SECTION 400
CONCRETE STRUCTURES

400-1 Description.

Construct concrete structures and other concrete members, with the exception of pavement and incidental concrete construction (which are specified in other Sections).

Refer to Section 450 for prestressed construction requirements additional to the requirements of this Section.

For precast concrete structures incorporating Microsilica, meet the requirements of Section 450 for finishing, curing, storage, shipping and erection.

400-2 Materials.

Meet the following requirements:

Concrete	Sections 346 and 347
Reinforcing Steel	Section 415
Curing Materials	*Section 925
Epoxy Bonding Compounds	Section 926
Joint Materials	Section 932
Bearing Pads	932-2
Self-Lubricating Bearing Plates	964-2
Copper Water Stops	964-4
Water	Section 923

*The Engineer will allow clean sand and sawdust for certain curing, when and as specified.

400-3 Depth of Footing.

Consider the elevations of the bottoms of footings, as shown in the plans, as approximate only. The Engineer may change dimensions or elevations of footings as necessary to secure a satisfactory foundation. If the elevation of a footing as shown in the plans is changed to a higher or lower elevation, the Engineer will not consider such change as a material change to the original Contract Documents, a waiver of any condition of the Contract, or an invalidation of any of the provisions of the Contract. If the excavation must be carried deeper than shown in the plans to obtain a satisfactory foundation, the Engineer will revise the plans in accordance with one of the following methods:

(a) The Engineer will keep the top of the footing at the elevation shown in the original plans and will increase the thickness to obtain a satisfactory foundation. The Engineer will follow this method when the change in bottom elevation of the footing is 12 inches [300 mm] or less. When this method is followed, place the reinforcing steel the same as if the footings, as shown in the original plans, were placed on a subfooting of plain concrete; make no alteration in the position of the reinforcing bars relative to the top of the footing.

(b) The Engineer will revise the plans and lower the footing, thereby increasing the height of stem, to obtain a satisfactory foundation. Generally, the Engineer will increase the thickness and width of footing over that shown in the original plans. If this method is followed, use the dimensions, sizes, and location of reinforcing steel shown in the revised plans. The Engineer will follow this method when the change in elevation of the bottom of footing exceeds 12 inches [300 mm].

The Engineer will determine which of the above methods to use.

400-4 Falsework.

400-4.1 Plans: At the Engineer's request, furnish detailed plans for falsework or centering to the Department. The Contractor is responsible for results obtained by using these plans.

400-4.2 Design and Erection: Design and construct all falsework to provide the necessary rigidity and to support the loads without appreciable settlement or deformation. Use screw jacks or hardwood wedges to take up any settlement in the framework, either before or during the placing of concrete. If any weakness develops and the centering shows undue settlement or distortion, stop the work, remove any masonry affected, and strengthen the falsework before resuming work. Support falsework which cannot be founded on a satisfactory footing on piling. Space, drive, and remove the piling in an approved manner.

400-4.3 Camber: Provide camber to correct for settlement and deflection of falsework. Give bridges permanent camber only when shown in the plans.

400-5 Forms.

400-5.1 General: Provide forms, either of wood or metal, that are as follows: (a) externally secured and braced where feasible; (b) substantial and unyielding; (c) of adequate strength to contain the concrete without bulging between supports and without apparent deviation from the neat lines, contours, and shapes shown in the plans. Design forms to withstand the additional forces of vibration without apparent deviation from the desired shape or position. Assemble forms to be mortartight. If using lumber forms, construct them of dressed wood of uniform thickness. Use form liners on wooden forms where Class 3 surface finish is specified. Construct assembled forms to render a concrete surface of smooth, uniform finish. Make provisions to remove forms without injury to concrete surfaces. Remove blocks and bracing with the forms, and do not leave any portion of the forms in the concrete. Use the same form system for a type of work throughout.

400-5.2 Inspection and Approval: Do not place concrete in a form until the form has been inspected and approved. Although the Engineer inspects and approves the forms, the Contractor is responsible for obtaining satisfactory concrete surfaces, free from warping, bulging, or other objectionable defects. Pay special attention to the ties and bracing. Where the forms appear to be insufficiently braced or unsatisfactorily built, stop and correct defects to the satisfaction of the Engineer.

400-5.3 Non-metallic Form Materials:

400-5.3.1 Lumber: For all surfaces, use lumber that is not less than 3/4 inch [19 mm] in thickness, dressed, and free of knot holes, loose knots, cracks, splits, warps, and other defects. Proportion the spacing of studs, joists, and wales to exclude warps and bulges and to produce true and accurate concrete surfaces. Only use structurally sound lumber.

400-5.3.2 Form Liners: Use form liners of durable, abrasion resistant materials that are unaffected by water. Use liners with a hard surface texture capable of rendering concrete surfaces of a smooth, uniform texture, without grain marks, patterns, or blemishes. Use form liner material of sufficient thickness to eliminate the reflection of irregularities, undesirable patterns, and marks from the forms to the surfaces. Replace liners as necessary to produce a consistent concrete surface texture. Use form liners in large sheets and with true, tight-fitted joints which are logically located. Obtain the Engineer's approval of the layout of sheets. Do not use liners which have been patched. Use liner material of the same stock throughout.

400-5.3.3 Plywood: The Contractor may use plywood of not less than 5/8 inch [15.9 mm] in thickness manufactured with waterproof glue or protected with an approved impervious coating. Do not use pieces with bulged plies or ravelled, untrue edges.

400-5.4 Special Requirements:

400-5.4.1 Re-entrant Angles: Use chamfered forms for re-entrant angles, and use filleted forms for corners. Use chamfers and fillets that are 3/4 by 3/4 inch [19 by 19 mm] and are mill-dressed on all sides to uniform dimensions. The Contractor may use plastic or metal chamfers and fillets provided they perform satisfactorily in producing uniform, smooth concrete corner surfaces without honeycomb.

400-5.4.2 Handrails and Parapets: For a portion of handrail or parapet cast in place, carefully secure smooth and tight-fitting forms that can be held to line and grade and that can be removed without injury to the concrete. Use only moldings, panel work, and bevel strips that are straight and true, with neatly mitered joints, and provide corners in the finished work that are true, sharp, and clean-cut. Recheck the alignment of forms and the grade of top chamfer strips immediately after placing concrete in the forms.

400-5.4.3 End-bent Caps: Do not place forms for end-bent caps until the embankment has been constructed to within 12 inches [300 mm] of the bottom of the cap. Place a mass of embankment that is sufficient to produce the subsidence, displacement, and settlement which may result from the construction of the total embankment.

400-5.4.4 Footings: Where footing concrete can be placed in dry excavation, the Contractor may omit cribs, cofferdams, and forms, subject to compliance with the following limitations and conditions:

(a) Use this procedure only in locations not exposed to view from traveled roadways.

(b) Obtain required elevations shown in the plans.

(c) Obtain neat line dimensions shown in the plans.

(d) Fill the entire excavation with concrete to the required elevation of the top of the footing.

(e) The Engineer will determine the volume of footing concrete to be paid for from the neat line dimensions shown in the plans.

400-5.5 Form Alignment, Bracing, and Ties: Construct forms in such manner that they may be adequately secured for alignment, shape, and grade. Use bracing systems, ties, and anchorages that are substantial and sufficient to ensure against apparent deviation from shape, alignment, and grade. Do not drive nails into existing concrete. Do not use bracing systems, ties, and anchorages which unnecessarily deface or mark, or have an injurious or undesirable effect on surfaces that will be a part of the finished surface.

If metal ties and anchorages are to remain in the concrete, construct them so as to permit the removal of metal to at least 1 inch [25 mm] beneath the finished surface of concrete. Use accessories for metal ties and anchorages that allow the removal of metal to the prescribed depth while leaving the smallest possible repairable cavity.

When using wire ties, cut or bend them back from the finished surface of the concrete a minimum of 1 inch [25 mm]. Do not use internal ties of wire when forming surfaces that are exposed to view.

400-5.6 Preparation and Cleaning: Meet the following requirements for the condition of forms at the time of beginning concrete casting:

(a) Treat all forms with an approved form-release agent before placing concrete. Do not use material which adheres to or discolors the concrete.

(b) Clean forms of all concrete laitance from previous use and all dirt, sawdust, shavings, loose wire ties and other debris.

(c) Close and secure all inspection and cleanout holes.

400-5.7 Stay-In-Place Metal Forms:

400-5.7.1 General:

(a) Use of permanent stay-in-place metal forms: Permanent stay-in-place metal forms may be used in lieu of removable forms to form all concrete bridge deck slabs except on bridge superstructures classified as Extremely Aggressive, subject to the conditions, limitations, and requirements contained herein and stated in the plans. Use forms made of corrugated material of cellular or non-cellular construction.

Stay-in-place metal forms may be used to form the portion of the top slab which lies between the webs of individual steel box girders regardless of the environmental classification.

Prior to using stay-in-place forms, submit detailed plans for approval of the forming system, including method of support and attachment and method of protecting the supporting structural steel components from welding effects. Submit design calculations. Detail stay-in-place forms such that they in no way infringe upon the concrete outline of the slab shown on the plans. Use stay-in-place forms that provide and maintain the dimensions and configuration of the original slab in regards to thickness and slope.

Do not weld stay-in-place metal form supports and connections to structural steel components. Make attachments by permissible welds, bolts, clips, or other approved means. If metal form supports and connections are field welded in place, protect structural steel components from damage by using a shield to guard against weld splatter, weld overrun, arc strikes, or other damaging effects of the welding process. Upon completion of welding, rest the metal form support flush on the supporting steel component. Should any weld spatter, weld overrun, arc strike, or other effects of the welding process be evident or occur to the structural steel component, immediately stop in place welding of the metal form supports for the remainder of the work. In this event, weld all metal form supports off of the structure and erect the forms after prefabrication, or use an alternate approved method of attaching the form supports. Remove improper weldment, repair the supporting steel component for any improper welding technique, and perform all required verification and testing at no expense to the Department and to the satisfaction of the Engineer.

Do not use stay-in-place forms until the forming system has been approved by the Engineer. The Contractor is responsible for the performance of the stay-in-place forms.

(b) Structures designed, detailed, and dimensioned for the use of removable forms: Where stay-in-place metal forms are permitted, the Contractor is responsible and shall obtain the approval of the Engineer for the additional slab thickness, elevation changes, changes in design, etc. to accommodate the use of stay-in-place forms. The Engineer will compute pay quantities of the various components of the structure which are paid on a cubic yard [cubic meter] basis from the design dimensions shown on the plans with no allowance for changes in deflection or dimensions necessary to accommodate the stay-in-place forms or concrete to fill the form flutes. The Engineer will limit pay quantities of other Contract items that the Contractor increases to accommodate the use of stay-in-place forms to the quantity required for the original plan design.

Submit all changes in design details of bridge structural members that support stay-in-place forms, showing all revisions necessary to enable the supporting components to withstand the additional weight of the forms and the weight of the extra concrete required to fill the form flutes. Include with the design calculations a comparative analysis of the stresses in the supporting components as detailed on the Contract plans and as modified to support the forms. Use the identical method of analysis in each case, and do not allow the stresses in the modified components to exceed those of the component as detailed in the Contract plans. Include with the design the adjusted cambers for any changes in deflection over those shown on the original plans. Modify the beams to provide additional strength to compensate for the added dead loads imposed by the use of stay-in-place forms. Obtain the additional strength by adding strands to the prestressed beams or by adding steel material to increase the section modulus of steel girders. Substantiate the added strength by the comparative calculations. Do not use stay-in-place forms until the forming system and all necessary design revisions of supporting members have been approved by the Engineer.

(c) Structures designed, detailed, and dimensioned for the use of stay-in-place metal forms: Prior to using stay-in-place forms, submit detailed plans for approval of the forming system (including method of support and attachment) together with design calculations. Include an analysis of the actual unit weight of the proposed forming system over the projected plan area of the metal forms. If the weight thus calculated exceeds the weight allowance for stay-in-place metal forms and concrete required to fill the form flutes shown on the plans, then modify the supporting components to support the excess in weight as stipulated in 400-5.7.1(b).

(d) Painting of top flange: For all structures utilizing structural steel supporting components for which stay-in-place metal forms are to be used, paint the vertical sides of the top flange prior to installation of the stay-in-place forms in accordance with 560-7.9.

(e) Zinc coating of supports and connections: Apply a zinc paint coating in accordance with Section 562 to all welded areas of supports and to accessories cut from galvanized sheets, which are not embedded in concrete.

400-5.7.2 Materials: Fabricate permanent stay-in-place metal forms and supports from steel meeting the requirements of ASTM A 653 [ASTM A 653M], having a coating designation of G165 [Z500]. Do not use form materials that are less than 22 gauge [0.7925 mm] in thickness.

400-5.7.3 Design: Meet the following criteria for the design of permanent bridge deck forms:

(1) Design the forms on the basis of deadload of form, reinforcement, and plastic concrete plus 50 lb/ft^2 [2.4 kPa] for construction loads. Use a unit working stress in the steel sheet of not more than 0.725 of the specified minimum yield strength of the material furnished, but not to exceed 36,000 psi [250 MPa].

(2) Do not allow deflection under the weight of the forms, reinforcement, and plastic concrete to exceed 1/180 of the form span or 1/2 inch [13 mm], whichever is less, for form spans of 10 feet [3 m] or less, or 1/240 of the form span or 3/4 inch [19 mm], whichever is less, for form spans greater than 10 feet [3 m]. In all cases, do not use a loading that is less than 120 psf [5.75 kPa] total.

(3) Use a design span of the form equal to the clear span of the form plus 2 inches [50 mm]. Measure the span parallel to the form flutes.

(4) Compute physical design properties in accordance with requirements of the AISI Specifications for the Design of Cold Formed Steel Structural Members, latest published edition.

(5) For all reinforcement, maintain the design concrete cover required by the plans.

(6) Maintain the plan dimensions of both layers of primary deck reinforcement from the top surface of the concrete deck.

(7) Do not consider the permanent bridge deck form as lateral bracing for compression flanges of supporting structural members.

(8) Do not use permanent steel bridge deck forms in panels where longitudinal deck construction joints are located between stringers.

(9) Secure forms to the supporting members by means other than welding.

400-5.7.4 Construction: Install all forms in accordance with approved fabrication and erection plans.

Do not rest form sheets directly on the top of the stringer of floor beam flanges. Fasten sheets securely to form supports, and maintain a minimum bearing length of 1 inch [25 mm] at each end for forms. Place form supports in direct contact with the flange of the stringer or floor beam. Make all attachments for forms by bolts, clips, or other approved means.

For any permanent exposed steel where the galvanized coating has been damaged, thoroughly clean, wire brush, and paint it with two coats of galvanizing compound in accordance with 971-15 to the satisfaction of the Engineer. Do not touch up minor heat discoloration in areas of welds.

Locate transverse construction joints at the bottom of a flute, and field drill 1/4 inch [6 mm] weep holes at not less than 12 inches [300 mm] on center along the line of the joints.

400-5.7.5 Placing of Concrete: Vibrate concrete to avoid honeycomb and voids, especially at construction joints, expansions joints, and valleys and ends of form sheets. Use approved pouring sequences. Do not use calcium chloride or any other admixture containing chloride salts in the concrete.

400-5.7.6 Inspection: The Engineer will observe the Contractor's method of construction during all phases of the construction of the bridge deck slab, including the 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, remove at least one section of the forms in each span for this purpose. Do this as soon after placing the concrete as practicable in order to provide visual evidence that the concrete mix and the procedures are obtaining the desired results. Remove an additional section in any span if the Engineer determines that there has been any change in the concrete mix or in the procedures warranting additional inspection.

After the deck concrete has been in place for a minimum period of two days, test for soundness and bonding of the forms by sounding with a hammer as directed by the Engineer. If sounding discloses areas of doubtful soundness to the Engineer, remove the forms from such areas for visual inspection after the concrete has attained adequate strength. Remove permanent bridge deck forms at no expense to the Department.

At locations where sections of the forms have been removed, the Engineer will not require the Contractor to replace the forms. Repair the adjacent forms and supports to present a neat appearance and to ensure their satisfactory retention. As soon as the form is removed, the Engineer will examine the concrete surfaces for cavities, honeycombing, and other defects. If irregularities are found, and the Engineer determines that these irregularities do not justify rejection of the work, repair the concrete as directed, and provide a General Surface Finish in accordance with 400-15. If the Engineer determines that the concrete where the form is removed is unsatisfactory, remove additional forms as necessary to inspect and repair the slab, and modify the method of construction as required to obtain satisfactory concrete in the slab. Remove and replace all unsatisfactory concrete as directed at no expense to the Department.

If the method of construction and the results of the inspections as outlined above indicate that sound concrete has been obtained throughout the slabs, the amount of sounding and form removal may be reduced when approved.

Provide the facilities for the safe and convenient conduct of the inspection procedures.

400-5.8 Stay-In-Place Concrete Forms:

400-5.8.1 General: Permanent stay-in-place concrete forms may be used in lieu of removable forms to form concrete bridge deck slabs subject to the conditions contained herein. Neither concrete stay-in-place forms nor precast prestressed panels are permitted to construct a composite concrete deck.

When detailed plans for structures are dimensioned for the use of removable forms, provide additional slab thickness, elevation changes, changes in design, etc. to accommodate the use of stay-in-place forms, subject to the Engineer's approval. The Engineer will compute pay quantities of the various component members of the structure which are paid on a cubic yard [cubic meter] basis from the design dimensions shown on the plans with no allowance for changes in deflection and changes in dimensions necessary to accommodate the stay-in-place forms. The Engineer will limit pay quantities of other Contract items which are increased to accommodate the use of stay-in-place forms to the quantity required for the original plan design.

Prior to using stay-in-place forms, submit for approval detailed plans of the forming system. Indicate on the plans the form panel sizes, placing patterns, type of mastic or felt bearing material and type and method of caulking between panels. A panel section design as shown in the table below may be chosen or a design may be submitted for approval. If a design is submitted, design calculations shall also be submitted. Also, submit appropriate changes in design details of structural members supporting stay-in-place forms showing any revisions necessary to enable the supporting components to withstand the additional weight of the forms and perform equally as contemplated in the plans. Modify the beams to provide additional strength to compensate for the added dead loads imposed by the use of stay-in-place forms. Obtain this strength by adding additional strands to prestressed girders or increasing the section modulus for steel girders. Do not use stay-in-place forms until the forming

system and any necessary design revisions of supporting structural members have been approved by the Engineer. The Department is not responsible for the performance of the stay-in-place forms by its approval.

TABLE OF PRESTRESSED FORM DESIGNS (NON SI UNITS)			
Clear Span	Form Depth	"E"	Maximum Strand Spacing
3'0"	2 3/8"	0	22.72"
4'0"	2 3/8"	0	12.72"
5'0"	2 3/8"	0	8.18"
6'0"	2 3/8"	0	5.68"
6'6"	2 3/8"	0	4.84"
6'7"	2 5/8"	1/8"	6.76"
7'0"	2 5/8"	1/8"	5.83"
8'0"	2 5/8"	1/8"	4.46"
8'3"	2 5/8"	1/8"	4.19"
8'4"	2 7/8"	1/4"	5.34"
9'0"	2 7/8"	1/4"	4.43"
9'9"	2 7/8"	1/4"	3.70"
10'0"	3 1/8"	3/8"	4.47"
10'6"	3 1/8"	3/8"	4.25"
11'0"	3 1/8"	3/8"	3.85"
NOTE: (a) Column "E" shows the required eccentricity to the centerline of the strand below the mid-depth of the panel. (b) The form panel designs shown above require 3/8" diameter S.R. Strands loaded to 14,000 pounds each.			

TABLE OF PRESTRESSED FORM DESIGNS (SI UNITS)			
Clear Span	Form Depth	"E"	Maximum Strand Spacing
0.91 m	60 mm	0	575 mm
1.22 m	60 mm	0	325 mm
1.52 m	60 mm	0	210 mm
1.83 m	60 mm	0	145 mm
1.99 m	60 mm	0	125 mm
2.01 m	70 mm	3 mm	170 mm
2.13 m	70 mm	3 mm	150 mm
2.44 m	70 mm	3 mm	115 mm
2.52 m	70 mm	3 mm	105 mm
2.54 m	75 mm	6 mm	135 mm
2.74 m	75 mm	6 mm	115 mm
2.97 m	75 mm	6 mm	95 mm
3.05 m	80 mm	10 mm	115 mm
3.20 m	80 mm	10 mm	110 mm
3.35 m	80 mm	10 mm	100 mm
NOTE: (a) Column "E" shows the required eccentricity to the centerline of the strand below the mid-depth of the panel. (b) The form panel designs shown above require 9.5 mm diameter S.R. Strands loaded to 62 kN each.			

400-5.8.2 Materials: Construct permanent concrete forms of prestressed concrete in accordance with Section 450. Use concrete having a 28-day minimum compressive strength of 5,000 psi [35 MPa]. Use stress steel with 250K [1.72 GPa], 270K [1.86 GPa], or LOK-Stress. For using all other metal reinforcement, meet the requirements of Section 931.

400-5.8.3 Design: Use the following criteria for the design of permanent bridge deck forms:

(1) Design the forms on the basis of deadload of form, reinforcement, and plastic concrete plus 50 psf [2.4 kPa] for construction loads. For the unit working stress of the concrete, meet the AASHTO design requirements.

(2) Deflection under the weight of the forms, reinforcement, and the plastic concrete shall not exceed 1/180 of the form span or 1/2 inch [13 mm], whichever is less. In all cases, do not use a loading that is less than 120 psf [5.75 kPa] total.

Base the permissible form camber on the actual deadload condition. Do not use camber to compensate for deflection in excess of the foregoing limits.

(3) Use a design span of the form equal to the clear span of the form between supports. Measure the span of concrete forms parallel to the centerline of the form panels.

(4) Compute physical design properties of concrete forms in accordance with current AASHTO design procedures.

(5) Ensure that all steel reinforcement contained in the cast-in-place concrete has the minimum cover shown on the plans or not less than 1 inch [25 mm], whichever is greater. Measure the minimum cover normal to the plane of the bottom of the cast-in-place concrete. For stay-in-place concrete forms with other than plane surfaces in contact with the cast-in-place concrete, such as regularly spaced geometrical shapes projecting above the plane of the bottom of the cast-in-place concrete, meet the following special requirements:

(a) Space geometrical shapes projecting above the bottom plane of the cast-in-place concrete used to provide support for reinforcement no closer than 3 feet [1.0 m] apart and of sufficient height to maintain the required concrete cover on the bottom mat of reinforcing steel.

(b) Construct all other geometrical shapes projecting above the plane of the bottom of the cast-in-place concrete to provide a minimum vertical clearance of 3/4 inch [19 mm] between the closest surface of the projections and the secondary longitudinal reinforcing steel in the deck slab.

(c) Do not allow a minimum horizontal distance from the surface of any transverse reinforcing steel to surfaces of the stay-in-place form of less than 1 1/2 inches [38 mm].

For all steel reinforcement for the stay-in-place form panels, provide a minimum of 1 inch [25 mm] concrete cover except that, for construction in a salt or other corrosive environment, provide a minimum of 1 1/2 inches [38 mm] concrete cover.

(6) Maintain the plan dimensions of both layers of primary deck reinforcement from the top surface of the concrete deck. Measure the minimum cover of the bottom mat of steel normal to the top of the precast concrete form panel.

(7) Do not consider the permanent bridge deck form as lateral bracing for compression flanges of supporting structural members.

(8) Do not use permanent concrete bridge deck forms in panels where longitudinal deck construction joints are located between stringers.

(9) Do not allow the maximum weight of the concrete form to exceed 40 lb/ft^2 [195 kg/m^2] of form surface.

400-5.8.4 Construction: Install all forms in accordance with approved fabrication and erection plans.

For concrete forms, provide a minimum bearing length of at least 1 1/2 inches [38 mm] but not exceeding 2 1/2 inches [64 mm]. Support concrete forms on the beams or girders by continuous layers of an approved mastic or felt bearing material that will provide a mortar tight uniform bearing. Use a mastic or felt bearing material that has a minimum width of 1 inch [25 mm] and a maximum width of 1 1/2 inches [38 mm]. Seal joints between concrete form panels with caulking, tape, or other approved method.

400-5.8.5 Placing of Concrete: Place the concrete in accordance with the requirements of 400-5.7.5. Immediately prior to placing the slab concrete, saturate concrete stay-in-place form panels with water.

400-5.8.6 Inspection: Inspect the concrete in accordance with the requirements of 400-5.7.6.

After the deck concrete has been in place for a minimum period of two days, inspect the forms for cracks and excessive form deflection, and test for soundness and bonding of the forms by sounding with a hammer as directed by the Engineer. Remove, for visual inspection, form panels found to be cracked that show evidence of leakage and form panels which have a deflection greater than adjacent panels by 1/2 inch [13 mm] or more which show signs of leakage. If sounding discloses areas of doubtful soundness to the Engineer, remove the form panels from such areas for visual inspection after the concrete has attained adequate strength. Remove permanent bridge deck form panels at no expense to the Department.

At locations where sections of the forms have been removed, the Engineer will not require the forms to be replaced. Repair the adjacent forms and supports to present a neat appearance and to ensure their satisfactory retention. As soon as the form is removed, the Engineer will examine the concrete surfaces for cavities, honeycombing, and other defects. If irregularities are found, and the Engineer determines that these irregularities do not justify rejection of the work, repair the concrete as directed and provide a General Surface Finish in accordance with 400-15. If the concrete where the form is removed is unsatisfactory, as determined by the Engineer, additional forms shall be removed as necessary to inspect and repair the slab, and modify the methods of construction as required to obtain satisfactory concrete in the slab. Remove and replace all unsatisfactory concrete as directed at no expense to the Department.

If the methods of construction and the results of the inspections as outlined above indicate that the Contractor has obtained sound concrete throughout the slabs, the Contractor may moderate the amount of sounding and form removal, when approved.

Provide all facilities for the safe and convenient conduct of the inspection procedures.

400-6 Weep Holes.

Provide weep holes in all abutments, retaining walls, and culverts over 5 feet [1.5 m] in height. Provide weep holes that are at least 3 inches [75 mm] in diameter and not more than 10 feet [3 m] apart, but do not place any weep holes under the area to be occupied by the base or pavement. Place the outlet ends of the weep holes just above the ground line in front of abutments and retaining walls. In culverts, place weep holes approximately 6 inches [150 mm] above the top of the floor slab. Cover the inside ends of all weep holes with wire mesh and at least 2 ft^3 [0.05 m^3] of clean, broken stone or gravel, so placed as to allow free drainage but at the same time prevent the fill from washing out. From approximately 6 inches [150 mm] below the bottom of the inside ends of the weep holes, carry a column of clean, broken stone or gravel at least 1 ft^2 [0.1 m^2] up against the back of the wall to the surface of the original ground.

400-7 Placing Concrete.

400-7.1 Temperature Restrictions:

400-7.1.1 Concreting in Cold Weather: Do not place concrete when the temperature of the concrete at placement is below 45ºF [7ºC].

Meet the air temperature requirements for mixing and placing concrete in cold weather as specified in Sections 346 and 347. During the curing period, if NOAA predicts the ambient temperature to fall below 35ºF [2ºC] for 12 hours or more or to fall below 30ºF [-1ºC] for more than four hours, enclose the structure in such a way that the concrete and air within the enclosure can be kept above 60ºF [16ºC] for a period of three days after placing the concrete or until the concrete reaches a minimum compressive strength of 1,500 psi [10 MPa].

Assume all risks connected with the placing and curing of concrete. Although the Engineer may give permission to place concrete, the Contractor is responsible for satisfactory results. If the placed concrete is determined to be unsatisfactory, remove, dispose of, and replace the concrete at no expense to the Department.

400-7.1.2 Concreting in Hot Weather: Meet the temperature requirements and special measures for mixing and placing concrete in hot weather as specified in Section 346.

When the temperature of the concrete as placed exceeds 75ºF [24ºC], incorporate in the concrete mix a water-reducing retarder or water reducer if allowed by Section 346.

Spray reinforcing steel and metal forms with cool fresh water just prior to placing the concrete in a method approved by the Engineer.

Assume all risks connected with the placing and curing of concrete. Although the Engineer may give permission to place concrete, the Contractor is responsible for satisfactory results. If the placed concrete is determined to be unsatisfactory, remove, dispose of, and replace the concrete at no expense to the Department.

400-7.2 Lighting Requirements: Provide adequate lighting for all concrete operations conducted at night. Obtain approval of the lighting system prior to starting the concrete operations.

400-7.3 Inspections before Placing Concrete: Do not place concrete until the depth and character of the foundation and the adequacy of the forms and falsework have been approved by the Engineer. Do not deposit any concrete until all reinforcement is in place and has been inspected and approved by the Engineer.

400-7.4 Exposure to Water: Do not expose concrete other than seal concrete in cofferdams to the action of water before final setting. Do not expose such concrete to the action of salt or brackish water for a period of seven days after placing the concrete. Protect the concrete during this period by keeping salt or brackish water pumped out of cofferdams.

400-7.5 General Requirements for Placing Concrete: Do not place any concrete prior to submitting an approved concrete placement plan as specified in Section 346. Deposit concrete as nearly as possible in its final position. Do not deposit large quantities at one point and then run or work it along the forms. Take special care to fill each part of the forms, to work coarse aggregate back from the face, and to force concrete under and around reinforcing bars without displacing them.

Use a method and manner of placing concrete that avoids the possibility of segregation or separation of aggregates. If the Engineer determines that the quality of concrete as it reaches its final position is unsatisfactory, remove it and discontinue or adjust the method of placing until the Engineer determines that the quality of the concrete as placed is satisfactory.

Use metal or metal-lined open troughs or chutes with no aluminum parts in contact with the concrete. Where steep slopes are required, use chutes that are equipped with baffles or are in short lengths that reverse the direction of movement. Where placing operations would involve dropping the concrete freely more than 5 feet [1.5 m], deposit it through pipes, troughs, or chutes of sheet metal or other approved material. Use troughs, chutes, or pipes with a combined length of more than 30 feet [10 m] only with the Department's authorization. Keep all troughs, chutes, and pipes clean and free from coatings of hardened concrete by thoroughly flushing them with water after each run or more often if necessary.

Place all foundation concrete against supporting material that is moist at the time of concrete placement. If additional water is required, uniformly apply it ahead of the concrete placement as directed by the Engineer. Do not place concrete on supporting material that is frozen. The Contractor may use a moisture barrier in lieu of controlling the foundation grade moisture when approved by the Engineer.

400-7.6 Placing Concrete by Belt Conveyor: Place concrete by means of a belt conveyor system with written Department authorization. Remove conveyor belt systems which produce unsatisfactory results before continuing operations. Take concrete samples for assurance testing at the discharge end of the belt conveyor system. Make available to the Engineer the necessary platform to

provide a safe and suitable place for sampling and testing. Remove any concrete placed in an unsatisfactory manner at no expense to the Department before continuing operations.

Use conveyor belt systems that do not exceed a total length of 550 feet [170 m], measured from end to end of the total assembly. Arrange the belt assembly so that each section discharges into a vertical hopper arrangement to the next section. To keep segregation to a minimum, situate scrapers over the hopper of each section to remove mortar adhering to the belt and to deposit it into the hopper. Equip the discharge end of the conveyor belt system with a hopper and a chute or suitable deflectors to cause the concrete to drop vertically to the deposit area.

In order to avoid delays due to breakdowns, provide stand-by equipment with an alternate power source prior to the beginning of the placement.

After the beginning of the placement, direct the discharge from the belt conveyor so that the concrete always falls on freshly placed concrete.

400-7.7 Placing Concrete by Pumping: In general, use concrete pumping equipment that is suitable in kind and adequate in capacity for the work proposed. Use a pump discharge line that has a minimum diameter of 4 inches [100 mm]. Use a pump and discharge lines that are constructed so that no aluminum surfaces are in contact with the concrete being pumped. Operate the pump to produce a continuous stream of concrete, without air pockets. When using cement slurry or similar material to lubricate the discharge line when pumping begins, collect such material at the point of discharge. Dispose of the collected slurry in areas provided by the Contractor. Control the pump discharge locations so that the placement locations of the various lots of concrete represented by strength test cylinders can be identified in the event the test cylinders indicate deficient strength. When concrete is placed by pumping, take all test samples of concrete at the end of the discharge line, except in accordance with the provisions of the Standard Operating Procedures for Quality Control of Concrete.

400-7.8 Consolidation: Consolidate the concrete by continuous working with a suitable tool in an acceptable manner, or by vibrating as set forth in 400-7.11. When not using vibrators, thoroughly work and compact all thin-section work with a steel slicing rod. Spade all faces, and flush the mortar to the surface by continuously working with a concrete spading implement.

400-7.9 Obstructions: In cases where, because of obstructions, difficulty is encountered in puddling the concrete adjacent to the forms, bring the mortar content of the mix into contact with the interior surfaces by vibrating the forms. Produce the vibrations by striking the outside surfaces of the forms with wooden mallets or by other satisfactory means. In placing concrete around steel shapes place it only on one side of the shape until it flushes up over the bottom flange of the shape on the opposite side, after which place it on both sides to completion. After the concrete has taken its initial set, exercise care to avoid jarring the forms or placing any strain on the ends of projecting reinforcing bars.

400-7.10 Requirements for Successive Layers: Generally, place concrete in continuous horizontal layers, approximately 12 inches [300 mm] thick. To avoid obtaining a plane of separation between batches, do not allow the time before placing the next successive layer to exceed 20 minutes, unless the Engineer determines that adequate fluidity exists in the underlying layer. Generally, leave each layer of concrete unfinished to secure efficient bonding with the overlying layer. To minimize the visibility of joints on exposed faces, finish the top surface of the concrete immediately adjacent to the forms of the exposed face, smoothing with a plaster mason's trowel. Where required, use inset form work to eliminate featheredges and to obtain concrete layers with a minimum thickness of 6 inches [150 mm]. Conduct the operation of depositing and consolidating the concrete so as to form a dense, impervious mass of uniform texture with smooth faces on exposed surfaces. Remove, dispose of, and replace defective concrete as directed by the Engineer and at no expense to the Department.

400-7.11 Vibration of Concrete:

400-7.11.1 General: Consolidate all concrete except seal, culvert floors, steel pile jackets, and concrete for incidental construction by the use of mechanical vibrators.

400-7.11.2 Vibrators: Provide adequate vibrators on the project that are approved by the Engineer before beginning concrete work. Generally, provide vibrators of the internal type. For thin

sections, where the forms are especially designed to resist vibration, the Contractor may use external vibrators. Use a vibrator with a minimum frequency of 4,500 impulses per minute with sufficient intensity and duration to cause complete consolidation of the concrete without causing segregation of the materials. For vibrating thin, heavily reinforced sections, use heads of such size to secure proper vibration of the concrete without disturbance of either the reinforcing steel or the forms.

400-7.11.3 Number of Vibrators Required: Use a sufficient number of vibrators to secure the compaction of each batch before the next batch is delivered, without delaying the delivery. In order to avoid delays due to breakdowns, provide at least one stand-by vibrator, with an appropriate power source.

400-7.11.4 Method of Vibration: Use vibrators to consolidate properly placed concrete. Do not use them to move concrete about in the forms. Insert the vibrators in the surface of concrete at points spaced to ensure uniform vibration of the entire mass of the concrete. Insert the vibrator at points that are no further apart than the radius over which the vibrator is visibly effective. Allow the vibrator to sink into the concrete by its own weight, and allow it to penetrate into the underlying layer sufficiently so that the two layers are thoroughly consolidated together. After thoroughly consolidating the concrete, withdraw the vibrator slowly to avoid formation of holes.

400-7.11.5 Hand Spading: When necessary in order to secure well-filled forms, free from aggregate pockets, honeycomb, bubbles, etc., spade the concrete by hand, along the surfaces of the forms and in all corners, following the vibration.

400-7.12 Columns: Place concrete in columns in one continuous operation for each lift as shown in the plans.

400-7.13 Slabs and Bridge Decks:

400-7.13.1 Bulkheads, Screed Rails, and Screeding Devices: Strike-off the concrete using an approved metal screed operating on rails or bulkheads. Use devices which do not contain aluminum parts. Prior to placing concrete, provide an approved screed capable of striking-off and screeding the surface of the slab or deck to the required shape. Set all necessary bulkheads and screed rails to the required grade. Use bulkheads, screed rails, and screeding devices that permit vertical profile adjustment to the grade, satisfactory for providing straight transverse slopes, differing transverse slopes broken as shown in the plans and/or tranversing slopes with changing grade along the longitudinal length of slab or deck. Locate the screed rails so the entire placement surface can be screeded to grade without using intermediate screed rails, unless approved otherwise by the Engineer.

Use a screed consisting of a truss or heavy beams that will retain it's shape under all working conditions, and a set of rotating drums with a diameter sufficient to carry a 2 inch [50 mm] mortar roll in front of and parallel to the axis of the drums, while making an initial pass. Adjust the drums to prevent mortar buildup forming behind the trailing edges of the drums. As an alternate to the drum type screed, a mechanical screed with a metal strike-off may be used. Equip the mechanical screed with mechanical vibrators to provide continuous uniform vibration to the entire length unless otherwise authorized by the Engineer. Small and irregularly shaped areas may be screeded in a manner approved by the Engineer.

400-7.13.2 Screed Demonstration: Subsequent to the placement of all reinforcing steel and prior to placing any slab or deck concrete, demonstrate that the proposed equipment and methods can finish the concrete to the specified grades while maintaining the specified cover over the reinforcement. Provide the demonstration over the entire length and width of the spans to be placed. During the demonstration, load the screed support rails that are cantilevered beyond the fascia girders to simulate the concrete loading that will be placed on the rail support system during actual placement and screeding operations.

400-7.13.3 Screeding Operations: Perform concrete placement and screeding as independently controlled mechanical operations. Ensure that the traverse of the screed and forward movement of the screeding equipment are independent of the movement of concrete placement equipment.

Level the concrete in front of the screed as near to the finished grade as possible to prevent the screed from rising off the rail and forming uneven ridges behind the screed. Pass the screed over the slab or deck as many times as necessary to obtain a satisfactory surface.

Provide a concrete surface true to grade and crown, and free of irregularities. Do not add water to the concrete surface to assist in finishing operations unless specifically authorized by the Engineer. If the Engineer permits the addition of water, apply only a fog mist, above the concrete surface, by means of approved power driven spray equipment.

400-7.13.4 Placing Operations: Select an approved concrete design mix which ensures complete placement of all slab or deck concrete between construction joints before initial set begins in the plastic concrete. On placements of 50 yd^3 [40 m^3] or less, the minimum placement rate is 20 yd^3/h [15 m^3/h]. On placements of greater than 50 yd^3 [40 m^3], the minimum placement rate is 30 yd^3/h [23 m^3/h].

The Engineer will not permit slab or deck placements until an acceptable plan for meeting the minimum placement rate is approved.

400-7.13.5 Concrete Decks on Steel Spans: Where concrete decks are placed on steel spans, release the temporary supports under the bridge before placing any concrete.

400-7.13.6 Concrete Decks on T-Beams: For cast-in-place T-beam construction, cast the slabs and beams in one continuous operation. As an exception, where special shear anchorage or keys are provided for in the plans or approved by the Engineer, the beams and slabs may be constructed in successive placements.

400-7.13.7 Diaphragms: Place concrete diaphragms at least 48 hours before the bridge deck slabs are placed unless otherwise indicated in the plans.

400-7.13.8 Weather Protection: Provide an approved means of protecting unhardened concrete from rain. Position the protection system to shield the concrete from rain and running water. Provide a shield impervious to water over the slab or deck concrete, of sufficient size to protect all areas of slab or deck concrete subject to water damage, and include a means of intercepting and diverting water away from freshly placed concrete. Arrange the equipment so that the weather protection system can be erected over unhardened concrete. When there is a possibility of rain during concrete placement operations, place the weather protection system in stand-by readiness, capable of being deployed in a timely manner. Use the weather protection immediately when rain begins so that slab or deck concrete damage will not occur. Do not place concrete during rain.

Assume responsibility for damage to the slab or deck in the case of failure of the weather protection system.

Describe the weather protection materials and methods in the Contractor's Level II Plan for Quality Control of Concrete.

400-7.14 Concrete Box Culverts: In general, place the base slab or footing of concrete box culverts, and allow them to set before constructing the remainder of the culvert. In this case, make suitable provision for longitudinal keys. Construct bottom slabs, footings, and apron walls as a monolith if practicable. Where transverse construction joints are necessary, place them at right angles to the culvert barrel, and make suitable provision for keys.

In the construction of box culverts having walls 6 feet [1.8 m] or less in height, the sidewalls and top slab may be constructed as a monolith or may place the concrete in the walls and allow it to set before placing the top slab concrete.

Where the height of the box culvert walls exceed 6 feet [1.8 m], place the walls, and allow the concrete to set at least 12 hours before placing the top slab concrete. In such cases, form keys in the sidewalls.

When casting the walls and top slabs of box culverts as a monolith, ensure that any necessary construction joints are vertical. Design all construction joints with formed keys. Provide keys that are beveled as shown in the plans or as directed, but do not allow the edge of the beveled material forming the key to be less than 1 1/2 inches [38 mm] from the edge of the concrete.

Construct each wingwall, if possible, as a monolith. Ensure that construction joints, where unavoidable, are horizontal and so located that no joints will be visible in the exposed face of the wing above the ground line.

Precast box culvert sections may be used in lieu of cast-in-place box culvert construction provided the provisions in Section 410 are satisfied.

400-8 Seals.

400-8.1 General: Wherever practicable, dewater all foundation excavations, and deposit the concrete in the dry as defined in 455-15.2. Where conditions are encountered which render it impracticable to dewater the foundation before placing concrete, the Engineer may authorize the construction of a concrete foundation seal of the required size. Then, dewater the foundation, and place the balance of the concrete in the dry.

When required to place seal concrete, the Contractor is responsible for the satisfactory performance of the seal in providing a watertight excavation for placing structural concrete. The Department will provide and pay for the seal concrete as an aid to the construction of the structure. Repair seal concrete as necessary to perform its required function at no expense to the Department.

400-8.2 Method of Placing: Carefully place concrete deposited under water in the space in which it is to remain by means of a tremie, a closed-bottom dump bucket of not less than 1 yd^3 [0.75 m^3] capacity, or other approved method. Do not disturb the concrete after depositing it. Deposit all seal concrete in one continuous placement. Do not place any concrete in running water, and ensure that all form work designed to retain concrete under water is watertight.

400-8.3 Use of Tremie: Use a tremie consisting of a tube having a minimum inside diameter of 10 inches [250 mm], constructed in sections having water-tight joints. Do not allow any aluminum parts to have contact with the concrete. Ensure that the discharge end is entirely seated at all times, and keep the tremie tube full to the bottom of the hopper. When dumping a batch into the hopper, keep the tremie slightly raised (but not out of the concrete at the bottom) until the batch discharges to the bottom of the hopper. Stop the flow by lowering the tremie. Support the tremie such as to permit the free movement of the discharge end over the entire top surface of the work and to permit its being lowered rapidly when necessary to choke off or retard the flow. Provide a continuous, uninterrupted flow until completing the work. Exercise special care to maintain still water at the point of deposit.

400-8.4 Time of Beginning Pumping: Do not commence pumping to dewater a sealed cofferdam until the seal has set sufficiently to withstand the hydrostatic pressure, and in no case earlier than 72 hours after placement of the concrete.

400-9 Construction Joints.

400-9.1 Location: Make construction joints only at locations shown in the plans or in the placement schedule, unless otherwise approved in writing. If not detailed in the plans or placement schedule, or in case of emergency, place construction joints as directed.

400-9.2 Provisions for Bond and Transmission of Shear: Use shear key reinforcement where necessary to transmit shear or to bond the two sections together.

400-9.3 Preparations of Surfaces: Before depositing new concrete on or against concrete which has hardened, re-tighten the forms. Roughen the surface of the hardened concrete in a manner that will not leave loosened particles, aggregate, or damaged concrete at the surface. Thoroughly clean the surface of foreign matter and laitance, and saturate it with water.

400-9.4 Placing Concrete: Continuously place concrete from joint to joint. Carefully finish the face edges of all joints which are exposed to view true to line and elevation.

400-9.5 Joints in Sea Water or Brackish Water: For concrete placed in sea water or brackish water, do not place any construction joints between points 2 feet [0.6 m] below extreme low tide and 4 feet [1.2 m] above extreme high tide.

400-9.6 Joints in Long Box Culverts: For long concrete box culverts, vertical construction joints may be placed at a spacing not less than 30 feet [9 m]. When using transverse construction joints, ensure that longitudinal reinforcing steel is continuous through the joint and that the joint is vertical.

400-9.7 Joints in Concrete Bridge Decks: When the plans provide an option for or require joints in concrete decks to be made with a saw cut, make the cut in accordance with plan details and no later than the day following concrete placement.

400-10 Expansion Joints.

400-10.1 General: After meeting the smoothness criteria in 400-15, construct expansion joints to permit absolute freedom of movement. Carefully remove all loose or thin shells of mortar likely to cause a spall with movement at a joint from all expansion joints as soon as possible.

400-10.2 Sealed Joints: Fill expansion joints with a preformed joint filler. Cut the filler to conform to the cross-section of the structure, and furnish it in as few pieces as practicable, using only a single piece in each curb section. Do not use small pieces that would tend to come loose. Prepare joints to be sealed and apply the sealer in accordance with approved manufacturer's directions.

400-10.3 Joint System Installation: After receiving the Engineer’s acceptance of the bridge deck and approach slab smoothness, install the joint following the manufacturers instructions, on a profile tangent between the ends of the deck and/or approach slab to within a +0 and -1/8 inch [+0 and -3.0 mm] variation as determined by string line parallel to the centerline of the structure at maximum 3 foot [1.0 m] intervals along the joint.

400-11 Contact and Bearing Surfaces.

400-11.1 Separation of Surfaces: In general, separate all contact surfaces between superstructure and substructure or end walls and between adjacent superstructure sections by a layer of 55 lb [25 kg] roofing felt.

400-11.2 Finishing of Bearing Surfaces: Pay special attention to bearing areas supporting shoes, bearing pads, or the ends of beams or slabs. In general, float-finish such areas, and grind them to true planes with carborundum. If precast, they may be cast against true metal surfaces. Check all such areas for accuracy with a steel straightedge prior to the setting of shoes, bearing pads or superstructure elements.

400-11.3 Beam and Deck Slab Units: Do not allow the bearing plate or bearing area plane of precast concrete beam and deck slab units, including prestressed units, to deviate from a true plane by more than 1/8 inch [3 mm] when both bearing areas of a unit are tested on a level plane. Provide a bearing plate or bearing area that also proves to be a true plane when tested in all directions of the plane surface with a steel straightedge. In the event that a 100% true plane is not achieved, the Engineer will accept a surface having not less than 80% of its area in a true plane provided the deviations from such true plane are evenly distributed. Remove minor convex projections by grinding with an abrasive stone. The Engineer will accept minor depressions, provided that they amount to not more than 20% of the bearing area, are evenly distributed over the entire bearing area, and are not deeper than 1/8 inch [3 mm].

400-11.4 Bearing Pads: Use bearing pads for seating bridge shoes, ends of beams, and slabs of the types specified or required in the plans.

Furnish and install Composite Neoprene Pads as detailed in the plans. Place neoprene pads, where specified or required, directly on masonry surfaces finished in accordance with the requirements of this Article. Ensure that pads, bearing areas of bridge seats, and metal bearing plates are thoroughly cleaned and free from oil, grease, and other foreign materials.

Exercise care in fabrication of related metal parts to avoid producing conditions detrimental to the performance of the pads, such as uneven bearing, excessive bulging, etc.

400-12 Anchor Bolts and Dowels.

Set anchor bolts and dowels as specified in 460-30.

Galvanize all anchor bolts as specified in 460-30.

400-13 Epoxy Bonding Compounds.

Where epoxy bonding compounds for bonding concrete are specified or required, apply the epoxy bonding materials only to clean, dry, structurally sound concrete surfaces. Provide surface preparation, application, and curing of epoxy bonding compound in strict accordance with the manufacturer's recommendations for each particular application. Use an epoxy bonding compound listed on the Department's Qualified Products List.

400-14 Removal of Forms.

Use the table below as the criterion for minimum time or compressive strength required before removal of forms or supports.

When using the time period criterion, include in the time period all days except days in which the temperature falls below 40ºF [4ºC].

Use the specified 28-day minimum compressive strength value as stated in 346-3.1 for each Class of Concrete utilized.

Location of Concrete Placement	Minimum Time for Form Removal for any Strength Concrete	Minimum (%) of 28-day Compressive Strength for Form Removal
(1) Centering under girders		
(a) Class II (Bridge Deck)	12 days	75
(b) Class III	12 days	70
(c) Class IV	12 days	60
(d) Class V	12 days	50
(2) Deck slabs, top slabs of culverts and bottom of caps, forms under sidewalks, and safety curb overhangs extending more than 2 feet [0.6 m]		
(a) Class II (Bridge Deck)	seven days*	75*
(b) Class II (Other than Bridge Deck)	seven days	75
(c) Class III	seven days	70
(d) Class IV	seven days	60
(e) Class V	seven days	50
(3) Walls, piers, columns, sides of beams and other vertical surfaces	24 hours**	50**
(4) Front face form of curbs	6 hours	70

* Reference 400-16.1.1 for alternate criteria.

**Do not place additional load on the section until 70% of the specified 28-day concrete strength is attained. Also, refer to 400-7.4.

When using the percent of required strength, cast test cylinders from representative concrete for compressive strength determination.

Provide the Engineer with a minimum of three cylinder breaks, established at different curing times and concrete strength, so he can develop a curve relating curing time to concrete strength. Cure such test cylinders as nearly as practical in the same manner as the concrete in the corresponding structural component, and test them in accordance with FM 1-T 022 and FM 1-T 023. Perform casting, curing, and testing at no expense to the Department and under the observation of the Engineer. When approved by the Engineer, the Contractor may use test results certified by a testing laboratory approved by the Department as a basis for form removal. When concrete strength tests indicate a compressive strength equal to or greater than the percentage of specified strength shown in the table above, the

Contractor may remove the forms. Curing periods so established may be used so long as the ambient temperature is equal to or greater than the temperature existing during the curing of the test cylinders. When the temperature falls 15ºF [8ºC] or more below the ambient temperature existing during the test cylinder curing period, repeat the test procedure outlined above, and establish a different curing period for the different ambient temperature.

Do not remove forms at any time without the consent of the Engineer. Even when the Engineer provides consent to remove the forms, the Contractor is responsible for the work.

400-15 Finishing Concrete.

400-15.1 General Surface Finish (Required for All Surfaces): After placing and consolidating the concrete, strike-off all exposed surfaces to the lines and grades indicated in the plans in a manner that will leave a surface of uniform texture free of undesirable surface irregularities, cavities, and other defects. Cut back metal ties supporting reinforcement, conduit, and other appurtenances a minimum of 1 inch [25 mm] from finished surface. After removing excess mortar and concrete and while the concrete is still in a workable state, carefully tool all construction and expansion joints. Leave joint filler exposed for its full length with clean edges. Ensure that finished work in addition to that specified above is compatible and complementary to the class of surface finish required.

Immediately after removing forms from any exposed concrete surface, remove all fins and irregular projections flush with the surface. Clean, saturate with water, and carefully point with mortar all holes, material tie cavities, honeycomb, chips, and spalls.

In the event unsatisfactory surfaces are obtained, repair these surfaces by methods approved by the Engineer or the affected concrete will be rejected. Repair any surface or remove rejected concrete at no expense to the Department.

For pointing, use mortar that is a blended mixture of cement and fine aggregates, mixed in the same proportions used for these components in the class of concrete being finished and composed of materials from the same source as used in the class of concrete being placed. To prevent shrinkage, allow the mortar to take its initial set, then rework and apply it without adding water. Carefully roughen and clean cavities to be filled with mortar to provide a mechanical bond. Exercise care during the roughening process to prevent additional defacement and damage to the formed surface.

400-15.2 Surface Finishes:

400-15.2.1 General: In addition to the general surface work specified for all exposed concrete surfaces, the Engineer may require one of the classes of surface finish listed below. For all such exposed surfaces, begin finish work for the applicable class specified, along with the general finish work, immediately after removal of the forms. In order to further ensure the required quality of the finish, remove forms no later than the minimum time specified for the forms to remain in place. Satisfactorily repair finished concrete surfaces which are subsequently disfigured or discolored at no expense to the Department.

Provide the required class of surface finish for the various items of structural concrete as shown in the plans.

400-15.2.2 Class 1 Surface Finish: As soon as the pointing has sufficiently set, thoroughly saturate the exposed surfaces with water, and rub them with a medium coarse carborundum stone. Continue rubbing until the surface has been ground to a paste and remove all form marks, irregularities, and projections. In this process, do not introduce any additive material other than water. After the rubbing has produced a smooth surface of uniform color, allow the material which has been ground to a paste to reset under proper curing conditions. Subsequently, as a second operation, re-saturate the concrete surfaces with water, and thoroughly rub them with a fine carborundum stone. Continue this rubbing until the surface has a smooth, fine grain texture of uniform color.

The Contractor may substitute a Class 5 applied finish coating in accordance with 400-15.2.6 as an alternate surface finish on all areas where Class 1 surface finish is specified.

400-15.2.3 Class 2 Surface Finish: As soon as pointing has sufficiently set, thoroughly saturate the exposed concrete surfaces with water and rub them with a medium coarse carborundum stone. Continue rubbing until the surface has been ground to a paste and remove all form marks, irregularities, and projections. In this process, do not introduce any additive material other than water.

After rubbing has produced a smooth surface finish, of uniform color, carefully brush the material which has been ground to a paste to a uniform texture, and allow it to reset under proper curing conditions. Carefully protect these surfaces from disfigurement and discoloration during subsequent construction operations.

400-15.2.4 Class 3 Surface Finish: Where this surface finish is specified, use metal forms or timber forms with a form liner. Where specified or required on the plans, use No. 89 coarse aggregate for concrete.

After concrete has been placed in the forms and compacted, finish all exposed surfaces which are not contained by the forms to produce a surface texture as nearly equal to that produced by the form as practicable. Generally, finish unformed surfaces to a smooth, dense surface with a steel trowel.

Perform all work, including general surface finish work, in a manner that will preserve the same surface texture and color produced by the form. Pointed areas may be rubbed with a dry carborundum stone.

400-15.2.5 Class 4 Floor Finish:

400-15.2.5.1 General: Apply a Class 4 finish on bridge decks and concrete approach slabs. On Short Bridges (bridges and approach slabs having a combined length less than or equal to 300 feet [100 m]), meet the finish and smoothness requirements of 400-15.2.5.2 and 400-15.2.5.3. On Long Bridges (bridges and approach slabs having a combined length greater than 300 feet [100 m]), meet the finish and smoothness requirements of 400-15.2.5.2 and 400-15.2.5.4. After meeting the curing requirements of 400-16 and the smoothness requirements, herein, groove the bridge deck and approach slab. Do not install expansion joints, except open joints, until the smoothness criteria has been met and accepted by the Engineer.

Meet the finish and smoothness requirements of 400-15.2.5.2 and 400-15.2.5.3 for all bridge widenings unless shown otherwise in the Contract Documents.

400-15.2.5.2 Plastic Finish and Surface Finish: After screeding is completed, check the surface of the plastic concrete with a 10 foot [3.048 m] straightedge, positioning and half-lapping the straightedge parallel to the centerline to cover the entire surface. Immediately correct deficiencies of more than 1/8 inch [3 mm], measured as an ordinate between the surface and the straightedge.

Finish the concrete surface to a uniform texture using a burlap drag, fine bristle broom or float. Finish the deck to a smooth surface having a sandy texture without blemishes, marks or scratches deeper than 1/16 inch [1.6 mm]. Decks to be planed will not require a sandy texture, and blemishes, marks or scratches may be up to 3/16 inch [5 mm] in depth. All other finish requirements will apply.

400-15.2.5.3 Smoothness Requirements for Short Bridges (including approach slabs): Perform a final straightedge check with a 10 foot [3.048 m] straightedge, positioning and half-lapping the straightedge parallel to the centerline, approximately 5 feet [1.5 m] apart to cover the entire surface. Correct all irregularities greater than 3/16 inch [5 mm] measured as an ordinate to the straightedge, by grinding. Perform grinding by the abrasive method using hand or power tools or by machine, to leave a smooth surface within a 1/8 inch [3 mm] tolerance.

400-15.2.5.4 Smoothness Evaluation, Bridges greater than 300 feet [100 m] in length (including approach slabs): Provide a smoothness evaluation of the completed bridge deck and concrete approach slab riding surfaces by a computerized Cox California-type profilograph in accordance with the criteria herein and FM 5-558. Furnish this evaluation through an independent provider approved by the Engineer, using equipment calibrated by the Engineer. The riding surfaces

subject to this evaluation include all traffic lanes, all full width acceleration and deceleration lanes, and lanes planned for future use, on both the bridge deck and concrete approach slabs. For areas outside the traffic lanes, perform testing and meet the smoothness requirements for short bridges.

Prior to initial profilograph testing and grooving, complete work on the bridge deck, except for expansion joint installations. Thoroughly clean and clear the bridge deck and approach slab area to be evaluated for smoothness of all obstructions and provide the smoothness evaluation. Ensure that no radio transmissions or other activities that might disrupt the automated profilograph equipment are allowed during the evaluation.

Average the Profile Index Value for the bridge deck, including the concrete approach slabs, for the left and right wheel path of each lane. The maximum allowable Profile Index Value for acceptable smoothness is 10 inches per mile [158 mm per kilometer] utilizing the 0.2 inch [5 mm] blanking band. Apply this criteria to each 300 feet [100 m] of each lane. Additionally, correct individual bumps or depressions exceeding a cutoff height of 0.3 inch [7.6 mm] from a chord of 25 feet [7.620 m] (see ASTM E-1274) on the profilograph trace and ensure that the surface meets a 1/4 inch in 10 feet [6 mm in 3.048 m] straightedge check made transversely across the deck and approach slabs as determined necessary by the Engineer. Provide at least one profilograph test per bridge deck and approach slabs. A single test will occur only when the initial profilograph results satisfy all acceptance criteria. Provide additional profilograph testing as necessary following longitudinal planing and any other actions taken to improve smoothness, until a profile meeting the acceptance criteria is obtained.

For bridges that do not pass the profilograph smoothness criteria given above, longitudinally plane the entire bridge deck and concrete approach slab surfaces using a self-propelled grinding machine with gang mounted diamond saw cutting blades specifically designed for such work. Use a machine with a minimum wheel base length of 15 feet [4.57 m], constructed and operated in such manner that it does not cause strain or damage to the deck surface, excessive ravels, aggregate fractures or spalling. The equipment shall be approved by the Engineer. Perform longitudinal planing parallel to the roadway centerline, and provide a consistent, textured surface that will meet or exceed the profilograph smoothness criteria. Clean the surface of all slurry/debris generated during this work concurrently with operation of the machine. Control the work to limit surface removal by all passes of the longitudinal planing equipment and any other grinding to a total maximum depth of 1/2 inch [13 mm].

After planing, reevaluate the pavement smoothness using the profilograph testing described above. Perform additional retesting with the same equipment if further corrective measures are necessary.

400-15.2.5.5 Grooving: After the concrete surface profile has been accepted by the Engineer, and prior to opening the bridge to traffic, groove the bridge deck and approach slabs perpendicular to the centerline of the structure. Cut grooves into the hardened concrete using a mechanical saw device which will leave grooves nominally 1/8 inch [3 mm] wide and 3/16 inch [5 mm] deep. Space the grooves apart in random spacing center of grooves in the following sequence: 3/4 inch [20 mm], 1 1/8 inch [30 mm], 5/8 inch [15 mm], 1 inch [25 mm], 5/8 inch [15 mm], 1 1/8 inch [30 mm], 3/4 inch [20 mm] in 6 inch [150 mm] repetitions across the width to be grooved in one pass of the mechanical saw device. One 6 inch [150 mm] sequence may be adjusted by 1/4 sequence increments to accommodate various cutting head widths provided the general pattern is carried out. The tolerance for the width of the grooves is +1/16 to - 0 inch [+1.6 to - 0 mm] and the tolerance for the depth of grooves is ±1/16 inch [±1.6 mm]. The tolerance for the spacing of the grooves is ±1/16 inch [±1.6 mm].

Cut grooves continuously across the deck or approach slab to within 18 inches [450 mm] of gutter lines at barrier rail, curb line and median divider. At skewed metal expansion joints in bridge deck surfaces, adjust groove cutting by using narrow width cutting heads so that all grooves of the bridge deck surface or approach slab surface end within 6 inches [150 mm], measured normal to centerline of the joint, leaving no ungrooved surface adjacent to each side of the joint greater than 6 inches [150 mm] in width. Ensure that the minimum distance to the first groove, measured normal

from the edge of the concrete joint or from the junction between the concrete and the metal leg of the armored joint angle, is 1 inch [25 mm]. Produce grooves that are continuous across construction joints or other joints in the concrete surface less than 1/2 inch [13 mm] wide. Apply the same procedure described above where the gutter lines at barrier rails, curb lines and median dividers are not parallel to the centerline of the bridge to maintain the 18 inches [450 mm] maximum dimension from the grooves to the gutter line. Cut grooves continuously across formed concrete joints.

400-15.2.6 Class 5 Applied Finish Coating:

400-15.2.6.1 General: Place an applied finish coating upon all concrete surfaces where the plans indicate Class 5 Applied Finish Coating. Apply the finish coating after completion of the general surface work specified for all exposed concrete surfaces. Select an Applied Finish Coating from the Departments Qualified Products List.

400-15.2.6.2 Material: For the coating material, use a commercial product designed specifically for this purpose. Use only coating material that is manufactured by one manufacturer and delivered to the job site in sealed containers bearing the manufacturer's original labels. Make available a copy of the manufacturer's printed instructions to the Engineer.

Use a coating material that, in the finished state, is capable of accommodating the thermal and elastic expansion ranges of the substrate without cracking.

400-15.2.6.3 Surface Preparation: Prepare the surface prior to the application of an applied finish coating by providing surface finish in accordance with the requirements of 400-15.1. The Engineer will not require air pockets that are 1/4 inch [6 mm] or less in width and depth to be grouted prior to application of the finish coating. Fill air pockets larger than 1/4 inch [6 mm] in width and depth with a grout composed of one part portland cement, two parts screened and washed sand graded to pass the 16 mesh [1.18 mm] sieve with not more than 5% retained on the 30 mesh [600 μm] sieve, and sufficient water to produce a thick liquid mix. As an alternate, a grout composed of the same materials used for the applied finish coating may be used. Apply the grout by filling the air pockets using burlap pads, float sponges, or other acceptable methods. As soon as the grout has taken its initial set, brush the surface to remove all loose grout, leaving the surface smooth and free of any air holes. Ensure that the surface to be coated is free from efflorescence, flaking coatings, dirt, oil, and other substances deleterious to the applied finish coating. Prior to application of the finish coating, prepare the surfaces in accordance with the manufacturer's recommendations, and ensure that they are in a condition consistent with the manufacturer's requirements.

400-15.2.6.4 Application: Apply the finish coating in a manner recommended by the manufacturer. When applying the finish coating by spraying, supply heavy duty spray equipment capable of maintaining a constant pressure necessary for proper application. Mix, apply, and cure all coating materials in accordance with the manufacturer's printed instructions. Apply the finished coating at a rate of 50 ± 10 ft^2/gal [1.25 ± 0.25 m^2/L].

400-15.2.6.5 Finished Product: Produce a texture of the completed finish coat that is generally similar to that of rubbed concrete. Ensure that the completed finished coating is tightly bonded to the structure and presents a uniform appearance and texture. If necessary, apply additional coats to produce the desired surface texture and uniformity.

Upon failure to adhere positively to the structure without chipping, flaking, or peeling, or to attain the desired surface appearance, remove coatings entirely from the structure, and reapply the finish coating after surface preparation until achieving the desired finished product. Do not allow the average thickness of the completed finish coating to exceed 1/8 inch [3 mm].

400-15.2.6.6 Color: Use a color for the applied finish coating that is similar to Federal Color Standard No. 595B, Table VIII, Shade No. 36622 or as specified in the plans.

400-15.2.6.7 Material Tests and Certification: Before any portion of any shipment of finish coating is applied on the project, furnish the Engineer with a certificate from the manufacturer attesting that the commercial product furnished conforms to the same formula as that previously subjected to the tests specified below and approved. Attach copies of the current test reports to

the certificate. The Engineer will not accept any test report for tests made more than four years prior to shipment to the project.

Ensure that all testing is performed by a qualified commercial testing laboratory acceptable to the Department.

The Contractor is responsible for the cost of testing necessary to provide material certification.

Prior to use of the applied finish coating on any structure, meet the requirements of the tests listed below:

(a) Freeze-Thaw Tests: Subject the applied finish coating to Freeze-Thaw Cycle Tests as follows:

(1) Cast and cure three concrete specimens, not less than 4 by 6 by 6 inches [102 by 152 by 152 mm], of the mix design for the structure. Moist cure the specimens for 14 days with a drying period in room air at 60 to 80ºF [16 to 27ºC] for 24 hours before coating the specimens with the applied finish.

Take caution that there is no excessive oil on specimen forms. Apply the finish coating to the sides of specimens (brush permitted) at a spreading rate of 50 ± 10 ft^2/gal [1.25 ± 0.25 m^2/L]. Cure cementitious coatings at room temperature and 50% relative humidity for 24 hours, at room temperature and 90% relative humidity for 48 hours, and at room temperature and 50% relative humidity for four days for a total cure of seven days. Cure other coatings at room temperature for 48 hours. After the completion of curing:

(2) Immerse in water at room temperature (60 to 80ºF [16 to 27ºC]) for three hours; remove and:

(3) Place in cold storage at -15º F [-26ºC] for one hour; remove and;

(4) Thaw at room temperature (60 to 80ºF [16 to 27ºC]) for one hour.

(5) Repeat Steps three and four to complete a total of 50 cycles. At the end of 50 cycles Freeze-Thaw Test, verify that the specimens show no visible defects.

(b) Accelerated Weathering: Subject the applied finish coating to a 5,000-hour exposure test in Twin-Carbon-Arc-Weather-ometer, ASTM G 23, Type D, at an operating temperature of 145ºF [63ºC]. Perform this test at 20-minute cycles consisting of 17 minutes of light and three minutes of water spray plus light. At the end of said exposure test, verify that the exposed samples show no chipping, flaking, or peeling. Prepare the panels for this test by applying the coating at a spreading rate of 50 ± 10 ft^2/gal [1.25 ± 0.25 m^2/L] to both sides and edges of panels cut from asbestos cement shingles conforming to Federal Specification SS-S-346, Type I. Use curing time as in (a).

(c) Fungus Growth Resistance: Ensure that the applied finish coating to be used passes a fungus resistance test as described by Federal Specification TT-P-29G with a minimum incubation period of 21 days where no growth is indicated after the test.

(d) Abrasion Resistance: Ensure that the applied finish coating to be used passes the 3000 L sand abrasion test, Federal Test Method Standard 141A Method 6191 Abrasion Resistance - Falling Sand.

Prepare the specimens for this test by applying the coating to a cleaned steel panel at a spreading rate of 50 ± 10 ft^2/gal [1.25 ± 0.25 m^2/L]. Cure at room temperature for 21 days.

(e) Impact Resistance: Apply the coating to a concrete panel prepared in accordance with Federal Test Method Standard 141A, Method 2051 at a spreading rate of 50 ± 10 ft^2/gal [1.25 ± 0.25 m^2/L], and allow it to cure for 21 days at room temperature. Then, run the test using the Gardner Mandrel Impact Tester and its method, applying an impact load of 24 inch-pounds [2.7 N·m]. Verify that the coating shows no chipping under this impact load.

(f) Salt-Spray Resistance Test: Coat a concrete specimen with the applied finish coating at a rate of 50 ft^2/gal ± 10% [1.25 m^2/L ± 10%], and cure it for 21 days at room temperature.

Using ASTM B 117 test method, expose the coated specimen to a 5% salt solution for 300 hours where the atmospheric temperature is maintained at 90 ± 2ºF [32 ± 1ºC]. At the end of 300 hours of exposure, verify that the coating shows no ill effects, loss of adhesion or deterioration.

(g) Flexibility Test: Coat a sheet metal specimen with the applied finish coating at a rate of 50 ± 10 ft^2/gal [1.25 ± 0.25 m^2/L]. Bend the coated specimen 180 degrees over a 1 inch [25 mm] round mandrel. After bending, verify that the coating shows no breaking.

Supply a service record showing that the finish coating material has a satisfactory service record for a period of not less than five years prior to the date of submission of the service record and that the finish coating has shown satisfactory service characteristics without peeling, chipping, flaking, or nonuniform change in texture or color. Name a specific structure for the specific product for the service record.

In addition to the above, ensure that the manufacturer submits, for each batch of material used, the following product analysis data:

(a) Weight per gallon [liter].
(b) Viscosity [Consistency] (Krebs Units).
(c) Weight percent pigment.
(d) Weight percent vehicle solids.
(e) Infra-red spectra of vehicle solution.

400-15.2.7 Final Straightedging for Surfaces to Receive Asphaltic Concrete Surface: Test the slab surfaces of poured-in-place floors which are to be surfaced with an asphaltic concrete wearing course for trueness with a 10 foot [3.048 m] straightedge, as specified above. As an exception, correct only irregularities of more than 1/4 inch [6 mm] measured as an ordinate (either above or below the general contour of the surface). The Engineer will not require belting or brooming of slabs that are to be surfaced with an asphaltic concrete wearing course. For curing, meet the requirements specified for other floor slabs.

400-15.2.8 Finishing Bridge Sidewalks: Provide bridge sidewalks, that are not finished in accordance with the requirements of Section 522, a Class 4 finish.

400-16 Curing Concrete.

400-16.1 General:

400-16.1.1 Methods and Curing Time: For surfaces other than bridge deck slabs on which forms are kept continuously in place, without loosening, for a period of 72 hours or more, the Engineer will not require further curing. For form removal from bridge deck slabs, meet the requirements of 400-14 or the following:

Bottom forms may be removed for bridge deck slabs after the concrete has attained at least 75% of the minimum 28-day strength as specified in 346-3.1 and a minimum curing time of 72 hours has occurred with the forms kept continuously in place, without loosening. Determine the concrete strength by procedure described in 400-14. Then, apply membrane curing compound in accordance with 400-16.1.2 no later than a two hour time period after form removal.

400-16.1.2 Curing Methods: For surfaces other than bridge deck slabs, continuous-moisture curing, steam curing, membrane curing compound, or an impervious covering for any concrete parts may be used. Mix membrane curing compound with a mechanically operated mixer immediately prior to each use to provide uniform consistency. Apply curing compound in accordance with the manufacturer's recommendations, subject to the rate of application specified herein. If curing compound is to be applied by spraying, use a compressor driven sprayer of sufficient size to provide uniform spray at the nozzle. Keep all nozzles clean, and ensure that they provide uniform mist. The Engineer will require

standby equipment in case of mechanical failure. The Engineer will allow hand-held pump-up sprayers for standby equipment. However, do not use the hand held pump-up sprayers except in case of mechanical failure or for applying compound on Class I Concrete (non-pavement). If these requirements are not met, the Engineer will suspend further concrete placements until proper control is re-established. Apply membrane curing compound at a rate of at least one gallon to every 200 ft^2 [1 liter to every 5 m^2] of exposed surface to be cured. Provide a membrane curing compound and impervious covering that is continuous, flexible, and without defects and that retains the required moisture in the concrete.

Keep cover materials used in continuous moisture curing methods continuously wet for a period of 72 hours.

400-16.2 Curing Bridge Deck Slabs: Apply Type 2 membrane curing compound as specified in 925-2 to the exposed surfaces of slabs which are not formed immediately after finishing the concrete. The Engineer will not require further application of curing compound prior to placing the curing blankets.

Place curing blankets on all exposed surfaces which are not formed. Place them as soon as possible without affecting the surface texture. Place the curing blankets as approved by the Engineer, overlapping sufficiently to form an effective moisture seal. Before using curing blankets, mend tears, splits, or other damage that makes them unsuitable. Discard curing blankets that are not mendable. Use curing blankets consisting of polyethylene-coated blankets or quilted blankets of cotton, burlap, or other suitable water absorbent material weighing not less than 10 oz per yard, 40 inches wide [0.3 kg/m^2].

Ensure that polyethylene used for coating blankets is white opaque and has a minimum thickness of 0.004 inch [0.1 mm]. Ensure that it is securely bonded to the blanket material so that there will be no separation of the materials during handling and curing of the concrete. Use polyethylene coated blankets that have a maximum moisture loss of 0.11 lb/ft^2 [0.55 kg/m^2].

Wet all curing blankets immediately after satisfactorily placing them and maintain them in a saturated condition throughout the seven day curing period. Supply a sufficient quantity of fresh water at the job site for wetting the blankets.

Where a bridge deck slab is to be subjected to walking, wheeling, or other approved construction traffic within the seven day curing period, protect the curing blankets and the slab surface from damage by placing wooden sheeting, plywood or other approved protective material in the travel areas.

When the ends of the curing blankets are rolled back to permit screeding of adjacent bridge deck slabs, keep the exposed surfaces wet by spraying water throughout the period of exposure.

The Engineer will not consider surfaces of parapets, sidewalk, end post, and horizontal and vertical faces of curbs to be a part of the bridge deck slab, and the Contractor shall cure the surfaces as specified in 400-16.1.2.

400-16.3 Curing Construction Joints: Cure construction joints for 72 hours by leaving the form in place without loosening or by continuous-moisture curing. The Continuous-moisture curing of construction joint areas may be accomplished by: covering the joints with at least three layers of burlap or other water absorbent material and maintaining the same in a moist condition; covering the joints with a 1 1/2 inch [38 mm] deep layer of sand or sawdust and maintaining the same in a moist condition; or sealing the areas beneath with an impervious layer of plastic material and maintaining the sealed condition.

Cure construction joint areas by continuous-moisture curing or by leaving the form in place. Construction joint areas include, but are not limited to, those areas: at the top of footings; in pier columns; in bascule piers below the trunion elevation; and in pier crash walls and pier struts. As an exception to this requirement, construction joint surface areas may be cured where projecting reinforcing steel or other interferences cause continuous-moisture or form curing to be impractical for 72 hours with a clear membrane curing compound as specified in 400-16.1.2. Construction joint surface areas include, but are not limited to, those areas: beneath a barrier wall; at the tops of diaphragms; between the backwall and the wingwall of bent caps; in drainage inlets, manholes, and junction boxes; between curtain walls of bent and pier caps; in non-reinforced pipe endwalls; and between pedestals and the top of footings for signs and highmast lighting.

400-17 Protection of Concrete.

400-17.1 Opening to Traffic: Close concrete bridge floor and culverts to traffic for a period of at least 14 days after placing and for such additional times as deemed advisable. In the operation of placing, the Contractor may wheel concrete across previously poured slabs after they have set for 24 hours, provided plank runways are used to keep the loads over the beams.

400-17.2 Storing Materials on Bridge Slabs: Do not store heavy equipment or material, other than light forms or tools, on concrete bridge slabs until 14 days after they have been poured. For all stockpiles, tools, and equipment stored on bridge slabs at any time, obtain prior approval by the Department, and the Engineer will require any such stored materials or equipment to be dispersed in order to avoid overloading any structural part.

400-17.3 Time of Placing Superstructure: In the case of piers or bents with concrete caps, do not place the weight of the superstructure or of beams on the caps until they have reached the ages required in the following table:

Superstructure	Seven days
Beams	Three days

400-17.4 Alternate Procedure: As an alternate procedure, in lieu of the time delay periods set forth in 400-17.1 and 400-17.3, test beams may be cast from representative concrete and cure them identically with the concrete in the corresponding structural component. Test the test beams in accordance with FM 1-T 023 and FM 1-T 097. When the test results indicate a flexural strength of 550 psi [3.8 MPa] or more, concrete bridge floors and culverts may be opened to traffic and the superstructure and beams placed on caps.

400-18 Precast Planks, Slabs, and Girders.

400-18.1 General: Where so shown in the Contract Documents, the Contractor may construct concrete planks, slabs, girders, and other structural elements by precasting. In general, use a method that consists of casting structural elements in a casting yard, curing as specified in 400-16, transporting them to the site of the work, installing them on previously prepared supports and, where so shown in the plans, joining them with poured-in-place slabs or keys. Handle and install precast prestressed members as specified in Section 450.

400-18.2 Casting: Cast precast elements on unyielding beds or pallets. Use special care in casting the bearing surfaces on both the elements and their foundations in order that these surfaces shall coincide when installing the elements. Check bearing surfaces on casting beds with a level and a straightedge prior to the casting. Similarly check corresponding surfaces on the foundations during finishing operations.

400-18.3 Poured-in-Place Keys: Where precast elements are to be joined with poured-in-place keys, carefully align the elements prior to pouring the keys.

400-18.4 Surface Finish: Finish the surface as specified in 400-15, except that where precast slabs and poured-in-place keys form the riding surface, give the entire surface a broomed finish.

400-18.5 Moving, Placing, and Opening to Traffic: Reinforced precast members may be moved from casting beds, placed in the structure, and opened to traffic at the ages shown in the following table:

Handling from casting beds to storage areas ..... 7 days
Placing in structure ..... 14 days
Opening to traffic:
Precast elements ..... 14 days
Cast-in-place slabs over precast girders ..... 14 days
Cast-in-place keys joining precast slabs ..... 7 days

As an alternate procedure, in lieu of the time delay periods set forth above, test beams may be cast from representative concrete, and cure them identically with the concrete in the corresponding structural component. Test the test beams in accordance with FM 1-T 023 and FM 1-T 097. When the test results indicate a flexural strength of 550 psi [3.8 MPa], or more, any of the operations listed above may proceed without completing the corresponding time delay period.

400-18.6 Setting Prestressed Slabs: Before permitting construction equipment on the bridge to erect slab units, submit sketches showing axle loads and spacing and a description of the intended method of setting slab units to the Engineer for approval. Do not use axle loads, spacing, and methods of setting which produce stresses in the slab units greater than the allowable stress.

400-18.7 Protection of Precast Elements: The Contractor is responsible for the safety of precast elements during all stages of construction. The Engineer will reject any precast elements that become cracked, broken, seriously spalled, or structurally impaired. Remove rejected precast elements from the work at no expense to the Department.

400-18.8 Form Material: Form material used to form hollow cores may be left in place. Ensure that the form material is neutral with respect to the generating of products harmful to the physical and structural properties of the concrete. The Contractor is responsible for any detrimental effects resulting from the presence of the form material within the precast element.

400-19 Cleaning and Coating Concrete Surfaces.

Water blast and coat existing concrete surfaces as shown in the plans. Use water blast equipment producing a minimum working pressure of 750 psi [5 Mpa] with a gauge at or near the nozzle to confirm the working pressure. Apply a Class 5 Applied Finish Coating unless otherwise directed in the plans.

400-20 Approach Slabs.

Construct approach slabs at the bridge ends in accordance with the applicable requirements of Section 350 using Class II (Bridge Deck) concrete. Place the reinforcement as specified in 350-7 and Section 415.

The approach slab may be opened to traffic, vehicular or construction equipment, 14 days after concrete placement or after the prescribed curing period has elapsed and the concrete has attained the required 28 day cylinder strength.

400-21 Classification of Cracks in Concrete Structures to be Sealed.

Cracks are classified as structural and nonstructural. Do not seal or repair structural cracks without having a repair procedure approved in advance by the Engineer. Seal nonstructural cracks in accordance with the criteria listed in Table I below. Structural cracks are those which are induced by external forces which produce internal stresses exceeding the tensile strength of the concrete, commonly referred to as working cracks, and those caused by overloads. Nonstructural cracks are those which appear as a result of atmospheric effects and localized constraint effects, commonly called shrinkage cracks. In any case, the Engineer will determine the classification of cracks.

Table I			
Criteria for Sealing Nonstructural Cracks During Construction			
Environment (*4)	Crack Width	Location (*2)	Treatment (*3) (*1)
Extremely Aggressive	Less than 0.006 in. [0.15 mm]	Substructure and Superstructure	Coat with penetrant sealer
	Greater than 0.006 in. [0.15 mm] and less than 0.012 in. [0.30 mm]	Substructure including Superstructure less than 18 feet [5.5 m] above existing ground or high water elevation	Epoxy injection
		Superstructure including Substructure more than 18 feet [5.5 m] above existing ground or high water elevation	Coat with penetrant sealer
	Greater than 0.012 in. [0.30 mm] and less than 0.025 in. [0.60 mm]	Substructure and Superstructure	Epoxy injection
Moderately Aggressive	Less than 0.006 in. [0.15 mm]	Substructure and Superstructure	No treatment
	Greater than 0.006 in. [0.15 mm] and less than 0.012 in. [0.30 mm]	Substructure including Superstructure less than 18 ft [5.5 m] above existing ground or high water elevation	Coat with penetrant sealer
		Superstructure including Substructure more than 18 ft [5.5 m] above existing ground or high water elevation	No treatment
	Greater than 0.012 in. [0.30 mm] and less than 0.025 in. [0.60 mm]	Substructure and Superstructure	Coat with penetrant sealer
Slightly Aggressive	Less than 0.025 in. [0.60 mm]	All locations	No treatment

Notes: (*1) Cracks greater than 0.025 inch [0.60 mm] require individual investigation. Report these cracks to the Engineer for initiation of an investigation.
(*2) When the substructure crack elevation is 18 feet [5.5 m] above the high water elevation or ground level, use the same method of treatment as the superstructure for that environment.
(*3) (a) Perform epoxy injection of cracks in accordance with Section 411. Apply penetrant sealers in accordance with Section 413. Select materials used for sealing and for epoxy injection from the Department's Qualified Products List.
(b) Use penetrant sealers to repair cracks that are compatible with previously applied materials.
(c) Use sealers to repair riding surfaces that are designated for that purpose.
(d) The Contractor may also repair riding surfaces of bridge decks with a methacrylate sealer for crack widths greater than 0.006 inch [0.15 mm] in extremely aggressive environments.
(e) Clean for epoxy injection in compliance with Section 411. Clean for penetrant sealer application in compliance with Section 413.
(f) Recoat cracks which reopen after the initial application of penetrant sealer with penetrant sealer.
(*4) Investigate cracks which occur underwater prior to treatment.

Seal cracks determined by the Engineer to be excessive due to inadequate curing effort or inadequate construction practice at no expense to the Department. Seal all other cracks occurring in concrete in accordance with the above and Sections 411 and 413. When such work is authorized by the

Engineer, the Department will pay for the work under the appropriate pay items contained in Sections 411 and 413.

Prepare the surface, clean the surface, and apply the sealant in accordance with the sealant material manufacturer's recommendations.

400-22 Method of Measurement.

400-22.1 General: The quantities of concrete to be paid for will be the volume, in cubic yards [cubic meters], of each of the various classes shown in the plans, in place, completed and accepted. The quantity of Traffic Railing Barrier and Pedestrian/Bicycle Parapet to be paid for will be the length, in feet [meters], completed and accepted. The quantity of precast anchor beams to be paid for will be the number in place and accepted. The quantity of bridge floor grooving to be paid for will be the area, in square yards [square meters] of bridge deck and approach slab, completed and accepted.

Except for concrete barriers, parapets and precast anchor beams, for any item of work constructed under this Section and for which measurement for payment is not to be made by the volume of concrete, measurement and payment for such work will be as specified in the Section under which the work is specified in detail.

No separate payment will be made for obtaining the required concrete finish.

400-22.2 Calculation of Volume of Concrete:

400-22.2.1 Dimensions: The quantity will be computed by the plan dimensions of the concrete, within the neat lines shown in the plans, except that no deduction will be made for weep holes, floor drains, or encroachment of inlets and pipes in box culverts, and no chamfers, scorings, fillets, or radii 1 1/2 in^2 [970 mm^2] or less in cross-sectional area will be taken into account.

400-22.2.2 Pay Quantity: The quantity to be paid for will be the original plan quantity, measured as provided in 400-22.2.1, except that where the plans call for an estimated quantity of miscellaneous concrete for contingent use, the contingent concrete will be measured as the actual quantity in place and accepted.

400-22.2.3 Items not Included in Measurement for Payment: No measurements or other allowances will be made for work or material for forms, falsework, cofferdams, pumping, bracing, expansion-joint material, etc. The volume of all materials embedded in the concrete, such as structural steel, pile heads, etc., except reinforcing steel, will be deducted when computing the volume of concrete to be paid for. For each foot [meter] of timber pile embedded, 0.8 ft^3 [0.074 m^3] of concrete will be deducted. The cost of furnishing and placing dowel bars shall be included in the Contract unit price for the concrete.

400-22.2.4 Deck Girders and Beam Spans: In computing the volume of concrete in deck girders and beam spans, the thickness of the slab will be taken as the nominal thickness shown on the drawings and the width will be taken as the horizontal distance measured across the roadway. The volume of haunches over beams will be included in the volume to be paid for.

400-22.2.5 Stay-in-Place Metal Forms: When using stay-in-place metal forms to form the slab of deck girder and beam spans, the volume of concrete will be computed in accordance with the provisions of 400-20.2.4 except that the thickness of the slab over the projected plan area of the stay-in-place metal forms will be taken as the thickness shown on the drawings above the top surface of the forms. The concrete required to fill the form flutes will not be included in the volume of concrete thus computed.

400-22.3 Traffic Railing Barrier and Pedestrian/Bicycle Parapets: The quantity will be computed by the plan quantity including the transitional sections and end sections where shown on the plans and including the volume occupied by expansion or open joints, not in excess of 1 inch [25 mm] in width.

400-22.4 Bridge Floor Grooving: The quantity will be computed by measurement of the area bounded by the gutter lines (at barrier rails, curbs and median dividers) and the beginning and end of the bridge or the end of approach slabs, whichever is applicable.

400-22.5 Composite Neoprene Pads: The quantity to be paid for will be the original plan quantity, computed using the dimensions of the pads shown in the plans.

400-22.6 Cleaning and Coating Concrete Surfaces: The quantity to be paid for will be the plan quantity in square feet [square meters] for the areas shown in the plans.

400-23 Basis of Payment.

400-23.1 Concrete:

400-23.1.1 General: Price and payment will be full compensation for each of the various classes of concrete shown in the proposal.

400-23.1.2 Concrete Placed below Plan Depth: Authorized concrete placed in seal or footings 5 feet [1.5 m] or less below the elevation of bottom of seal or footing as shown in the plans will be paid for at the Contract price set forth in the proposal under the pay items for substructure concrete.

Authorized concrete used in seal (or in the substructure where no seal is used) at a depth greater than 5 feet [1.5 m] below the bottom of seal or footing as shown in the plans will be paid for as Unforeseeable Work.

Such payment will be full compensation for the cofferdam construction, for excavation, and for all other expenses caused by the lowering of the footings.

400-23.1.3 Seal Concrete Required but Not Shown in Plans: When seal concrete is required as provided in 400-8 and there is no seal concrete shown in the plans, it will be paid for as Unforeseeable Work.

400-23.2 Traffic Railing Barrier and Pedestrian/Bicycle Parapets: The quantity, as determined in 400-22.3, will be paid for at the Contract unit price per foot [meter] for Traffic Railing Barrier or Pedestrian/Bicycle Parapets. Price and payment will include the furnishing and placing all concrete and reinforcing steel contained in the railing/parapet.

400-23.3 Precast Anchor Beams: Price and payment will be full compensation for the beams, including all reinforcing steel and materials necessary to complete the beams in place and accepted.

No separate prices will be allowed for the various types of anchor beams.

400-23.4 Reinforcing Steel: Reinforcing steel will be measured and paid for as provided in Section 415, except that no separate payment will be made for the fabric reinforcement used in concrete jackets on steel piles or reinforcement contained in barriers, traffic separators or parapets. Where so indicated in the plans, the Department will not separately pay for reinforcing steel used in incidental concrete work, but the cost of such reinforcement shall be included in the Contract unit price for the concrete.

400-23.5 Bridge Floor Grooving: Price and payment will be full compensation for all grinding, grooving, equipment, labor, and material required to complete the work in an acceptable manner.

400-23.6 Composite Neoprene Pads: Price and payment will be full compensation for all work and materials required to complete installation of the pads.

400-23.7 Cleaning and Coating Concrete Surfaces: Price and payment will be full compensation for all work and materials required. The cost of coating new concrete will not be paid for separately, but will be included in the cost of the item to which it is applied.

400-23.8 General: The above prices and payments will be full compensation for all work specified in this Section, including all forms, falsework, joints, weep holes, drains, pipes, conduits, bearing pads, setting anchor bolts and dowels, surface finish, and cleaning up, as shown in the plans or as directed. Where the plans call for water stops, include the cost of the water stops in the Contract unit price for the concrete.

Unless payment is provided under a separate item in the proposal, the above prices and payments will also include all clearing and grubbing; removal of existing structures; excavation, as provided in Section 125; and expansion joint angles and bolts.

The Department will not change the rate of payment for the various classes of concrete in which steel may be used due to the addition or reduction of reinforcing steel.

The Department will not make an allowance for cofferdams, pumping, bracing, or other materials or equipment not becoming a part of the finished structure. The Department will not pay for concrete placed outside the neat lines as shown in the plans.

When using stay-in-place metal forms to form bridge floors, the forms, concrete required to fill the form flutes, attachments, supports, shoring, accessories, and all miscellaneous items or work required to install the forms shall be included in the Contract unit price of the superstructure concrete.

400-23.9 Payment Items: Payment will be made under:

Item No.	400- 1-	Class I Concrete - per cubic yard.
Item No.	2400- 1-	Class I Concrete - per cubic meter.
Item No.	400- 2-	Class II Concrete - per cubic yard.
Item No.	2400- 2-	Class II Concrete - per cubic meter.
Item No.	400- 3-	Class III Concrete - per cubic yard.
Item No.	2400- 3-	Class III Concrete - per cubic meter.
Item No.	400- 4-	Class IV Concrete - per cubic yard.
Item No.	2400- 4-	Class IV Concrete - per cubic meter.
Item No.	400- 6-	Precast Anchor Beams - each.
Item No.	2400- 6-	Precast Anchor Beams - each.
Item No.	400- 7-	Bridge Floor Grooving - per square yard.
Item No.	2400- 7-	Bridge Floor Grooving - per square meter.
Item No.	400-143-	Cleaning and Coating Concrete Surfaces - per square foot.
Item No.	2400-143-	Cleaning and Coating Concrete Surfaces - per square meter.
Item No.	400-147-	Composite Neoprene Pads - per cubic foot.
Item No.	2400-147-	Composite Neoprene Pads - per cubic meter.
Item No.	400-148-	Traffic Railing - per foot.
Item No.	2400-148-	Traffic Railing - per meter.
Item No.	400-160-	Pedestrian/Bicycle Parapet - per foot.
Item No.	2400-160-	Pedestrian/Bicycle Parapet - per meter.