

502 Concrete Bridges

502.1 Description

- (1) This section describes constructing concrete bridges and concrete parts of other bridges.

502.2 Materials

502.2.1 General

- (1) Furnish grade A concrete conforming to [501](#) as modified for class I structure concrete in [715](#). Provide QMP for class I structure concrete as specified in [715](#).

- (2) For other materials, conform to the following:

Steel reinforcement.....	505
Structural steel and miscellaneous metals.....	506
Waterproofing	516

- (3) Except for form ties, use hot-dipped galvanized or epoxy-coated steel, stainless steel, or non-metallic materials for hardware incorporated into the structure. Repair cuts and other damage to galvanized or epoxy coatings according to [ASTM A780](#). Do not use galvanized hardware where it is in contact with weathering steel.

502.2.2 Concrete Composition

- (1) If the contract specifies, or the engineer allows, the contractor may use high early strength concrete.
- (2) Do not use high early strength concrete in cast in place bridge superstructures.
- (3) Do not use high early strength concrete in bridge substructures or in other structures unless the contract requires it, or if the engineer allows the contractor, in writing, to use high early strength concrete to expedite the work.
- (4) Use the coarse aggregate sizes specified in [501.2.7.4](#) and [501.3.2.2](#).

502.2.3 Falsework

- (1) The engineer will not require the contractor to use new or unused materials in falsework.
- (2) Use timber and piling in falsework of adequate strength and shape, suitable for the purpose intended. Use material that is in good condition, sound, and free from defects that might impair its strength. Use reasonably straight piling capable of withstanding pile driving.
- (3) Use straight steel members, of adequate strength and shape suitable for the purpose intended.

502.2.4 Forms

- (1) The contractor may use wood or metal, or, with the engineer's approval, composite construction. The engineer will not require the use of new, unused material. Use material in good condition, of adequate strength, and of a shape suitable for the purpose intended.

502.2.5 Waterstops

- (1) If not specified in the contract, the contractor may furnish and use either polyvinyl chloride (PVC) or rubberized membrane waterstops. Use polyvinyl chloride waterstops that are a dense, homogeneous material, free from holes and other imperfections, extruded from an elastomeric plastic compound. If using PVC waterstops, conform to the Corps of Engineers' Specification CRD-C 572.
- (2) Select the rubberized membrane, primer, and mastic waterstops from the [APL](#). Use membrane with a minimum thickness of 60 mils.

502.2.6 Concrete Curing Compound

- (1) Use liquid curing compound conforming to [ASTM C309](#), type 1-D, clear or translucent with fugitive dye.

502.2.7 Expansion Joint Materials

502.2.7.1 Preformed Joint Filler

- (1) Use preformed joint filler conforming to [AASHTO M153](#), [AASHTO M213](#), or [ASTM D8139](#).

502.2.7.2 Preformed Elastomeric Compression Joint Seals

- (1) Use preformed elastomeric compression joint seals conforming to [AASHTO M297](#).
- (2) Use a compatible lubricant-adhesive the seal manufacturer recommends.
- (3) Ensure the viscosity of the lubricant-adhesive performs suitably with the application equipment. The engineer will reject any lubricant-adhesive not used within 9 months of manufacture.

- (4) Ensure the lubricant-adhesive consistency works well at the temperatures the seals are installed, is compatible with the seals and the concrete, and is relatively unaffected by the normal moisture in the concrete.
- (5) Deliver the lubricant-adhesive in containers plainly marked with the manufacturer's name or trademark, lot number, and manufacture date.
- (6) Use joint seals compatible with concrete, or steel and resistant to abrasion, oxidation, oils, gasoline, salt, and other materials spilled on or applied to the surface.
- (7) Shape the seal so that in its compressed condition the top center of the exposed surface is depressed below the edges of the installed seal. At the joints maximum opening, the minimum unit pressure on the sides of the joint seal must be 3 psi.
- (8) Mark the top surface of the seal at one-foot intervals clearly, in a manner durable enough to make length determinations of the seal after installing in the pavement joints.
- (9) Mark shipping containers for seals clearly, with the manufacturer's name, the size of the seal, the lot number, and the manufacture date.

502.2.7.3 Expansion Devices

- (1) Ensure that expansion devices are fabricated by an approved fabricator selected from the [APL](#) for fabricated bridge components. Furnish [ASTM A 709](#) grade 36 steel extrusions and retainers galvanized according to [ASTM A123](#) after fabrication.
- (2) The minimum thickness of the polychloroprene strip seal must be 1/4 inch for non-reinforced elastomeric glands and 1/8 inch for reinforced glands. Furnish the strip seal gland in lengths suitable for a continuous one-piece installation at each individual expansion joint location. Conform to [ASTM D3542](#) and as follows.

POLYCHLOROPRENE STRIP SEALS^[1]

PROPERTY	VALUE	TEST METHOD
Tensile strength, min	2000 psi	ASTM D412
Elongation @ break, min	250 %	ASTM D412
Hardness, type A, durometer	55 +/- 5 points	ASTM D2240
Compression set, 70 hours @ 212 F, max	35 %	ASTM D395 Method B Modified
Ozone resistance, after 70 hours at 100 F under 20 percent strain with 100 pphm ozone	no cracks	ASTM D1149 Method A
Mass change, in oil #3 after 70 hours at 212 F, max	45 %	ASTM D471

^[1] Submit a manufacturer's certified report of test or analysis for production of polychloroprene represented showing test results for the cured material supplied and certifying that it meets the specifications.

502.2.8 (Vacant)

502.2.9 Non-Bituminous Joint Sealer

- (1) Furnish gray sealant complying with [ASTM C920](#) for non-sagging grade NS, class 25, traffic area use T, and either single-component type S, or multi-component type M.

502.2.10 Hot-Poured Elastic Joint Sealer

- (1) Furnish material conforming to [ASTM D6690](#).

502.2.11 Crack and Surface Sealers

- (1) Furnish crack and surface sealers from the [APL](#) as follows:
 - Crack sealer: Low viscosity bridge deck sealers list.
 - Protective surface treatment: Concrete protective surface treatment list.
 - Pigmented surface sealer: Cure and seal compound - non-traffic structural masonry list.

502.2.12 Adhesive Anchors

- (1) Unless the plans show stainless steel, furnish either stainless steel or galvanized anchors, bolts, studs, nuts, and washers. Ensure that galvanized materials are either hot dipped according to [ASTM F2329](#) or mechanically galvanized according to [ASTM B695](#) Class 55; ensure that the same galvanization process is used for all parts of the assembly. If the plans show using reinforcing bars, use grade 60 bars conforming to [AASHTO M31](#) and to [505.2](#).
- (2) Furnish adhesive from the [APL](#).

- (3) Do not substitute adhesive anchors for anchors the plans show unless the plans allow adhesive anchors. Do not use adhesive anchors in overhead applications with sustained tensile loads.

502.2.13 Clear Protective Coating

- (1) Furnish clear protective coating composed of the following:

MATERIAL	MINIMUM PERCENT BY WEIGHT
Vinyl resin ^[1]	25.0
Methyl ethyl ketone solvent	37.0
Toluene solvent	37.0
^[1] Use resin of an engineer-approved vinyl chloride-acetate copolymer containing 86 percent vinyl chloride and 14 percent vinyl acetate. Ensure a viscosity of 250-500 centipoises for a 22 percent by weight solution or resin in a solvent, consisting of equal parts of methyl iso-butyl ketone and toluene at 77 F.	
COATING PROPERTY	
Weight per gallon at 77 F	7.6 pounds minimum
Viscosity at 77 F	60-70 Krebs units
Color	Clear and colorless
Drying time	1/2 hour maximum

502.3 Construction

502.3.1 General

- (1) Use construction methods conforming to the specifications for the several parts of the structure. Do not slip-form parapets unless the department explicitly allows by special provision.

502.3.2 Falsework

502.3.2.1 Detailed Plans

- (1) At the engineer's request, submit one copy of signed and sealed detailed plans and computations for falsework, as specified in [105.2](#), and place on file. If the engineer requests, submit 2 additional copies of plans for review. Revise the plans as the engineer directs. Understand that whether or not the engineer requests submission of these plans or concurs in the use of the submitted or corrected plans, the contractor is responsible for obtaining satisfactory results.

502.3.2.2 Design

- (1) Design falsework to support a weight of 160 pounds per cubic foot for concrete plus a live load allowance of not less than 10 pounds per square foot of horizontal projection of forms; and must also provide the necessary rigidity and support for the loads without appreciable settlement or deformation. Consider the potential effects of high wind and high water in the design.

502.3.2.3 Erection

- (1) Build falsework on foundations adequate to support the load without appreciable settlement. Drive an ample quantity of falsework piling to support the falsework unless there is firm foundation material for the support of mud sills that is not subject to undermining or softening. Construct mud sills of a size and thickness to support the load at the soil's safe bearing value. Generally, found mud sills only on rock, firm sand, gravel, or very firm, silty, sands or clays in their natural beds. Place mud sills founded on well-compacted slopes of berm fills or natural slopes on benches, with the edge of the sill not closer than one foot from the intersection of the bench and the surface of the slope, except if the engineer allows placing sills on slope paving. The safe design bearing value for foundation material, other than rock, under mud sills must not exceed 2 tons per square foot. Unless supporting the excavation for footings adequately with sheeting, place the edge of the falsework sill no closer than 4 feet from the excavation edge.
- (2) If supporting falsework by mud sills placed on paved, well-compacted slopes of berm fills, do not strut the falsework to columns, unless founding the column on rock or supporting by piling.
- (3) Set falsework at the proper elevation to produce, in conjunction with engineer-approved wedges, shims, or jacks, the specified permanent camber plus a construction camber covering allowance for settlement. Construct slab **spans** and girder spans to provide a permanent camber as the plans show.
- (4) If extending existing concrete bridges, then extend the falsework and forms for the new construction one foot under the edge of the existing structure and make the existing structure bear on the falsework by driving wedges between the falsework and the forms.
- (5) If the plans show, brace and tie the exterior girders supporting bridge decks to the interior girders as necessary to preclude rotation of the exterior girders if supporting the deck overhang by knee braces bearing against the exterior girders.

- (6) If the plans do not show the above requirement, determine the need for any bracing or stabilization necessary to prevent girder rotation and overhang settlement.
- (7) The contractor's responsibility includes obtaining satisfactory results whether or not the plans show a requirement for bracing or stabilizing the exterior girders.
- (8) If building falsework over a stream or lake subject to boating use, construct it to provide ample horizontal and vertical clearance for rowboats and small powerboats to pass. If building falsework over a highway or street used by traffic provide a minimum clearance, unless the plans show otherwise or special provisions specify otherwise, of 22 feet horizontal and 13 1/2 feet vertical. Ensure that no part of the falsework protrudes into the clear areas reserved for water or highway traffic. For signing, conform to plan details or contract provision requirements.

502.3.3 Forms

502.3.3.1 Detailed Plans

- (1) The engineer reviews the details for formwork, bracing, tying, etc., and will not give permission to place concrete until this work is complete. If the engineer directs, submit detailed plans and computations for forms to the engineer for examination. Revise the plans as the engineer directs. Understand that whether or not the engineer requests submission of these plans or concurs in the use of the submitted or corrected plans, the contractor is responsible for obtaining satisfactory results.

502.3.3.2 Design

- (1) Design forms to sustain the pressures resulting from considering concrete without initial set as a liquid weighing 160 pounds per cubic foot plus a live load allowance of not less than 10 pounds per square foot of horizontal projection of forms. Use substantial and unyielding forms designed so that the finished concrete conforms to the proper dimensions and contours. Design forms to account for vibration forces.

502.3.3.3 Erection

- (1) Build forms mortar-tight and sufficiently rigid to prevent distortion from concrete pressure and other loads that occur due to construction operations. Construct and maintain forms to prevent warping and joint openings due to lumber shrinkage, and so they remain true to the lines designated until the concrete hardens sufficiently. Forms must remain in place for the periods specified below in [502.3.4](#).
- (2) If forms appear unsatisfactory in any way, before or during concrete placement, the engineer will order the work stopped until correction of the defects. If the engineer orders, remove and replace the concrete within the defective area at no expense to the department.

502.3.3.4 Timber Forms

- (1) Use forms for exposed surfaces made of dressed lumber, of uniform thickness and make mortar-tight.
- (2) Fillet the forms with triangular molding chamfer strips at exposed, sharp corners and at the edges of the concrete. Unless specified otherwise, use triangular molding that measures 3/4 inch on the sides.
- (3) Construct forms for railing, copings, and ornamental work to standards equivalent to first-class millwork. Make moldings, panel work, and bevel strips, straight and true, with neatly mitered joints, and design so that the finished work is true, sharp, and clean cut. Exercise special care to secure smooth and tight fitting forms, hold the forms rigidly to line and grade, and remove without injuring the concrete.
- (4) In forming copings, offsets, and recesses, give the forms sufficient taper to allow removal without damaging the concrete. The maximum draft must equal one inch per foot.
- (5) Use bolts or rods to hold forms in place. Construct metal appliances used inside forms to hold them to correct alignment and location so that, after removing the forms, removal of the metal to a depth of at least one inch from the surface of the concrete does not injure the surface. Hold bolts or rods in place by attaching devices to the wales that develop the strength of the rod. Fill cavities left by removing bolts and rods with cement mortar conforming to [502.3.7.1](#) and leave a sound, smooth, and even surface uniform in color. If exposing the completed concrete, use tie rods of a diameter, or fitted with cones, or other means to provide cavities large enough to allow filling and finishing with cement mortar.
- (6) Do not use spreaders for metal pipe, precast concrete, or rolled sections unless it removes them while placing the concrete.
- (7) Secure forms for exposed surfaces to the studs or uprights with true horizontal joints.
- (8) If reusing forms or form lumber maintain them in clean and good condition as to accuracy, shape, strength, rigidity, tightness, and smoothness of surface. Do not reuse any split, warped, bulged, or marred lumber, or use lumber with defects that may produce inferior work.

- (9) If possible, daylight columnar forms at vertical intervals and with sufficient openings to allow free access to forms for inspecting and working the concrete.

502.3.3.5 Metal Forms

- (1) Apply the above specifications for forms, if they are applicable, to metal forms carrying an equivalent loading. Use metal forms thick enough so they remain true to shape. Countersink bolt and rivet heads in the form face. Use clamps, pins, or other connection devices designed to hold the forms rigidly together and to allow removal without injuring the concrete. Do not use metal forms that do not present a smooth surface or line up properly. Exercise special care to keep metal forms free from rust, grease, or other foreign matter that tends to discolor concrete.

502.3.3.6 Clean Outs

- (1) For narrow walls and other locations where no reasonable access to the bottom of the forms exists, provide adequate clean-out openings. Ensure forms are clean and entirely free from chips, dirt, sawdust, nails, wire, and other extraneous matter during concrete placement.

502.3.3.7 Oiling and Wetting

- (1) Oil the inside of forms used for exposed concrete surfaces with a light, clear, paraffin base oil, or treat with other engineer-approved bond-inhibiting materials that will not discolor or injuriously affect the concrete surface. Perform oiling before placing the reinforcement. Thoroughly wet forms with water immediately before placing concrete.

502.3.3.8 Lined Forms

- (1) Use lined forms for the exposed surfaces of endwalls, substructure units, retaining walls, rigid frames, underside surfaces of superstructures, except **decks** between beams or girders, the outside surfaces of superstructures, and railing and parapet surfaces.
- (2) Ensure lined form surfaces completely contact the concrete faced with metal, plywood, composition, or other engineer-approved material to the engineer's satisfaction. Submit samples, specifications, and other pertinent information on these forms to the engineer if requested and secure the engineer's permission to use the contemplated form lining.
- (3) Form lining material must not bulge, warp or blister, or stain the concrete. Keep the number of pieces of material used line forms to a minimum. Make splices in form lining material neatly and break joints with the form material.
- (4) The contractor may use forms constructed of metal, plywood, or other engineer-approved material that satisfactorily produces the desired surface finish for the concrete instead of lined forms.

502.3.3.9 Cylindrical Column Forms

- (1) If forming cylindrical columns with fiber pulpboard tubes, use truly cylindrical tubes of uniform diameter and with adequate strength to support the concrete. Ensure that the surfaces of the tube are waterproof with a treated interior surface that prevents adhesion of the tube to the concrete and after finishing, does not leave protruding seams or fins. The tube must provide a smooth and true column surface, free from discoloration.

502.3.4 Removing Forms and Falsework

502.3.4.1 Removing Forms

- (1) If removing forms under slabs, **decks**, beams, girders, brackets, and supports, conform to the removal requirements for falsework specified below in [502.3.4.2](#). The contractor may remove other forms 12 hours after casting concrete if the concrete is sufficiently set to be self-supporting.
- (2) If forms are an integral part of the falsework, keep them in place until falsework removal. During hot weather, use water, as the engineer directs, to cool the concrete within the forms.
- (3) Remove forms in a manner causing no injury to the concrete.

502.3.4.2 Removing Falsework

- (1) Do not remove falsework and form supports without the engineer's approval. Remove supports in a way that allows the concrete to uniformly and gradually take the stresses due to its own mass.
- (2) In determining the removal time of falsework, consider the location and character of the structure, the weather, the materials used in the mix, and other conditions influencing the concrete setting.
- (3) The engineer may determine when to remove falsework or form supports by using test cylinders or by using the minimum requirements specified below:
 - 1. If not controlling field operations by cylinder tests, keep falsework supporting concrete in bridges, including slabs, beams, girders, arches, or concrete **decks** on steel or concrete girders in place according to the minimum requirements for equivalent curing days specified in [502.3.10.1](#). Except do not remove falsework

from cast in place bridge slabs or box girder spans until at least 7 days elapse, for deflection control, exclude days that the concrete surface was subjected to temperatures below 40 F.

2. If controlling field operations by cylinder tests, remove falsework or form supports, with the engineer's approval, when the tests of cylinders show a concrete compressive strength of not less than 2000 psi for spans 12 feet or less; and not less than 2500 psi for spans over 12 feet. Except, do not remove falsework from cast-in-place bridge slabs or box girder spans until at least 7 days elapse, for deflection control; exclude days that the concrete surface was subjected to temperatures below 40 F.
- (4) Double the length of the horizontal projection of cantilevered portions of piers, abutments, and similar sections for determining span length for falsework removal.
- (5) Test at least 2 cylinders to determine the attained strength of concrete for falsework removal. Use the average test results for the 2 cylinders to determine compliance, except that both cylinders must be no less than 10 percent below the required strength. Cure the cylinders under conditions that at best equal the most unfavorable conditions for concrete sampled that the cylinders represent.
- (6) Remove falsework piles down to at least 24 inches below streambed or finished ground line. Remove temporary mud sills and footings.
- (7) For multiple concrete spans of continuous design, do not remove the falsework from any one span until the concrete in an entire unit of continuous span cures for the required time. If providing a longitudinal joint in the roadway of any one span, do not remove the falsework from any portion of the span until the entire span cures for the required time.

502.3.5 Handling and Placing Concrete

502.3.5.1 General

- (1) Notify the engineer before placing concrete to allow inspection of the forms, reinforcement, and placement preparations.
- (2) Before placing any concrete in a given pour, have sufficient labor, material, and equipment at the work site to complete the pour. Use equipment that is adequate for the work and in first-class working order.
- (3) Complete the forming and placing reinforcement before placing the concrete in any unit. Place and rigidly support in the correct position bar steel reinforcement extending into a subsequent pour before placing the first concrete in a given pour, unless the plans show otherwise. Complete adjacent pile driving and other operations detrimental to freshly placed concrete before placing concrete.
- (4) Before placing concrete, remove sawdust, chips, nails, wire, other construction debris, and extraneous matter from the forms interior. Clean the contact surfaces of structural steel members embedded in the placed concrete to ensure they are free from oil, grease, loose rust scale, or other materials that would affect the bond between the concrete and the steel.
- (5) Do not support construction equipment on reinforcement steel or bar chairs.
- (6) Place the concrete in a way that avoids segregating the aggregate or displacing the reinforcement. If the engineer finds any defective concrete section, remove and replace it, as the engineer directs, at no expense to the department.
- (7) Arrange and use chutes, troughs, belts, and pipes as aids in placing concrete so no separation of the concrete ingredients occur. Provide enough chutes, troughs, or pipes to carry the concrete up at a uniform level without shifting them. Keep chutes, troughs, belts, and pipes clean and free from coatings of hardened concrete. Discharge water used for flushing away from the concrete in place.
- (8) If placing concrete in structures, the distance from the discharge ends to the point of deposit for chutes, troughs, pipes, belts, and buckets must not exceed 4 feet.
- (9) If using conveyor belt systems, equip the belts with suitable hoods or chutes to control the discharge.
- (10) If conveying or placing concrete by pumping, use suitable equipment with adequate capacity for the work. Arrange the equipment so that any resulting vibrations do not damage freshly placed concrete. Operate the pump in a way that produces a continuous stream of concrete without air pockets. After pumping is complete, if using the concrete remaining in the pipeline, eject it so there is no concrete contamination or ingredients separation. After this operation, thoroughly clean the equipment.
- (11) If placing concrete by pumping, take measures to minimize entrained air loss. The point of discharge from the flexible hose at the end of the boom must be higher than the lowest point of the flexible hose. If using an extended boom, the contractor may lay part of the flexible hose on the **bridge floor**. If completely suspending the flexible hose from the boom, tie the discharge end of the flexible hose back toward the end of the rigid boom to form a partial loop. The engineer may approve alternate methods if the contractor can demonstrate that the air loss in the concrete created by the pumping process does not exceed 1.0 percent in any boom orientation.

- (12) Do not use aluminum pipes, chutes, troughs, spouts, or tremies for pumping, conveying, or placing concrete.
- (13) If placing operations involve placing concrete through the completed forms, as for, piers, columns, and retaining walls over 5 feet in height, with the exception of cast in place concrete piles and walls less than 10 inches thick, deposit concrete through sheet metal or other engineer-approved pipes. Assemble these pipes in sections to facilitate adjusting outlets to proper heights during pouring operations. The distance from the bottom of these pipes to the point of deposit must not exceed 4 feet at any time.
- (14) If using troughs or chutes, extend them down inside the forms, or through holes left in the forms, to within 2 feet of the point of deposit unless they end in vertical downspouts that extend to within 4 feet of the point of deposit. Equip steep chutes with baffle boards or assemble them in short lengths that reverse the direction of movement. Do not use long chutes for conveying concrete from the mixing plant to the forms.
- (15) Place concrete in continuous horizontal layers approximately 12 inches thick, except that the engineer may allow increasing this thickness to 24 inches. Place each layer in a continuous pour and consolidate before the concrete in the preceding layer takes initial set.
- (16) Make construction joints only at locations the plans show unless the engineer directs otherwise. In case of an emergency, place construction joints at the engineer's direction. Use shear keys or inclined reinforcement at necessary points to transmit shear, or bond the 2 sections together.
- (17) Regulate placing the concrete so that the pressure of the concrete does not exceed that of the form design.
- (18) Take special care to fill each part of the forms by depositing concrete directly as near the final position as possible, to work the coarse aggregate back from the face, and to force the concrete under and around the reinforcement bars without displacing them. Also, try to prevent spattering the forms or reinforcement bars so that the spattered concrete does not dry or harden before incorporating into the mix. Clean foreign material from reinforcement bars before the succeeding pour.
- (19) Remove removable form spreaders before placing concrete at the spreader elevation.
- (20) Take care to avoid accumulating laitance or foreign matter inside forms, recesses, or corners. Provide openings in forms for removing any accumulations, as the engineer directs.
- (21) After the concrete takes initial set, avoid jarring the forms or placing any strain on the ends of projecting reinforcement.
- (22) Use mechanical vibration to consolidate the concrete for superstructures. Consolidate other concrete for structures by vibrating unless using other methods the engineer finds satisfactory. Use vibrators capable of operating at frequencies sufficient to achieve thorough and uniform consolidation, but at not less than 7000 impulses per minute. Make available at least one spare vibrator, in working order and of sufficient frequency, on the work site before pouring concrete.
- (23) Apply vibration to the freshly deposited concrete by slowly inserting and withdrawing the vibrator. Perform this procedure at enough locations and for as long as necessary to uniformly and thoroughly consolidate the entire weight of fresh concrete without causing aggregate segregation, or forming localized areas of mortar.
- (24) Consolidate each concrete layer thoroughly before placing the next layer on top. Ensure that the vibrator penetrates through each successive layer and sufficiently into the preceding layer to uniformly blend the 2 concrete layers together.
- (25) Do not perform vibration directly to or through the reinforcement of sections or layers that harden so that they are no longer plastic under vibration. Do not use the vibrator to transport, or to flow, the concrete within the forms to the extent of causing segregation.
- (26) Supplement vibration with as much spading as necessary, to ensure smooth surfaces and dense concrete, along form surfaces and in corners and locations impossible to reach with the vibrator.
- (27) If required to continue mixing, placing, or finishing concrete after daylight hours, employ artificial light at the work site to the engineer's satisfaction.

502.3.5.2 Substructures

- (1) If possible, place concrete for substructures in unwatered foundation pits. The contractor may omit the forms and fill the entire excavation with concrete, if the material type encountered in excavation for structures allows placing concrete for footings wholly or in part without forms, and if the engineer approves.

- (2) Place concrete in columns in one continuous operation unless the engineer specifies, or the plans show otherwise. Allow the concrete to set at least 12 hours before placing the concrete in the cap, cross girder, or superstructure.
- (3) If the plans show, ensure the thorough and effective drainage of the filling material behind culverts, retaining walls, and abutments by placing weep holes in conjunction with the construction specified in [206.3.12](#). Discharge the drainage water through the abutment, the wall of the culvert, or through the retaining wall in a manner and at locations that do not cause discoloration of exposed masonry surfaces. Form weep holes and, if necessary, fit with suitable screens or gratings to protect the intake against clogging. Constructing weep holes the plans show is incidental to the work.
- (4) Do not place concrete on a frozen foundation.

502.3.5.3 Depositing Concrete Underwater

- (1) Deposit concrete underwater only if the engineer orders, the plans show, or the contract specifies.
- (2) Provide concrete as specified in [501](#), except increase the slump to 5 - 9 inches without exceeding the maximum mix water allowed for that grade.
- (3) For concrete deposited underwater, place it carefully in a compacted weight in its final position using a tremie. The tremie consists of a tube that has a diameter of not less than 10 inches and constructed in sections having flanged couplings fitted with gaskets. The tremie support must allow free movement of the discharge end over the entire work surface and allow its rapid lowering if necessary to choke off or retard the flow. Keep the discharge end sealed at all times and the tremie tube full to the bottom of the hopper. If dumping a batch into the hopper, raise the tremie slightly, but not out of the concrete at the bottom, until the batch discharges to the bottom of the hopper. Then stop the flow by lowering the tremie. Ensure a continuous uninterrupted flow until the work is complete. The contractor may use a tremie equipped with a suitable mechanical seal or valve at the discharge point instead of the open tube tremie, if the engineer approves of the design, method of operation, and control of the device.
- (4) Exercise special care not to disturb concrete deposited underwater and to maintain still water at the deposit point. Do not place concrete in running water. Ensure watertight formwork.
- (5) Place the concrete in a way that precludes developing a cold joint between successive layers or placement stages. Accomplish this by either placing the concrete layers deep enough to accommodate satisfactory tremie operation, while ensuring that the previously layer does not take initial set by pouring at a rate sufficient to raise the concrete level between 1 1/2 to 2 feet per hour; or by placing the concrete full depth in one continuous operation and completing the work to grade progressively from one end of the cofferdam to the other.
- (6) Design cofferdams to accommodate appropriate and planned pour rates. The contractor may place underwater concrete by pumping, if the engineer approves.
- (7) Do not dewater the cofferdam until at least 3 days pass from the time placed and not before the concrete hardens and is strong enough to withstand the hydrostatic pressure.
- (8) After dewatering, remove laitance or other unsatisfactory material on the top of seals and underlying proposed substructure units by scraping, chipping, or other means.

502.3.5.4 Superstructures

- (1) Except for parapets or similar pours, do not place concrete in bridge decks if housing is required at time of placement, unless the engineer specifically allows or requires in writing. Except for rigid frame bridges, remove the forms for the substructure units that support any proposed superstructure before placing the superstructure.
- (2) Ensure continuous concrete placement in superstructures between joints the plans show.
- (3) Exercise care to minimize honeycombed concrete. The engineer may require the removal and replacement of honeycombed concrete at no expense to the department.
- (4) Do not place concrete parapets, sidewalks, and medians on cast in place **slab span** structures until the falsework is released for that superstructure unit. The contractor may place those portions of the railings directly attached to substructure units while the falsework is in place.
- (5) The contractor may form and place concrete parapets, sidewalks and medians on steel girder, I-beam, or pre-stressed girder structures after 48 hours following deck placement, provided it uses no heavy equipment on the deck and it properly cures the deck adjacent to the pours.
- (6) Place floor drains, conduits, expansion joints, and other fittings as the plans show. Place and securely fastened them before placing the concrete.
- (7) Before placing concrete **decks** on steel superstructures, release the falsework and swing the span free on its supports.

502.3.6 Joints

502.3.6.1 General

- (1) Construction joints are those joints that do not provide for movement of abutting surfaces. Expansion joints are those joints that provide for movement by sliding or by deflection. Contraction joints are those joints that provide for accommodating movement resulting from contraction, and control cracking.
- (2) Place joints only at the locations that the plans show. Do not omit any joints the plans show, except upon the engineer's written authorization. If constructing joints not as the plans show, but required due to emergency, use shear keys or inclined reinforcement at locations necessary to transmit shear, or to bond the 2 sections together.
- (3) Do not edge joints that have reinforcing steel carried through.
- (4) Conform to the plans for constructing construction, expansion, and contraction joints. Unless the plans show otherwise, make joints normal to the forms. Provide bulkheads for all except horizontal joints. Ensure that joints are true to alignment and uniform in width.
- (5) If the plans show, seal expansion joints with a hot-poured elastic joint sealer, conforming to [502.2.10](#). Seal contraction joints with a non-bituminous joint sealer conforming to [502.2.9](#).

502.3.6.2 Construction Joints

- (1) Form keyed construction joints by inserting and subsequently removing a template. Use a method to insert and remove the template that avoids chipping, breaking, or damaging the concrete.
- (2) If joining fresh concrete to concrete previously set, remove loose material, laitance, dirt, and foreign matter from the previously set concrete surface and keep the surface saturated with water until the new concrete is placed. Immediately before placing the new concrete, draw forms tightly against the previously set concrete.

502.3.6.3 Expansion Joints

502.3.6.3.1 Preformed Joint Filler

- (1) Use preformed joint filler conforming to [502.2.7](#), carefully placed, and accurately fit to the adjacent concrete. Take special care to prevent displacing the joint filler during concrete placing and to prevent forming concrete fins under or between the sections of material. Do not assemble a series of small pieces of joint filler to produce a shape that could be cut from a single piece. Edge or chamfer exposed concrete edges adjacent to preformed fillers, as the plans show.

502.3.6.3.2 Preformed Elastomeric Compression Joint Sealer

- (1) Use preformed elastomeric compression joint sealer conforming to [502.2.8](#) and install in the joint with a lubricant-adhesive.
- (2) Clean joint faces to ensure they are free of laitance, oils, greases, dirt, free water, and other foreign matter immediately before installing the seal. The engineer will direct the method of cleaning the joints.
- (3) Install the seals, in the properly prepared joint, using tools designed for installing joint seals. Remove and replace any seal damaged during installation with an undamaged seal. Remove and reinstall any seal improperly positioned in the joint at the proper elevation.
- (4) Before placement, cut the seals to the lengths of the joints or as much longer as needed for proper installation. Measure each seal before and after installing as a check against stretch. Remove and reinstall any installed seal showing more than 5 percent stretch.
- (5) Install the seals so they are secure and free from any objectionable curling or twisting in the joint groove. Use a lubricant to facilitate installation and to cover both sides of the seal over the full area in contact with the sides of the joint. The contractor may apply the lubricant to the joint faces, or the seal, or both. Install the seals in a highly compressed state and ensure the top of the seal is below the pavement surface by approximately 1/8 inch but not more than 3/8 inch. Install the seal in one piece, without field or factory splicing, for the full length of each transverse joint.
- (6) Observe the manufacturer-specified temperature limitations.

502.3.6.3.3 Expansion Device

- (1) Install the steel extrusions with field splices located to match the stage construction. The department will not allow welding in the steel extrusion's internal section where the neoprene extrusion is located. Weld splices conforming to the following:

For steel: AWS D 1.5, Bridge Welding Code.

For stainless steel: AWS D 1.6, Structural Welding Code - Stainless Steel.

- (2) Submit an annual field welding plan conforming to [CMM 520.6.5.4](#) on department form [DT2337](#). Do not begin field welding without a department-approved welding plan that includes the specific welding procedures required to perform the work under the contract.
- (3) Visually inspect and certify the quality of field welds as follows:
 1. Designate an inspector listed in the contractor's current approved field welding plan.
 2. Have the designated inspector complete department form [DT2320](#) for each day of field welding and submit to the engineer for inclusion in the permanent project record.
- (4) Blast clean the steel extrusion's internal section that comes in contact with the neoprene extrusion so that surfaces are dry, free from dirt, grease, and contaminants before installing the neoprene extrusion and cover or fill this internal section before placing concrete, to prevent concrete from entering.
- (5) Install elastomeric strip seal glands with tools and a lubricant adhesive recommended by the device manufacturer.

502.3.6.4 Waterstops

- (1) Waterproof construction and expansion joints, if the plans show, by installing rubberized membrane or polyvinyl chloride waterstops. Make the field splices for rubberized membrane or polyvinyl chloride waterstops watertight. Install rubberized membrane waterstops as specified for rubberized membrane in [516.3.3](#). Install polyvinyl waterstops as the plans show.
- (2) Install waterstops so they do not transfer forces into the concrete embedded in until the concrete is sufficiently strong to withstand that force.

502.3.7 Surface Finish of Concrete

502.3.7.1 General

- (1) After removing forms, remove metal devices used to tie forms together in a way that leaves no metal within less than one inch of the concrete surface and does not injure the concrete surface. Do not burn off rods, bolts, or other metal devices. After removing the ties, roughen the opening and remove concrete containing any oil.
- (2) Immediately after removing forms, saturate cavities produced, and other holes, depressions, and honeycomb spots with water and carefully point with a cement and fine aggregate mortar mixed in the same proportions as the concrete being treated and of as dry a consistency as possible to use. For exposed surfaces, add as much white cement as necessary to provide a mortar the approximate color of the concrete. Use mortar in pointing that is not more than one hour old.
- (3) Clean open joints in the completed work to make them free of mortar and concrete.
- (4) If using insulated forms or if allowed to leave forms in place more than 72 hours, point holes, cavities, depressions, and honeycomb areas and apply a sack rubbed or rubbed surface finish as soon after removing the forms as weather and curing conditions allow.

502.3.7.2 Ordinary Surface Finish

- (1) Unless specified otherwise, provide an ordinary surface finish on formed surfaces.
- (2) Work the concrete up against formed surfaces during placement by using engineer-approved concrete vibrators or spading implements. Force coarse aggregate from the surface, and thoroughly work the mortar against the forms to produce as smooth a finish as possible, free from water pockets, air bubbles, and honeycomb.
- (3) Immediately after form removal, point tie rod holes, pits, or defects and remove or correct fins and irregularities. If the engineer determines the final surface is not satisfactory and that an ordinary surface finish was not provided, apply a rubbed surface finish conforming to [502.3.7.3](#) to the affected exposed areas. There is no requirement to extend the rubbed surface finish into nondefective areas solely to obtain a uniform texture.

502.3.7.3 Rubbed Surface Finish

- (1) Apply a rubbed surface finish by carefully rubbing the ordinary surface finish with a fine carborundum brick immediately after removing the forms. Begin by moistening the surface with water and then immediately rubbing it with the carborundum brick, using light pressure and a circular motion. Continue rubbing until filling air holes and small depressions and a thin, uniform coating of mortar is on the surface and until obtaining a smooth surface, free from lumber marks and irregularities.
- (2) The contractor may employ machine methods to produce the rubbed surface finish if the engineer approves.
- (3) Keep rubbed surfaces wet and covered for at least 4 days or cure by applying membrane curing material as specified in [502.3.8](#).

- (4) Before acceptance, remove lather, powder, and dust on rubbed surfaces.

502.3.7.4 Float Surface Finish

- (1) Unless specified otherwise, apply a float surface finish to unformed upper surfaces.
- (2) To provide a float surface finish, place excess material in the forms and remove or strike off the excess with a wooden template, forcing the coarse aggregate below the mortar surface. After striking off the concrete, work the surface thoroughly with a float. Before this last finish sets, lightly stripe surfaces finished this way and exposed in the finished work with a fine brush to remove the surface cement film and leave a fine-grained, smooth, but sanded texture.
- (3) Do not mortar top surfaces that will receive a float surface finish.

502.3.7.5 Sack Rubbed Surface Finish

- (1) If the plans show, or specifications indicate, provide a sack rubbed finish on concrete surfaces.
- (2) Before applying the sack-rubbed finish fill tie rod holes and large cavities and remove or correct fins and irregularities as specified in [502.3.7.1](#) and [502.3.7.2](#).
- (3) Produce a sack rubbed surface finish by rubbing the concrete surface with a clean rubber float or wad of burlap and mortar. Use mortar made of one part cement and 2 parts, by volume, sand passing a No. 16 sieve, mixed with sufficient water to provide a consistency equal to that of thick cream. Use the same type and brand cement as used in the concrete. If necessary, blend white cement into the cement to match the surrounding concrete surface.
- (4) Thoroughly wet the surface of the concrete and then perform sack rubbing while the surface is damp but not wet. Thoroughly rub the mortar over the area with a rubber float or wad of burlap, filling pits. While the mortar is still plastic in the pits, rub the surface with the rubber float or burlap using a dry mix of the above proportions, removing excess plastic material and placing enough dry material in the pits to stiffen and solidify the mortar, then finish the mortar fillings flush with the surface. At the end of the rubbing, ensure that no mortar or material remains on the surface other than that within the pits.
- (5) Ensure the completed surface is free of surface voids and blemishes, and is uniform in appearance and texture, except for the difference in texture between the filled voids and the remainder of the surface.

502.3.7.6 Substructures

- (1) Provide an ordinary surface finish for formed faces of substructure units. Except, give exposed formed surfaces of parapets built integrally with substructure units the same surface finish specified for similar work on superstructures in [502.3.7.7](#). Rubbed or special surface finish is not required for any formed faces of substructure units unless the plans or special provisions require, or as specified in [502.3.7.2](#) for applying a rubbed surface finish.
- (2) Strike off and float bent caps, bridge seats, tops of parapet walls supporting a superimposed load, and tops of piers with a wooden float as specified for float surface finish. Before this last finish sets, steel trowel the entire area. If finishing areas to receive bearing plates, secure a true plane at the correct elevation.

502.3.7.7 Superstructures

- (1) Apply a sack rubbed surface finish to exposed formed surfaces of parapets, posts, and sidewalks as well as to exposed side surfaces of superstructures, including the outer face of outside pre-stressed girders as specified in [503.3.3.4](#).
- (2) There is no requirement to provide a rubbed surface finish for any formed surface of superstructures except, if the engineer determines the sack rubbed finish provided is unsatisfactory, apply a rubbed surface finish conforming to [502.3.7.3](#) to the affected exposed areas.
- (3) Strike off and float the tops of safety curbs, sidewalks, or copings that serve as sidewalks in the completed structure with a wooden float as specified for float surface finish. Before this last finish sets, steel trowel these areas and then brush them.

502.3.7.8 Floors

- (1) Prepare the concrete for bridge floors, if and as required in [501.3.2.4.3](#), with a retarding admixture. Deliver the mixed concrete at a uniform rate to provide a continuous placing operation for each pour section. Handle and place the concrete by methods and equipment that minimize segregating the ingredients. Deposit it as closely as possible to its final position without forming piles and so that it requires a minimum of rehandling.
- (2) Immediately after depositing the concrete, consolidate, strike off, screed, and finish it to the required grade, section, and surface tolerance. Uniformly consolidate the concrete by internal vibratory methods as specified in [502.3.5.1](#), except that, the contractor may use a vibratory screed for

consolidating and finishing in conjunction with internal vibration. Operate the internal vibrators or the vibratory screed, or both, in a way that avoids over-vibration.

- (3) Unless the contract specifies otherwise, construct concrete bridge floors with self-propelled machine finishers.
- (4) Use a machine finisher designed for finishing bridge floors. It must consist of a rigid supporting frame mounted on wheels that ride on removable tracks or rails and is equipped with the necessary screeding apparatus to strike off and finish the concrete to required crown and grade. It must have one or more power-driven oscillating, rotating or vibratory screeds. The screeds may suspend from the machine either transversely or longitudinally with the bridge centerline, except as required for skew angles of 20 degrees or greater. Use a finishing machine capable of propelling itself both forward and backward to allow repeated passes of the screed in order to correct surface irregularities. Adjust its screed or screeds and operate in manner that finishes the concrete to required grade and crown and requires a minimum of cutting or filling in any subsequent float-finishing operations.
- (5) Set the rails or tracks, that the machine finisher rides on, to the required elevation; and ensure they adjust to allow for settlement under load. If the rail supports are located in the concrete, ensure their removal without disturbing the concrete, or partially remove so that no piece remains less than 2 inches below the finished concrete surface. Remove these supports, fill the resulting holes with concrete, and finish flush with the deck concrete before it hardens.
- (6) Ensure the rails or tracks extend beyond each end of the floor sufficiently to support the finishing machine at the correct grade and entirely free of the floor area.
- (7) Finish floor areas inaccessible to machine operation by hand methods.
- (8) On bridge decks supported on prestressed concrete or steel girders and having skew angles of 20 degrees or greater, operate the finishing machine so that its longitudinal axis is within 20 degrees of the centerline of bearing of the substructure units. Make transverse screeds parallel to the longitudinal axis of the machine.
- (9) If using hand-operated strike-off screeds, design, construct, and operate them to provide the required crown and grade in the finished floor. The contractor may use vibratory or nonvibratory type screeds that operate on forms or temporary guides set and maintained at the required elevation. Use sectioned, temporary guides that remain rigid and unyielding under screed operation and, if located within the pour limits, can be removed as the work progresses. If using vibratory screeds to supplement required internal vibration, operate them so they do not over vibrate the concrete.
- (10) Hand finish gutter lines and areas around floor drains not reached by the templates and finishing equipment to the grade and section needed to insure proper drainage.
- (11) Strike off and remove the laitance from floor areas that will receive concrete for sidewalks or similar items.
- (12) Following screeding, unless obtaining a satisfactory surface with a self-propelled finishing machine, float the surface as needed to produce a uniform surface.
- (13) While the concrete is still plastic and following screeding operations, and float finishing if performed, work laitance, surplus water, and inert material off the floor and make it smooth. Test for smoothness by dragging the entire floor surface with a 10-foot straightedge as specified in [415.3.6.1](#) for straightedging concrete pavement. Use bridges to facilitate straightedge operations on pour sections wider than 2 lanes.
- (14) Unless specified otherwise, transversely trowel finish the floors of structures with approach pavements designed for speeds of 40 mph or greater as specified in [415.3.8.3](#), except make the tining 1/8 inch in depth and do not perform tining within 12 inches of gutters. The contractor may apply a broom finish, described below, instead of the artificial turf drag finish required before tining. The contractor may perform tining manually, if it obtains a finish satisfactory to the engineer. Perform tining within 20 degrees of the centerline of bearing of the substructure units on bridge decks having skew angles of 20 degrees or greater.
- (15) Unless specified otherwise, provide a turf drag finish on floors of structures with approach pavements designed for speeds of less than 40 mph as specified in [415.3.8.2](#) or provide a broom finish. If providing a broom finish, draw the broom transversely across the full width of the pavement with adjacent strokes slightly overlapping. Perform brooming to produce uniform corrugations and approximately 1/8 inch in depth. Complete brooming before the concrete hardens and this operation tears or roughens the surface. Brooming must provide a surface free from rough or porous areas, irregularities, and depressions that result from improper broom handling. Furnish brooms of a sufficient quality, size, and construction, and operate them to produce a surface finish the engineer approves.

Provided the contractor obtains satisfactory results, the engineer will allow manual brooming instead of mechanical brooming.

- (16) The finished bridge floor must conform to the surface test specified in [415.3.10](#). The engineer will not direct corrective grinding without authorization from BOS.
- (17) Make available suitable platforms to use, as required, over steel reinforcement projecting from previously placed concrete, during the period necessary for the concrete to achieve sufficient strength to preclude damage from contractor's operations on the unprotected reinforcement.
- (18) Make available adequate bridges, if and as the engineer requires, for inspecting and testing the placed concrete, and furnish bridges, if necessary, to perform work operations that follow the screeding operations.

502.3.8 Curing

502.3.8.1 General

- (1) Maintain adequate moisture throughout the concrete mass to support hydration until the concrete develops sufficient strength to open it to service. Cure concrete by one or a combination of the following methods:
 - 1. Impervious coating.
 - 2. Impervious sheeting.
 - 3. Continuous wet cure.
 - 4. Alternate method the engineer approves.
- (2) If the contractor fails to cure concrete as specified here in 502.3.8, the engineer may suspend concrete placement operations.

502.3.8.1.1 Impervious Coating Method

- (1) After finishing operations, and as soon as the free water disappears, spray the concrete surface with a uniform coating of curing compound conforming to [502.2.6](#). Seal moisture in the concrete by applying a continuous water-impermeable film on exposed concrete surfaces.
- (2) Provide sufficient agitation of pigment within the curing compound during spraying to ensure uniform consistency and dispersion as applied.
- (3) Apply the curing compound with spraying equipment that produces a continuous, uniform film that does not run or sag.
- (4) Apply the curing compound uniformly at a minimum rate of one gallon per 150 square feet. Apply the membrane curing material in 2 applications at the rate of not less than one gallon per 300 square feet.
- (5) If damage to the curing compound coating occurs before the concrete conforms to the opening criteria specified in [502.3.10](#), recoat the affected area immediately. If removing forms before the concrete conforms to the opening criteria specified in [502.3.10](#), coat newly exposed surfaces within 30 minutes after form removal.

502.3.8.1.2 Impervious Sheeting Method

- (1) As soon as the concrete receives a finish and hardens sufficiently to prevent excessive marring, cover exposed concrete surfaces with one or a combination of the following impervious sheeting materials:
 - 1. Polyethylene sheeting conforming to the curing materials specified in [501.2.8](#).
 - 2. Polyethylene-coated burlap conforming to the curing materials specified in [501.2.8](#). Pre-wet the polyethylene-coated burlap and place with the uncoated side against the concrete.
 - 3. Insulated curing blankets with an impervious coating, with the engineer's approval.
 - 4. Alternate impervious sheeting materials, with the engineer's approval.
- (2) Provide sheeting material sufficient to cover exposed surfaces and edges, with enough excess to hold the material securely in place by weighting or an alternate anchoring method. Provide a minimum of 12 inches overlap between adjacent pieces of sheeting. Place the sheeting material so that it is in direct contact with exposed concrete surfaces.
- (3) Maintain the sheeting material in place until the concrete conforms to the opening criteria specified in [502.3.10](#). If temporary removal is required, to remove forms or perform other necessary work, re-cover exposed concrete as quickly as practicable, or as the engineer directs.
- (4) If the engineer approves, the contractor may reuse sheeting materials in serviceable condition.

502.3.8.1.3 Continuous Wet Cure Method

- (1) As soon as the concrete receives a finish and hardens sufficiently to prevent excessive marring, spray or fog the exposed surfaces of the concrete to keep it moist until the concrete conforms to the opening

criteria specified in [502.3.10](#). Apply a layer of thoroughly wetted burlap to protect the surface from the mechanical impact of the spray.

- (2) If the concrete surface shows evidence of erosion by the curing water, the engineer will immediately suspend the spraying or fogging. Remedy the conditions causing erosion or switch to another cure method that does not involve continuous wet cure.
- (3) If ambient temperatures are predicted to fall below 32 F within the next 24 hours, suspend continuous wet curing and switch to another curing method.

502.3.8.1.4 Alternate Curing Methods

- (1) If the contractor requests, the engineer may approve using alternate materials or curing methods. Supply technical specifications, test results, or performance records to support its proposed alternative method, if the engineer requests.

502.3.8.2 Curing Requirements

502.3.8.2.1 General

- (1) Do not use reinforcing steel to support or attach covering materials.
- (2) If curing formed concrete by the impervious coating method, apply the first application immediately after form removal and surface finish application. If the surface is dry, wet the concrete thoroughly with water and apply the curing compound just as the surface film of water disappears. Apply the second application as soon as the first application sets.
- (3) Do not apply impervious coating curing material to construction joints, or to surfaces being bonded to other concrete, or to surfaces being waterproofed, or to which applying sealants. Ensure that steel reinforcement, anchors, waterstops, and similar devices are free of compound before placing concrete.
- (4) Do not use the impervious coating method on concrete before applying the required surface finish. Use other allowed curing procedures before applying the surface finish.
- (5) The contractor may delay applying the required surface finish, if the engineer approves, until after completing curing with wetted burlap or polyethylene-coated burlap, in order to allow uniform and continuous finish application. Provide at least 4 hours of an engineer-approved moisture cure to prevent the finish from sanding-out.
- (6) If the structure or any portion of it is enclosed, and artificial heat is provided for protection, this does not waive the above requirements for moisture for curing. The contractor may use steam for heating and to produce an adequate supply of moisture within the enclosure.
- (7) The contractor may leave forms in place instead of using burlap or membrane curing.

502.3.8.2.2 Substructures

- (1) Cure concrete footings, not backfilled upon form removal, and the exposed surfaces of backfilled footings as specified in [502.3.8.1](#) or by submersion, if the engineer approves. If necessary to remove wetted burlap to allow form setting, keep the exposed concrete surface thoroughly damp.

502.3.8.2.3 Floors

502.3.8 <i>Revise name for subsection and throughout section to clarify.</i>

- (1) For structures under 100 feet in length, cure the concrete in **floors**, medians, and sidewalks for at least 7 days with polyethylene-coated burlap or other coated material conforming to [501.2.8](#). As soon as the concrete sets sufficiently to support the covering, place the coated burlap with the coated side up; or perform an initial cure of the concrete by using wetted burlap for at least 12 hours and then apply the coated burlap to a thoroughly wetted concrete surface. Place each strip or sheet of coated burlap so that it overlaps the preceding sheet by at least 12 inches. Secure the coated burlap covering in place. Ensure adequate moisture is present on the surface of the floor, wearing surfaces, or sidewalks beneath the curing material for the 7-day curing period.
- (2) For Structures 100 feet or greater in length, cure the concrete in **floors**, medians, and sidewalks by the following method. Begin curing the horizontal concrete surfaces by fogging within 15 minutes of finishing and tining. Apply the fog or fine water spray so that no water marks result and no mortar washes from the concrete surface. Keep the concrete surface continuously wet by fogging until applying the burlap strips to the finished concrete. Wet the burlap immediately after placement. During the first day, until placing the soaker hose system, keep the burlap continuously wet. Through the remainder of the curing period, keep the burlap continuously wet with soaker hoses hooked up to a continuous water source. Inspect the burlap on a daily basis to ensure that the entire surface is moist. If necessary, alter the soaker hose system as needed to ensure the entire surface is moist. Do not use white polyethylene sheeting or plastic-coated burlap blankets. Continue moist curing at least 7 days.

502.3.8.2.4 Parapets

- (1) Cure concrete in the inside faces of railings and parapets by covering with wetted burlap immediately after form removal and surface finish application. Keep the burlap thoroughly wet for at least 4 days; or by covering for the same period with thoroughly wetted polyethylene-coated burlap conforming to [501.2.8](#).
- (2) Cure concrete in the outside faces of railings, parapets, exterior girders, and similar parts of the structure by one of the following methods:
 1. Apply impervious coating curing material immediately after removing the forms and applying the required surface finish.
 2. Cover with wetted burlap immediately after form removal and applying the required surface finish and keeping the burlap thoroughly wet for at least 4 days.
 3. Cover for at least 4 days with thoroughly wetted polyethylene-coated burlap conforming to [501.2.8](#).
- (3) Secure coverings along all edges to prevent moisture loss.

502.3.9 Cold Weather Protection

502.3.9.1 General

- (1) Maintain the quality of the concrete placed in cold weather. Provide the protection necessary to prevent concrete freezing until it develops sufficient strength to conform to the opening criteria specified in [502.3.10](#). Remove and replace frozen or frost damaged concrete at no expense to the department.
- (2) Unless the engineer directs otherwise, protect concrete under both of the following conditions:
 1. The air temperature is 40 F or less.
 2. The air temperature is predicted to be 40 F or less within 24 hours.
- (3) Ensure that forms, reinforcement, base, and subgrade are free of ice, snow, and frost during pouring. If the atmospheric temperature is below 40 F, preheat the interior surfaces of forms, reinforcement, and the concrete surface adjacent to the pour to 40 F or higher.
- (4) Adjust forms or insulation, as necessary, to control the temperature of the concrete. Unless the engineer allows otherwise, ensure the temperature of the concrete does not exceed 120 F, or fall below 40 F during the protection period.

502.3.9.2 Mixing

- (1) Heat the mixing water, aggregates, or both under both of the following conditions:
 1. The air temperature is 40 F or less at the time of mixing or placement.
 2. The air temperature is predicted to be 40 F or less within 24 hours following placement.
- (2) During concrete placement, ensure the mixed concrete temperature is not less than 50 F or more than 80 F, unless otherwise directed.
- (3) Do not heat the cement, or add salt or other chemicals to the mix to prevent freezing.

502.3.9.3 Heating

- (1) Protect exposed concrete surfaces within a heated housing from drying and carbonation throughout the curing period by the impervious coating method or the impervious sheeting method specified in [502.3.8](#).
- (2) If heated housing is required before placing concrete, heat the housing sufficiently before placing the concrete to ensure a temperature of the forms and reinforcing steel of not less than 40 F. Ensure a reasonably uniform temperature throughout the enclosure.
- (3) If the engineer allows, the contractor may protect footings by completely and continuously submerging in water inside the cofferdam.

502.3.9.4 Temperature Records

- (1) Take temperature readings within the enclosure at necessary times to show the true temperature conditions that the concrete is subjected to. At a minimum, provide high/low thermometers that retain the minimum and maximum temperature readings for each measurement period. Provide facilities suitable to the engineer to verify the temperature inside and outside the insulation, and within the mass of the concrete at various locations in the unit. Make temperature recordings at least every 24 hours. Make outside air temperature recordings at the same time making the recordings within the enclosure. Provide a copy of the temperature record to the engineer at the close of each day's work.

502.3.9.5 Cessation of Heating or Cold Weather Protection

- (1) At the end of the heating or cold weather protection period, gradually reduce the temperature within the enclosure to avoid a sudden temperature change of the new concrete. Make this decrease by loosening the forms and other insulating layers in a manner to allow the whole mass of concrete to gradually approach the outside air temperature at the end of the curing period. Ensure the average rate of decrease does not exceed 5 F in any hour, or 40 F in any 24-hours, until reaching the outside air temperature. Allow the concrete surface to dry while equalizing the temperatures.

502.3.9.6 Bridge Floors

- (1) Protect concrete in bridge floors as specified for structural masonry, and except for parapets and similar pours, according to the following requirements:
 1. Do not place concrete for bridge floors or other superstructure elements when the national weather service forecast for the construction area predicts temperatures to fall below 32 F within 24 hours, unless the engineer specifically allows or requires in writing.
 2. Protect the underside of the bridge floor by housing and heating when the national weather service forecast for the construction area predicts temperatures to fall below 20 F during the cold weather protection period.

502.3.10 Applying Loads to Concrete

502.3.10.1 Opening to Service

502.3.10.1.1 General

- (1) Maintain moisture, temperature, and physical protection for concrete until it develops sufficient strength to open it to service. The engineer will use the same criteria to allow the opening of structural masonry concrete items to service as is used to allow the opening of bridge superstructures to traffic.
- (2) The engineer will allow the contractor to open bridge superstructures or other structural masonry items to construction and public traffic when the concrete attains a verified compressive strength of 3500 psi. Without compressive strength information, the engineer may allow the contractor to open the affected structural masonry after the following minimum times as adjusted for concrete surface temperature.

APPLICATION	EQUIVALENT CURING DAYS
High early strength concrete	4
Grade A general purpose concrete Without blended cements or field-added supplementary cementitious materials	5
Grade A general purpose concrete With blended cements or field-added supplementary cementitious materials	7

- (3) The equivalent curing day is based on a daily average concrete surface temperature of 60 F. Calculate the daily average concrete surface temperature by taking the average of the high and low temperatures at the least favorable location of the affected concrete unit, as verified by the engineer, for each day. If this daily average concrete surface temperature falls below 60 F, then equivalent curing days accumulate at a reduced rate. Use the following guidelines to calculate equivalent curing days; for a daily average concrete surface temperature of:
 1. 60 F or more; accumulate one equivalent curing day per calendar day.
 2. 40 to less than 60 F; accumulate 0.6 equivalent curing day per calendar day.
 3. Less than 40 F; no curing credit is accumulated.

502.3.10.1.2 Exceptions

502.3.10.1.2.1 General

- (1) If the contract prescribes a specific wet curing period, do not open to service until after wet curing is complete and the strength or equivalent curing day requirements are met.
- (2) The contractor may conduct construction operations on concrete not conforming to these opening criteria as specified in [502.3.10.1.2.2](#) and [502.3.10.1.2.3](#). The engineer may suspend or delay operations that injure the surface or otherwise damage the concrete. Clean the surface before allowing any traffic to use the structure.

502.3.10.1.2.2 Substructures

- (1) If placing footings on seals, the contractor may set the footing forms and place the concrete immediately after dewatering the cofferdam and preparing the surface of the seal. Unless the engineer directs otherwise, the contractor may set the column and wall forms on the day after placing the

concrete in the footing; and may place the concrete in columns and walls after the concrete footing for the column or wall cures for at least 24 hours over 40 F.

- (2) Do not apply any load of the superstructure, or any dead load, except as specified in [502.3.10.1.2.2\(1\)](#), to concrete substructure units until the concrete in the unit cures for at least 48 hours. Do not apply loads to the beams of open-type substructure units until after the required falsework support period.

502.3.10.1.2.3 Superstructures

- (1) After the concrete cures sufficiently, the contractor may, with the engineer's approval, apply loads to decks that result from storing small articles, and operating concrete buggies and other necessary light equipment, if applied in a way that causes no injury to the concrete.
- (2) If the deck concrete conforms to [502.3.10.1.1\(2\)](#) the contractor may operate hauling equipment as necessary to perform subsequent pours on that structure. Do not operate or park hauling equipment outside of the centerline of an exterior girder until at least 24 hours after placing the parapet.

502.3.10.1.3 Opening Strength

502.3.10.1.3.1 General

- (1) Determine opening strength and provide the engineer with the information required to verify that strength by one or a combination of the following methods:
 1. Compressive strength testing of cylinders.
 2. Maturity method.
- (2) The resulting opening strength, when the engineer verifies, will apply to concrete on the same project conforming to the following criteria:
 1. Of the same mix design as the test location.
 2. Cured under similar or more desirable conditions.
 3. Placed on or before the test location.
- (3) If both direct compressive strength test results and maturity data are not available, the engineer may estimate compressive strength based on test results of concrete of the same mix design placed adjacent to and under similar conditions on the same project.

502.3.10.1.3.2 Compressive Strength Testing of Cylinders

- (1) Submit the compressive strength test results to the engineer for verification. Compute the opening strength as the average of compressive strength test results for 2 cylinders. If the strength of a cylinder is less than 90 percent of the required strength, the engineer will reject the resulting average. Field cure cylinders under conditions similar to those prevailing for the structural masonry unit they represent. Fabricate cylinders according to [WTM R100](#) and test the cylinders according to [WTM T22](#).

502.3.10.1.3.3 Maturity Method

- (1) Develop a strength/maturity relationship for each concrete mix design. Base that relationship on the strength of cylinders from concrete incorporated into the work. Submit the maturity data to the engineer for approval before placing more concrete using that mix design. Develop a new strength/maturity relationship every time the mix changes or if engineer verification cylinder strength varies more than 10 percent from the required opening strength when tested at the calibrated opening maturity.
- (2) Conform to [CMM 870](#) for strength/maturity relationship development, field verification of the resulting curves, and maturity testing. Use a default datum temperature of 32 F or use a mix-specific datum temperature determined according to Annex A1 of [ASTM C1074](#). Develop data points for the strength/maturity relationship up to 120 percent of the required opening strength.
- (3) Place sensors based on contractor operations for concrete pavement bid items and one sensor for each 100 cubic yards of concrete placed under non-pavement bid items. The resulting maturity, after engineer verification, will apply to concrete on the same project conforming to the following:
 1. Of the same mix design as the test location.
 2. Cured under conditions similar to or more favorable than that of the test location.
 3. Placed on or before the time the test location was placed.
- (4) Each work week provide a set of 3 verification cylinders to the engineer for each strength/maturity field calibration curve currently in use on the project. The engineer will designate the sampling location for these verification cylinders. Provide 2 cylinders for compressive strength testing and one with a data-encrypted sensor embedded in its center for maturity evaluation. Cast and cure these cylinders on-site as the engineer directs and conforming to the requirements of [ASTM C31](#) for field curing. Deliver the 2

compressive strength cylinders to the engineer after attaining 50 percent of their opening maturity. Notify the engineer promptly when the instrumented cylinder reaches the opening maturity so the engineer can perform verification testing as closely as possible to that opening maturity level.

502.3.11 Name Plates

- (1) Install nameplates conforming to [506.2.4](#) at the locations the plans show. Embed or epoxy the plate lugs in the concrete. Except for survey benchmarks, do not attach other permanent plates or markers to a structure.

502.3.12 Bridge Seat Protection

- (1) Unless the contract specifies otherwise, apply a mopping of epoxy to the top surfaces of abutments and piers beneath transverse joints.
- (2) Use the type of epoxy resin the manufacturer recommends for sealing exterior concrete surfaces, subject to the engineer's approval.
- (3) Apply the epoxy before placing bearing pads or plates and before erecting the superstructure, unless the engineer directs otherwise.
- (4) Do not apply resin in wet weather, or if the surface temperature of the concrete is below 60 F unless the engineer specifically allows.
- (5) If applying resin, ensure the concrete surface is dry, thoroughly clean, and free from dust or other loose material.
- (6) Furnish a 2-part epoxy resin system. Combine immediately before use and apply according to the manufacturer's written instructions. If no application rate is recommended, apply the epoxy at approximately one gallon per 100 square feet.

502.3.13 Concrete Crack and Surface Sealing

502.3.13.1 Crack Sealing

- (1) For newly constructed bridge **floors**, seal cracks visible during dry weather conditions with low-viscosity crack sealer. Conduct an initial crack survey with the engineer within 7 days after wet curing is complete, or when the **bridge floor** dries enough to expose cracks requiring sealing. Seal the cracks identified in the survey. Seal crack areas only. Do not flood seal the **bridge floor** unless the engineer allows as a part of overseeding with aggregate.
- (2) Prepare the **bridge floor** by water blasting and apply crack sealer as the sealer manufacturer recommends except as follows:
 1. The contractor need only wait 7 days after completing moist curing before sealing.
 2. Seal only if drying conditions have existed for the preceding 48 hours.
 3. Immediately before applying sealer, direct an air blast over the surface to remove dust and any loose particles.
 4. Seal before opening to public traffic.
- (3) Conduct a follow-up crack survey as late as possible, but allowing time for sealing additional cracks and subsequently applying surface sealer, before opening to public traffic. Seal additional cracks identified in the follow-up survey before applying protective surface treatment.

502.3.13.2 Protective Surface Treatment

- (1) Apply protective surface treatment conforming to [502.2.11](#) to concrete **slabs**, decks, deck overlays, medians, and sidewalks. After deck crack sealing is completed, apply surface treatment to the top of new bridge **floors**. Do not apply to surfaces where the contract requires staining or other treatment.
- (2) Under the Protective Surface Treatment Reseal bid item, prepare existing surfaces before cleaning by sand or water blasting as required to remove material that might prevent bonding; confine, collect, and dispose of the resulting waste materials.
- (3) Clean and dry surfaces before applying surface treatment. Immediately before application, direct an air blast over the surface to remove dust and any loose particles. Ensure that application equipment is clean inside before filling and that the equipment is functioning properly.
- (4) Apply surface treatment no less than 7 days, but preferably a minimum of 21 days, after the curing period has expired. Apply according to manufacturer recommendations, except ensure the concrete is surface dry for a minimum of 2 consecutive days before applying. Ensure that the crack sealer is dry to the touch before applying surface treatment. Apply at the manufacturer's recommended rate. If application in a single coat causes ponding, use two lighter coats allowed to dry between coats. Protect from rain for at least 12 hours after application.

- (5) Complete surface treatment before opening to traffic and before suspending work for the winter. Do not open the bridge floor to traffic until the surface treatment is dry enough to sustain traffic without causing damage to the surface treatment or creating a hazard to traffic.

502.3.13.3 Pigmented Surface Sealer

- (1) Apply pigmented surface sealer conforming to [502.2.11](#) to the inside and top faces of parapets, including parapets on abutment wings. Use gray sealer unless the contract specifies a different color. Do not seal surfaces where the contract requires staining or other treatment.
- (2) Under the Pigmented Surface Sealer Reseal bid item, prepare existing surfaces before cleaning by sand or water blasting as required to remove material that might prevent bonding; confine, collect, and dispose of the resulting waste materials.
- (3) Clean and dry surfaces before sealing. Immediately before sealing, direct an air blast over the surface to remove dust and any loose particles. Ensure that application equipment is clean inside before filling and that the equipment is functioning properly.
- (4) Seal after providing the required surface finish under [502.3.7](#). Conform to sealer manufacturer recommended application procedures and coverage rate. If application in a single coat causes running, use two lighter coats allowed to dry between coats.
- (5) Complete sealing before opening to traffic and before suspending work for the winter.

502.3.14 Adhesive Anchors

502.3.14 Revise to clean and prepare drilled holes according to manufacturer instructions.

502.3.14.1 General

- (1) Notify the engineer and provide the adhesive manufacturer's installation instructions to the engineer before installing anchors. Do not install anchors before 21 days after concrete placement. Notify the engineer if reinforcement is encountered during drilling.
- (2) **Clean and prepare drilled holes in accordance with Manufacturer's Printed Installation Instructions (MPII).** Follow additional cleaning procedures and temperature restrictions the adhesive manufacturer recommends.
- (3) Place adhesive and install reinforcing bars to the depth and of the length and bar size the plans show following the adhesive manufacturer's installation recommendations. Fill holes completely with adhesive.
- (4) Ensure proper installation by one or both of the following:
 - Installation by or under the direct supervision of an ACI/CRSI certified installer.
 - Field-verified by non-destructive pullout testing according to [ASTM E488](#).

502.3.14.2 ACI/CRSI Certified Installer

- (1) Have an ACI/CRSI certified installer install or directly supervise anchor installation. Direct supervision is directly viewing installation of 2 or more anchors per installer. Submit department form [DT1641](#) to the engineer certifying that anchor installation conforms to the contract.
- (2) The engineer will verify anchor installation by periodically observing the contractor's installation procedures and may direct the contractor to perform pull-out testing conforming to [502.3.14.3](#).

502.3.14.3 Non-Destructive Pullout Testing

- (1) Demonstrate anchor installation and perform both installation and static tension testing according to [ASTM E488](#) for the first 3 anchors of each rebar size installed under the contract. Do not proceed with production installation without the engineer's approval. Do not test before 28 days after concrete placement.
- (2) Do not allow any portion of the pull-out testing device to bear on the concrete within a distance equal to the embedment depth the plans show. Test anchors to a proof load of 80 percent of the anchor yield strength unless the plans show otherwise. If an anchor fails, modify installation procedures or use a different anchor system and retest.
- (3) In addition to tests performed on the first 3 anchors of each size, test one or 5 percent of the anchors placed during production installation whichever is greater. Provide an approximate installation schedule to the engineer and immediately notify the engineer if a test fails. The engineer will increase testing frequency by one percent for each failed anchor. Submit test reports and specification sheets prescribed under [ASTM E488](#) to the engineer upon request.
- (4) The engineer will verify anchor installation by periodically observing the contractor's installation and testing procedures and may direct the contractor to perform additional pull-out testing.

502.3.15 Clear Protective Coating

- (1) Apply a clear protective coating to specified areas of the substructure.
- (2) Apply the coating to the concrete surface before erecting structural steel. Do not apply coating at temperatures lower than the manufacturer recommends.
- (3) Clean the exposed vertical surfaces of the piers, and the front face of the abutments including the backwalls and the ends of the body wall to remove dust and dirt.
- (4) Apply the coating to these areas by brush or roller to give a smooth coating, completely covering the concrete. Apply the coating at the rate of one gallon per 200 square feet. If the coating runs or sags when applied in one coat, apply the material in 2 approximately equal coats of thickness. Apply the second coat within 10 minutes of the first.
- (5) If, because of weather conditions, the contractor cannot apply coating to the substructure before starting steel erection, protect the above-mentioned areas from staining until applying the coating. Obtain the engineer's approval for the method of temporary protection.

502.4 Measurement

502.4.1 Concrete for Bridges

- (1) The department measures the Concrete Masonry Bridges bid items by the cubic yard acceptably completed, based on the dimensions the plans show or, if the engineer revises the plan, on revised plan dimensions. The volume in haunches of prestressed concrete girder bridges is based on the average haunch height the plans show.
- (2) The department deducts for the volume displaced within components as follows:
 - Cast-in-place concrete piling embedded in footings, pile caps, and abutments.
 - Prestressed concrete girders embedded in superstructure diaphragms.
 - Flanges of steel and precast concrete beams embedded in **decks**.

502.4.2 Concrete for Seals

- (1) The department will measure Concrete Masonry Seal by cubic yard acceptably completed, measured as the volume of concrete placed up to a maximum of the volume the plans show, or the engineer directs. The department will deduct the volume displaced by cast-in-place concrete piles embedded in seals.

502.4.3 Preformed Elastomeric Compression Joint Sealers

- (1) The department will measure the Compression Joint Sealer Preformed Elastomeric bid items by the linear foot acceptably completed, measured along the centerline of the joint.

502.4.4 Expansion Devices

- (1) The department will measure Expansion Device by the linear foot acceptably completed, measured from the outermost extent of the expansion device not including turn-ups.

502.4.5 Surface Sealing

- (1) The department will measure the Protective Surface Treatment and Pigmented Surface Sealer bid items by the square yard acceptably completed, measured as the net area treated with no additional area measured where re-sealing after applying pavement marking as required under [646.3.1.1](#).

502.4.6 Adhesive Anchors

- (1) The department will measure the Adhesive Anchors bid items as each individual anchor acceptably completed.

502.4.7 Clear Protective Coatings

- (1) The department will measure Protective Coating Clear by the gallon acceptably completed. The quantity measured equals the actual number of gallons used to treat the abutments and piers.

502.5 Payment

502.5.1 General

- (1) The department will pay for measured quantities at the contract unit price under the following bid items:

<u>ITEM NUMBER</u>	<u>DESCRIPTION</u>	<u>UNIT</u>
502.0100	Concrete Masonry Bridges	CY
502.0200	Concrete Masonry Bridges HES	CY
502.1100	Concrete Masonry Seal	CY
502.2000	Compression Joint Sealer Preformed Elastomeric (width)	LF

502.3101	Expansion Device	LF
502.3200	Protective Surface Treatment	SY
502.3205	Pigmented Surface Sealer Reseal	SY
502.3210	Pigmented Surface Sealer	SY
502.3215	Protective Surface Treatment Reseal	SY
502.4100 - 4199	Adhesive Anchors (inch)	EACH
502.4200 - 4299	Adhesive Anchors (bar)	EACH
502.6500	Protective Coating Clear	GAL

502.5.2 Concrete for Bridges

- (1) Payment for the Concrete Masonry Bridges bid items is full compensation for providing forms and falsework; for placing, finishing, curing, protecting, and heating concrete; for measuring concrete opening strength, including fabricating and testing cylinders, and evaluating maturity; for treating joints, including sealing, providing preformed joint filler and waterproofing; for sealing cracks identified in the initial crack survey; for providing bridge seat protection; and for providing nameplates.
- (2) If the engineer allows the contractor to substitute high early strength concrete to expedite the work as allowed under [502.2.2](#), the contractor will bear the additional costs associated with that substitution.
- (3) The department will pay separately under the Follow-Up Deck Crack Sealing administrative item for sealing additional deck cracks identified in the follow-up crack survey at the fixed price of \$3.00 per linear foot of crack acceptably sealed. The department will also pay separately for traffic control required for the follow-up sealing operations.

502.5.3 Concrete for Seals

- (1) Payment for Concrete Masonry Seal is full compensation for providing concrete seals including forms, placing, curing, protecting, and pumping.
- (2) If the contract does not contain the Concrete Masonry Seal bid item and the engineer orders this work, the department will pay for this work as extra work.

502.5.4 Preformed Elastomeric Compression Joint Sealers

- (1) Payment for the Compression Joint Sealer Preformed Elastomeric bid items is full compensation for providing the seal, including lubricant-adhesive.

502.5.5 Expansion Devices

- (1) Payment for the Expansion Device bid items is full compensation for providing devices.

502.5.6 Surface Sealing

- (1) Payment for the Protective Surface Treatment and Pigmented Surface Sealer bid items is full compensation for treating and sealing surfaces including surface preparation and color-matching as required. Resealing after pavement marking is incidental to the applicable pavement marking bid item under [646.5](#). Payment for the Reseal bid items also includes initial surface preparation and waste material confinement, collection, and disposal.

502.5.7 Adhesive Anchors

- (1) Payment for the Adhesive Anchors bid items is full compensation for providing adhesive anchors; and for pullout testing including additional engineer-directed verification testing.
- (2) The department will pay separately for reinforcing bars under the appropriate Bar Steel Reinforcement HS bid item as specified in [505.5](#).

502.5.8 Clear Protective Coatings

- (1) Payment for Protective Coating Clear is full compensation for providing the coating, including temporary protection, and surface preparation.