8.0 Reinforced Concrete Structures

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8.0 Reinforced Concrete Structures

8.1 General

Reinforced concrete structures include any cured concrete element using mild steel reinforcement encased within and bonded to the cured concrete. This definition includes reinforced concrete boxes, precast boxes, columns, pier caps, bridge decks, bridge rails or barriers, abutments, piers, spread footings or pile caps, seal courses, embankment walls, noise walls, and drilled shafts as structural elements of a larger structure, or as the structure itself. Aesthetic treatments to structural concrete are also commonplace. Typically, any reinforced concrete structure visible to the travelling public and in an urban or suburban area will receive some type of aesthetic finish. The aesthetic treatments are not important as far as the structure durability or longevity, but the traveling public is less likely to think an area is unsightly with these treatments and the structure will typically appear more “finished.”

8.2 Purpose

As simplistic as the combination of steel and concrete may seem each item mentioned in the specifications guides the Contractor’s actions and processes to produce an economical, efficient, durable concrete structure. The specifications concerning reinforced concrete structures address vital elements to prevent varying severity levels of failure of the concrete structural element. From the time the reinforcement arrives on-site, to the placement of the steel and concrete, to final cure of the concrete, the specification requirements are in place to bring about the most efficient use of the Contractor’s time and the taxpayer’s dollar. From storage of materials used in construction to the curing process of the concrete proper procedures are all specified, and if the requirements are met, or exceeded, the reinforced concrete structure will be a durable, cost-effective, long-lasting structure. The specifications are not intended to empower the inspector or to limit the Contractor; the specifications state basic requirements for successful use of forms, equipment, concrete and steel to construct a quality reinforced concrete element or structure.

8.3 Description

Reinforced concrete structures are often used as foundation elements such as drilled shafts, pile cap footings, or spread footings. A reinforced pile cap transfers load from a column, or an entire pier or abutment, into a pile group. Spread footings transfer loads into the rock or soil layer the footing is founded on. Drilled shafts typically transfer load from a single column into the rock, or soil the shaft rests in. All foundation elements may be subject to a combination of gravity loads (compression), uplift loads (tension), or bending. The reinforcement primarily acts to resist tension loading, the concrete primarily acts to resist compression loads, and the combination of both materials resists any bending loads.

8.3.1 Terms

Abutment—substructure element at each end of a bridge structure supporting the superstructure of the bridge

Backwall Protection—material used to deter water infiltration into solid concrete

Beam—horizontal structural element which transfers loads to bearings or a diaphragm

Bearing—device designed to transfer superstructure loads to the substructure

Black Steel—mild reinforcement without any type of corrosion protection

Bond—describes the attachment, or lack of attachment (debonding) between the reinforcing steel and the concrete

Chair—metallic or non-metallic support placed on formwork to maintain reinforcing steel at a specific distance from the forms or top surface of finished concrete

Compression—type of loading that tries to **shorten** the element

Column—substructure element transferring load from the bearings to the foundation elements

Cover—distance from the surface of the cured concrete to the nearest surface of reinforcing steel

Cure—describes the process of the chemical reaction between cement and water causing the concrete to gain additional strength after its initial set

Deck—structural element formed to cause beams/girders to act as a system and to stiffen the superstructure

Diaphragm—a solid structural element which acts similar to a bearing transferring load to the substructure

Epoxy Steel—mild reinforcement with an epoxy coating bonded to the steel

Footing—substructure element transferring load from the bridge structure to the earth

Forms—elements used to hold plastic/liquid concrete to the shape specified in the plans until the concrete has cured

Girder—horizontal structural element that transfers load to a bearing or diaphragm

Load—any force induced or placed upon a structure or structural element

Pier—substructure element supporting the superstructure located between the bridge abutments

Pile—foundation elements used to penetrate soil and transfer loads to bedrock (bearing pile), or transfer loads to the surrounding soils through friction (friction pile)

Pile Cap—a concrete element used to cause pile to act as a group

Pile Group—describes pile in close proximity to one another and acting as a group instead of acting as a single pile

Seal Course—substructure element poured to inhibit or stop flow of water into a work area typically located below the watertable

Splice—term used to describe how reinforcing bars will transfer load to another bar or to the surrounding concrete

Stripdrain—system placed to introduce an air void between two materials to prevent water pressure from building, collect water and control drainage

Substructure—any part of the bridge structure supporting or located below the bearings, foundation elements of a bridge structure

Superstructure—any part of the bridge structure integrated into the structure located above the bearings or bearing seats

Tension—type of loading that tries to **lengthen** the element

8.3.2 General Inspection Concerns

Bridge abutments, piers, and columns constructed with reinforced concrete transfer superstructure loads to the foundation elements. Each of these structural elements transfers load similar to pile caps, spread footings, or drilled shafts. The combination of concrete bonded to the reinforcement steel creates a very useful tool to design engineers. The design engineers specify dimensions, cover, sizes, and strengths to provide the capacity to transfer the loads from the superstructure, through the abutment, pier or column and into the foundation elements. Any changes to the specified items, because of potential impact on the function of the reinforced concrete element, should be approved by the designer.

The primary, natural enemy of a concrete structure is water. Water infiltrates into cracks in the concrete and acts to increase the size of cracks and oxidize the reinforcement steel. Cover is the distance between the surface of finished concrete and the outer surface of the first reinforcing steel bar (see Figure 1). The cover distance is specified to reduce water infiltration that may cause rust scale to form on the steel. Whether the steel is epoxy coated, or plain steel, if water can be kept from contacting the steel after the concrete has cured, the longevity of the concrete structure will be extended.

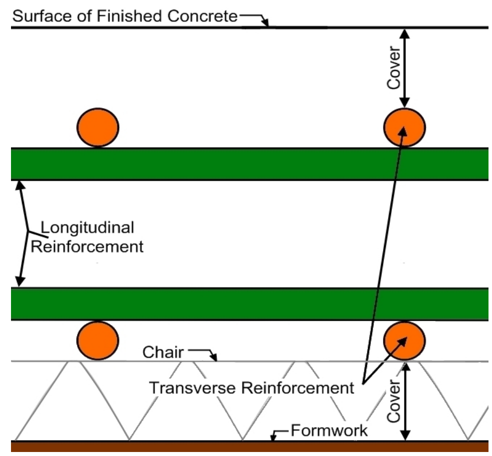


Figure 1: Diagram of concrete "cover"

Reinforced concrete structures rely on the correct placement of the reinforcement steel to resist the real-world loads placed on the structure. The length of a reinforcement lap splice is specified to provide enough length to transfer load to the adjacent reinforcing bar. A lap splice is typically in a region where loads will not be at a maximum. The importance of correct splice procedure is illustrated in the example covered below.

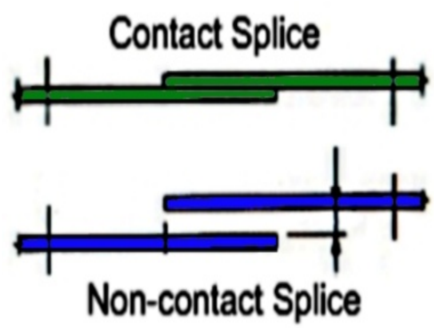


Figure 2: Lap splice types

Example: Each bar pattern in the longitudinal reinforcement layout for a bridge deck may have several lap splices. During the steel placement if one lap splice is over-overlapped by an inch, another lap splice in the same bar pattern will end up under-lapped by one inch. If this occurs, and the splice is loaded to the maximum load accounted for in the design, the concrete surrounding the splice absorbs the overload and cracks. Cracked concrete allows water to infiltrate and begin corroding the steel reinforcement which further reduces the bar's ability to carry load. In a worst case scenario, the crack continues to grow until the bars in the lap splice are allowed to de bond, slip, and pull out of the surrounding concrete. The Contact Lap Splice is typically the type of splice KDOT specifies in the contract documents. The contact lap splice tied together using the correct type and number of wire ties. Other types of splices are welded splices, thermochemical splices, mechanical splices, or non-contact lap splices.

Mechanical splices or mechanical couplers are occasionally used in phased construction of a reinforced concrete structure. Mechanical splices serve the same purpose as a lap splice, or a hook, but forming is much easier to accomplish for the contractor. The mechanical splice is attached to the reinforcement steel in phase one and the female end is butted tight to the formwork defining the line between phase one and phase two, or pour number one and pour number two.

Figure 3: Set Screw Splice

After the forms are stripped for phase one and the reinforcement is placed for phase two, short bars are mechanically connected to the female end of the mechanical splice and the phase two reinforcement is tied to those bars.

The contractor's formwork does not require as much customizing when mechanical splices are used. The added thickness of the coupler devices can cause an issue with clearance or cover distances, so the inspector will need to keep a watchful eye on the distances called out on the plan sheets for the reinforcement.

Figure 4: Threaded Splice

Similar to a lap splice, an embedment length is specified to provide a length of steel bonded to the concrete to develop the full tensile force capability of the steel bar. Obviously all of the bar will be bonded to the concrete, but at the end of a bar it takes a certain distance along the bar based on the size of the bar for the steel to transfer the stress to the concrete. Ninety degree bends, or full hooks are sometimes used to shorten this length. Hooked bars protruding out of the deck just above the approach slab rest are a great example of these bars, and the purpose they serve. In this case, the deck reinforcement near the abutment needs full strength at the point the deck meets the inside face of the abutment. The hooked bars sticking out above the slab rest provide the restraint needed to develop the full strength of each bar. The correct installation of the reinforcement steel, the correct material makeup of the concrete and the correct dimensions of the structure all contribute to the longevity and durability of the concrete structure.

A relatively new construction option to "shorten" the development length of reinforcement bars are headed reinforcement. A mechanical anchor with a flat plate on the end is joined to the end of the reinforcement to develop the strength of the bar over a much shorter distance. The contractor is not allowed to weld a flat plate onto the end of reinforcement. A commercially developed headed anchor must be obtained and fabricated onto the reinforcement.

8.4 Materials

8.4.1 Concrete

Inspectors must verify the concrete and reinforcement arrive with the properties specified by the designer. The concrete strength, density, air content, cement factor, slump and other factors must be within the range specified in the specifications, or within the approved mix design. The materials used in the concrete are prequalified, but on-site testing plays an important role. Air, for example, is a key material in concrete. The correct amount of air helps to keep concrete from cracking in freeze-thaw conditions. It is important to obtain the amount of air specified within the tolerances listed in Division 400 of the Standard Specifications. If the concrete air volume is low, the concrete will not withstand freeze-thaw conditions, if the concrete air volume is high, the strength of the concrete is compromised.

8.4.2 Reinforcement

Black steel, epoxy steel, and fiberglass strands are common types of reinforcement used in concrete. The Type and Strength of the material are specified by the designer and are verified in the field. Use of epoxy coated reinforcement requires more stringent construction practices, such as non-metallic straps, non-metallic chairs and ties. Black steel may require additional protection measures to be installed with the reinforcement. Installation of protection measures will typically follow manufacturer recommendations. Whether the reinforcement is supposed to be epoxy or plain steel, the thickness of the epoxy, the strength of the steel, and the size and shape of the bars must all match the contract documents and specifications. Also, errors in the type of tie wire used, errors in the height and type of chairs used, or circular spacers in the case of drilled shafts, are better caught at an early stage before installation.

8.4.3 Formwork and Falsework

The Formwork and Falsework chapter of the Bridge Construction Manual describes, in greater detail, the specifications defining materials requirements for each. To briefly state key requirements, forms and falsework must consist of sound, straight lumber, forms must be in sound condition, and if aluminum forms are used, there must be a veneer of material to separate the aluminum from the liquid concrete. See Chapter 6.0 for additional information.

8.4.4 Waterproofing

Waterproofing concrete surfaces above or below grade is often specified as Substructure Waterproofing Membrane, or Bridge Backwall Protection System. The systems used must provide an impermeable seal to prevent water from contacting the concrete, maintain a bond to the concrete, self repair punctures to the membrane, and be flexible enough to span, or seal cracks that develop in the concrete element. For use below grade, a coal-tar membrane, or an epoxy-mastic system produces the desired results. A coal-tar membrane is most often used as the Bridge Backwall Protection membrane because the abutment backwall will always have compacted backfill behind it. The mastic/bituminous systems are not used above grade because UV light causes elements in those types of systems to become brittle and crack. If the concrete element is above grade, a full epoxy system is used that is impermeable and resistant to the affects of UV light.

8.4.5 Strip Drains

Strip Drains are specified in order to keep water pressure from building behind concrete structures or within backfill. This system creates an air void between the backfill and the backwall protection membrane. The strip drain is installed with the fabric material in contact with the backfilled soil, with the rigid surface against the protection membrane bonded to the concrete backwall. This orientation allows the water to leach out of the backfill into the air void between the fabric and the backwall protection membrane. The fabric acts as a filter, so the water does not carry the backfill material into the strip drain. The strip drain is coupled with, or drains into a fabric wrapped pipe that is used to convey the water out from behind the abutment to drain out onto the bridge berm slope. Strip drains may also be used as a barrier between cut material and backfill material. In any install, the strip drain fabric is placed against the material that will require draining.

8.4.6 Curing and Protection

Wet burlap, liquid membrane-forming compound, white polyethylene sheeting, or other impermeable materials are placed on concrete surfaces shortly after initial set. Action is taken through the use of a work bridge to prevent marring the concrete surface while placing the burlap or poly sheeting and the objects used to weigh down the sheeting, and/or hoses used to keep the burlap soaked. A minimum 14 day wet cure is required on most flat-work, while a 4 day cure is required for other formed surfaces. During the curing period, water is supplied to the chemical reaction taking place in the formed concrete. Time constraints and environmental conditions control when to place Polyethylene sheeting over the wet burlap. The sheeting is used to maintain a humid environment and reduce excessive use of water to keep the burlap damp. After the minimum curing period, a protective membrane is applied to the surface of the concrete to extend the amount of time it takes for the moisture inside the concrete volume to evaporate into the atmosphere. Both processes, curing and sealing, are in place to reduce early cracking in reinforced concrete structures and by reducing early cracking overall cracking is also reduced significantly which reduces long-term maintenance costs for the structure.

Reinforced concrete structures rely heavily upon the specified properties of the materials, geometric distances, installation requirements, falsework and forming practices, and the finishing and curing procedures after the pour is complete. Deviations from the plans, specifications and procedures can lead to cracking, corrosion, spalling, or total failure of the reinforced concrete.

8.5 Equipment

Formwork is covered in greater detail in the Forms and Falsework chapter of the manual. In short, formwork is used to contain and give shape to liquid concrete. Steel, aluminum, and plywood forms are all used in commercial construction and each type is able to perform well where other types may not.

8.5.1 Forms

The many different materials, systems, and types of formwork used on a typical job-site can vary widely. How the formwork is used, the materials it is made of, and how the formwork is prepped can vary widely, as well. Inspection of the forms is vital to the final product and vital to time and materials savings on the part of the contractor. The Engineer can reject the use of forms not meeting specification requirements.

First, the forms must be clean and dry (except see requirement for bedrock below) before concrete placement occurs. This includes removal of debris from construction activities and water accumulation from site drainage. Inclusion of spills, sand, mud, trash, water, etc. in the liquid concrete and the condition of the surfaces of the forms may all cause issues in concrete placement and can weaken the final product. Water inflow into the forms at the time of concrete placement is unacceptable. The clean and dry requirement is easily accomplished by pumping out or blowing out the forms with compressed air.

Steel forms or prestressed reinforced concrete panels may occasionally be used as stay-in-place (SIP) formwork for bridge decks under limited circumstances and when approved by the designer. Both steel and prestressed concrete panels used as stay in place forms preclude the close inspection of the bottom of the bridge deck concrete during the life of the deck which can result in minor bridge deck issues going undetected until they become major problems. The correct on-site fabrication of steel SIP formwork has been an issue and often has had an adverse affect on the construction schedule. These fabrication issues coupled with the inspection issues throughout the deck life has led to steel SIP forms rarely being permitted for use in Kansas bridge decks. Prestressed concrete panels are used in Kansas when the site characteristics, or construction limitations, require their use. The use of prestressed panels is limited primarily because the bridge deck tends to crack at each transverse panel joint which reduces the overall life of the bridge deck.

Figure 3 Steel SIP Forms Incorrectly Installed

Figure 4 Prestressed RC Deck Panels

Figure 3 shows improper installation of steel SIP forms. The forms sit on a ladder structure, and the tack welds made have also been welded to the top flange of the girder. The ladders should be fabricated at a location off of the bridge structure, and away from the girders. Small welds can create substantial problems in how the steel performs in the service life of the girder. Figure 4 is an example of prestressed deck panels used to form the bridge deck. Strips of dense expanded polystyrene foam are typically used under the panels to both construct the “fillet” required for the bridge deck and provide a more forgiving bearing seat between the panel and the beam.
Forms are typically made up of steel, concrete, and/or wood. Reinforced concrete poured as a seal course in a cofferdam is also considered formwork. Dirt, limestone, or shale, may also be

considered a form since these materials may be used to form the sides, or bottom of a footing. Bedrock may be used to form the sides of a reinforced concrete element, and dirt is occasionally used to form the underside of a pilecap, a footing, or an abutment. “Neat lines” is a designation used when the forms will be made of in situ materia, specifically a type of footing formed in bedrock. “Neat lines” simply means the sides and bottom dimensions must be near to the dimensions stated on the plans without large outcroppings, or cavities. The designer intends for the concrete to bond to the bedrock, so the rock must also be clean. Bedrock will tend to suck the water out of fresh poured concrete, so to prevent this from occurring, the rock must be wetted, without any puddles forming, similar to a silica fume overlay being placed on a subdeck. The term used to describe this is saturated surface dry.

Occasionally dirt may be used to form the bottom surfaces of footing structures. The plans will typically define a cover for the bottom bars if a rigid form is used for the bottom surface and a different cover will be specified if dirt will be used to form the bottom surface. The weight of the concrete and the reinforcement will try to push chairs into the soil, so the size of the base of the chair also comes into question if dirt is used to form the bottom surface of a footing. A chair that will work to support deck reinforcement will perform poorly as a rebar support on soil.

Treating forms with release agents must be done before placement of the steel reinforcement to make form removal easy and relatively effortless. The concrete will still be in a “green” state when form removal takes place, and it will be prone to spalling or cracking if the forms do not come off easily. The form treatments typically used prevent the liquid concrete from bonding to the surface of the form. As such, it is extremely important the treatment materials do not come in to contact with the reinforcing bars. If the bond between the bars and the concrete is compromised, many problems are introduced from a design and a maintenance standpoint.

Forms occasionally stay in place for a significant amount of time. Anchor bolt forms placed in a pier beam, in particular, may stay in place through a season until the bearings are placed and the structural steel is hung. Section 842 in the 2007 specification does not allow an anchor bolt well to be left ungrouted and subject to freezing. Water expands a great deal when it converts to a solid from a liquid and exerts a load from the anchor bolt well to the exterior edge of the pier beam. If the anchor bolts have not been grouted in place before the fall/winter/spring seasons, where overnight temperatures can drop below freezing, the well needs to be filled with a liquid that will not freeze. Salt water is an unacceptable liquid to put in the anchor bolt wells; salt water does not freeze, but chlorides in the salt water damage the concrete in other ways and will not be allowed. Also, attempts to seal the holes to keep water from collecting in the wells are most often unsuccessful; water infiltrates, freezes, and cracks develop in the concrete.

8.5.2 Reinforcement Placement

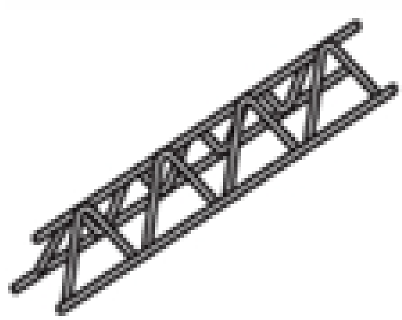


Figure 5 Reinforcement Chair

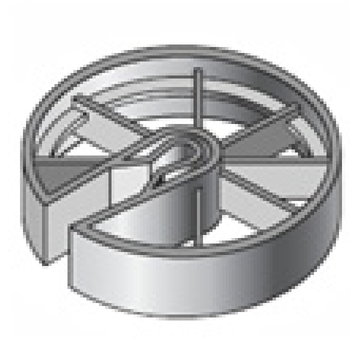


Figure 6 Circular Spacer

Chairs, ties, and spacers (as per chart in Appendix B) are used to hold reinforcement in the correct position within the forms as stated in the plan details. Deck chairs, or chairs, hold the reinforcement a specific distance up from the formwork they rest on. Looped ties, or tie wire is used to mechanically hold pieces of reinforcement together by looping the wire around the connection and twisting the ends of the wire until the connection is tight and secure. Mats of reinforcement are required to withstand a substantial amount of abuse from laborers walking on the bars; concrete dropping on top of, or falling through, the mats; and vibration from handheld or gang mounted vibrators. When epoxy coated reinforcement is being used, coated chairs and ties must be used. The coating prevents the steel ties or chairs from damaging the epoxy coating on the reinforcement. When plain steel (black steel) reinforcement is being used, coated or uncoated chairs and ties may be used. Circular spacers are used primarily to hold drilled shaft reinforcement cages away from the sides of an open, or cased, excavation. When the spacers are correctly placed around and along the reinforcement cage, it is unlikely the cage will move side to side, or bend, while filling the drilled shaft with concrete.

Spacers and chairs maintain the minimum cover the designer specifies. The minimum cover and the specified layout of the reinforcement are both critical to the calculations the designer has used to determine the load carrying capacity of the reinforced concrete. For example, a typical bridge deck is designed with the transverse and longitudinal reinforcement as depicted in Figure 7. This could also be typical of horizontal and vertical bars in a retaining wall structure. If the reinforcement were mistakenly placed with the longitudinal reinforcement outside of the transverse reinforcement, the opposite of what is shown in Figure 7, the load carrying capacity of the bridge deck, between the girders, would be reduced considerably. On occasion, reinforcement details in the design plans will have one cross section with one type of bar shown below another, but in a different cross section, the bars will be reversed. This does not indicate the desire of the designer is to "weave" the bars into position. In any case when the design details are unclear or clarification is needed, call the State Bridge Office or Bureau of Local Projects for clarification of what the designer initially intended so proper placement will result.

Specifications also explain how reinforcement must be stored and handled. Similar to structural steel, bundles of reinforcement should be blocked up off of the ground, kept dry, and epoxy coated reinforcement should be covered to protect it from UV radiation. As bundled reinforcement is craned over to the forms to be tied in place, the bundles need to be supported well enough to keep the bars from bending excessively. A bundle allowed to bend too much will maintain some, or the entire bend because the bars have permanently deformed. A deformed bar is a damaged bar and can not be bent back into shape; it must be rejected.

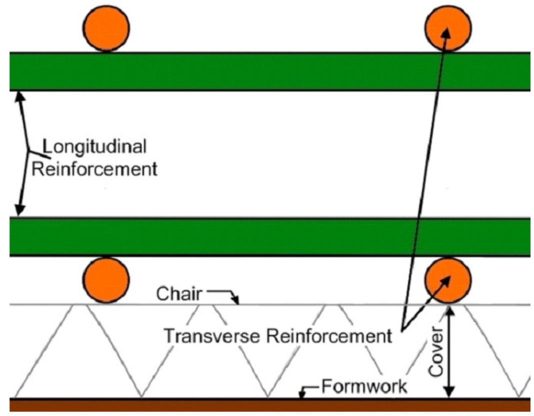


Figure 7 Deck Reinforcement Example

With epoxy reinforcement, individual bars will knock against one another if the bundle is not strapped tight. As the bars knock together, the epoxy coating suffers damage and requires repair. During the life of the structure, instead of the electrolysis taking place and causing rust to form along the length of the entire bar, all of the damage will occur at the damaged area of the epoxy. This intensifies the reaction over a very small area, and will completely destroy the bar in that location in a short period of time. The soundness of the epoxy and repairing any blemish in the coating is extremely important to the life of the structure.

Once placed, reinforcement may be damaged through construction activities. Before placing concrete and encasing the reinforcement, the reinforcement should be inspected for visible damage, and repaired. If bars have been bent out of the original shape, the bar is required to be replaced. Bars embedded into concrete that will act across a cold joint are generally more vulnerable to abuse as construction takes place around them. KDOT will allow an embedded bar to be bent back into position only if the bar has been bent less than 45 degrees for #3 thru #6 bars, and less than 30 degrees for #7 thru #18 reinforcement.

Figure 8 Embedded Epoxy Reinforcement

In the case of embedded reinforcement, replacing damaged bars would likely cause more damage to surrounding concrete and steel bars, however, if the bar is simply tied in place and has been kinked, deformed, or bent, the bar is required to be replaced. Reinforcement which is not embedded in concrete can be replaced and retied easily. KDOT specifications do not allow the Contractor to attempt to bend a freestanding bar back into shape after it has been unintentionally deformed. KDOT specifications do allow field bending in certain, limited situations and only as directed by the engineer. Occasionally field bending will be specified within the contract documents for a project. Field bending will not be a precise operation, but the Contractor should make every effort to bend the specified bars a single time and move to the next bar. Bending a bar multiple times to correct improper bends is not allowed. In most cases the bars designated to be field bent will be within the angle limits listed above and if those limits are exceeded the bar should be rejected.

8.5.3 Concrete Placement and Finishing

Pumps, conveyors, or concrete buckets are all methods of placing the liquid concrete into the formwork. Experience has proven the need to test concrete fresh out of the concrete chute, and at the end of the device used to place the concrete.

Figure 9 Conveyor with Trunk

Figure 10 Concrete Pump Truck

Pressure associated with pumping concrete can cause a portion of the water used at the time of batching the concrete to be forced into the aggregate if the aggregate is not one hundred percent saturated. This will actually help later in the curing process. However, by removing water from the paste and driving it into the aggregate the pumpability and workability of the mix are reduced. By testing the mix in both places, several variables that will change throughout the pour can be monitored and corrected if there is good communication between the site and the readymix plant. The placing and finishing equipment, and backup equipment, should be discussed with the Contractor well before any concrete is ordered.

Division 150 and Division 700 of the Standard Specifications cover, in detail, the equipment the Contractor should have available for use during a concrete pour, procedures the Contractor should follow based upon different site characteristics, and methods the Contractor should employ to achieve a successful concrete pour. Throughout a concrete pour, it is practical to occasionally check and verify the finishing equipment settings remain consistent. Liquid concrete falling onto reinforcement, being pumped against all surfaces of the form work, and laborers climbing on forms and reinforcement cages can all cause slight movement of the reinforcement cage, the forms, or the strikeoff chamfer.

Figure 11 Deck Finishing Machine

Verifying the elevations, dimensions, and clearances as the pour progresses can save time and money. For example, a situation arises where the formwork slips a half inch on one side of a four foot wide pierbeam during a pour. The concrete is then struck off at the chamfer strip and finished. The top of the pierbeam would have a slope (0.5 inches in 4 feet) across the four foot width of the pierbeam which exceeds the limits stated in KDOT specifications which would then require additional time, materials and money to reconstruct to the proper tolerances. Another situation which could arise: if a large surface area of concrete towards the end of a deck pour cannot be covered before the arrival of a weather system. Consider adding a sacrificial thickness of concrete to finish the pour. Whether, or not, the weather system affects the concrete surface the Contractor can then grind off the over-poured concrete down to the correct concrete surface elevation. The sacrificial concrete added during the pour is considered a risk management measure, or risk "insurance" with the potential of saving the contractor time and money.

8.5.4 Mix Designs and Testing

Most mix designs are specified to have a certain percentage of air voids, a range of the water to cement ratio, a range of density and slump, and temperature limitations at the time of placement. Testing at the mixing plant, at the end of the concrete chute once the concrete has arrived on site, and at the end of the placement device allows the inspector to compare the slump loss, air void loss, and other characteristics that may change during transportation to the site or due to the concrete placement equipment. The use of pumps, conveyors, or buckets can cause situations where the concrete must free-fall a distance to the reinforcement and formwork and the contractor must use methods to limit this distance as shown in Figure 9 above. (The distance concrete is allowed to freefall is limited in KDOT specifications).

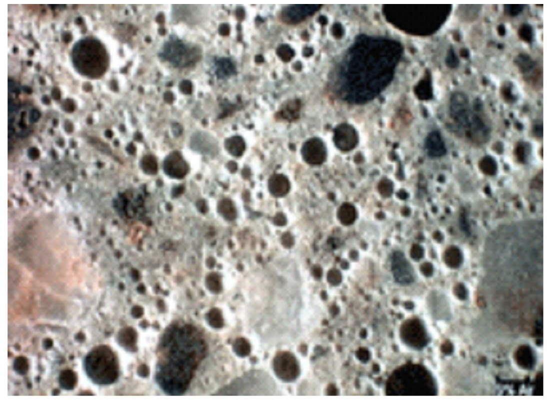


Figure 12 Air Entrained Concrete
(Portland Cement Association)

Air voids in liquid concrete act as lubricant to the aggregates and the cement paste and aid in workability and finishing. Often the air voids aid in workability more than higher slump concrete. However, no single characteristic can stand alone as the most important due to the various applications reinforced concrete can be used in. The desired mix design for the specified applications is approved as stated in the material specifications so a variation outside the allowed tolerance is unacceptable. Again, by testing at several places, the inspector can relay information to the contractor's supplier to account for the changes in the concrete due to transport and the placement device. Specified limits, drop distance, consolidation, and segregation are all primary concerns during the placement of the concrete.

8.5.5 Consolidation

Consolidation of the concrete is important in order to prevent air entrapment (large air voids), cold joints, seams, or other types of inconsistencies within the concrete structure. Consolidation is accomplished by uniformly vibrating the concrete to work the course aggregate away from exposed surfaces, making the concrete easier to finish. Vibrators should not be used to move the concrete horizontally within the forms. A mechanized vibration system working in conjunction with the finishing machine, set up to vibrate the concrete at regular geometric intervals and to vibrate the concrete for a predetermined amount of time is the easiest method to accomplish a uniform placement with uniform scatter of the aggregate. If epoxy reinforcement is present in the concrete, according to specifications the vibrators must be made of, or securely covered with rubber, or a similar resilient material. As mentioned above, due to the time constraints inherent with concrete construction, the Contractor needs to have backup equipment available in the event the primary equipment breaks down.

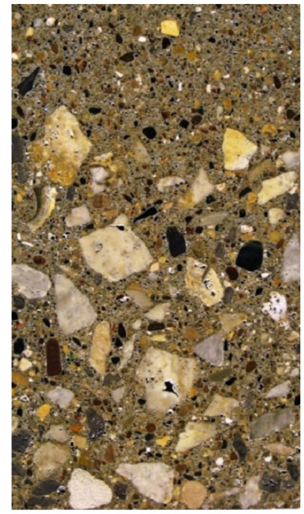


Figure 13 Over-consolidated Concrete

Over-consolidation should be avoided. Over-consolidation can occur through several lifts of concrete, or it can occur in a single lift. Over-consolidation through several lifts will cause partially set concrete to re-liquefy. Re-liquefied concrete may place excessive fluid pressure on the form ties at the bottom of vertical formwork and cause the forms to fail. Over-consolidation in a single lift occurs when the concrete has been vibrated too much and the aggregates are no longer scattered throughout the cross section as shown in Figure 13.

Handheld concrete vibrators are essential to a concrete pour. Particularly, when the reinforced concrete element is deep, requiring several “lifts” of concrete, consolidating a short distance through the joint between the last two lifts will remove air pockets trapped between the lifts and meld the two layers of plastic concrete together. Division 150 covers the minimum requirements for these vibrators, where they may be used, and the specifications the equipment must meet **{154.2}**. Additional requirements are listed in specifications within Division 700 **{710.3, 711.3, 717.3, and 731.3}**. Typically, Division 150 denotes the general requirements for equipment, and the more specific requirements are listed within the specifications contained within Division 700. Any time epoxy reinforcement is present in the concrete being consolidated by vibrators (mounted or handheld), the vibrators must have rubber heads, or be covered with a securely fastened rubber cover.

Consolidation, removal of open voids, flow of the concrete around tightly spaced reinforcement, and ensuring concrete has flowed around tight corners and “filled” an area entirely can all be accomplished by selective use of a handheld vibrator. Again, vibrators should never be used to move concrete horizontally because the probability of over-consolidation increases considerably. Overfilling one area of the forms and then using vibrators to move the concrete into the rest of the form is an incorrect procedure. Concrete should be placed in lifts evenly throughout the forms to an approximately uniform depth. Vibration of the concrete then liquefies the plastic concrete and causes the concrete to flow around obstructions or into tight areas more easily.

Particularly dense concretes with low water to cement ratios, or low slump concrete, will not fill the formed space just by placing the concrete in the center of the forms. Over-vibrating the concrete in order to get the concrete to move horizontally into the rest of the form will have negative effects on the finished product. A well thought plan of concrete placement (placing the concrete around the entire footprint of the forms) will accomplish the goal of having the correct amount of concrete needed to fill the forms, and have it in the correct area. Proper use of consolidation techniques will accomplish the goal of limiting voids, joints, seams, or pockets in the concrete structure.

Figure 14 Badly Consolidated Concrete

A monolithically poured abutment with rolled beams is shown in Figure 14 as an example of the concrete not flowing around the top of the top flange and filling the space between the web and the bottom of the top flange. The visible portion of the void is similar in shape to a triangle and nearly the size of a clenched fist, so it does not appear to be a significant flaw. However, the depth of the void shown is nearly the same as the embedded portion of the rolled beam, one and a half to two feet into the abutment. Figure 14 also clearly shows how the aggregate was not consolidated into the liquid concrete. Instead, the aggregate effectively blocks the cement paste from molding to the shape of the beam flange to web corner. This type of defect can be repaired, but the repair will not be as strong, or as durable, as the initial liquid concrete forming and consolidating into the corner of the rolled beam. Repairs are time consuming and labor intensive.

It is important to consolidate only the top two lifts of concrete in a deep concrete element. Forms, and form ties are only capable of resisting a limited amount of hydrostatic pressure, but if the procedures mentioned above and the process of pouring the element in lifts are followed, the capacities of the formwork and the form ties will never be exceeded. Deep, long concrete elements, such as a bridge abutment backwall, typically require a large quantity of concrete. As relatively shallow lifts are made from end to end of the element, the top-most lift of the concrete should be thoroughly consolidated, but the vibrator should also pass, at least partially, into the previously placed layer of concrete. This procedure will guarantee a cold joint will not develop between lifts if the procedure is followed for each lift. The previously placed concrete below the top two lifts will begin to setup and stiffen adequately to reduce the hydrostatic pressure load on the lower levels of the forms and ties. If the vibrator passes through all lifts, from the top of the freshly placed concrete to the bottom of the formwork, each time a lift is placed, the concrete will not setup, or stiffen, and the pressure on the forms and ties will increase substantially, possibly leading to failure of the forms. Again, the vibrator must be an internal type (tube or spud) vibrator that meets the frequency requirements, and must have a head of rubber, or a secure fastened rubber cover if epoxy reinforcement is being used.

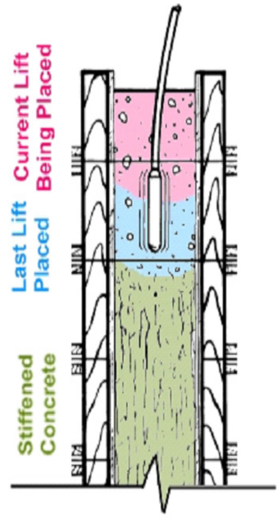


Figure 15 Lift Consolidation
(Modified Dayton Superior Image

8.5.6 Slip forming

Slip-forming machines are allowed for concrete barrier construction for bridges. Slip-forming the barrier is a time-saving benefit offered to the contractor, but has additional material and construction requirements. The open dimensions of the bridge deck may not be modified, i.e. the dimension across the deck from inside of barrier to inside of barrier cannot be reduced. The contractor is allowed to increase the entire bridge deck width a maximum of four inches (a maximum of two inches on each side) in order to accommodate for the support of the slip-form machine to rest, or ride, on the edge of the deck (shown in Figure 16). In addition to widening of the bridge deck, the contractor must construct a 100 foot test section to demonstrate acceptability of the slip-formed barrier.

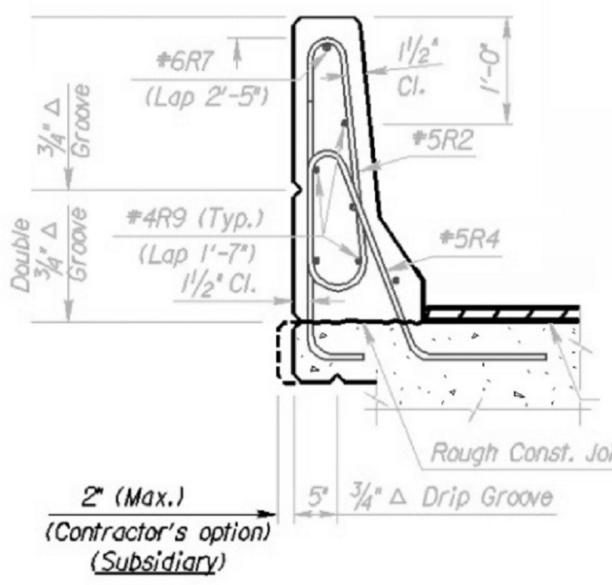


Figure 16 Slipform Section Detail

Due to the low slump (½" maximum) requirement of the slip-formed concrete, additional reinforcement may be required in order to keep the barrier reinforcement from wracking in the direction the forming machine travels. Two to three foot long, straight, number four bars used as tension struts, tied to the barrier reinforcement every four to six feet will typically resist the "wracking" caused by the low slump concrete attempting to push the top of the reinforcement in the direction of the machine's travel.

The test section will become part of the bridge barrier if it meets all specification requirements. Before beginning the slip-forming procedures, the Contractor must verify the clearance of all reinforcement for the entire length of the barrier, and monitor the clearance after the concrete pour begins. The engineer will determine the acceptability of the test section and decide if the remaining barrier will be slip-formed, or conventionally formed. All end sections must be conventionally formed, as well as any sections that will receive an attachment of any kind. Load limits and cure time must be strictly adhered to before beginning the slip-forming procedures.

Figure 17 Slipforming Machine

Slip-form machines are typically very heavy and will essentially be nearly a point load on a very "green" overhang. By lengthening the cure time of the overhang, the strength of the new concrete is allowed to develop and cracking is reduced the also decreases the possibility of excessive deflection.

Traffic loads and vibrations must be monitored closely during and after the concrete placement of the barrier. The freshly placed barrier concrete is in a liquid state for a certain amount of time, and is susceptible to settling if the deck vibration caused by vehicular traffic on the deck exceeds specification limits. Typically, all surfaces must be lightly broomed and all contraction joints must be cut into the slip-formed barrier just prior to the initial set without spalling of the concrete. By specification, immediately following the broom finish, the contractor must apply two coats of curing compound at 1 gallon per 250 square feet of surface area for each coat. The second coat must be applied at right angles to the first coat to ensure thorough coverage. In the future, specifications may be require an opaque curing compound, but current specifications require only clear or translucent compound with a fugitive dye. With the current type of curing compound required by specification, inspectors will need to carefully watch the application process to verify the correct amount of compound is applied, and the coats are applied according to specification. Verification after the dye has soaked into the concrete is extremely difficult.

8.5.7 Surface Finish

Concrete grinders or planers machines, will occasionally be required to correct flaws in finished concrete. Concrete grinding is occasionally used to correct flatness errors in fully hardened concrete, remove burrs, or remove general surface variations defined as any variation of greater than one-eighth inch variance in ten feet. These implements must be self-propelled with diamond blades mounted on a multi-blade arbor. The machine must be capable of grinding fully hardened concrete without causing excessive ravels, aggregate fractures, or spalls.

Figure 18 Concrete Grinding Machine

Vacuum equipment, or another continuous cleaning method, must be used in conjunction with the grinder to remove residue caused by the grinding operations. Typically used only on bridge decks, grooving equipment requirements are very similar to the grinding equipment requirements. The use of diamond blades, the requirement the equipment must not cause excessive ravels, aggregate fractures, or spalls are identical to the grinding requirements, and the cleanup operations are identical to the grinding requirements.

For new concrete deck slab construction float tining plastic is no longer allowed. The requirement of covering the concrete with wet burlap within 15 minutes of placement does not allow time to form the tines. Mechanical grooving is required, this is done a minimum of 7 days after the membrane curing compound has been placed. The grooving equipment is required to be self-propelled like the grinding equipment, the contractor must demonstrate proficiency with this type of equipment. The grooves must at right angles to the center line of the bridge, be 3/16" wide, spaced at 3/4" centers, with the groove depth approximately 1/8". For bridge decks with drains, the transverse grooving will stop one foot from the gutter line. For bridge decks without drains, the transverse grooving will stop two feet from the base of the rail. Currently KDOT specifications allow float tining to be carried out as part of the concrete placement and finishing operations on deck bridges that do not receive an overlay. The dimensional requirements remain the same, and the grooving is accomplished by tining float, or a vibratory tining float having a single set of fins **{710.3.d}**. All tining and groove is done perpendicular to the center line of the roadway to minimize the potential of winter snow melt freezing to the surface.

Another type of surface finish is primarily for aesthetic purposes. Trowelled or floated finishing may be required at particular areas designated in the contract documents, but a good rule of thumb for where this type of finishing will take place is any area clearly seen by the travelling public other than the surface of the deck. On most structures, this will include the rails, curbs, and the backside of rails on side by side structures. A trowelled or floated finish will remove the minor defects in the concrete elements such as pocks, depressions, projections, honeycomb, or noticeable color variations.

Figure 19 Carborundum Brick

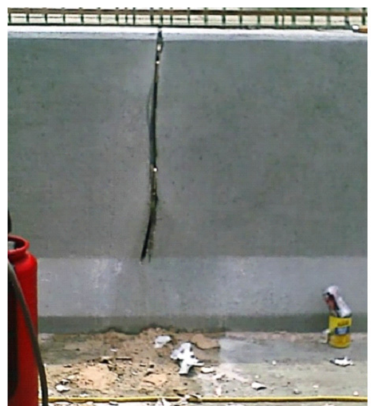
The rubbed finish must take place while the concrete is still green and moist. Mortar is an acceptable material to use to supplement the finish but must be applied to the concrete while it is still moist. Mortar must not be rubbed on to concrete that has become dry. After the floating, and after the finish has cured a carborundum brick is used to knock down any loose material from the finished surfaces. A carborundum brick is simply an abrasive brick that will not mark the surfaces and is durable enough to remove mortar/concrete to an even plane surface.

Many bridges now being constructed in urban areas use some type of form liner to emulate a cut stone, brick, or similar finished pattern or appearance. Piers, abutment walls, and often times the outside face of corral rail or barrier rails receive this type of finished appearance and most of the concrete not enhanced by the form liner will require a rubbed finish. If a form liner is required for a barrier rail, the contractor is not able to slip-form the rail, so the rail will require forms and form ties. As mentioned above, a rubbed finish must take place while the concrete is still green and moist. Twist-off or snap-ties cannot be broken until the concrete has sufficiently cured, so this presents a problem with implementing a rubbed finish on the other surfaces. The only available solution is to strip the form work while the concrete is still green, complete the rubbed finish as close to the ties as possible, snap the ties after the concrete has cured, complete the finish by filling the tie holes with a grout or mortar, then use the carborundum brick to even out the concrete surfaces. Barrier rails present the most obstacles due to the shape and depth of the concrete forms. The formwork for corral rail is typically stiff enough to resist the liquid pressure and gravity loads of the concrete during the pouring so very few or no form ties are necessary.

8.5.8 Joints

Expansion and contraction joints are used in concrete elements as an additional method to prevent cracking. Simply stated, a contraction joint allows the concrete in between joints to contract and pull away from adjacent slabs but there will be reinforcing steel “crossing” the joint to control the size of the crack that will form. An expansion joint is a gap which allows two adjacent slabs to expand without coming into contact with each other and this joint will not have steel crossing the joint. For example, a long sidewalk will have contraction joints trowelled into the surface of the concrete during placement to a certain depth. If the joint is cut deep enough into the concrete, as the piece between two joints contracts due to low temperatures, a full depth crack will form at the joint but the steel will limit the size of that crack. However, if the joint is not cut deep enough, the concrete at the joint is not made weak enough for the concrete to only crack at the joint and other cracks may develop in the sidewalk weakening and deteriorating the overall sidewalk slab. Grooving and tining are not cut deep enough to be considered contraction joints. Expansion joints do not have steel across the joint and can be open joints, filled joints, or covered joints. For example, the gaps between sections of corral rail are considered expansion joints, as well as the gaps formed, or cut into formed, or slip-formed barriers. Below are pictures of a structure where the contractor used drywall to form the joints in a barrier. The left image shows the barrier before the drywall joint has been removed, the middle image shows a nicely formed expansion joint after removal of the drywall, and the third image shows how drywall can warp and move when it is employed to form wet concrete causing an unacceptable expansion joint.





Expansion Joints: Before Removal, After Removal (Good), After Removal (Bad)

8.5.9 Evaporation and Fogging

Fogging equipment is used to reduce or eliminate concrete shrinkage cracking. Concrete elements with very little surface area exposed to the open air will not typically require fogging, but the surface must not be allowed to become dry. Once a volume of concrete dries out, the curing process stops and cannot be restarted. The specification requires a wet cure to reduce the amount of early cracking in the concrete **{Table 710-1}**. By reducing early cracking in the concrete, long term cracking is also reduced. Concrete structures with a large amount of surface area, such as decks, spread footings or approach slabs, will require fogging if the environmental conditions exceed 0.2 lb/ft^2/hr. The “Standard Practice for Curing Concrete” chart is available, full scale, in Division 700 of the 2007 Standard Specifications **{710.3, Figure 710-1},** or in the Appendix for this chapter. The chart is also included here as an inset, in the appendix to this chapter, and in the “Decks” chapter of the BCM. The proper method of using the chart is also located in the figure in the specifications and briefly explained here and the “Decks” chapter.

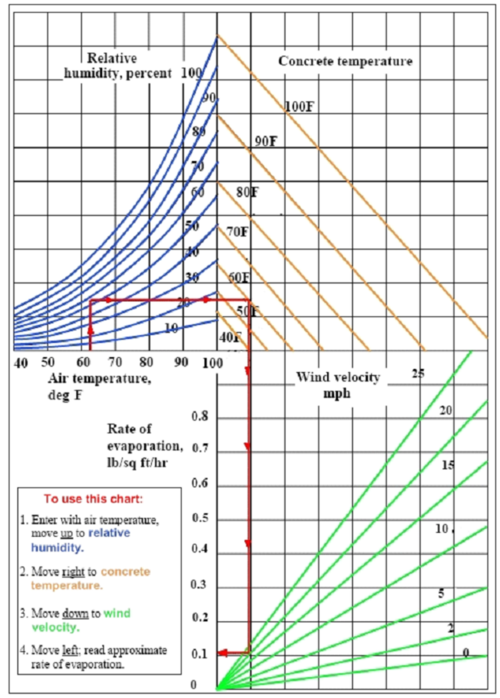


Figure 20 Evaporation Rate (Curing)

Beginning with the ambient air temperature, about 62 degrees in the above chart draw a line straight up to the measured relative humidity. Interpolate between the curved, blue lines if the measured relative humidity does not fall on a round ten number, approximately 55 percent in the above chart. From that point, draw a line horizontally to the right until the correct concrete temperature is reached, about 60 degrees in the chart example. The orange concrete temperature lines represent multiples of ten. Simply eyeball the approximate location of the point defining the actual concrete temperature. After determining that point, draw a line vertically down until you reach the green wind velocity line, or interpolation, corresponding to the wind velocity as measured at about 12 inches above the concrete surface. From that point, draw a horizontal line to the left and determine the evaporation rate. An evaporation rate above 0.2 lb/ft^2/hr indicates measures must be taken to reduce the air temperature above the surface by shading, reduce the concrete temperature, increase humidity above the surface, or reduce the velocity of the wind across the surface with windbreaks until the evaporation rate can be maintained under the 0.2 maximum. The measurements of the environmental conditions need to be taken at least once per hour during a concrete pour and more often if individual conditions are highly variable throughout the placement. Environmental conditions testing equipment should be onsite prior to any concrete placement. Specifications require one test prior to the placement, and at least once per hour throughout the placement. Even relatively short duration placements will need to have at least one environmental conditions test documented prior to the placement.

For deck slabs supported on girders the requirements of the Specifications is that the Contractor is required to have the concrete covered with presoaked burlap within 15 minutes of concrete placement. This time frame, while very challenging, is possible with the correct equipment and planing. The specification requires a curing plan to be discussed at the project progress meeting prior to deck concrete placement.

As can be seen in the adjacent pictures some Contractors have designed equipment and trained there personnel to be efficient to meet the 15 minute cover up limitation.

The example pictures shown illustrates the ingenuity of this Contractor. Prior to developing this method six men where required to work at an exhaustive pace to complete the deck pour curing requirement. After using this equipment two men are able to keep up and work at a reasonable pace.

8.6 Concrete Construction Specifications

Section 710.3 contains three separate tables clearly stating what amount of time must elapse before, for example, legal loads may be placed on a bridge deck. These tables (710-1, 710-2, and 710-3) allow the inspector to find the minimum cure times and curing mediums, load limitations for bridge decks, and minimum strength gain times before removal of forms and falsework for various types of reinforced concrete structures.

8.6.1 Minimum Cure Time

Table 710-1

TABLE 710-1: MINIMUM CURE TIMES AND CURING MEDIUMS		
Type of Work	**Cure Time**	**Curing Medium**
Bridge subdecks (decks with overlays)	14 days	Wet burlap covered with polyethylene sheeting
Bridge decks (full-depth decks)	14 days	Wet burlap covered with polyethylene sheeting during the 14 day period. Opaque liquid membrane forming compound (2 coats). [**subsection 710.3.e .(2)**]
Other unformed or exposed surfaces	7 days	Wet burlap, moisture-proofed burlap, liquid membrane forming compound (2 coats), white polyethylene sheeting
Formed sides and ends of bridge wearing surfaces and bridge curbs	7 days	Forms*
Other formed surfaces	4 days	Forms*

Figure 21 Table 710-1

Curing concrete is the process, during which, the cement in the concrete is given the time to react with the water provided. By slowing down this process, the concrete is allowed to achieve its maximum strength with limited cracking. If cracking of the concrete is limited at the outset, less cracking will occur through the life of the concrete structure, which means less time and money will be spent on maintenance, or repair of the structure. In short, curing is vital to the long life and durability of the concrete.

The table specifies the length of time required, and the type of cure required, depending on the type of structure. Subdecks require a seven day cure with wet burlap covered with polyethylene sheeting, but they do not receive any type of liquid membrane compound application. The type of work listed as “Other unformed or exposed surfaces” may include structures like a slip-formed barrier, rails that require a rubbed finish, or spread footings poured into excavated rock. The primary focus of curing any concrete structure is to keep the concrete from drying out prematurely on the surface. When in doubt, have the contractor cover an exposed surface of concrete with wet burlap as a minimum to aid in curing the concrete.

The asterisk footnote for the last two items in the table state the Engineer’s approval is required for the contractor to remove the forms early. If the forms are removed before the minimum of four days, the contractor must apply a Type 1-D curing compound to all exposed surfaces.

8.6.2 Maximum Load Limits

Table 710-2

TABLE 710-2: CONCRETE LOAD LIMITATIONS ON BRIDGE DECKS		
Days after concrete is placed	**Element**	**Allowable Loads**
1*	Subdeck, one-course deck or concrete overlay	Foot traffic only.
3*	One-course deck or concrete overlay	Work to place reinforcing steel or forms for the bridge rail or barrier.
7*	Concrete overlays	Legal Loads; Heavy stationary loads with the Engineer's approval.***
10 (15)**	Subdeck, one-course deck or post-tensioned haunched slab bridges**	Light truck traffic (gross vehicle weight less than 5 tons).****
14 (21)**	Subdeck, one-course deck or post-tensioned haunched slab bridges**	Legal Loads; Heavy stationary loads with the Engineer's approval.***Overlays on new decks.
28	Bridge decks	Overloads, only with the State Bridge Engineer's approval.***

Figure 22 Table 710-2

As stated above, during the curing process the concrete is slowly gaining all of its required strength. Load limits in **Table 710-2** have been stated based loosely upon the age of the concrete. These bridge deck load limits are given to further prevent early cracking in green concrete.

The bridge deck allowable loads do not override the curing requirements. The wet cure must be maintained the full seven days. Do not allow the bridge deck concrete to be exposed to open air during the ongoing work taking place on the deck, such as forming the rail. Once an area of concrete has dried, the curing process is basically stopped, and it cannot be restarted again, regardless of how much water is supplied. If the surface of a section of concrete is accidentally uncovered and dries out then gets covered back up and rewetted the curing process will stop for the concrete to a depth of one to two inches, but the concrete below that depth will continue to cure and gain additional strength. The end product for that patch of concrete will be similar to a deck requiring partial depth patching: substandard concrete on top of quality concrete. For a new structure, this is unacceptable and will be avoided by maintaining the wet cure across the entire surface of the curing concrete.

8.6.3 Minimum Strength Gain

Table 710-3

TABLE 710-3: MINIMUM STRENGTH GAIN TIME BEFORE REMOVAL OF FORMS & FALSEWORK (DAYS)							
Type of Work	Span Length (feet)						
	Less than 10	10 or less	Greater than 10	10 to 20	20 + to 30	Greater than 20	Greater than 30
Cantilevered Piers - Formwork (supporting the pier beam) supported on column		7 [4]*	10 [6]*				
Column Bent Piers - Falsework supporting pier beam**	4			7 [4]*		10 [6]*	
Forms and Falsework under slabs, beams, girders, arches and brackets	4			7 [4]*	10 [6]*		15 [10]*
RCB and RFB top slabs not re-shored		7 [4]*		7 [4]*		10 [6]*	

Figure 23 Table 710-3 (top)

Separate from curing, the minimum strength table specifies when the forms and falsework can be removed from concrete elements. Curing allows the concrete to gain strength, and prevents early cracking on the exposed surfaces. Forms and falsework supports the concrete shape until it has gained strength and, therefore, prevents structural or deflection cracking of the shape. For example, if the joists and forms were removed too early from under a deck slab supported on girders, the green concrete could “sag” under its own weight which would cause structural cracking on the bottom surface of the slab between the girders.

From the above table, if girders for a bridge were spaced at 15 feet, the time required before removing the forms under the deck slab would be 7 days. For an RCB “roof” that spans 8 feet and is not reshored, the requirement is also 7 days for form removal.

Type of Work	Time (Days)
Walls, Wing Walls and vertical sides of sides of RCB and RFB structures Do not Backfill until 3 days after forms are removed per **SECTION 207**.	4 [3]*
Footing Supported on Piles - minimum cure before erecting forms and reinforcing steel for columns	4 [2]*
Spread Footing founded in rock – minimum before erecting forms and reinforcing steel for columns	2
Footing supported on piles - minimum cure before erecting forms and reinforcing steel for columns	4 [2]*
Columns for cantilevered piers - 1. minimum before supporting forms and reinforcing steel for the pier beam on the column. 2. minimum before placing concrete for the pier beam	4 [2]* 7 [4]*
Columns for bent piers - 1. minimum before erecting formwork and reinforcing steel for the pier beam 2. minimum before placing concrete for the pier beam	2 4 [2]*
Drilled shafts - minimum before erecting forms and reinforcing steel for the columns	2
Floors for RCB and RFB structures on rock or a seal course - minimum before erecting forms and reinforcing steel	2
Floors for RCB and RFB structures on soil or foundation stabilization - minimum before erecting forms and reinforcing steel	4

Figure 24 Table 710-3 (bottom)

The bottom half of table 710-3 is concerned primarily with the time delay required before continuing construction work on top of freshly cured concrete. The first item covers form removal for vertical walls of structures, with a reminder that additional time after form removal is required before loading the wall horizontally by backfilling. All the other types of work involve the minimum amount of time delay before erecting elements to continue construction work.

Approval of the Engineer is applicable only to the specific element, or elements. If approval is given for the contractor to strike the forms a day early on all of the pile caps for pier one, the approval does not apply, also, to the pile caps for pier two. Specific approval is given for a specific situation. An inspector would never allow cylinders from abutment one to be used for verification of the concrete in abutment two. The concrete in both abutments may very well be the same concrete mix from the same plant, and all of the pouring conditions may have been very similar, but this would not be done. The same applies to the Engineer's approval.

8.6.4 Measurement and Payment

Measurement of the different grades of concrete used in the structure is in cubic yards. Designers calculate the volume of concrete without taking into account the volume taken up by the reinforcement steel, or piling extended into the concrete. Even for very large structures the ratio of the volume of reinforcement unaccounted for versus the volume of concrete will remain essentially the same, however, the actual volume difference between what is listed on the plans and what is used in the structure may be significant. Payment is made based upon the contract unit prices per cubic yard of concrete for the various grades, and is considered full compensation for the work.

8.6.5 Field Testing & Concrete Batch Rejection

A global “rule of thumb” does not necessarily exist to decide when the failure of a field test should be used to reject a batch of concrete because of the various structure types, concrete types, and the severity level of each test result. For example, if a test of air-entrained concrete for a pilecap resulted in 4.9% air, but all other tests were within tolerance, it would not be standard procedure to reject the entire load of concrete. The inspector could simply call the plant and draw attention to the need for slightly more air, and allow placement of the concrete. However, if the air result was 9.0% and the density of the concrete was 135 lbs/ft^3, the load would be a firm candidate for rejection as two items are well outside the tolerance range for air and for density.
That being said, it is not unreasonable to expect the very first batch of concrete to arrive on site to start any pour meet all specification requirements: density, air, ycf, slump, etc. If the pour does not begin until a truck arrives that meets all test requirements the first batch of concrete placed into the structure will meet all specification requirements and future trucks are assumed to have the same quality concrete. The supplier needs to prove to the inspector they are capable of meeting all of the specification requirements and all of the requirements listed in the mix design. The level of quality of the concrete needs to first be established by the supplier before it is relied upon. It needs to be understood that KDOT will not sacrifice quality at our expense by letting the first few trucks act as the test batches to fine tune the final mix for the rest of the structure. Sub-standard concrete at the outset of a pour is not acceptable.

If the very first batch of concrete to arrive on site meets all specification requirements stated for the concrete, then testing taking place at regular intervals throughout the rest of the pour is simply verification of previous results. Testing during the middle of a pour takes place while the batch is being placed in the structure. Since the tests require a fair amount of time to complete, most of the batch of concrete is in the structure before test results are available.

One general rule does apply, however, which is if or when a test fails for a batch of concrete, it needs to be well documented and cylinders need to be made. Making cylinders and clearly documenting where the concrete was placed in the structure will provide a method to verify the final strength and durability of the cured concrete and will locate the concrete if the quality is low enough to require the contractor to remove the substandard concrete and replace with quality concrete. Making cylinders benefits both the contractor and KDOT. At times cylinders are used to quantify the quality of questionable concrete, possibly allowing the contractor to leave the concrete in place because it has met minimum expectations for KDOT. Cylinders are also occasionally used to determine that minimum expectations have not been met for the concrete and in order to continue with construction on the structure, the contractor will need to remove and replace with quality concrete. It is vital the cylinders be cured under the same conditions as the concrete in the structure. If blankets have been placed to protect the structure concrete from the elements, the cylinders must be placed under the blankets, as well. This is commonly overlooked, but very important. If the cylinders are not cured under the same conditions as the concrete in the structure, they become an inaccurate representation of the concrete in the structure.

8.6.6 Ternary Mix Designs

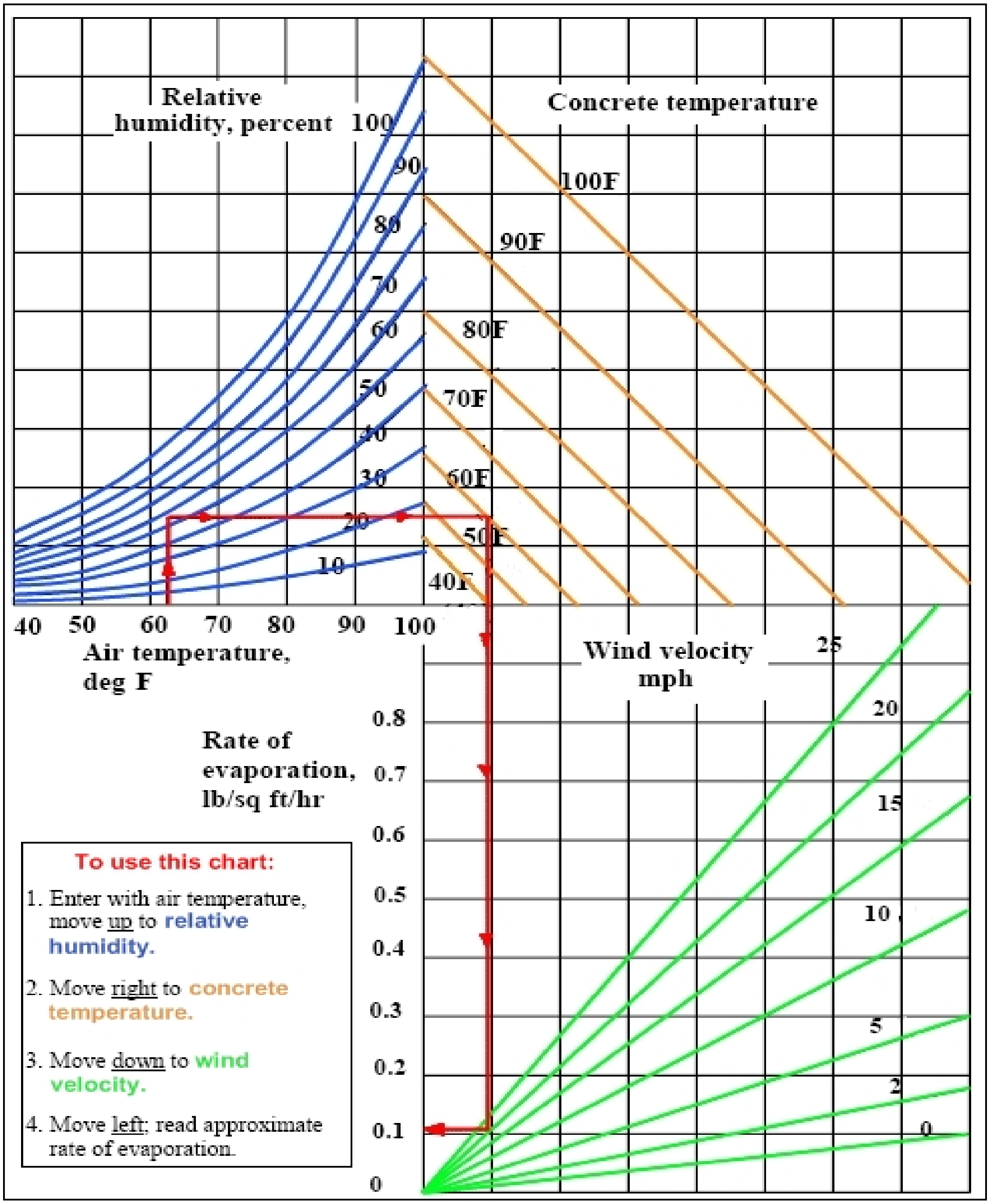
Ternary concrete mix designs incorporate the use of supplemental cementitious materials (SCM's). The SCM's are typically substituted for a portion of the cement in a standard mix design. Silica fume is considered to be an SCM, and the Design Cement Factor can be seen in Figure 27 to be "585.0". Below the 585.0 value, the sheet lists 545 pounds of Type I/II cement and 40 pounds of silica fume. Recently Materials and Research released a technical advisory related to the use of SCM's for concrete. This advisory does not apply to SFO concrete when silica fume is the only SCM used in the mix.

However, for other ternary mix designs the technical advisory now allows the Contractor to pour the concrete between October 1 and April 1. The Cure, Load and Strength tables covered in this chapter have been modified due to the low early strength of ternary mixes in cooler temperatures, and the engineer and inspector must be aware of this change and communicate the change to the Contractor. The entire technical advisory can be viewed in the Appendix to this chapter.

The technical advisory released by Materials and Research has increased all minimum time requirements by three days in Tables 710-1, 710-2, and 710-3. An additional requirement is the concrete must achieve a minimum of 75% of the required design strength before construction continues. It is necessary to mention both requirements are minimums. This means they must both be met in Table 710-3 before construction continues. If 75% design strength is met before the additional time requirement, the Contractor must wait until the time requirement is met. More importantly, if the time requirement has been met, but the concrete cylinders are breaking at only 60% of the specified design strength, the Contractor must wait until the cylinders break at the minimum of 75% of the specified design strength.

The additional time and strength requirements will affect the Contractor's schedule so it is vital the inspector is able to recognize whether the new requirements are applicable and clearly communicate the potential effect to the Contractor. Again, the entire technical advisory is available in the Appendix of this chapter.

Appendix A Rate of Evaporation Chart



Standard Mix Design Example

CONCRETE MIX DESIGN (KDOT)

Project: | Date: 1/9/2009 | Mix Design No: C | Designed By:

ADMIXTURES Name	Amount					Specific Gravity	Percent	AGG type
AEA	0.0	oz/yd³	Design Air (%)	2.5	Agg. #1	2.57	50	CA-LS
Type A	0.0	oz/yd³	Design w/c:	0.38	Agg. #2	2.63	50	Fine
Type F	0.0	oz/yd³	Design CF:	602.0	Agg. #3			
					Agg. #4			
					Agg. #5			
					Cement	3.15		

LAB/TRUCK MIX VOLUME (ft³): 1

BATCH WEIGHT CALCULATIONS

Lab Mix Weights for 1.00 Cubic Feet			WEIGHTS FOR ONE CUBIC YARD		
Cement	22.30	lbs.	Cement	602	lbs.
Water	8.47	lbs.	Water	229	lbs.
Aggregate #1	58.87	lbs. SSD	Aggregate #1	1589	lbs. SSD
Aggregate #2	58.87	lbs. SSD	Aggregate #2	1589	lbs. SSD
Aggregate #3	0.00	lbs. SSD	Aggregate #3	0	lbs. SSD
Aggregate #4	0.00	lbs. SSD	Aggregate #4	0	lbs. SSD
Aggregate #5	0.00	lbs. SSD	Aggregate #5	0	lbs. SSD
Total Batch Weight	148.51	lbs.	**ONE CUBIC YARD**	4010	lbs.

UNIT WEIGHT

Weight per Cu. Ft. Fresh Concrete | Design = 148.51 pcf | Air Free = 152.31 pcf

AGGREGATE GRADATIONS (Percent Retained)

Sieve Size inches	Agg 1	Agg 2	Agg 3	Agg 4	Agg 5		Cumulative % retained	% retained per sieve
1							0.0	0.0
3/4	0.0	0.0					0.0	0.0
1/2	25.0	0.0					12.5	12.5
3/8	60.0	0.0					30.0	17.5
No 4	95.0	3.0					49.0	19.0
No 8	98.0	19.0					58.5	9.5
No 16	98.0	41.0					69.5	11.0
No 30	98.0	66.0					82.0	12.5
No 50	98.0	91.0					94.5	12.5
No 100	98.0	98.0					98.0	3.5
No 200	99.1	99.0				Total FM	99.1	1.1
Fineness Modulus	6.45	3.18	0.00	0.00	0.00	4.82		

GRADATION PARAMETERS

Percent Mortar < 6 mm	65.2	Coarseness Factor	51
Percent Mortar < No. 8	54.7	Workability	42
Percent Paste	24.9	Target Workability	36
09/08/08		Workability Difference	5.7

Standard SFO Mix Design Example

Project:		Date:	7/1/2009	Mix Design No:	Silica Fume OL		Designed By:	

ADMIXTURES						Specific Gravity	Percent	AGG type
Name	Amount		Design Air (%)	6.5	Agg. #1	2.62	60	SCA-5
AEA	2.9	oz/yd^3	Design w/c:	0.35	Agg. #2	2.62	40	FA-A
Type A	41.0	oz/yd^3	Design CF:	585.0	Agg. #3			
Type F		oz/yd^3		545# I/II	Agg. #4			
				40# SF	Agg. #5			
LAB/TRUCK MIX VOLUME (ft^3):			1		Cement	3.17		

BATCH WEIGHT CALCULATIONS

Lab Mix Weights for	**1.00**	**Cubic Feet**	**WEIGHTS FOR ONE CUBIC YARD**		
Cement	21.67	lbs.	Cement	585	lbs.
Water	7.58	lbs.	Water	205	lbs.
Aggregate #1	69.05	lbs. SSD	Aggregate #1	1864	lbs. SSD
Aggregate #2	46.03	lbs. SSD	Aggregate #2	1243	lbs. SSD
Aggregate #3	0.00	lbs. SSD	Aggregate #3	0	lbs. SSD
Aggregate #4	0.00	lbs. SSD	Aggregate #4	0	lbs. SSD
Aggregate #5	0.00	lbs. SSD	Aggregate #5	0	lbs. SSD
Total Batch Weight	144.34	lbs.	**ONE CUBIC YARD**	3897	lbs.

UNIT WEIGHT

Weight per Cu. Ft. Fresh Concrete	Design =	144.34	pcf	Air Free =	154.37	pcf

AGGREGATE GRADATIONS (Percent Retained)

Sieve Size inches	Agg 1	Agg 2	Agg 3	Agg 4	Agg 5		Cumulative % retained	% retained per sieve
1							0.0	0.0
3/4	0.0	0.0					0.0	0.0
1/2	18.0	0.0					10.8	10.8
3/8	37.0	0.0					22.2	11.4
No 4	75.0	2.0					45.8	23.6
No 8	93.0	12.0					60.6	14.8
No 16	96.0	33.0					70.8	10.2
No 30	97.0	55.0					80.2	9.4
No 50	97.0	82.0					91.0	10.8
No 100	98.0	97.0					97.6	6.6
No 200	98.0	99.5				Total FM	98.6	1.0
Fineness Modulus	5.93	2.81	0.00	0.00	0.00	4.68		

GRADATION PARAMETERS

Percent Mortar < 6 mm	65.6	less than 64	Coarseness Factor	37
Percent Mortar < No. 8	50.8	less than 55	Workability	39
Percent Paste	23.1	less than 25	Target Workability	38
01/26/09			Workability Difference	1.0

General Concrete Structure Checklist

As a minimum, the following inspections should be made prior to, during, and after the concrete placement. This list does not include the barrage of tests necessary to take during a concrete pour.

1. Forms/Falsework is located at the correct point according to surveyed measurements
2. Overall dimensions of formwork are correct, or within tolerance depending on type of forming, horizontally and vertically
3. Grains of forms are aligned correctly and/or all formwork is mortar-tight. No aluminum surfaces will contact fresh concrete
4. Forms have been treated with a release agent before reinforcement is placed
5. Correct type and size of reinforcement, chairs and wire ties are prepped for rebar placement
6. Spacing of reinforcement is within tolerance, relatively straight, correctly tied, and correct cover dimensions are verified
7. Strike off or finish elevation chamfer strip is secure and is verified with survey to be at the correct elevation
8. Forms have been moistened with water prior to concrete placement
9. Placement equipment (and reserve equipment) has been tested and calibrated
10. Environmental conditions are forecast and measured to be acceptable for pouring concrete, or Contractor has equipment to improve environmental conditions
11. Correct concrete is delivered and field tests verify all specification requirements before placement begins
12. Concrete curing equipment is tested and ready to be placed after initial concrete set
13. Environmental conditions are measured, documented, and forecasted and Contractor has all necessary equipment to account for inclement weather such as blankets, heaters, fogging equipment, wind breaks, as needed
14. Pace of concrete placement, concrete finishing, and placement of curing materials are nearly equal and at no point during the pour is the concrete allowed to begin to dry out necessitating rewetting or reconsolidation
15. If aesthetic treatment is called for, forms are carefully stripped as early as possible and the surfaces will be float-finished while the concrete is still green
16. A wet condition is maintained for the correct number of days, polyethylene sheeting is placed at the correct time. Temperature of the curing concrete is maintained and documented

17. Sheeting and forms are stripped at the specified number of days

18. Correct curing agent is supplied, and applied correctly, if necessary, immediately following form/sheeting removal

19. Form ties are removed and cavities are filled with approved grout

20. Load limits/backfilling limits are followed unless otherwise directed by the Engineer

21. Grinding to a uniform profile is accomplished within tolerances

22.Grooving

23. SCM Technical Advisory

Kansas Department of Transportation

Bureau of Materials and Research

Dwight D. Eisenhower State Office Building, 8th Floor Tower

700 SW Harrison Street

Topeka, Kansas 66603-3745

Telephone – (785) 296-2231

Fax # - (785) 296-6665

MEMORANDUM

MEMO TO: District Engineers

Materials Engineers

Construction Engineers

FROM: Richard Kreider Jr., P.E.; Chief, Bureau of Material and Research

DATE: October 6, 2009

SUBJECT: The Use of Supplemental Cementitious Materials

Between October 1 and April 1 (Section 401.8 b).

This technical advisory relates to the use of supplemental cementitious materials (SCM's) for concrete between October 1 and April 1. The SCM's to be aware of are Ground Granulated Blast Furnace Slag (GGBFS) and Fly Ash (Type C and Type F). Silica Fume when used in Silica Fume Concrete is not an issue.

In the interest of higher quality, lower permeability concrete KDOT recently introduced the use of ternary mixes for concrete for structures and concrete pavement. The ternary mixes are produced using SCM's. The SCM's that are available in Kansas include, Silica Fume, GGBFS, and Type C and F fly ash. The typical ternary mixes being produced in Kansas are using Type I/II cement, GGBFS and Silica Fume or Type I/II Cement, GGBFS and Fly Ash.

The restriction in Section 401.8 b in the Standard Specifications is due to the tendency of GGBFS and Fly Ash to have a slower early strength gain when placed at cooler temperatures. The final 28 day strength is typically equal or greater than the same concrete mix with only Type I/II cement.

To ensure that there is sufficient strength of the ternary mix concretes used in structures between October 1 and April 1 the following adjustments should be made to Tables 710-1, 710-2, and 710-3:

Increase all minimum time requirements by three (3) days and have compressive strength of 75% of the design concrete compressive strength. Verification of the compressive strength can be done by the use of additional cylinders broken at intervals to verify concrete strength or by the use of maturity meters and maturity curves that have been previously established for the concrete mix being placed.

Concrete Paving Contractors should also be aware of the effect that the use of SCM's after October 1 may have on their statistics and moving averages.

If you have questions please contact Rod Montney, Engineer of Research (785-291-3841) or Dave Meggers, Research Development Engineer (785-291-3845).

Types of structures:

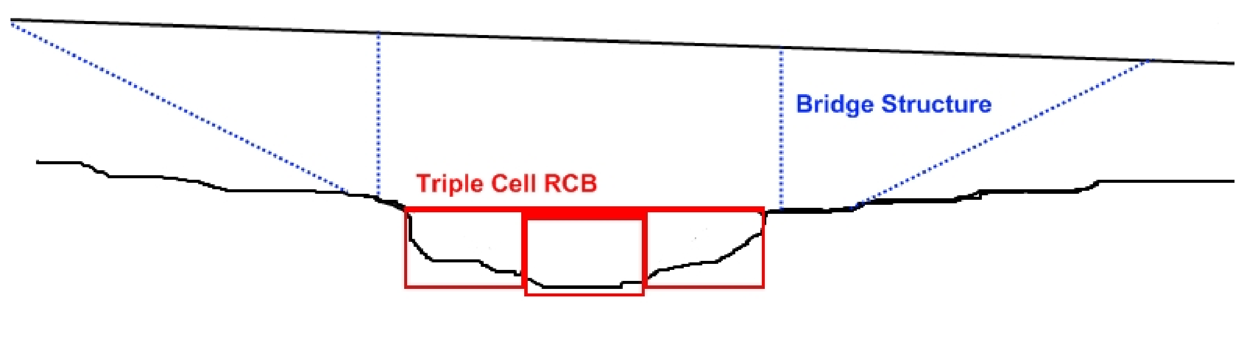


Figure 28 RCB compared to Bridge Structure

Reinforced concrete box structures are typically used for shorter spans due to the geometry, low volume, reduced load requirements, or because a longer span bridge alternative would not be economical. RCB's, or RFB's, can be designed for a single span of up to twenty feet. Several cells can be joined together in order to create a larger opening, however, the added labor cost of pouring a floor for each cell, a wall every twenty feet, and a ceiling for each cell can exceed the cost of a bridge structure, such as a haunched slab, of the same length. Box structures are typically used where there is need for a relatively small opening or in situations where an excessively large bridge structure would need to be constructed due to the height of the roadway in relation to the flow line of a stream to allow for abutment spill slopes. Costs associated with installation of a box structure (excavation, guardfence, fill, grading, etc…) are compared to the costs of a span structure to determine the most efficient structure.

Concerning box structures, the reinforced concrete load capacity is based upon the compressive strength of the concrete, the tensile strength of the steel reinforcement, the thickness of the concrete at the supports, and the depth of the concrete spanning the opening. The ceiling of the box transfers load to the vertical elements which transfer the load to the soil.

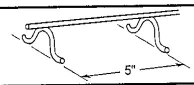
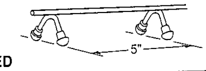
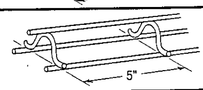
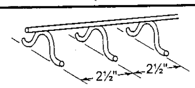
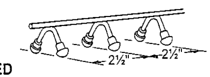
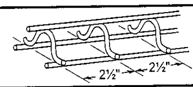
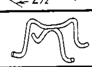
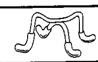
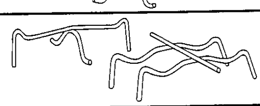
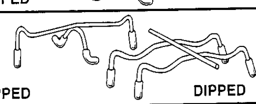
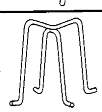
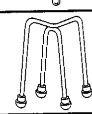
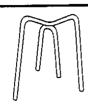
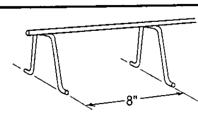
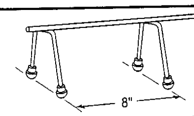
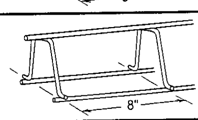
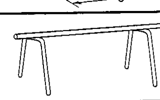
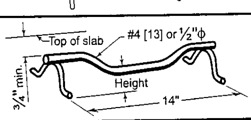
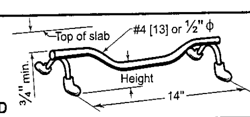
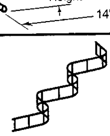
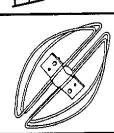
Appendix B: Bar Supports

Referenced From:

"Manual of Standard Practice",
Concrete Reinforcement Steel Institute,
27th Edition, Second Printing 2003

CHAPTER 3

TABLE 3-1 TYPICAL TYPES AND SIZES OF WIRE BAR SUPPORTS

SYMBOL	BAR SUPPORT ILLUSTRATION	BAR SUPPORT ILLUSTRATION PLASTIC CAPPED OR DIPPED	TYPE OF SUPPORT	TYPICAL SIZES
SB		CAPPED 	Slab Bolster	¾, 1, 1½, and 2 in. heights in 5 ft and 10 ft lengths
SBU*			Slab Bolster Upper	Same as SB
BB		CAPPED 	Beam Bolster	1, 1½, 2 to 5 in. heights in increments of ¼ in. in lengths of 5 ft
BBU*			Beam Bolster Upper	Same as BB
BC		DIPPED 	Individual Bar Chair	¾, 1, 1½, and 1¾ in. heights
JC		DIPPED  DIPPED	Joist Chair	4, 5, and 6 in. widths and ¾, 1 and 1½ in. heights
HC		CAPPED 	Individual High Chair	2 to 15 in. heights in increments of ¼ in.
HCM*			High Chair for Metal Deck	2 to 15 in. heights in increments of ¼ in.
CHC		CAPPED 	Continuous High Chair	Same as HC in 5 ft and 10 ft lengths
CHCU*			Continuous High Chair Upper	Same as CHC
CHCM*			Continuous High Chair for Metal Deck	Up to 5 in. heights in increments of ¼ in.
JCU**		DIPPED 	Joist Chair Upper	14 in. span; heights −1 in. thru +3½ in. vary in ¼ in. increments
CS			Continuous Support	1½ to 12 in. in increments of ¼ in. in lengths of 6'-8"
SBC			Single Bar Centralizer (Friction)	6 in. to 24 in. diameter

*Usually available in Class 3 only, except on special order.
**Usually available in Class 3 only, with upturned or end-bearing legs.

1 in. = 25.4 mm
1 ft = 304.8 mm

CHAPTER 3

BAR SUPPORTS

TABLE 3-2 TYPICAL WIRE SIZES[1] AND GEOMETRY

SYMBOL	NOMINAL HEIGHTS[2]	TYPICAL WIRE SIZES				USUAL GEOMETRY
		CARBON STEEL			STAINLESS STEEL[4]	
		TOP[3]	LEGS	RUNNER	LEGS	
SB	All	4 ga.	6 ga.	N/A	8 ga.	Legs spaced 5 in. on center.
SBU	All	4 ga.	6 ga.	7 ga.	—	Same as SB
BB	Up to 1½ in. incl Over 1½ in. to 2 in. incl Over 2 in. to 3½ in. incl Over 3½ in.	7 ga. 7 ga. 4 ga. 4 ga.	7 ga. 7 ga. 4 ga. 4 ga.	N/A N/A N/A N/A	9 ga. 8 ga. 7 ga. —	Legs spaced 2½ in. on center.
BBU	Up to 2 in. incl Over 2 in.	7 ga. 4 ga.	7 ga. 4 ga.	7 ga. 4 ga.	— —	Same as BB.
BC	All	N/A	7 ga.	N/A	9 ga.	—
JC	All	N/A	6 ga.	N/A	9 ga.	—
HC	2 in. to 3½ in. incl Over 3½ in. to 5 in. incl Over 5 in. to 9 in. incl Over 9 in. to 15 in. incl	N/A N/A N/A N/A	4 ga. 4 ga. 2 ga. 0 ga.	N/A N/A N/A N/A	7 ga. — — —	Legs at 20° or less with vertical. When height exceeds 12 in., legs are reinforced with welded cross wires or encircling wires.
HCM	2 in. to 5 in. incl Over 5 in. to 9 in. incl Over 9 in. to 15 in. incl	N/A N/A N/A	4 ga. 2 ga. 0 ga.	N/A N/A N/A	— — —	Same as HC. The longest leg will govern the size of wire to be used.
CHC	2 in. to 3½ in. incl Over 3½ in. to 5 in. incl Over 5 in. to 9 in. incl Over 9 in. to 15 in. incl	2 ga. 2 ga. 2 ga. 2 ga.	4 ga. 4 ga. 2 ga. 0 ga.	N/A N/A N/A N/A	7 ga. — — —	Legs at 20° or less with vertical. All legs 8¼ in. on center maximum, with leg within 4 in. of end of chair, and spread between legs not less than 50% of nominal height.
CHCU	2 in. to 5 in. incl Over 5 in. to 9 in. incl Over 9 in. to 15 in. incl	2 ga. 2 ga. 2 ga.	4 ga. 2 ga. 0 ga.	4 ga. 4 ga. 4 ga.	— — —	Same as CHC
CHCM	Up to 2 in. incl Up to 2 in. incl Over 2 in. to 5 in. incl	4 ga. 2 ga. 2 ga.	6 ga. 4 ga. 4 ga.	N/A N/A N/A	— — —	With 4 ga. top wire, maximum leg spacing is 5 in. on center. With 2 ga. top wire, maximum spacing is 10 in. on center.
JCU	–1 in. to +3½ in. incl (Measured from form to top of middle portion of saddle bar) in ¼ in. increments.	#4 [#13] bar or ½ in. dia	2 ga.	N/A	—	Legs spaced 14 in. on center. Maximum height of JCU at support legs should be slab thickness minus ¾ in.
CS	1½ in. to 7 in. incl 5 in. to 12 in. incl 7½ in. to 12 in. incl	8 ga. 6 ga. 4 ga.	8 ga. 6 ga. 4 ga.	8 ga. 6 ga. 4 ga.	— — —	Legs spaced 6 in. on center, 4 in. on center at bend point. Middle runner used for heights over 7 in.
SBC	6 in.[5] 12 in. to 14 in.[5] 16 in. to 18 in.[5]	N/A N/A N/A	3 ga. 3 ga. 3 ga.	N/A N/A N/A	— — —	—

1 in. = 25.4 mm

[1] Wire sizes are American Steel & Wire gauges.

[2] The nominal height of the bar support is taken as the distance from the bottom of the leg, sandplate or runner wire to the bottom of the reinforcement. Variations of ± ⅛ in. [3 mm] from the stated nominal height are generally permitted by usual construction specifications for tolerances.

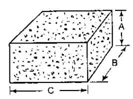
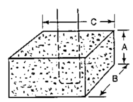
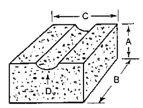
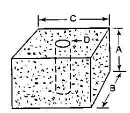
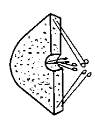
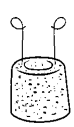
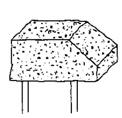
[3] Top wire on continuous supports may be straight or corrugated, at the option of the Manufacturer.

[4] When no wire size is shown for a stainless steel leg, use plain carbon steel legs and attach stainless steel tips to them as noted in Section 3.2.7.

[5] Represents the diameter of the hole where the bar is being centered.

BAR SUPPORTS

TABLE 3-3 TYPICAL TYPES AND SIZES OF PRECAST CONCRETE BAR SUPPORTS

SYMBOL	BAR SUPPORT ILLUSTRATION	TYPE OF SUPPORT	TYPICAL SIZES, IN.	DESCRIPTION
PB		Plain Block	A—¾ to 6 B—2 to 6 C—2 to 48	Used when placing bars off grade and formwork. When "C" dimension exceeds 16 in. the block should be cast with a piece of reinforcing bar inside the block.
WB		Wired Block	A—¾ to 4 B—2 to 3 C—2 to 3	Generally, block is cast with embedded 16-gauge tie wire, commonly used against vertical forms or in positions necessary to secure the block by tying to the reinforcing bars.
CB		Combination Block	A—2 to 4 B—2 to 4 C—2 to 4 D—fits #3 to #5 [#10 to #16] bar	Commonly used on horizontal work.
DB		Dowel Block	A—3 B—3 to 5 C—3 to 5 D—hole to accommodate a #4 [#13] bar	Used to support top mat from dowel placed in hole. Block can also be used to support bottom mat.
DSSS		Side-Form Spacer - Wired	Concrete cover, 2 to 6	Used to align the reinforcing bar cage in a drilled shaft.* Commonly 16-gauge tie wires are cast in the spacer. Supports for 5 in. to 6 in. cover have 9-gauge tie wires at top and bottom of the spacer.
DSBB		Bottom Bolster - Wired	Concrete cover, 3 to 6	Used to keep the reinforcing bar cage off of the floor of the drilled shaft.* Support for 6 in. concrete cover is actually 8 in. in height with a 2 in. shaft cast in the top of the bolster to hold the vertical bar.
DSWS		Side-form spacer for drilled shaft applications	Concrete cover, 3 to 6	Generally used to align reinforcing bar in a drilled shaft.* Commonly manufactured with two sets of 12-gauge annealed wires, assuring proper clearance from the shaft wall surface.

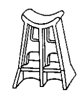
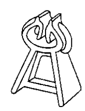
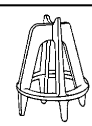
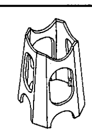
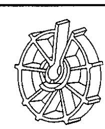
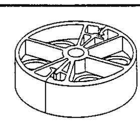
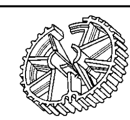
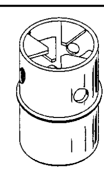
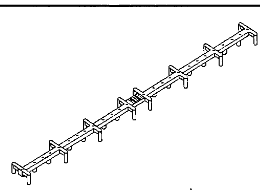
* Also known as a pier, caisson or cast-in-drilled hole.

1 inch = 25.4 mm

CHAPTER 3

BAR SUPPORTS

TABLE 3-4 TYPICAL TYPES AND SIZES OF ALL-PLASTIC BAR SUPPORTS

SYMBOL	BAR SUPPORT ILLUSTRATION	TYPE OF SUPPORT	TYPICAL SIZES, IN.	DESCRIPTION
BS		Bottom Support	Heights, ¾ to 6	Generally for horizontal work. Not recommended for ground or exposed aggregate finish.
BS-CL		Bottom Support	Heights, ¾ to 2	Generally for horizontal work, provides bar clamping action. Not recommended for ground or exposed aggregate finish.
HC		High Chair	Heights, ¾ to 5	For use in slabs or panels.
HC-V		High Chair, Variable	Heights, 2½ to 6¼	For horizontal and vertical work. Provides for different heights.
WS		Wheel Side-Form Spacer	Concrete cover, ⅜ to 3	Generally for vertical work. Bar clamping action and minimum contact with forms. Applicable for column reinforcing bars.
DSWS		Side-Form Spacer for drilled shaft applications	Concrete cover, 2½ to 6	Generally used to align reinforcing bars in a drilled shaft.* Two-piece wheel that closes and locks on to the tie or spiral assuring proper clearance from the shaft wall surface.
VLWS		Locking Wheel Side-Form Spacer for all vertical applications	Concrete cover, ¾ to 6	Generally used in both drilled shaft* and vertical applications where heavy loading occurs. Surface spines provide minimal contact while maintaining required tolerance.
DSBB		Bottom Bolster (Gripping)	Concrete cover, 3 Height, 6	Used to keep the reinforcing bar cage off of the bottom floor of a drilled shaft.* Fits #6 through #11 [#19 through #36] reinforcing bars.
SB		Slab Bolster	Heights, ¾ to 3 Lengths up to 32**	Commonly used in horizontal and vertical applications. When used as a side-form spacer in vertical work, slab bolster must be tied to the reinforcement.

* Also known as a pier, caisson or cast-in-drilled hole.
** Pieces can be locked together to form longer lengths.

1 inch = 25.4 mm