

SECTION 602 CONCRETE STRUCTURES

602.01 Description. This work consists of furnishing and placing portland cement concrete for structures and incidental construction.

MATERIALS.

602.02 Materials. Materials for concrete structures shall conform to the following Section and Subsections:

Materials for Sealing Joints:	
Prefomed Elastomeric Compression Seals	808
Rubber Joint Sealant	808
Hot Poured Joint Sealer	808
Prefomed Expansion Joint Fillers, Type III	808
Portland Cement Concrete	812.02
Chemical Admixtures	812.02
Curing Materials:	
Liquid Membrane Compounds	812.02
Polyethylene Sheeting	812.02
Waterproof Paper	812.02
Mix Composition, Classes A, B, C, and D	812.04
Bar Reinforcement	824.01
Bar Reinforcement, Epoxy Coated	824.02

602.03 Permanent Steel Bridge Deck Forms and Supports. Permanent steel bridge deck forms and supports shall be fabricated from steel conforming to ASTM A 653/A 653M Grade 40 for 14-18 gage, Grade 80 for 19-22 gage and Grade 40 for accessories, and shall have a coating of Z600 according to ASTM A 924/A 924M. Deck forms shall be 20 gage (0.9 mm) minimum.

602.04 Pipe For Weep Holes. Cast iron soil pipe for weep holes shall conform to the requirements of ASTM A 74. Plastic pipe shall conform to the requirements of ASTM D 2665.

602.05 Waterstops. Sheet copper shall conform to the requirements of ASTM B 370. Sheet lead shall conform to the requirements of ASTM B 29. Sheet zinc shall conform to the requirements of ASTM B 69.

602.06 Form Oil For Concrete Formwork. Form oil shall be a non-staining petroleum distillate free from water, asphaltic, and other insoluble residue or equivalent product.

602.07 Waterstops. Waterstops shall be polyvinyl chloride (PVC) compounded as necessary to conform to the requirements of U.S. Army Corps of Engineers Specification CDR-C572. No reclaimed PVC from any sources shall be incorporated in the compounding. The extruded material shall be dense, homogeneous, and free from porosity or other imperfections that could affect its durability or performance.

CONSTRUCTION METHODS.

602.08 Formwork. Except where indicated elsewhere in this Section, forms shall be designed and constructed so they can be removed without injuring the concrete. Forms shall be designed for strength and deflection to resist all loads and pressures of the wet concrete, the weight of the forms, the rate of pour, the affect of vibration, the time of setting, and an addition of 50 lb/ft² (2.4 kPa) of construction live load applied to all horizontal surfaces. For removable forms, no member shall have a deflection, under total load, in excess

of 1/360 of its span length, and in no case shall the deflection exceed 30 (6 mm), except that deflections of form surfaces for concrete floor slabs where such forms are supported by beams, stringers, or girders may be 1/180 of the span length but not to exceed 20 (13 mm). Where the design of the forms requires deflections in excess of these amounts, the forms shall be cambered.

Concrete shall be assumed to weigh 150 lb/ft³; (2400 kg/m³). Lumber in forms shall be assumed to weigh 4lb per board foot (700 kg/m³). For all other materials, other than lumber in forms, the unit weight of the material shall be used.

Formwork plywood (without backing) shall be used with the face plies running parallel to the span (or perpendicular to supports) for maximum working strength and minimum deflection.

The Contractor shall prepare and submit for approval complete detailed plans of all formwork to be constructed. Working formwork drawings shall be submitted in accordance with Subsection 105.04. The Contractor shall not proceed with formwork construction until its plans have been approved. However, approval of these plans shall not relieve the Contractor of complete responsibility for the safety and adequacy of all formwork.

The form drawings shall show all major design values and loading conditions. These include assumed values of live and dead load, rate of placement, temperature of concrete, height of drop, weight of moving equipment which may be operating on formwork, foundation pressures, design stresses, deflection and camber diagrams, and other pertinent applicable information. All pertinent design calculations shall be submitted for walls greater than 10ft (3 m) in height. In addition to specifying types of materials, sizes, lengths, and connection details, formwork drawings shall provide for applicable details such as: 1) Anchors, shores, and braces; 2) field adjustment of the form during placing of concrete; 3) waterstops, keyways and inserts; 4) working scaffolds and runways; 5) weepholes or vibrated holes where required; 6) screed and grade strips; 7) crush plates or wrecking plates; 8) removal of spreaders or temporary blocking; 9) cleanout holes; 10) construction, control and expansion joints; 11) chamfer strips; 12) notes to cover conduits and pipes to be embedded; and 13) details on shoring, re-shoring, or leaving original shores in place as forms are stripped.

The material to be used for forms for exposed surfaces shall be either plywood, metal in which all bolts and rivet holes are countersunk, fiber, or other approved material. In either case, a plain, smooth surface of the desired contour must be obtained. For surfaces to be given a rubbed finish, the material shall be plywood unless otherwise specifically approved. For curved or special surfaces, the above requirements may be modified.

The form material shall be placed so a smooth surface free from irregularities is obtained. Sheets of material shall be placed so that joints are in regular and true horizontal and vertical lines. Full sized plywood sheets shall be used except where a single smaller piece covers an entire area. Where form lining is used, it shall be used in pieces as large as possible. All joints shall be solidly backed, butted tightly together, and sealed with white lead paste or other approved crack fillers. All holes shall be filled as well as depressions or hammer marks so that the completed surface is as smooth as possible. When steel forms are used, the panels shall be as large as practical and of sufficient thickness to prevent surface irregularities. Panels shall be assembled in uniform patterns and firmly locked and braced together to form a smooth surface. Bent or irregular panels shall not be used. Round fiber column forms shall be furnished full height and shall be fitted with circular wooden templates at top and bottom and with wooden collars at intermediate points. Fiber forms shall be removed not later than ten days after pouring.

Moldings, fluting, rustification, and other ornamental details shall be formed of material specifically manufactured for the job. Samples or details of the material shall be submitted for approval by the Engineer prior to use.

All lumber shall be free from knotholes, loose knots, cracks, splits, warps, or other defects impairing the strength or the appearance of the finished structure.

When necessary because of thin wall construction, forms shall be daylighted at intervals not greater than 10M (3 m) vertically, the openings being sufficient to permit free access to the forms for the purpose of inspecting, working, and vibrating the concrete.

The forms shall be built true to line and braced in a substantial and unyielding manner. They shall be mortar tight and, to close cracks due to shrinkage, shall be thoroughly soaked with water.

Dimensions affecting the construction of subsequent portions of the work shall be carefully checked after the forms are erected and before any concrete is placed. The interior surfaces of the forms shall be adequately oiled, greased, or soaped to ensure non-adhesion of mortar. Form plywood and/or lumber which is reused shall be free from bulge, warp or damage and shall be thoroughly cleaned. The forms shall be inspected immediately preceding the placing of concrete and any defects shall be remedied and all dirt, sawdust, shavings, or other debris within the forms shall be removed.

Blocks and bracing shall be removed with the forms and in no case shall any portion of the wood forms be left in the concrete. Special attention shall be paid to the ties and bracing and when forms appear to be insufficiently braced or unsatisfactorily built, either before or during construction, the work will be ordered stopped until the defects have been corrected. The forms shall be so constructed that the finished concrete shall be of the form and dimensions shown on the Plans and true to line and grade.

On the structures having cement concrete masonry decks, supported by beams and girders, the forms for the deck slabs shall be so constructed that under full dead load, the slabs will be of the required thickness shown on the Plans and the surface of the roadway will accurately conform to the profile grades, cross-sections and alignments as shown on the Plans. Allowance shall be made for the camber of the beams and stringers as fabricated and erected and also for the additional deflections due to dead load. The depth of haunches between the top of the stringers and the bottom of the slab as shown on the Plans, is theoretical, and due to variations in obtainable camber in the stringers and to usual inaccuracies of fabrication and erection, the depths of haunches to be constructed may vary considerably from the theoretical. The formwork shall be constructed so as to provide for any and all necessary variations in actual depths of haunches required.

602.09 Falsework. Falsework shall be designed in accordance with FHWA-RD-93-032, dated November 1993. Falsework shall be designed to be built on a firm foundation and to carry the anticipated loads without appreciable deflections as specified in Subsection 602.08 for formwork. It shall be constructed so as to provide the camber shown on the Plans for the completed structure. Proper allowance shall be made for take-up in timbers and probable falsework settlement. A "telltale" or other approved type indicator shall be attached to the forms in a manner to indicate any settlement, movement or deflections in the forms or falsework. If any of them is in excess of the prescribed tolerance(s), the work shall be stopped and the Contractor shall be required to rectify the problem to the full satisfaction of the Engineer.

The Contractor shall engage a Professional Engineer registered in Delaware to design the falsework separately for every bridge on the Project. The Professional Engineer's signature and seal shall be affixed to the working drawings. Working falsework drawings shall be submitted in accordance with [Subsection 105.04](#). It is the Contractor's responsibility to obtain approval of the working drawings from the Department prior to the construction of the falsework. Such approval, when given by the Department, shall not relieve the Contractor from the responsibility for the adequacy and satisfactory performance of the falsework.

Falsework systems shall be designed to handle all vertical and horizontal loadings and should contain enough redundancy to prevent a failure in the entire system. Vertical loading and differential settlement forces, and horizontal lateral and longitudinal forces shall also be taken into account for design of the falsework.

After placement of the falsework, the Contractor's Professional Engineer shall certify that the falsework system has been assembled according to the approved falsework drawing prior to placing loads on the falsework. When falsework installations are to be erected adjacent to a highway, special design consideration and protection shall be taken to ensure that falsework system is not disturbed by errant highway vehicles or by the vibration forces caused by the passing vehicles.

In the event falsework is moved from one bridge to another, the falsework shall be thoroughly inspected for structural damage and plumbness and approved by the Contractor's Professional Engineer prior to its use to ensure that all members are in place and properly aligned and connected.

602.10 Placing Concrete. No concrete shall be placed until the depth of the excavation and character of the foundation material, the adequacy of the forms and falsework, and the placing of reinforcement and other embedded items have been inspected and approved by the Engineer.

Concrete shall be placed in daylight unless an adequate lighting system meeting the approval of the Engineer is provided.

In preparation for the placing of concrete, all sawdust, chips, and other construction debris and extraneous matter shall be removed from the interior of forms. Hardened concrete and foreign matter shall be removed from tools, screeds, and conveying equipment.

The temperature of the concrete shall not be greater than 90 EF (32 EC), nor less than 50 EF (10 EC) at the time of placing, except where other temperatures are required in this Section. The temperature of concrete for bridge decks shall not exceed 85 EF (29 EC). During hot weather, the Contractor may be required to chill the mixing water, incorporate ice into the concrete mixture as part of the mixing water, or take other measures as prescribed in Section 812 to maintain concrete temperatures below the specified maximum temperatures. In addition, any combination of wind velocity, high air temperatures and low relative humidity, which, in the opinion of the Engineer, will impair the quality of fresh or hardened concrete due to rapid concrete moisture evaporation shall be sufficient cause to discontinue or prohibit concrete placement. The ACI Recommended Practice for Hot Weather Concreting will be used as a guide in assessing the hazards of hot weather.

No concrete shall be used which does not reach its final position in the forms within the time stipulated in Subsection 812.06.

Surfaces other than foundations on which concrete is to be placed shall be thoroughly cleaned and wetted immediately before placing concrete in order to facilitate bonding.

Placing of concrete shall be so regulated that the pressures caused by the wet concrete shall not exceed those used in the design of the forms.

The external surface of all concrete shall be thoroughly worked during the placing by means of tools of an approved type. During the placing of concrete, care shall be taken that the methods of compaction used will result in a surface of even texture free from voids, water, or air pockets, and that the coarse aggregate is forced away from the forms in order to leave a mortar surface.

Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. Concrete may be placed with the aid of buckets, chutes, troughs, pipes, or conveyors. Open troughs or chutes shall be metal or metal lined and extend as nearly as possible to the point of deposit. Aluminum will not be permitted as the contact surface for concrete placed through any conveyance.

Chutes on steep slopes shall be equipped with baffle boards or be in short lengths that reverse the direction of concrete movement. Chutes shall not slope greater than 1:2 (vertical to horizontal) or less than 1:3 (vertical to horizontal). Concrete placed with chutes over 25m (7.6 m) long or not meeting these slope standards shall discharge into a hopper before distribution unless otherwise directed.

All chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the structure.

Dropping the concrete a distance of more than 5m (1.5 m) or depositing a large quantity at any point and running or working it along the forms will not be permitted, except that the 5m (1.5 m) limitation will not apply to the dropping of concrete into the forms for the walls of box culverts, or retaining walls unless directed by the Engineer.

Care shall be taken to fill each part of the form by depositing the concrete as near its final position as possible. The coarse aggregate shall be worked back from the forms and worked around the reinforcement without displacing the bars. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the projecting reinforcement or other items embedded in the concrete, except where unavoidable on structures being widened under traffic.

Concrete shall be placed in continuous horizontal layers, the thickness of which generally shall not exceed 10 to 120 (250 to 300 mm). However, slabs shall be placed in a single layer. When it is necessary in an emergency to place less than a complete horizontal layer in one operation, such layer shall terminate in a vertical bulkhead. In any given layer, the separate batches shall follow each other so closely that each one shall be placed and consolidated before the preceding one has taken initial set in order that the fresh concrete shall not be injured and there shall be no lines of separation between the batches. Each layer of concrete shall generally be left somewhat rough to secure efficient bonding with the next layer above. A succeeding layer placed before the underlying layer has become set shall be consolidated in a manner that will entirely break up and obliterate the tendency to produce a construction joint between the layers.

Layers completing a day's work or placed prior to temporarily discontinuing operations shall be cleaned of all laitance and other objectionable material as soon as the surface has become sufficiently firm to retain its form. To avoid visible joints as far as possible upon exposed faces, the top surface of the concrete adjacent to the forms shall be finished being smoothed with a trowel.

Horizontal layers so located as to produce a construction joint at a location wherein a feather edge might be produced in the succeeding layer shall be so formed by inset formwork that the succeeding layer will end in a body of concrete having a thickness of not less than 60 (150 mm).

In no case shall the work on any section or layer be stopped or temporarily discontinued within 180 (450 mm) of the top of any face, unless the details of the work provide for a coping having a thickness of less than 180 (450 mm) in which case at the option of the Engineer, the construction joint may be made at the underside of the coping.

Care shall be exercised during the placement of concrete to minimize the coating of reinforcing steel, structural steel, forms, and other items which extend into areas involved in a subsequent placement. In the event coating of the steel does occur, no attempt shall be made to remove the mortar until after the concrete steel bond of the earlier placement has developed sufficiently to withstand a cleaning operation. Any coating of mortar on deformed bars which cannot be removed by hand brushing with a wire bristle brush, or by a light chipping action, will not have to be removed.

The method and manner of placing concrete shall be so regulated as to place all construction joints across regions of low shearing stress and in such locations as will be hidden from view to the greatest possible extent.

The operations of depositing and consolidating the concrete shall, in general, be conducted so as to form a compact, dense, impervious mass of uniform texture which will show smooth faces on exposed surfaces. Any section of concrete found to be defective shall be removed or repaired as directed by the Engineer.

If concrete operations are permitted to extend into the night, the work shall be brightly lighted so that all operations are plainly visible. Lighting requirements are indicated in [Subsection 602.24](#).

602.11 Placing Concrete During Cold Weather. The following requirements shall govern the placing of concrete during cold weather:

- a. *General.* No concrete shall be placed when the air temperature, measured at the location of the concreting operation in the shade away from artificial heat, is below 35 °F (2 °C) without permission of the Engineer. The temperature of the concrete shall not be less than 55 °F (13 °C) and not more than 80 °F (27°C) at the time it is placed in the forms.

The aggregates shall be free from ice, frost, and frozen particles, and concrete shall not be placed on frozen foundation material.

The Contractor shall protect all concrete by means of heated enclosures or by insulation whenever any of the following conditions occur:

1. The concrete has been placed when the air temperature, measured at the location of the concreting operation in the shade away from artificial heat, is below 35 °F (2 °C).
2. The air temperature, measured at the location of the freshly placed concrete in the shade away from artificial heat, is below 35 °F (2 °C) and the concrete has not yet attained an age of 72 hours.

The Contractor shall provide and place at locations directed by the Engineer a sufficient number of maximum-minimum recording thermometers to provide an accurate record of the temperature surrounding the concrete during the entire protection period.

The Contractor shall assume all risks connected with the placing of concrete under the cold weather conditions referred to herein. Permission given by the Engineer to place concrete when the temperature is below 35 °F (2 °C) and the subsequent protection of the concrete as required herein shall not relieve the Contractor in any way of the responsibility for obtaining the required results.

- b. *Heated Enclosures.* Portland cement concrete, that is placed when the air temperature is below 35 °F (2 °C) and portland cement concrete that has not yet attained an age of 72 hours before the air temperature falls below 35 °F (2 °C), shall be immediately enclosed with a housing consisting of canvas or other approved material supported by an open framework or with an equally satisfactory housing, and the air surrounding the concrete shall be maintained at a temperature of not less than 50 °F (10 °C) nor more than 70 °F (21 °C) for the remainder of the 72-hour period. The air surrounding the concrete shall be maintained at temperatures above 32 °F (0 °C) for not less than 48 hours immediately thereafter. The time periods referred to above shall not begin until the manipulation of each separate mass of concrete has been completed.

The Contractor shall provide such heating apparatus as stoves, salamanders, or steam equipment, and the necessary fuel. When dry heat is used, means of preventing loss of moisture from the concrete shall be provided.

- c. *Insulation.* Protection of concrete by the use of approved insulated forms or insulation blankets will be permitted in lieu of the heated enclosure. Insulation will be required under the same

conditions that heated enclosures are required, and shall be placed on the concrete as soon as initial set will permit.

Insulating materials shall have a minimum thickness of 10 (25 mm). The thermal conductivity ("k" factor) of the insulation shall not exceed 0.27 BTU per hour square foot (0.85 W/m²) for a thermal gradient of one degree F per inch (0.02 °C/mm) as determined by ASTM C 177. Results of tests conducted in accordance with ASTM C 177 by an acceptable commercial testing laboratory shall be furnished to the Engineer for approval. Such approval shall be secured prior to use of the material. Insulating blankets shall be faced or covered, top and bottom, with polyethylene or similar waterproofing material. Blankets shall be placed on the concrete in such a manner that they form a waterproof surface for the concrete being protected. When the anticipated low temperature expected to occur during the protection period is lower than 10 °F (-12 °C), 20 (50 mm) of insulation will be required.

Blanket insulation mats shall overlap at the edges by at least 60 (150 mm). Rigid type insulation sheets shall be tightly butted together and sealed. Particular care shall be taken to provide effective protection of curbs, corners, and around protruding reinforcing steel. Overhang forms shall be insulated both on the outside vertical faces and on the underside with a 10 (25 mm) minimum thickness of either rigid or blanket type insulation.

Should the air under the insulation fall below 50 °F (10 °C) during the protection period, the Contractor will be required to immediately cover the concrete with canvas and framework or other satisfactory housing and apply heat uniformly at a rate such that the air surrounding the concrete is not less than 50 °F (10 °C) for the remainder of the protection period.

602.12 Pumping Concrete. Placement of concrete by pumping will be permitted only when approved by the Engineer. Prior to starting the pumping operation, the Contractor shall also get a method approved by the Engineer for maintaining continuous placement of concrete in case of breakdown of the concrete pump. Pumping equipment shall be located so that no vibrations result which might damage the freshly placed concrete. Pumping equipment, including the conduit system, shall not contain any aluminum or aluminum alloy in contact with the concrete. The conduit system shall consist of 50 (125 mm) minimum inside diameter rigid or flexible pipe.

Grout used to lubricate the inner surfaces of the conduit system shall be wasted.

Operation of the pump shall be such that a continuous stream of concrete without air pockets is delivered. When pumping is completed, any concrete remaining in the pipeline which is to be used in the work shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients.

Samples of concrete to be used for test purposes shall be taken from the discharge end of the conduit system and shall be taken as close as possible to the final position of the concrete.

602.13 Consolidation of Concrete by Vibration. Concrete, except that placed under water, or as otherwise approved, shall be compacted during and immediately after depositing by means of approved mechanical vibrating equipment.

Internal mechanical vibrators shall be of sturdy construction, with a cutoff switch at the vibrator, adequately powered and capable of transmitting vibrations to the concrete in frequencies of not less than 5000 impulses per minute and shall produce a vibration of sufficient intensity and amplitude to cause settlement of the concrete into place without a separation of the aggregates.

In using internal vibrators, the vibratory element shall be inserted into the concrete at the point of deposit and in the areas of freshly-placed concrete. The time of vibration shall be long enough to accomplish thorough consolidation of the concrete and complete embedment of the reinforcement, to produce a smooth surface

free from honeycombing and air bubbles, and to work the concrete into all angles and corners of the forms. However, over-vibrating shall be avoided. Vibration shall continue in a spot only until the concrete has become plastic and shall not continue to the extent that pools of grout are formed. The correct length of time of vibration will depend upon the frequency of the vibration impulses per minute, the size of vibrators and the slump of the concrete.

Internal vibrators shall be applied at points uniformly spaced, not farther than the radius over which the vibration is visibly effective and shall be applied close enough to the forms to effectively vibrate the surface concrete. The vibration shall not be dissipated in lateral motion but shall be concentrated in vertical settlement in consolidating the concrete. Vibrators shall not be used to move concrete.

The vibrating element shall be inserted in the concrete mass a sufficient depth to vibrate the bottom of each layer effectively and in as nearly a vertical position as practicable. It shall be withdrawn completely from the concrete before being advanced to the next point of application.

To secure an even and dense surface free from aggregate pockets or honeycomb, vibration shall be supplemented by working or spading by hand in the corners or angles of the forms and along form surface while the concrete is plastic under the vibratory action.

A sufficient number of vibrators shall be employed so that at the required rate of placement thorough consolidation is secured throughout the entire volume of each layer of concrete. Extra vibrators shall be on hand for emergency use and for use when other vibrators are being serviced.

The use of surface vibrators to supplement internal vibration will be permitted only when satisfactory surfaces cannot be obtained by internal vibration alone, and only upon approval. Surface vibrators shall be applied only long enough to embed the coarse aggregate and to bring enough mortar to the surface for satisfactory finishing.

The use of approved form vibrators will be permitted only when it is impossible to use internal or surface vibrators. When permitted, they shall be attached to or held on the forms in such manner as to effectively transmit the vibration to the concrete and so that the principal paths or motions of the vibration are in a horizontal plane.

602.14 Joints.

- a. *Construction Joints.* Construction joints shall be made only where located on the Plans or shown in the placing schedule, unless otherwise approved by the Engineer.

If not detailed on the Plans, or in the case of emergency, construction joints shall be placed as directed by the Engineer. Shear keys or inclined reinforcement shall be used where necessary to transmit shear or bond the two sections together. Joints shall be so constructed that feather edging does not occur.

For construction joints in deck slabs, a 2 by 120 (50 by 38 mm) shear key shall be provided between the mats of reinforcing steel.

In construction joints exposed to view or in other construction joints where seepage of water is particularly objectionable, or where specified on the Plans, an approved waterstop shall be inserted. The waterstop shall be placed not less than 30 (75 mm) from the face of the concrete and shall extend into each section of the concrete a distance of not less than 20 (50 mm) or as specified on the Plans.

When longitudinal joints are specified or permitted, they shall be spaced so that each placement of concrete is not less than 10M (3 m) in width. Transverse joints shall be placed at the centerlines of

piers or as specified on the Plans. Concrete shall be placed in one continuous operation between construction joints. The minimum volume of concrete in any one placement shall be not less than the volume of concrete in one end span. The falsework under all spans from edge to edge of slab or from edge of the slab to an open joint shall remain in place until the concrete in the entire slab has attained the minimum 28-day design compressive strength required for the mix.

- b. *Bonded Construction Joints.* If joining fresh concrete to concrete that has already set, the work already in place shall have its surface roughened thoroughly with a suitable tool and all shavings, sawdust or other loose and foreign material shall be removed. The surface shall be washed and scrubbed with wire brooms when necessary to remove substances that may interfere with the bond. The concrete of the preceding placement shall be thoroughly wetted prior to the placement of the next unit of fresh concrete.

For construction joints in deck slabs, the vertical face shall be epoxy coated prior to placement of adjoining concrete with epoxy bonding compound.

In order to bond successive courses, suitable keys shall be formed at the top of the upper layer of each day' s work and at other levels where work is interrupted. These keys shall be formed by the insertion and subsequent removal of beveled wood strips which shall be saturated thoroughly with water to induce swell prior to insertion in the fresh concrete. Rough stone or steel dowels may, at the discretion of the Engineer, be used in lieu of keys. Dowels shall extend an equal distance on each side of the construction joint. Prior to inserting or driving of dowels into predrilled or preformed holes, the holes shall be filled with portland cement grout in the proportion of one part cement to two parts sand. The size and spacing of keys and dowels shall be determined by the Engineer.

When bonding fresh concrete to hardened concrete, or hardened concrete or steel to hardened concrete, an epoxy bonding compound conforming to AASHTO M 235 shall be used. Surface preparation, mixing and application requirements, and limitations as specified by the manufacturer shall be strictly followed. Bonding compounds shall be approved prior to use.

The Contractor shall schedule its concreting operations so that the concrete is placed while the epoxy bonding compound is still uncured and tacky. If, in the opinion of the Engineer, the bonding compound has begun to cure, no concrete shall be placed until a new film of bonding compound has been applied to the required areas.

- c. *Expansion Joints.* Expansion joints shall be provided as shown on the Plans. They shall be made by building keyed faces and are to be covered with bituminous expansion felt or other approved material to prevent leakage and the adhesion of the concrete faces. Roofing paper will not be considered as expansion material.

602.15 Joint Sealants. Sealant type shall be as specified on the Plans.

- a. *Rubber Joint Sealant.* A primer shall be used as recommended by the sealant manufacturer. A bond breaker such as masking tape, polyethylene film, or backing rod as supplied by the manufacturer shall be used at the bottom of the joint.

The surfaces of the joints or recesses must be clean and dry, and free of corrosion, scale, rust, oil, wax, tar, paint, and other contamination. Masonry joints shall be sandblasted to remove contamination. Metal surfaces shall be given a commercial sandblast.

Masking tape shall be applied along the edges of joints where required. Joint faces shall be primed in accordance with sealant manufacturer' s instructions. Sealant shall be placed following the manufacturer' s instructions regarding mixing and application. Sealant shall not be applied on wet or frosty surfaces or when the surface temperatures are below 40 °F (4 °C) or above 130 °F (55 °C). Adjacent surface shall be cleaned free of sealant with mechanical action or solvent as necessary. Finished work shall be left in a neat and clean condition.

- b. *Bituminous Joint Sealant.* Bituminous joint sealant shall be hot applied or cold applied elastomeric sealant.

602.16 Waterstops. The size and configuration of waterstop shall be as shown on the Plans. Waterstop should preferably be spliced only at joints made necessary by construction design. All joints shall be made in strict accordance with the procedures recommended by the manufacturer. No appreciable loss in strength, elasticity, or durability shall result at splices.

Plastic waterstop shall be carefully placed at the locations shown on the Plans or as directed. A split form technique shall be used during installation. Bending of the waterstop along the face of form shall not be permitted. Precautions shall be taken that the waterstop shall neither be displaced nor damaged by construction operations or other means. All surfaces of the waterstop shall be free from oil, grease, dried mortar, or other foreign matter while the waterstop is being embedded in concrete. Means shall be used to ensure that all portions of the waterstop designed for embedment are tightly enclosed by dense concrete.

If requesting approval of a waterstop, the Contractor shall furnish a 120 (300 mm) length of the extruded section of waterstop that it intends to supply, with a certification that the material conforms to all requirements of this Subsection.

602.17 Finishing Concrete Surfaces.

- a. *General.* All concrete surfaces shall be true, even, and free from open or rough places, depressions, or projections. The concrete in all bridge seats, parapets, sidewalks, curbs, railings, and walls shall be brought flush with the finished top surface and shall be struck off with a template and floated to a finish free from irregularities and true to line and grade.

All masonry bearing areas as prescribed in [Subsection 605.29](#) shall be placed to the final elevation specified. They shall be bush-hammered down to within 30 (6 mm) of the final elevation and ground with an approved device to a smooth, level, true plain surface which must be within 1/80 (3 mm) of the prescribed bearing elevation. The concrete in the bearing area shall be poured high enough so that no part of the bearing area, after bush-hammering, is lower than the surrounding bridge seating surface.

Unless otherwise specified on the Plans, all surfaces shall be given an ordinary surface finish unless after form removal they are in such a condition that they cannot be repaired to the satisfaction of the Engineer. In these cases, the entire structural unit shall be given a rubbed finish.

- b. *Ordinary Surface Finish.* Immediately following the removal of the forms, all fins and irregular projections shall be removed from all surfaces except from those which are not to be exposed or are not to be water-proofed. On all surfaces, the cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects shall be thoroughly cleaned, saturated with water, and carefully pointed and trued with a mortar of cement and fine aggregate mixed in the proportions used in the grade of the concrete being finished. Mortar used in pointing shall be not more than 30 minutes old. The mortar patches shall be cured as specified in [Subsection 602.18](#). All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.
- c. *Rubbed Surface Finish.* After removal of forms, the rubbing of concrete shall be started as soon as its condition permits. Immediately before starting this work, the concrete shall be kept thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the pointing to thoroughly set. The surface to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in proportions used in the concrete being finished. Rubbing shall be continued until all form marks, projections, and irregularities have been removed,

all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This rubbing shall be continued until the entire surface is of a smooth texture and uniform color.

After the final rubbing is completed and the surface has dried, it shall be rubbed with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder, and objectionable marks.

- d. *Float Finish.* This finish, for horizontal surfaces, shall be achieved by placing an excess of material in the form and removing or striking-off the excess with a template, forcing the coarse aggregate below the mortar surface. Creation of a concave surface shall be avoided. After the concrete has been struck off, the surface shall be thoroughly worked and floated with a suitable wood, canvas, or cork floating tool. Before the finish has set, the surface cement film shall be removed with a fine brush in order to have a fine grained, smooth but sanded texture.
- e. *Special Surface Finish.* As an alternative to the rubbed surface finish, an acrylic or latex bonded mortar finish may be used when and where designated in the Plans and Special Provisions.
- f. *Tooled Finish.* A tooled finish shall be made on the surfaces previously spaded by cutting into the body of the concrete with a pointing tool or bush-hammer as indicated on the Plans.

602.18 Curing. All exposed surfaces shall be cured by one of the following methods:

- a. *Water Methods.* The concrete shall be kept continuously wet by the application of water for a minimum period of seven curing days after the concrete has been placed.

When cotton mats, burlap, or earth or sand blankets are to be used to retain the moisture, the entire surface of the concrete shall be kept damp by applying water with a nozzle that so atomizes the flow that a mist and not a spray is formed, until the surface of the concrete is covered with the curing medium. The moisture from the nozzle shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or wash the surface. At the expiration of the curing period, the concrete surface shall be cleared of all curing mediums.

- b. *Membrane Curing Compound Method.* The entire surface of the concrete shall be sprayed uniformly with a liquid membrane curing compound conforming to the requirements of [Subsection 812.02](#).

The membrane curing compound shall be applied after the surface finishing has been completed, and immediately after the free surface moisture has disappeared.

The surface shall be sealed with a single uniform coating of the specified type of curing compound applied at the rate of coverage recommended by the manufacturer or as directed by the Engineer, but not less than 1 gal/150 ft² (0.27 L/m²) of area.

At the time of use, the compound shall be in a thoroughly mixed condition with the pigment uniformly dispersed throughout the vehicle. If the application of the compound does not result in satisfactory coverage, the method shall be stopped and water curing, as set out above, applied until the cause of the defective work is corrected.

At locations where the coating shows discontinuities, pinholes, or other defects, or if rain falls on the newly coated surface before the film has dried sufficiently to resist damage, an additional coat of the compound shall be applied immediately after the rain has stopped at the same rate specified herein.

Any curing compound adhering to a surface to which new concrete is to be bonded shall be completely removed by sandblasting, steel wire brushes, bush-hammers, or other approved means.

The concrete surfaces to which the compound has been applied shall be protected from abrasion or other damage which results in perforation of the membrane film for seven curing days after the concrete is placed. If the film of membrane compound is damaged or removed before the expiration of seven curing days, the exposed concrete shall be immediately cured by the water method until additional compound is applied or until seven curing days have expired.

In the event that the application of curing compound is delayed, the application of water shall be started immediately and shall be continued until application of the compound is resumed or started.

- c. *Waterproof Sheeting Method.* The exposed finished surface of concrete shall be wetted with water, using a nozzle that so atomizes the flow that a mist and not a spray is formed, until the concrete has set, after which the waterproof sheeting shall be placed. Curing shall continue for seven curing days after the concrete has been placed. If the sheeting is damaged or removed before the expiration of seven curing days, the exposed concrete shall be immediately cured by the water method until additional sheeting is placed or until seven curing days have expired.

Waterproof sheeting shall consist of paper or polyethylene conforming to the requirements of [Subsection 812.02](#). The waterproof sheeting shall provide a complete continuous cover of the entire concrete surface. Sheets shall lap a minimum of 120 (300 mm) and shall be securely weighed down or cemented together in such a manner as to provide a waterproof joint.

Should any portion of the sheets be broken or damaged before the expiration of the curing period, the broken or damaged portions shall be immediately repaired with new sheets properly cemented in place.

Sections of sheeting which have been damaged to such an extent as to render them unfit for curing the concrete shall not be used

- d. *Forms-In-Place Method.* Formed surfaces of concrete shall be cured by retaining the forms in place for a minimum period of seven days after the concrete has been placed. If the Contractor elects to leave forms in place for a part of the curing period and use one of the other methods of curing included in this article for the remainder of the curing period, the concrete surfaces shall be kept wet during the time the curing methods are being changed.

602.19 Removal of Forms and Falsework, and Placement of Superimposed Vertical Loads. The minimum period during which forms and supports for concrete structures must remain in place are listed in [Table 602-A](#) and are defined either by the "Time" or the "Cylinder Strength" requirements.

Table 602-A

Minimum Requirements for Removal of Formwork, Placement of

Superimposed Vertical Loads, and Placement of Backfill

Structural Element	Removal of Formwork		Placing Superimposed Vertical Dead Loads*		Placement of Backfill	
	Time (days)	Strength (%f _{lc})	Time (days)	Strength (%f _{lc})	Time (days)	Strength (%f _{lc})

Arch [Span # 65N (20 m)](B.F.)	3	40	21	95	21	95
Arch (Span # 65N (20 m)](S.F.)	2	30				
Concrete Beam (B.F.)	7	60	12	80	n/a	n/a
Concrete Beam (S.F.)	2	30				
Slab [Span # 10N (3 m)] and Diaphragms	2	30	14	85	n/a	n/a
Slab [Span > 10N (3 m)]	5	50				
Piers/Columns	2	30	5	50	n/a	n/a
Pile Cap and Pier Cap	5	50	7	60	5	50
Footing	2	30	3	40	2	30
Cast-In- Place Concrete Piles	n/a	n/a	5	50	n/a	n/a
Subfoundation Concrete	1	20	2	30	1	20
Retaining Wall, Headwall, and Wingwall	2	30	2	30	21	95
Parapet Wall, Curb, and Backwall	1	20	1	20	5	50
Abutment Wall, Rigid Frame Wall, and Box Culvert Wall	2	30	5	50	21	95

B.F. - Bottom Form

S.F. - Side Form

* Examples of such are as follows; placement of parapet on slab, placement of wall on footing, placement of beam on pier cap, etc...

During cold weather [less than 40 °F (4 °C)] and hot weather [greater than 85 °F (30 °C)] forms for vertical surfaces shall remain in place for a minimum of five days. Forms may be removed prior to five days only if the concrete is protected in a manner suitable to the Engineer. The Contractor shall submit a protection plan for the concrete in writing to the Engineer and have it approved by the Engineer prior to form removal.

Upon removal of the forms or protection, surface cavity repairs, finishing, and curing of the exposed areas shall begin immediately.

Except during weather conditions noted above, the forms for rubbed surfaces shall be removed no longer than 48 hours after placing of the concrete.

In using [Table 602-A](#), consideration shall be given to the location and character of the structure, the weather and other conditions influencing the setting of the concrete, and the material used in the mix. The use of retarder or special cements shall require special attention.

The minimum required strength of concrete listed in [Table 602-A](#) shall be used as a guide when and where field operations are controlled by the "Cylinder Strength" and approved by the Engineer. If the Contractor intends to begin removing forms as soon as the concrete has reached the minimum required strength of [Table 602-A](#), the Contractor shall give the Engineer written notice, 48 hours prior to pouring the concrete, that the start of form removal will depend on the "Cylinder Strength" requirements.

When the Contractor desires cylinder testing other than seven- and 28-day testing, it shall be the responsibility of the Contractor to supply the molds and to make the cylinders under the supervision of the Engineer. The molds for structural concrete shall be 40 (100 mm) by 80 (200 mm) and shall meet the requirements of *Cylinder Molds* under AASHTO T 23. If the Contractor requests cylinder testing other than seven- and 28-day testing and does not perform the testing, the Department's Materials and Research Section will perform the testing; however, the Contractor shall be charged for the testing and a credit will be given to the Department.

Cylinders cast for the specific use as "Cylinder Strength" testing for form removal shall be cured in the field under the same conditions as the concrete they represent. It shall also be the responsibility of the Contractor to ensure that the seven- and 28-day cylinders are cured for the first 24 to 48 hours in an environment to provide satisfactory moisture and temperature control as per AASHTO T 23.

Department personnel will test the cylinders made by the Contractor to determine concrete strength at the time the Contractor wishes to remove forms or place loads on the concrete.

These "Strength" and "Time" requirements listed in [Table 602-A](#) are intended only for the construction operations indicated and shall not apply to the use of equipment or other live loads on the structure. Stockpiling of materials and the use of unauthorized equipment on the structure will not be permitted.

Truck mixers, dump trucks, cranes, and other heavy construction equipment will be not permitted to cross or to be parked on a completed structure, nor will the structure be opened to construction or public traffic until so authorized by the Engineer. The "Cylinder Strength" must have attained full design compressive strength (f'_c), and concrete must be at least ten days old before this authorization will be given.

All forms shall be removed whether above or below the ground line or water level.

Methods of form removal likely to cause overstressing of the concrete shall not be used. Forms and their supports shall not be removed without the approval of the Engineer.

Supports shall be removed in such a manner as to permit the concrete to take, uniformly and gradually, the stress due to its own weight.

Falsework under all spans shall be completely released before forms are constructed and concrete is placed for parapets and curb.

Forms for footings constructed within cofferdams or cribs may be left in place, when, in the opinion of the Engineer, their removal would endanger the safety of the cofferdam or crib, and when the forms so left intact will not be exposed to view in the finished structure.

The interior forms supporting the roadway slab of box girder type structures shall be supported on wales or similar supports fastened, as nearly as possible, to the top of side walls, and may be left in place. The interior forms supporting the roadway slab shall not be shored to or supported on the box girders bottom slab.

As soon as forms are removed, all form ties used for holding the forms in place shall be removed and the holes, depressions, or small voids thus made which show upon the removal of the forms, shall be filled with cement mortar mixed in the same proportions as that which was used in the body of the work.

The work shall be so planned and executed that form removal and specified finishing is performed within the required limits. Otherwise, subsequent placement of concrete in other parts of the structure or structures shall be ordered stopped.

Concrete which is to be exposed to sea water or tidal brackish water shall be placed in the dry unless otherwise directed. Sea water or brackish water shall not come in direct contact with concrete prior to the times indicated in [Table 602-B](#) unless otherwise directed.

Table 602-B

Requirements for the Removal of Formwork for Concrete

in Contact with Sea Water or Brackish Water

<i>Water Salinity</i> <i>(ppm dissolved salts)</i>	<i>Days to Elapse</i> <i>Prior to Salt Water Contact</i>
0 to 10 000	Normal Curing
10 000 to 20 000	15
20 000 to 30 000	25
over 30 000	30

602.20 Bridge Decks.

- a. *Permanent Steel Bridge Deck Formwork.* Permanent steel bridge deck forms for concrete deck slabs of bridges shall be used when shown on the Plans.
1. *Design.* The steel forms shall be designed on the basis of dead load of the form, reinforcement, and plastic concrete plus 50 lb/ft² (2.4 kPa) for construction loads. The unit working stress in the steel sheet shall be not more than 72.5% of the specified minimum yield strength of the material furnished, but not to exceed 36,000 lb/in² (250 MPa).

Deflection under the weight of the forms, the plastic concrete, and the reinforcement shall not exceed 1/180 of the form span or 20 (13 mm), whichever is less, however, the deadload design weight for this minimum deflection shall be no less than 120 lb/ft² (5.75 kPa) total.

The permissible form camber shall be based on the actual dead load condition. Camber shall not be used to compensate for deflection in excess of the foregoing limits.

The design span of the form sheets shall be the clear span of the form plus 20 (50 mm) measured parallel to the form flutes. Physical design properties shall be computed in accordance with requirements of the AISI Specification for the Design of Cold-Formed Steel Structural Members.

All deck reinforcement shall have a minimum concrete cover of 20 (50 mm) for the top mat of steel and 10 (25 mm) for the bottom mat unless otherwise specified on the Plans.

The plan dimensions of both layers of primary deck reinforcement from the top surface of the concrete deck shall be maintained.

Permanent steel bridge deck forms shall not be considered as lateral bracing for compression flanges of supporting structural members.

Permanent steel bridge deck forms shall not be used in panels where longitudinal deck expansion joints are located between stringers.

Welding shall not be permitted to flanges in tension or to structural steel bridge elements fabricated from non-weldable grades of steel.

Fabricators' shop and erection drawings shall be submitted to the Engineer for approval. These drawings shall indicate the grade of steel, the physical and section properties for all permanent steel bridge deck form sheets, and a clear indication of locations where the forms are supported by steel beam flanges subject to tensile stresses.

2. *Construction.* All forms shall be installed in accordance with approved fabrication and erection drawings.

Form sheets shall not be permitted to rest directly on the top of the stringer or floor beam flanges. Sheets shall be securely fastened to form supports and shall have a minimum bearing length of 10 (25 mm) at each end. Form supports shall be placed in direct contact with the flange of stringer or floor beam. All attachments shall be made by permissible welds, bolts, clips, or other approved means. However, welding of form supports to flanges of steels not considered weldable and to portions of a flange subject to tensile stresses shall not be permitted. Welding and welds shall be in accordance with the provisions of AWS D2.0 pertaining to fillet welds, except that 1/80 (3 mm) fillet welds will be permitted.

Any permanently exposed form metal where the galvanized coating has been damaged shall be thoroughly cleaned, wire brushed, and painted with one coat of organic zinc paint, to the satisfaction of the Engineer. Minor heat discoloration in areas of welds need not be touched up.

The direction lapping of forms shall be consistent with the direction of concrete placement.

3. *Inspection.* The Contractor's method of construction should be carefully observed during all phases of the construction of the bridge deck slab. These phases include installation of the metal forms; location and fastening of the reinforcement; composition of concrete items; mixing procedures; concrete placement and vibration; and finishing of the bridge deck. Should the Engineer determine that the procedures used during the placement of the concrete warrant inspection of the underside of the deck, the Contractor shall remove at least one section of the forms at a location and time selected by the Engineer for each span in the Contract. This should be done as soon after placing the concrete as practicable in order to provide visual evidence that the concrete mix and the Contractor's procedures are obtaining the desired results. An additional section shall be removed if the Engineer determines that there has been any change in the concrete mix or in the Contractor's procedures warranting additional inspection.

After the deck concrete has been in place for a minimum period of two days, the concrete shall be tested for soundness and bonding to the forms by sounding with a hammer as directed by the Engineer. If areas of doubtful soundness are disclosed by this procedure, the Contractor will be required to remove the forms from such areas for visual inspection after the pour has attained adequate strength.

At locations where sections of the forms are removed, the Contractor will not be required to replace the forms, but the adjacent metal forms and support shall be repaired to present a

neat appearance and ensure their satisfactory retention. As soon as the form is removed, the concrete surfaces will be examined for cavities, honeycombing and other defects. If irregularities are found, and it is determined by the Engineer that these irregularities do not justify rejection of the work, the concrete shall be repaired as the Engineer may direct and shall be given an ordinary surface finish, in accordance with the Contract. If the concrete where the form is removed is unsatisfactory, additional forms, as necessary, shall be removed to inspect and repair the slab, and the Contractor's methods of construction shall be modified as required to obtain satisfactory concrete in the slab. All unsatisfactory concrete shall be removed and repaired as directed by the Engineer.

The amount of sounding and form removal may be moderated, at the Engineer's discretion, after a substantial amount of slab has been constructed and inspected, if the Contractor's methods of construction and the result of the inspections as outlined above indicate that sound concrete is being obtained throughout the slabs.

The Contractor shall provide all facilities as are reasonably required for the safe and convenient conduct of the Engineer's inspection procedures

- b. *Concrete Work.* A smooth, durable riding surface of uniform texture, true to the required grade and cross-section, shall be obtained on all bridge decks.

Concrete shall be placed in accordance with the Contract. Particular emphasis should be placed on proper vibration of the concrete to avoid honeycomb and voids, especially at construction joints, expansion joints, and valleys and ends of form sheets. Pouring sequences, procedures, and mixes shall be approved by the Engineer.

The placing of concrete in bridge decks will not be permitted until the Contractor has satisfied the Engineer that it has adequate personnel and equipment to deliver, place, spread, finish, and cure a minimum of 20 yd³; (15 m³) of concrete per hour, that experienced finishing machine operators and concrete finishers are employed to finish the deck, and that weather protective equipment and all necessary finishing tools and equipment are on hand at the site of the work and in satisfactory condition for use.

Prior to any deck concreting, a "pre-pour" conference will be held with the Contractor and representatives of the Department in attendance. At this time, the Contractor shall present its plan and procedures for deck construction.

Supports for screeds or finishing machines shall be completely in place and firmly secured before placing of concrete will be permitted. Supports shall be set to elevations necessary to obtain a bridge deck true to the required grade and cross-section, with allowance being made for anticipated settlement. Supports shall be of a type and shall be so installed that no springing or deflection will occur under the weight of the finishing equipment, and shall be so located that finishing equipment may operate without interruption over the entire bridge deck being furnished.

Immediately prior to placing bridge deck concrete, the Contractor shall check all falsework and shall make all necessary adjustments. Suitable means such as telltales shall be provided by the Contractor to permit ready measurement by the Engineer of deflection as it occurs.

On continuous steel beam or girder spans, the order of casting shall be as shown on the Plans. On simple spans, and for any section between construction joints for continuous spans, the concrete in the floor slab may be placed by beginning at the end and working along the roadway or by beginning at the side and working across the roadway. The screeding method used shall have been approved by the Engineer.

Screeding operations shall include a mechanical screed of the power-actuated oscillating type.

Vibrating screeds will not be permitted unless specifically approved by the Engineer. The screed shall be sufficiently rigid and easy to control in order to provide substantially uniform treatment over the deck surface. Screeds shall be of the transverse type and shall be of sufficient weight to strike off the surface at the specified grade. Longitudinal type screeds shall not be used without prior written approval from the Engineer.

When the longitudinal type screed is used, the over-all length shall be such as to screed independently supported spans up to and including 80N (24 m). In no case shall the length of the screed be less than the full length of the span for spans less than 80N (24 m). When using the longitudinal type screed on independently supported spans exceeding 80N (24 m) in length with a screed length less than the full length of the span, the center half of the span, preferably more, shall be completed first and then the remaining portions completed. Bulkheads or other substantial supports for the screed shall be placed over the abutments and/or piers and at the terminal point of placements within the span. The surface of a previously placed section shall not be used as a bearing area for the screed track until control cylinders have attained a minimum strength of $0.6 f'_{lc}$ where f'_{lc} is the design minimum laboratory compressive strength as specified on the Plans.

When a transverse screed is used, the screed shall be of a sufficient size to finish the full width of the deck between curbs or parapets unless a longitudinal joint in the deck is specified. In this case, the portion on either side of the joint shall be placed and finished separately. The wheels of the screed shall bear on temporary rails which shall be adequately supported on and directly above the main structural members or on form supports. In case of continuous spans, the form supports shall be fully supported by the principal structural members supporting the deck. The rails shall be sufficiently rigid and strong to permit the screed to finish the surface of the deck within the requirements of this Section. If the rails are placed within the roadway area, they shall be elevated a sufficient distance above the deck to permit the simultaneous finishing by hand of any portion not finished by the screed. Rail supports extending above the roadway surface shall be fabricated and installed in such a manner as to permit their removal to at least 20 (50 mm) below the top surface of the deck slab. Any portion of the rail support to remain in the deck concrete shall be fusion bonded epoxy coated. Where rail supports are placed in that portion of the deck under the curbs or parapets, the supports shall be so placed that they will be at least 20 (50 mm) from the face of the curb parapet walls or outside edge of the slab.

During the screeding operation, an adequate supply of concrete shall be kept ahead of the screed and a slight excess shall be maintained immediately in front of the screed. Workers will not be permitted to walk on the concrete after screeding. The Contractor shall provide a sufficient number of work bridges or other suitable platforms to provide adequate access to the work, and so that screeding, finishing, and curing operations can progress without delay. The work bridge shall be supported outside the limits of the concreting.

An adequate supply of suitable coverings which will protect the surface of the freshly placed bridge deck from rain shall be readily available at the site of the work.

Where the concrete in the deck of a continuous beam or girder span group cannot be placed in one operation, the location of construction joints and sequence of placement shall be in accordance with an approved placement schedule. After the initial placement has been made in any one group of a continuous span, no further placement shall be made until all previously placed concrete in the deck of that group has been in place for at least three days or until the cylinder strength is at least $0.5 f'_{lc}$.

Roadway surfaces of bridge decks and approach slabs shall be wet cured, as soon as possible, according to Subsection 602.18 (a). Membrane curing compound shall not be used on bridge decks and approach slabs except when cold weather dictates its use. The Engineer will determine when cold weather requires membrane curing. When required, membrane curing compound shall be applied in accordance with the requirements of Subsection 501.11 immediately after the finishing operation. Within 24 hours, the roadway surfaces shall also be covered with waterproof covers as set forth in Subsection 501.13. The waterproof covers shall remain in place for not less than seven

days. Extreme care shall be taken to protect adjacent reinforcing steel from the membrane curing compound.

The Contractor shall test the fresh concrete deck surface with a 10' (3.048 m) straightedge, and the Contractor shall re-screed the deck surface as many times as is necessary to ensure a smooth riding surface. The straightedge shall be held in successive positions at the edges, quarter points, and on the centerline, parallel thereto and in contact with the surface. Advancement along the deck shall be in successive stages of not more than one-half the length of the straightedge. The surface shall also be checked transversely at the ends, quarter points, and center of the span. Areas showing high spots or depressions of more than 1/80 (3 mm) in 10' (3.048m) in the longitudinal direction and 1/40 (6 mm) in 10' (3.048 m) in the transverse direction shall be struck off or filled with freshly mixed concrete as the case may be. Special attention shall be given to ensure that the surface across joints meets the requirements for smoothness.

After the deck has cured the surface will be tested using either a straightedge, a rolling straightedge, or a California-type profilograph. If surface testing using a California-type profilograph is required, testing and corrective work shall conform to the requirements of Subsection 501.17. Surface testing of the cured concrete with a straightedge or rolling straightedge will be performed as described above for fresh concrete. High spots or depressions of more than 1/80 (3 mm) in 10' (3.048 m) in the longitudinal direction and 1/40 (6 mm) in 10' (3.048 m) in the transverse direction shall be corrected by patching and/or grinding at no cost to the Department. Any cracking which occurs prior to opening to traffic shall be sealed or repaired in a manner approved by the Engineer at no cost to the Department. The deck shall also be sounded and any delaminated areas shall be removed and replaced in a manner approved by the Engineer at no cost to the Department.

c. *Surface Texture.* All bridge deck surfaces shall be textured either by mechanical grooving or by manual texturing. Unless otherwise noted in the Contract, texturing will be done by mechanical grooving.

1. *Mechanical Grooving.* Bridge deck and approach slab surfaces shall be textured by first dragging a fabric over the final screeded concrete and then by sawing transverse grooves in the cured concrete. After final screeding of the surface, the Contractor shall drag multiple damp fabric over the surface to provide a gritty texture. After the bridge deck or approach slab has been cured and attained 75% of the 28-day design compressive strength, the Contractor shall saw uniformly pronounced grooves transverse to the centerlines.

Grooves shall be sawn approximately 1/100 (2.5 mm) wide, 1/8 to 3/160 (3 to 5 mm) deep, and on 120 (38 mm) (nominal) centers. Grooves shall terminate 18 " 10 (450 " 25 mm) from the face of the parapet. Grooves shall not be sawn any closer than 20 (50 mm) nor further than 30 (75 mm) from the edge of any joint. When the width of the cutting head on the grooving machine is such that grooves can not be practically sawn to within the required tolerance for a skewed transverse joint, grooving shall begin on the side of the deck having the acute angle corner, and nominal spacing of the grooves at the starting point shall be 120 (38 mm) on center. In the event that a single pass of the grooving machine can not be made across the width of the bridge or approach slab, then the mating ends of subsequent passes shall not overlap previous grooves nor leave more than 10 (25 mm) of surface ungrooved.

For bridge lengths over 300' (90 m), a randomly spaced groove pattern shall be used. The random spacing shall be from 1 3/80 (35 mm) centers to 1 5/80 (40 mm) centers, as determined by the Engineer.

Removal of all debris, including slurry, resulting from the grooving operations shall be continuous. Surfaces must be immediately left in a washed and clean condition, free of all

slipperiness from the slurry. All debris and surplus material removed from the grooving operations shall be deposited in a truck, or other conveyance, and disposed.

2. *Manual Texturing.* When specified, after the concrete has been consolidated and struck off and before the concrete becomes non-plastic, the surface shall then receive a transverse texture. Texturing shall be done by use of a wire broom having a single row of tines or a finned float having a single row of fins. The broom or float shall produce transverse grooves that are spaced at intervals of approximately 2 to 3/4 (13 to 19 mm) center to center. The grooves in the hardened surface shall be approximately 0.08 to 0.120 (2 to 5 mm) in width and 0.15 to 0.250 (3 to 6 mm) in depth. The grooving shall be applied to the entire deck surface except that area within 180 (450 mm) from the face of curb.

602.21 Holes. Drainage openings and weep holes shall be constructed in the manner and at locations indicated on the Plans, or as directed. No deduction in the computed volume of concrete masonry, except for openings in pipe headwalls, will be made.

602.22 Placing Pipe and Conduits. Pipes and conduits which are to be encased in the concrete, as shown on the Plans, shall be placed by the Contractor during construction. Such pipes and conduits shall be furnished and placed by the Contractor unless otherwise stated on the Plans.

602.23 Placing Anchors, Bolts, Grills, and Other Embedments. Anchors, bolts, grills, and other embedments, which are to be placed in the concrete as indicated on the Plans, shall be furnished and placed by the Contractor during construction.

602.24 Night Lighting. The Contractor shall be responsible for submitting to the Engineer a lighting plan showing the locations and aiming of the floodlights. After the Engineer has reviewed the lighting plan, the Contractor shall conduct a test run of the floodlighting system at the proposed construction area prior to the proposed use. The lighting system will be checked for proper aiming and positioning, level and uniformity of illuminance, and any hazard to maintenance of traffic. The floodlighting system shall be capable of being adjusted to avoid glare that may blind the traffic and mobile enough to allow for proper aiming and positioning to provide the desired results. Any adjustments required by the Engineer shall be corrected by the Contractor. No nighttime construction shall begin until the floodlighting system with the lighting plan has been approved in writing by the Engineer.

Lamps for floodlights shall be either tungsten halogen, mercury vapor, metal halide, or high pressure sodium. The floodlighting system shall provide maximum uniformity of light, producing a level of illuminance of 20 average horizontal ft-c (215 lx) over the construction work area. The Contractor shall supply a photometer to test the illuminance level during the test run. The Contractor shall submit to the Engineer, not less than 30 days prior to the test, the type, style, or catalog number of the photometer to be used for the test. At the same time, the Contractor shall include a written certification that the equipment was calibrated by a testing agency approved by the Engineer not more than 60 days prior to the date when such tests are to be performed. The test is to be performed by the Contractor and witnessed by the Engineer. The photometer is to be of the latest available type and cosine corrected. The angle between the beam center of the flood light and vertical shall not exceed 60 degrees. The mounting height of the floodlights shall be not less than 30ft (9 m) above any traveled roadway which is directly influenced by the floodlights. Otherwise, the floodlights shall be not less than 20ft (6 m) above the work area.

The Contractor shall exercise reasonable care to avoid any interruptions of the lighting system during working operations. If a portable generator is used, it shall have a rated capacity large enough not to create flickering during work operations. An emergency backup system shall be available on the job site if a portable generator is used. The fuel tank for the generator shall be of sufficient capacity to permit operation at full load for at least 12 hours.

All materials involved in this Subsection shall remain the property of the Contractor.

602.25 Defective Work. Any defective work discovered after the forms have been removed shall be immediately removed and replaced. If the surface of the concrete is bulged or uneven, or shows honeycombing that cannot be repaired satisfactorily, the entire section shall be removed and replaced.

Concrete which fails to reach full 28-day design strength (f'_c) will be considered defective concrete. If the concrete is determined to not be structurally adequate by the Engineer, then it shall be removed and replaced. If the concrete is determined to be structurally adequate by the Engineer and the concrete can remain in place, the Contractor shall have the following options:

1. Accept the low strength concrete test results and all remedial action as described in the below categories or;
2. Challenge the low strength concrete test result by coring the area which the test cylinders represent.

If the Contractor elects to take cores to challenge the cylinder strength results, it shall be the Contractor's responsibility to obtain two cores (one for the Department and one for the Contractor) at the location determined by the Engineer. After the cores have been obtained, the concrete cores shall be tested for compressive strength in the as-cored moisture condition and the Contractor's core testing results shall be provided to the Department no later than five working days after verbal notification that the cylinder strength test results were substandard.

If the average of the core testing results (Department and Contractor) are greater than or equal to the specified 28-day design strength, the Contractor shall be paid the full bid price for the concrete in question. If the average core testing results are less than the specified strength, the remedial action as described in the following categories will be required:

<i>Category A:</i>	<i>0 to 250 psi (0 to 1.66 MPa) below 28-day Design Strength</i> No repair required, full payment as specified in Subsection 602.27.
<i>Category B:</i>	<i>251 to 500 psi (1.67 to 3.33 MPa) below 28-day Design Strength</i> Prorated payment as specified in Subsection 602.27.
<i>Category C:</i>	<i>501 to 1000 psi (3.34 to 6.66 MPa) below 28-day Design Strength</i> Prorated payment as specified in Subsection 602.27 plus the application of a protective waterproofing that is approved by the Department's Materials and Research Section. The coating shall be clear and shall only be applied to the pour area that the core represents.
<i>Category D:</i>	<i>1000 psi (6.67 MPa) or greater below 28-day Design Strength</i> Strengthen area of low strength concrete as approved by the Engineer at no cost to the Department.

If the difference in strength between the Department's results and the Contractor's independent test laboratory results are greater than 501 psi (3.34 MPa), the core testing results will be considered void and the prorated payment as specified in [Subsection 602.27](#) will be applied to the concrete in question based upon the field-cast cylinders.

602.26 Method of Measurement. The quantity of portland cement concrete will be measured as the number of cubic yards (cubic meters) of concrete placed and accepted. The volume will be computed using the dimensions shown on the Plans, or as ordered in writing. The quantity of concrete in floor slabs will be computed from the dimensions shown on the Plans with no allowance for form deflection or stay-in-place

form corrugations. No deduction in the computed volume of portland cement concrete will be made for pipes with outside diameters of 120 (300 mm) or less, conduits, anchors, bolts, and scuppers. The quantity of concrete in deck slabs will be computed from design deck thickness.

- Floodlighting will not be measured.
- The quantity of grooving will not be measured.

602.27 Basis of Payment.

- General.* The quantity of portland cement concrete will be paid for at the Contract unit price per cubic yard (cubic meter). Price and payment will constitute full compensation for furnishing all materials, forms, and falsework; for cold weather protection; for removal of bridge deck forms to allow visual inspection of areas of doubtful soundness and bonding of concrete; for construction of drainage openings and weepholes; for furnishing and placing pipes and conduits; for furnishing and placing anchors, bolts, and scuppers; for furnishing and maintaining light plants and lighting equipment; for grooving and removing all debris or for manual texturing; and for furnishing all equipment, tools, labor, and incidentals required to complete the work.
- Price Adjustment for Low Strength Concrete.* Prorated payment for concrete as specified in [Subsection 602.25](#) shall be calculated as shown in the following equation:

$$\text{Prorated Payment} = \frac{\text{Low Compressive Strength Concrete} \times (\text{Quantity of Concrete}) \times (\text{Bid Price}^*)}{\text{Specified Compressive Strength}}$$

* The quantity for which the low compressive strength results represent.

** Item bid price; not material cost.