its option, provide materials for a given test method for a “round-robin” type of comparison for all laboratories. If the necessary materials are not available at the time of the inspection, the affected tests will be considered deficient.

## **8. LABORATORY INSPECTION SCHEDULING**

**8.1.** Scheduling for laboratory inspections shall be arranged as early as possible in the year. Materials Quality Management Section will annually make a request to the District Materials Engineer for a list of

Materials personnel involved in testing or Independent Assurance (IA) witness functions. This list should include the tests that each person runs or witnesses.

**8.2.** A list of persons who need to be witnessed for Superpave renewal should also be provided by the District Materials Engineer at that time. A list of six possible weeks, prior to November 1, for conducting a lab inspection within the calendar year should also be provided by the District Materials Engineer. The Materials Quality Management Section will select one week from the list to conduct each lab inspection.

## **9. WITNESS FOR RECERTIFICATIONS**

**9.1.** At the time the inspection is being scheduled, the District Materials Engineer should notify the Materials Quality Management of any personnel that will be renewing their certifications in Superpave, Aggregate Lab, and Aggregate Field in the next year and wish to be witnessed for the purpose of renewal. Inspectors will witness these people during the laboratory inspection.

## **10. LABORATORY INSPECTION CLOSEOUT**

**10.1.** When the inspection is finished, the inspectors shall hold a closeout meeting. The Lab Chief should be notified when the closeout will occur and should invite the District Materials Engineer and other interested parties.

**10.2.** During the closeout, the inspectors will list the test methods observed. Deficiencies in test equipment and demonstrated methods should be noted. Suggestions for improvement may be offered at this time. Laboratory personnel will be given a chance to respond to the noted deficiencies at this time.

## **11. REPORT OF LABORATORY INSPECTION**

**11.1.** A report of the inspection will be issued in the form of a memorandum. An example is given later in this document. The memorandum shall note any deficiencies, the date of the inspection, personnel involved in the inspection and the test methods presented.

**11.2.** Observations of equipment calibration, wear or deficiencies will be noted as well as any deficiencies in the Quality Manual.

**11.3.** The memo should be addressed to the District Engineer and the District Materials Engineer.

## **12. MAINTENANCE**

**12.1.** This document shall be updated annually to reflect any changes in test procedures or policies. Test methods should be reviewed and updates made to the check sheets. Lab Chiefs should be notified of any changes.

## **13. INSPECTION EQUIPMENT CHECKLIST**

The following list of equipment and material will be required to complete laboratory inspections.

**13.1** Policy and Procedure Manual for the Inspection of Kansas Department of Transportation District Laboratories.

**13.1.1.** Test method check sheets.

**13.2** Part V of the Construction Manual.

**13.3.** English/Metric Ruler.

**13.4.** Tape Measure.

**13.5.** Certified thermometer (thermocouple).

**13.6.** Certified Manometer and hardware.

**13.7.** Bore gauge.

**13.8.** Bore gauge proof ring.

**13.9.** Spacer blocks for bore gauge.

**13.10.** Radiation Safety Badges.

**13.11.** Material Samples if required:  
Soil Sample

**13.12.** Timer.

## 14. Closeout Memo Example

**DATE:** September 17, 2013

**TO:** Jeff Stewart, P.E., District Three Engineer

**FROM:** C. Craig Rutherford

**RE:** District Three Laboratory Inspection

On September 9<sup>th</sup> and 10<sup>th</sup> Joyce Paynter, Michael Kabriel and Craig Rutherford visited the District Three Materials Laboratory in Norton. The equipment and test methods were examined for compliance with the standard KT procedures. At the close of the inspection an oral presentation was made to discuss deviations noted, to make recommendations, and to allow laboratory personnel a time to respond. The following is a list of tests observed.

**TEST PROCEDURES:** KT -1, 2, 3, 5, 6, 10, 11, 12, 13, 15, 22, 23, 25, 32, 39, 50, 55, 56, 57, 58, 59, 76 and 77. Items discussed during closeout included: The need to use a 0.70” gauge to check perpendicularity on 4x8” cylinders after capping. The need to use a 0.004” feeler gauge to determine if leather shims are required when testing flexural beams.

**CAL/VER:** The manometer (for vacuum pump) S/N 1328, was checked during the inspection and found to be 0.2 mm higher than the Q/A manometer. An appropriate correction should be applied.

The Lab was requested to keep a log to track the age of the solution used for KT-55. The temperature recorder for the concrete curing tank needed a battery that was on order.

The Laboratory checks their thermometers with a reference thermometer with a current NIST certification annually.

Temperature for the 77°F water bath used for specific gravity was adjusted during the inspection. The temperature for the water bath used for concrete curing was found to be within tolerance. The temperature for 140°F water bath used for KT-56 was found to be within tolerance. The freezer temperature was adjusted during the inspection.

Two SGC molds used in the Superpave Gyratory compactor numbered C0938088 and C0938089 were measured and found to be in tolerance.

All other equipment was found to be in good condition and properly calibrated.

Stewart Memo  
Page 2  
September 17, 2013

**QUALITY MANUAL:** The Quality Manual for the District Three Laboratory has been well maintained. This manual provides proper calibration/verification procedures on critical equipment.

We would like to express our appreciation to the District Materials staff for helping to make the inspection a success.

Please contact me at (785) 296-5105 if you have any questions.

c: Blair Heptig, P.E., Field Engineer  
Albert Oyerly, P.E. Materials Quality Assurance Engineer  
Travis Scott, P.E., District Construction and Materials Engineer