

CHAPTER 9

FIELD INSPECTION AND CONTROL OF CONCRETE

Field control begins long before concrete arrives at the job site and continues long after the concrete has been placed in the forms. There are many factors in the field which may adversely affect the concrete in such a way that the required strength and durability are greatly reduced. For these reasons, it is necessary that field conditions be controlled to achieve the desired product.

FACTORS THAT AFFECT QUALITY CONTROL IN THE FIELD

1. Supporting Foundations and Forms
2. Storage and Construction of Supporting Structures
3. Transporting and Handling of Concrete
4. Placing and Finishing of Concrete
5. Curing
6. Concreting During Hot and Cold Weather

Supporting Foundations and Forms

Foundations: The purpose of a foundation is to create a uniform bearing. There are 3 types of foundations: soil, rock and gravel.

Bridge design is based on foundation material. If the foundation material is poor, piles can be used. If the bearing capacity of the material is medium, a spread footing can be used and if the foundation is sound rock, a smaller footing can be used. For all other concrete work the foundation or subgrade must be of uniform density and bearing.

The contractor explores the foundation 5 feet below the bottom of the footing, when requested, to determine to the satisfaction of the Engineer, the adequacy of the foundation to support the structure.

Forms: Forms should be clean, mortar-tight and of sufficient rigidity to prevent distortion caused by the pressure of the concrete and other loads incidental to construction operations. Forms are to be set and maintained true to line.

Forms are to be coated with an approved oil or form-coating material or thoroughly wetted with water immediately before concrete placement to prevent the forms from sticking to the concrete or drawing moisture from the concrete. Material that will discolor the concrete is not to be used.

Storage and Construction of Supporting Structures

Storage of Steel: Reinforcing steel is to be stored on platforms, skids, or other supports that will keep the steel above ground, well drained, and protected against deformation.

When placed in the work, steel reinforcement is to be free from dirt, paint, oil, or other foreign substances. Steel reinforcement with rust or mill scale will be permitted provided samples wire brushed by hand conform to the requirements for weight and height of deformation.

When epoxy coated reinforcing steel is delivered to the project it is to be covered with an opaque covering. Exposed surfaces of epoxy coated reinforcing steel which

have been partially embedded in concrete or placed in formwork and not covered with concrete are to be covered with an opaque covering after 30 days exposure to sunlight. The opaque covering is to be placed in a manner that provides air circulation and prevents condensation on the reinforcing steel.

Construction of Supporting Structures: Steel reinforcement is to be firmly held during the placing and setting of concrete. Bars, except those to be placed in vertical mats, are to be tied at every intersection where the spacing is more than 12 inches in any direction. Bars in vertical mats and in other mats where the spacing is 12 inches or less in each direction are to be tied at every intersection or at alternate intersections provided such alternate ties accurately maintain the position of steel reinforcement during the placing and setting of concrete.

Reinforcement in bridge deck slabs and slab spans is to be supported by standard CRSI metal or precast concrete bar supports. Bar supports are to be spaced as recommended by CRSI but not more than 4 feet apart transversely or longitudinally. Precast concrete supports are to be less than 1 foot in length and staggered so as not to form a continuous line. The lower mat of steel is to be supported by a bolster block or individual bar chair supports, and the upper mat is to be supported by high chair supports. Bar supports are to be firmly stabilized so as not to displace under construction activities. Reinforcing bar supports (STANDEES) may be used for the top mat of steel of simple slab spans provided they hold the reinforcing steel to the requirements specified herein and are firmly tied to the lower mat to prevent slippage.

Precast bar supports are to have a 28-day design compressive strength of at least 4,500 pounds per square inch and be from the Department's list of approved products for the use specified. Supports are to be furnished with epoxy-coated or plastic ties or shaped to prevent slippage from beneath the reinforcing bar. Metal bar supports are to be fabricated from one of the following: stainless steel wire conforming to the requirements of ASTM A493, or cold-drawn wire protected by plastic coating conforming to CRSI standards, epoxy coating, or other protective coating as approved by the Engineer.

In reinforced concrete sections other than bridge slabs, the specified clear distance from the face of concrete to any reinforcing bar and the specified spacing between bars shall be maintained by means of approved types of stays, ties, hangers or other supports. Pieces of gravel, stone, brick, concrete, metal pipe or wooden blocks are not to be used as supports or spacers for reinforcing steel. The clear distance between bars is to be at least 1 ½ times the specified maximum size of coarse aggregate but not less than 1 ½ inches.

Bars are to be placed so that the concrete cover as indicated on the plans will be maintained within a tolerance of 0 to +1/2 inch in the finally cast concrete.

Reinforcement is to be furnished in full lengths as indicated on the plans. Except where shown on the plans, splicing bars will be not permitted without the written approval of the Engineer. Splices are to be as far apart as possible. Bars are to be lapped at least 30 bar diameters to make the splice. In lapped splices, bars are to be placed in contact and wired together. For example: A #8 bar (1 inch) must be lapped at least 30 inches.

Following placement of epoxy-coated reinforcement and prior to concrete placement, the reinforcement will be inspected. Tie-wires used with epoxy-coated steel shall be plastic coated or epoxy coated. All visible damage of the epoxy coating is to be repaired in accordance with Section 223.

Before concrete is placed, reinforcing steel is to be inspected and approved for proper position and the adequacy of the method for maintaining position.

On concrete beam bridges, the Contractor has the option of using corrugated metal bridge deck forms, prestressed deck panels or wood forms to form the portion of bridge deck between beams unless specified otherwise in the plans. On steel beam bridges, the Contractor has the option of using corrugated metal bridge deck forms or wood forms to form the portion of bridge deck between beams or girders unless specified otherwise in the plans.

If the Contractor elects to use corrugated metal bridge deck forms, details of the forms, including fabrication and erection details, are to be submitted to the Engineer for approval.

Corrugated metal forms are to be positioned to maintain the specified cover for the reinforcing steel and minimum design slab thickness above the crests of the corrugation. Supports are not to be welded to steel beams or girders unless specified on the plans. Damage to galvanized coating on permanently exposed for metal is to be repaired in accordance with Section 233. Formwork is to be mortar-tight and of sufficient rigidity to prevent distortion attributable to the pressure of concrete and other load incidental to construction operations.

Transportation and Handling of Concrete

Concrete is to be transported and handled to ensure uniformity from batch to batch and to avoid segregation of coarse aggregate from mortar.

Before concrete is delivered to the job site, the mix design must be submitted and approved, an aggregate moisture correction must be made, and the transit mix truck must be approved.

Mechanical details of the mixer, such as the water-measuring and discharge apparatus, condition of the blades, speed of rotation of the drum, general mechanical condition of the unit, and cleanliness of the drum, are to be checked before use of the unit is permitted.

Each transit mix truck shall have a metal plate(s) attached in a prominent place by the manufacturer on which the following are marked: the various uses for which the equipment is designed, capacity of the drum or container in terms of the volume of mixed concrete, and speed of rotation of the mixing drum or blades. Each truck mixer shall be equipped with a calibrated water measuring device and an approved counter by which the number of revolutions of the drum or blades may be readily verified. The minimum and maximum limits of volume of concrete that can be mixed in the mixer are 15% to 110%. Aluminum forms, chutes, buckets, pump lines, and other conveying devices are not to be used if the aluminum comes in contact with concrete.

The mixer is to be capable of thoroughly mixing the ingredients into a uniform mass and uniformly discharging the concrete. Mixing is to begin immediately after all ingredients are in the mixer and continue for at least 70 revolutions of the drum or blades at the rate of at least 14 but not more than 20 revolutions per minute. The Engineer can request consistency tests to evaluate the uniformity of loads from the mixer. Additional rotations of the drum or blades are to be at the rated agitating speed.

The main volume of water is added at the plant; however, one gallon per cubic yard of water may normally be withheld and added after the concrete arrives at the job site. Therefore, it is desirable that the truck's water tank be full when it arrives on the project. An additional 25 mixing revolutions are necessary each time water is added at the job site. The maximum water/cement ratio and slump are not to be exceeded.

The first load of concrete arriving on a project each day shall be accompanied by Form TL-28A issued by the certified plant technician. The form is to be delivered to the Inspector at the site of work. The Inspector should receive a new Form TL-28A each day or whenever anything changes as far as the mix. Each batch of concrete delivered to the site of work is to be discharged within 90 minutes of the time the cement is introduced into the mixture, unless approved otherwise by the Engineer.

The Contractor's certified field technician is responsible for all quality control at the job site. All adjustments, other than water, made to the concrete at the job site shall be made by the Producer's certified concrete plant technician.

Once the load of concrete is submitted to the VDOT inspector for acceptance testing, no adjustments can be made. One test and retest will be made to determine the acceptance or rejection prior to any concrete being discharged into the forms.

Placing and Finishing

Fresh concrete is to be sampled and tested by VDOT's Certified Concrete Field Technician prior to discharging into forms to ensure specification requirements are consistently being complied with for each class of concrete. The sample secured for air and consistency tests is to be taken after at least 2 cubic feet of concrete has been discharged from the delivery vehicle. The 2 cubic feet discharged is not to be used as part of the test sample. Air and slump requirements are located in Table II-17 of the Road and Bridge Specifications. If air or consistency is outside the allowable range a recheck will be immediately performed and if the results confirm the original test results, the load will be rejected.

Concrete cylinders are made on the accepted loads. The sample is to be obtained after at least 2 cubic feet of concrete has been discharged from the delivery vehicle. The 2 cubic feet discharged is not to be used as part of the test sample. Three 4" by 8" design quality control cylinders are to be made. They are to be labeled with project number, cylinder number, class of concrete and date cast and should be immediately stored in a curing box provided by the contractor at his expense. The contractor shall be responsible for the chamber maintaining the concrete test cylinders in a continuously moist condition within a temperature range of 60°F to 80°F and it must be equipped with a continuously recording thermometer accurate to $\pm 2^\circ\text{F}$ for the duration of concrete field cylinder curing period. The chamber shall be located in an area where the test cylinders will not be subject to vibration and shall be of sufficient size or number to store, without crowding or wedging, the required number of test cylinders based on the Contractor's plan of operations. The chamber and location of the chamber must be approved by the Engineer. After 24 hours cylinders will be transported to VDOT's laboratory where they will be tested for compressive strength at 28 days. If required, two 4" x 8" permeability cylinders are to be made the same way as strength cylinders.

Concrete is not to be placed against surfaces whose temperature is below 40°F. The specified temperature limitations for the placement of concrete are dependent on the class of concrete and the type of structure. These can be found in Section 217.10 of the Road and Bridge Specifications.

Concrete is to be placed as near its final position as possible in a manner to avoid segregating ingredients and displacing forms. Subgrade and forms are to be moistened before placing concrete so they won't absorb moisture from the concrete. Concrete is not to be dropped a distance of more than 5 feet or deposited in a large quantity at any point and run or worked along forms. The 5 foot limitation does not apply to concrete dropped into forms for walls of box culverts, catch basins, drop inlets, or end walls unless there is evidence of segregation. The use of long chutes for conveying concrete from the

mixing plant to the forms is permitted only with the written permission of the Engineer. If chutes are allowed and the quality of the concrete is not satisfactory when it reaches the forms, the Engineer can discontinue the use of chutes.

Concrete is to be thoroughly consolidated during and immediately following placement. Consolidation is to be accomplished by mechanical vibration. Internal vibrators are to be approved by the Engineer and are not to be applied to the reinforcement or formwork. Vibrators are to be inserted vertically, at points uniformly spaced, and shall be of sufficient duration and intensity to consolidate concrete thoroughly around reinforcement and embedded fixtures and into corners and angles of forms. Vibrators are not to be pulled through the concrete, used to transport concrete in the forms, or operated for more than 15 seconds in any one location as this will cause segregation. Vibration is to be supplemented by spading if necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations not accessible to vibrators.

Vibrators for full width vibration of concrete pavements are to be internal vibrators with multiple spuds. They may be attached to the spreader or mounted on a separate carriage operating directly behind the spreader. The frequency of vibrators is to be at least 7,000 impulses per minute. If spud internal vibrators are used adjacent to forms, either hand operated or attached to spreaders, they are to have a frequency of at least 3,400 impulses per minute. Vibration is to be controlled by the forward movement of the spreader so that vibration automatically ceases when the forward movement of the spreader is stopped.

After concrete is consolidated it is to be floated, any laitance removed, straight-edged, and then finished. When a finishing machine is used, a uniform roll of concrete is to be maintained ahead of the front screed for its entire length. Hand finishing is permitted only to finish concrete already deposited on grade if mechanical equipment breaks down or to finish narrow widths, approach slabs, or areas where operation of mechanical equipment is impractical.

The concrete surface finish is based on the type of concrete structure. To determine the concrete surface finish, check the specifications and contract documents.

The Contractor is responsible for the quality of concrete placed in any weather or atmospheric condition. Concrete is to be immediately protected following placement in the formwork and protection shall continue without interruption throughout the curing period. Concrete is to be protected from the effects of rain before it has attained final set. The Contractor is to have available at the site of work covering material such as, burlap, cotton mats, curing paper, or plastic sheeting. Damages that occur prior to final acceptance may require repair or replacement of the damaged pavement.

Curing

No matter what care has been taken in the preparation of the material, the uniformity of the mix, or the design of the concrete, many of the advantages gained by this care are lost if the concrete, during or after placing, is not maintained at the proper temperature or is not properly cured.

The treatment received by the concrete during the first 24 hours after it is placed is by far the most important, and the strength lost by failure to keep concrete moist during this period can never be regained.

Curing has a strong influence on the properties of hardened concrete. Proper curing will increase durability, strength, watertightness, abrasion resistance, and resistance to freezing and thawing.

Plastic shrinkage is caused by rapid evaporation of moisture from the concrete surface and can occur if there is an appreciable delay between finishing and initiation of proper curing, without adequate fogging and/or other protective measures. Plastic shrinkage cracking is usually associated with hot weather concreting; however, it can occur at any time when circumstances produce rapid evaporation of moisture from the concrete surface. Conditions such as low humidity, high winds, concrete temperature higher than atmospheric temperature, or a combination thereof, increase evaporation of surface moisture. Water and salt penetrate these cracks causing the pavement to break up and the steel to corrode. Overlays are more susceptible to plastic shrinkage cracking than regular deck placements because there is less water to bleed to the surface due to the high surface area to depth ratios and lower limits on the water cement ratio.

The Contractor is to perform evaporation rate testing for bridge deck placements and concrete overlays using the Evaporation Rate Nomograph. The Contractor will need the proper equipment to determine the wind velocity, relative humidity, concrete temperature and air temperature. Precautionary measures are necessary if the evaporation rate is greater than 0.1 lb/ft²/hr for Class A4 bridge deck placements or greater than 0.05 lb/ft²/hr for latex modified concrete overlays.

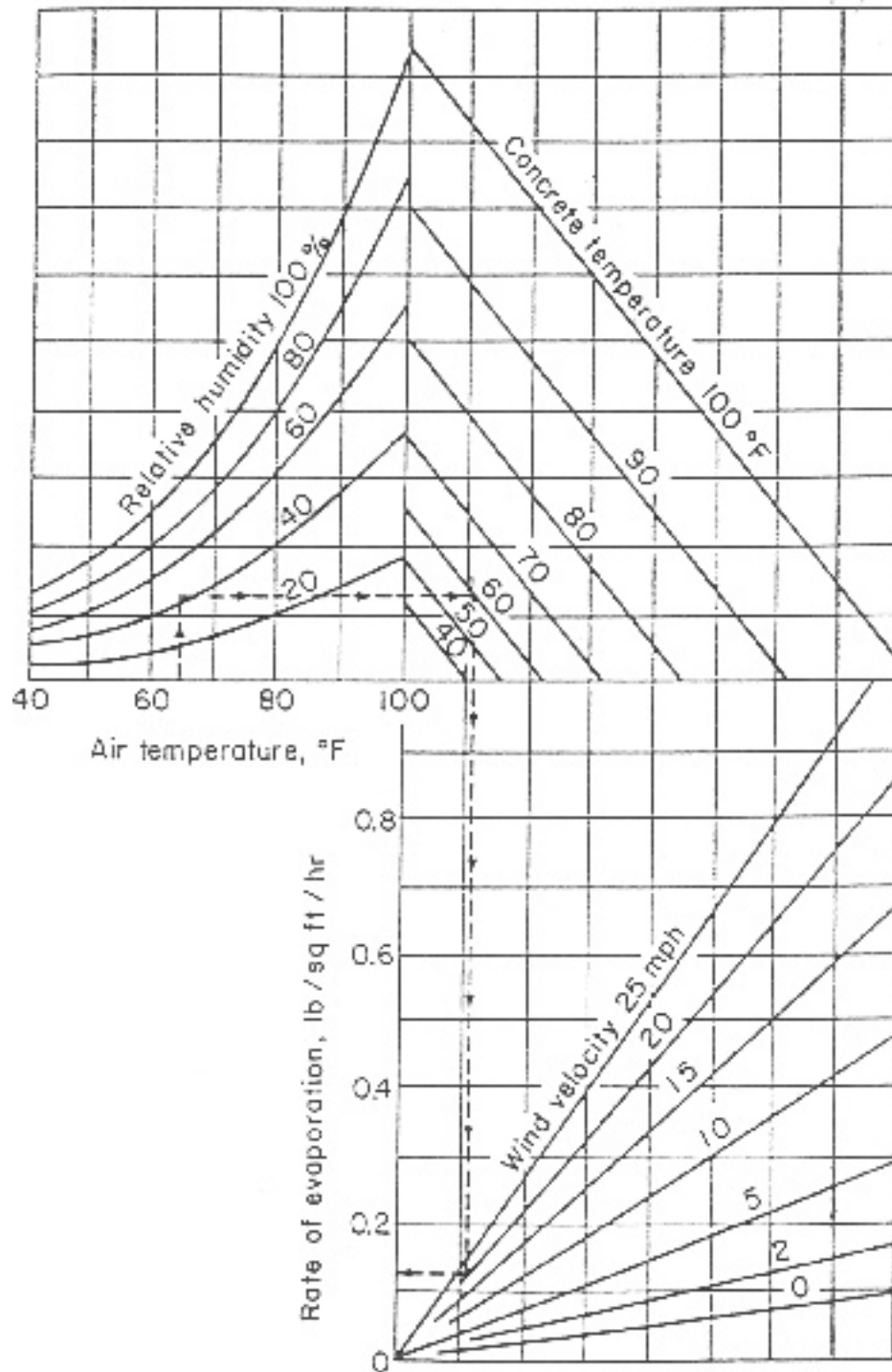
To minimize the possibility of plastic shrinkage cracking, dampen the subgrade or forms, dampen the aggregates, erect windbreaks, erect sunshades, lower the fresh concrete temperature, avoid overheating the fresh concrete during cold weather, protect the concrete with wet coverings if there is a delay between placing and finishing, reduce time between placing and start of curing, apply curing compound as soon as the water sheen has disappeared, and protect the concrete during the first few hours after placing and finishing to minimize evaporation. Application of moisture to the surface, using a fog spray nozzle, is an effective means of preventing evaporation from the concrete. It cools the surface and surrounding air and increases the relative humidity and should be used until a suitable curing material can be applied.

Concrete is to be cured by applying a liquid-membrane forming compound, ponding or misting with water, covering with waterproof paper, polyethylene film, or by using a combination of burlap and polyethylene film. Curing materials are to be in conformance with Section 220.02 of the Road and Bridge Specifications.

The method of concrete curing is subject to the approval of the Engineer prior to mixing and placing concrete. Concrete curing specifications are located in Section 404.03(k) of the Road and Bridge Specifications.

After concrete in finished surfaces has begun to set, it shall not be walked on or otherwise disturbed for at least 24 hours.

Evaporation Rate Nomograph



Example: Air temperature 65°F, Relative humidity 40%, Concrete temperature 60°F
 Wind velocity 20 m/h. Rate of evaporation equals 0.125 lb/ft²/hr.
 Precautionary measures are necessary if over 0.1 lb/ft²/hr. for class A4
 concrete bridge deck placements or 0.05 lb/ft²/hr. for latex modified concrete
 overlays.

Concreting During Hot and Cold Weather

Precautions should be taken during mixing, transport and placing of concrete to alleviate difficulties in placement during all weather conditions.

In hot weather all efforts should be made to mix and place the concrete at or below the air temperature. You should be mindful of wind conditions, high temperatures, and low relative humidity as each increases evaporation of moisture from the concrete. The two worst conditions are high winds and low humidity.

Hot weather effects include: increased water demand, more rapid slump loss, faster set, rapid drying, variable air contents and plastic cracking is more likely to occur. Precautions to protect and cure the concrete within the specified temperature range include: cooling aggregates; using cool water or adding ice; cooling subgrade, forms, reinforcing steel by fogging or sprinkling with cool water; cooling the surroundings by fogging; cooling equipment by shading, painting white or covering with wet burlap. The contractor can also provide sun and wind shade and cover and cure the concrete immediately after placement. If ice is used, it must be taken into consideration as part of the total mixing water.

During cold weather, the hydration process is retarded, which slows the hardening and strength gain of the cement. Significant strength reductions can occur if freshly mixed concrete is frozen within a few hours of placement.

Concrete can be placed in cold weather if precautions are taken. Every effort should be made to place and cure the concrete at the optimum curing temperature of 55°F. Concrete must be at least 40°F when placed and concrete can not be placed against surfaces that are less than 40°F as the sudden cooling of the concrete surface while the interior is still warm can cause cracking. Plans need to be made well in advance to protect the fresh concrete.

Precautions to protect and cure the concrete at this temperature include heating water and aggregates to a maximum of 150°F. Materials are to be heated uniformly and steam is not to come in contact with aggregates. Cement is not to be heated. Methods that alter or prevent the required amount of air entrainment are not to be used. Materials containing frost, lumps, crusts, or hardened material are not to be used. Other methods to use in cold weather include use of portable heaters, heated enclosures, or insulated forms or blankets.

Chapter 9

Study Questions

1. When transporting concrete to the job site, how much water can be withheld and added after concrete arrives on the site?
2. True or False? All forms must be mortar-tight, sufficiently rigid, and oiled or wetted down before concrete placing.
3. The conditions which are most conducive to causing plastic shrinkage cracks are _____.
4. Exploration of the sub-foundation to determine its adequacy is done by the _____.
5. All forms must be treated with _____.
6. It is permissible to use reinforcing steel bars with _____.
7. Proper use of the vibrator involves _____.
8. Before placing concrete on a surface, the surface should be _____.
9. During cold weather concreting, the surface on which the concrete is to be placed should not be less than _____°F.
10. The _____ is responsible for removing and replacing concrete injured by frost action or freezing.
11. On a given day, if the air temperature was 60°F; relative humidity 40%; surface temperature of the plastic concrete 75°F and the wind velocity if 15 m/h, the Surface Evaporation Rate for Plastic Concrete on concrete bridge deck would be _____ lb/ft²/h.
12. What are the requirements for heating water, aggregates and cement in cold weather?
13. In hot weather, all efforts should be made to place the concrete at or below _____.

USE APPENDIX C TO ANSWER THE FOLLOWING:

14. Reinforcing steel bars, except those to be placed in vertical mats, shall be tied at every intersection where the spacing is more than _____ inches in any direction as found in Section _____.
15. When control cylinders are being used to determine removal of form work from a deck slab, the minimum compressive strength of the deck slab is _____ as found in Section _____.
16. The requirements for the protection of reinforcing steel bars are found in Section _____.
17. Once concrete has begun to set in the finished surface, it shall not be disturbed or walked upon for a minimum of _____ hours as stated in Section _____.
18. Concrete may be permitted to freely drop a maximum of _____ as stated in Section _____.
19. Forms can be removed from a stem footer when the minimum compressive strength of the footer is _____ as found in Section _____.
20. In splicing a reinforcing bar, the minimum allowable length of lap is _____ as found in Section _____.