DIVISION 600 STRUCTURES

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SECTION 601 TIMBER STRUCTURES

601.01 Description. This work consists of furnishing, treating, and constructing timber structures of treated, untreated, and structural glue-laminated (glulam) timber.

MATERIALS

601.02 Structural Lumber and Timber. The lumber and timber shall be dense quality long leaf or short leaf southern yellow pine or close-grained Douglas fir conforming to the requirements of AASHTO M 168. The grade of structural lumber and timber shall be as shown on the Plans. Unless otherwise specified, the timber shall be cut square and surfaced on four sides.

601.03 Glue-Laminated Timber.

(a) *General.* Glulam lumber shall be kiln-dried Douglas fir or southern pine meeting the engineering properties, such as bending stress, shear, and modulus of elasticity, as stated on the Plans and the standards of ANSI/AITC A190.1. All members shall be bonded with an exterior "Wet-Use" adhesive conforming to Voluntary product Standard PS 56-73 of the U.S. Department of Commerce, NIST.

(b) *Decks.* All milling and glue lamination shall be performed prior to treating. Planing shall be done on one side only. The top of the deck shall be left rough to ensure proper bonding with bituminous material.

The deck panel manufacturer shall have experience in manufacturing glue-laminated wood bridge members, and a qualified licensee of the American Institute of Timber Construction (AITC).

(c) *Members.* Glulam timber members manufactured for the Department's bridges shall bear a custom quality product mark as specified in ANSI/AITC A190.1. A certificate of material conformance shall be provided to the Engineer upon delivery of the member to the Project.

601.04 Preservative Treatment. Preservative treatment of timber shall conform to the requirements of Section 814 and the requirements of the AASHTO Standard Specifications for Highway Bridges.

601.05 Inspection. The timber, and the operation of treatment, will be inspected at the treating plant, both before and after treating, and all acceptable timber will be marked with the Department's standard hammer mark. All timber shall also be subject to inspection at the site of the work. If the timber is found defective, it shall be subject to rejection.

601.06 Structural Steel. Structural steel shall conform to the requirements covering carbon shapes, plates, and bars of structural quality for use in the construction of bridges. Carbon shapes, plates, and bars shall be completely galvanized according to AASHTO M 111. Thickness Grade 85 shall be used. For further material requirements refer to Section 826.

601.07 Hardware. Machine bolts, drift pins, dowels, nuts, washers, lag screws, and nails shall conform to the requirements of ASTM A 307.

Machine bolts shall have square heads and nuts, unless otherwise specified. Nails shall be cut or round wire of standard form. Spikes shall be cut or wire spikes, or boat spikes, as specified.
Nails, spikes, bolts, dowels, washers, rods, plates, and lag screws shall be completely galvanized according to the requirements of AASHTO M 232.

For glulam timber, the fabricator shall provide all steel connections and all hardware for joining wood members to each other and to the substructure. All hardware shall be galvanized mild steel ASTM A 36/A 36M. Washers may be cast iron or malleable iron.

601.08 Working Drawings. Working drawings shall be submitted in accordance with Subsection 105.04.

CONSTRUCTION METHODS.

601.09 Storing and Handling. All lumber and timber on the site of the work shall be stacked to prevent warping. Untreated material shall be open stacked at least 300 mm above the ground surface, and so piled as to shed water. Material shall be protected from the weather by suitable covering. Treated timber shall be carefully handled, without sudden dropping, breaking of outer fibers, bruising, or penetrating the surface with tools. Treated timber, other than piling, shall be handled with rope slings. Canthooks, peaveys, pikepoles, or hooks shall not be used. Treated timber shall be close stacked. The ground under and in the vicinity of all stacks shall be cleared of weeds and rubbish.
All bridge lumber shall be delivered and stored above grade on wooden blocks. Members shall be well supported and be leveled to avoid warping. When stacking, measures shall be taken to permit air to circulate around all four sides of each member.

601.10 Workmanship. All framing shall be true and exact. Unless otherwise specified, heads of nails and spikes shall be driven flush with the surface of the wood. Deep hammer marks in wood surfaces, splitting due to nailing, or spiking shall be considered evidence of poor quality of work and will be sufficient cause for removal of the workers causing them.

601.11 Cutting and Framing. All lumber and timber shall be accurately cut and framed to a close fit in such a manner that the joints have an even bearing over all contact surfaces. No shimming will be permitted in making joints, nor will open joints be accepted. All cutting and framing of treated timber shall be done before treatment insofar as is practicable.

All cuts and abrasions in creosote treated timbers glulam timber shall be treated shall be carefully trimmed, and then covered with two applications of a mixture of 60% creosote oil and 40% roofing pitch, or brush coated with at least two applications of hot creosote oil and covered with hot roofing pitch. The creosote oil shall be heated sufficiently to secure deep penetration but shall not be heated to the boiling point.

All cuts and abrasions in CCA treated timbers shall receive one brush application of the CCA solution used in the treatment process.

601.12 Holes for Bolts, Dowels, Rods, and Lag Screws. Boltholes shall be treated with creosote oil-tar or CCA solution as applicable, by means of an approved device that applies the creosote oil-tar or CCA solution to the inside of the hole. Any unfilled holes shall be treated in the same manner and then shall be plugged with creosote or CCA treated plugs.

Holes for round driftbolts or dowels shall be bored with a bit 1.6 mm less in diameter than the bolt or dowel to be used. The diameter of the holes for square driftbolts or dowels shall be equal to the least dimension of the bolt or dowel. Holes for machine bolts shall be bored with a bit of the same diameter as the bolt.
Holes for lag screws shall be bored with a bit not larger than the body of the screw at the base of the thread.
A washer, of the size and type specified, shall be used under all bolt heads and nuts that would otherwise come in contact with the wood.

All bolts shall be thoroughly checked after the nuts have been finally tightened.

601.13 Countersinking. Countersinking shall be done wherever smooth faces are required. Recesses formed for countersinking shall be treated with material as specified in Subsection 601.12 and as approved by the Engineer.

601.14 Caps. Timber caps shall be placed to secure an even and uniform bearing over the tops of the supporting posts or piles and to secure an even alignment of their ends. All pile caps shall be secured in the manner shown on the Plans.

601.15 Bracing. The ends of bracing shall be bolted through the pile, post, or cap as shown on the Plans. Intermediate intersections shall be bolted as shown on the Plans.

601.16 Stringers. Stringers shall be sized at bearings and shall be placed in position so that knots near edges are in the top portion of the stringers, except over continuous supports.
Outside stringers may have butt joints, but interior stringers shall be lapped to take bearings over the full width of the floor beam or cap at each end.

Cross-bridging between stringers shall be neatly and accurately framed and securely toenailed with at least two nails in each end.

601.17 Method of Measurement. The quantity of structural lumber and timber will be measured by the cubic meter. The quantity will be determined from actual widths and thicknesses and the actual lengths of the pieces in the finished and accepted structure.

The quantity of glue-laminated timber deck will be measured by the square meter. The quantity will be determined from the actual length and width of the finished deck completed and accepted.
The quantity of glue-laminated timber used for other members of the structure as specified on the Plans will be measured by the cubic meter.

601.18 Basis of Payment. The quantity of timber will be paid for at the Contract unit price per cubic meter. Price and payment will constitute full compensation for furnishing all materials; for applying preservative treatment when required; for placing all material including hardware; for the replacement of all defective materials; and for all labor, equipment, tools, and incidentals required to complete the work.

The quantity of glue-laminated timber deck will be paid for at the Contract unit price per square meter. The quantity of glue-laminated timber used for other members of the structure will be paid for at the Contract unit price per cubic meter. Price and payment will constitute full compensation for furnishing and placing all materials, including hardware; for fabricating glue-laminated timber decks and members; for applying preservative treatment; and for all labor, equipment, tools, and incidentals required to complete the work.

SECTION 602 CONCRETE STRUCTURES

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

MATERIALS.

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

- Preformed Elastomeric Compression Seals
- Rubber Joint Sealant
- Hot Poured Joint Sealer
- Preformed Expansion Joint Fillers, Type III
- Portland Cement Concrete
- Chemical Admixtures

Curing Materials:

- Liquid Membrane Compounds
- Polyethylene Sheeting
- Waterproof Paper
- Concrete Mix Composition, Classes A, B, C, and D
- Bar Reinforcement
- Bar Reinforcement, Epoxy Coated

602.03 Permanent Steel Bridge Deck Forms and Supports. Permanent steel bridge deck forms and supports shall be fabricated from steel conforming to ASTM A 446/A 446M, Grades A through E and shall have a coating of Z450 according to ASTM A 525M. Deck forms shall be 0.9 mm minimum.

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

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

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

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

CONSTRUCTION METHODS.

602.08 Formwork. Except where indicated elsewhere in this Section, forms shall be designed and constructed so they can be removed without injuring the concrete. Forms shall be designed for strength and deflection to resist all loads and pressures of the wet concrete, the weight of the forms, the rate of pour, the affect of vibration, the time of setting, and an addition of 2.4 kPa of construction live load applied to all horizontal surfaces.

For removable forms, no member shall have a deflection, under total load, in excess of 1/360 of its span length, and in no case shall the deflection exceed 6 mm, except that deflections of form surfaces for concrete floor slabs where such forms are supported by beams, stringers, or girders may be 1/180 of the span length but not to exceed 13 mm. Where the design of the forms requires deflections in excess of these amounts, the forms shall be cambered.
Concrete shall be assumed to weigh 2400 kg/m^3. Lumber in forms shall be assumed to weigh 700 kg/m^3. For all other materials, other than lumber in forms, the unit weight of the material shall be used.

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

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

The form drawings shall show all major design values and loading conditions. These include assumed values of live and dead load, rate of placement, temperature of concrete, height of drop, weight of moving equipment which may be operating on formwork, foundation pressures, design stresses, deflection and camber diagrams, and other pertinent applicable information. All pertinent design calculations shall be submitted for walls greater than 3 m in height. In

addition to specifying types of materials, sizes, lengths, and connection details, formwork drawings shall provide for applicable details such as: 1) Anchors, shores, and braces; 2) field adjustment of the form during placing of concrete; 3) waterstops, keyways and inserts; 4) working scaffolds and runways; 5) weepholes or vibrated holes where required; 6) screed and grade strips; 7) crush plates or wrecking plates; 8) removal of spreaders or temporary blocking; 9) cleanout holes; 10) construction, control and expansion joints; 11) chamfer strips; 12) notes to cover conduits and pipes to be embedded; and 13) details on shoring, reshoring, or leaving original shores in place as forms are stripped. The material to be used for forms for exposed surfaces shall be either plywood, metal in which all bolts and rivet holes are countersunk, fiber, or other approved material. In either case, a plain, smooth surface of the desired contour must be obtained. For surfaces to be given a rubbed finish, the material shall be plywood unless otherwise specifically approved. For curved or special surfaces, the above requirements may be modified.

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

Moldings, fluting, rustification, and other ornamental details shall be formed of material specifically manufactured for the job. Samples or details of the material shall be submitted for approval by the Engineer prior to use.
All lumber shall be free from knotholes, loose knots, cracks, splits, warps, or other defects impairing the strength or the appearance of the finished structure.

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

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

Dimensions affecting the construction of subsequent portions of the work shall be carefully checked after the forms are erected and before any concrete is placed. The interior surfaces of the forms shall be adequately oiled, greased, or soaped to ensure non-adhesion of mortar. Form plywood and/or lumber that is reused shall be free from bulge, warp or damage and shall be thoroughly cleaned. The forms shall be inspected immediately preceding the placing of concrete and any defects shall be remedied and all dirt, sawdust, shavings, or other debris within the forms shall be removed. Blocks and bracing shall be removed with the forms and in no case shall any portion of the wood forms be left in the concrete. Special attention shall be paid to the ties and bracing and when forms appear to be insufficiently braced or unsatisfactorily built, either before or during construction, the work will be ordered stopped until the defects have been corrected. The forms shall be so constructed that the finished concrete shall be of the form and dimensions shown on the Plans and true to line and grade.

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

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

tolerance(s), the work shall be stopped and the Contractor shall be required to rectify the problem to the full satisfaction of the Engineer.

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

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

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

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

602.10 Placing Concrete. No concrete shall be placed until the depth of the excavation and character of the foundation material, the adequacy of the forms and falsework, and the placing of reinforcement and other embedded items have been inspected and approved by the Engineer.
Concrete shall be placed in daylight unless an adequate lighting system meeting the approval of the Engineer is provided.

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

The temperature of the concrete shall not be greater than 32 C, nor less than 10 C at the time of placing, except where other temperatures are required in this Section. The temperature of concrete for bridge decks shall not exceed 29 C. During hot weather, the Contractor may be required to chill the mixing water, incorporate ice into the concrete mixture as part of the mixing water, or take other measures as prescribed in Section 812 to maintain concrete temperatures below the specified maximum temperatures. In addition, any combination of wind velocity, high air temperatures and low relative humidity, which, in the opinion of the Engineer, will impair the quality of fresh or hardened concrete due to rapid concrete moisture evaporation shall be sufficient cause to discontinue or prohibit concrete placement. The ACI Recommended Practice for Hot Weather Concreting will be used as a guide in assessing the hazards of hot weather. No concrete shall be used which does not reach its final position in the forms within the time stipulated in Subsection 812.06.

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

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

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

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

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

All chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the structure.
Dropping the concrete a distance of more than 1.5 m or depositing a large quantity at any point and running or working it along the forms will not be permitted, except that the 1.5 m limitation will not apply to the dropping of concrete into the forms for the walls of box culverts, or retaining walls unless directed by the Engineer.

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

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

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

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

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

Care shall be exercised during the placement of concrete to minimize the coating of reinforcing steel, structural steel, forms, and other items that extend into areas involved in a subsequent placement. In the event coating of the steel does occur, no attempt shall be made to remove the mortar until after the concrete steel bond of the earlier placement has developed sufficiently to withstand a cleaning operation. Any coating of mortar on deformed bars that cannot be removed by hand brushing with a wire bristle brush, or by a light chipping action, will not have to be removed.
The method and manner of placing concrete shall be so regulated as to place all construction joints across regions of low shearing stress and in such locations as will be hidden from view to the greatest possible extent.
The operations of depositing and consolidating the concrete shall, in general, be conducted so as to form a compact, dense, impervious mass of uniform texture that will show smooth faces on exposed surfaces. Any section of concrete found to be defective shall be removed or repaired as directed by the Engineer.

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

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

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

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

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

(1) The concrete has been placed when the air temperature, measured at the location of the concrete operation in the shade away from artificial heat, is below 2 C.

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

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

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

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

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

(c) *Insulation.* Protection of concrete by the use of approved insulated forms or insulation blankets will be permitted in lieu of the heated enclosure. Insulation will be required under the same conditions that heated enclosures are required, and shall be placed on the concrete as soon as initial set will permit.

Insulating materials shall have a minimum thickness of 25 mm. The thermal conductivity ("k" factor) of the insulation shall not exceed 0.85 W/m^2 for a thermal gradient of 0.02 C/mm as determined by ASTM C 177. Results of tests conducted in accordance with ASTM C 177 by an acceptable commercial testing laboratory shall be furnished to the Engineer for approval. Such approval shall be secured prior to use of the material. Insulating blankets shall be faced or covered, top and bottom, with polyethylene or similar waterproofing material. Blankets shall be placed on the concrete in such a manner that they form a waterproof surface for the concrete being protected. When the anticipated low temperature expected to occur during the protection period is lower than -12 C, 50 mm of insulation will be required.

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

mm minimum thickness of either rigid or blanket type insulation.

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

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

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

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

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

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

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

In using internal vibrators, the vibratory element shall be inserted into the concrete at the point of deposit and in the areas of freshly-placed concrete. The time of vibration shall be long enough to accomplish thorough consolidation of the concrete and complete embedment of the reinforcement, to produce a smooth surface free from honeycombing and air bubbles, and to work the concrete into all angles and corners of the forms. However, over-vibrating shall be avoided. Vibration shall continue in a spot only until the concrete has become plastic and shall not continue to the extent that pools of grout are formed. The correct length of time of vibration will depend upon the frequency of the vibration impulses per minute, the size of vibrators and the slump of the concrete.

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

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

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

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

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

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

602.14 Joints.

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

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

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

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

When longitudinal joints are specified or permitted, they shall be spaced so that each placement of concrete is not less than 3 m in width. Transverse joints shall be placed at the centerlines of piers or as specified on the Plans. Concrete shall be placed in one continuous operation between construction joints. The minimum volume of concrete in any one placement shall be not less than the volume of concrete in one end span. The falsework under all spans from edge to edge of slab or from edge of the slab to an open joint shall remain in place until the concrete in the entire slab has attained the minimum 28-day design compressive strength required for the mix.

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

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

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

When bonding fresh concrete to hardened concrete, or hardened concrete or steel to hardened concrete, an epoxy bonding compound conforming to ASTM C 881 shall be used. Surface preparation, mixing and application requirements, and limitations as specified by the manufacturer shall be strictly followed. Bonding compounds shall be approved prior to use.

The Contractor shall schedule its concrete operations so that the concrete is placed while the epoxy bonding compound is still uncured and tacky. If, in the opinion of the Engineer, the bonding compound has begun to cure, no

concrete shall be placed until a new film of bonding compound has been applied to the required areas.

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

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

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

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

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

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

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

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

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

602.17 Finishing Concrete Surfaces.

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

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

Unless otherwise specified on the Plans, all surfaces shall be given an ordinary

surface finish unless after form removal they are in such a condition that they cannot be repaired to the satisfaction of the Engineer. In these cases, the entire structural unit shall be given a rubbed finish.

(b) *Ordinary Surface Finish.* Immediately following the removal of the forms, all fins and irregular projections shall be removed from all surfaces except from those which are not to be exposed or are not to be water-proofed. On all surfaces, the cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects shall be thoroughly cleaned, saturated with water, and carefully pointed and trued with a mortar of cement and fine aggregate mixed in the proportions used in the grade of the concrete being finished. Mortar used in pointing shall be not more than 30 minutes old. The mortar patches shall be cured as specified in Subsection 602.18. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.

(c) *Rubbed Surface Finish.* After removal of forms, the rubbing of concrete shall be started as soon as its condition permits. Immediately before starting this work, the concrete shall be kept thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the pointing to thoroughly set. The surface to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in proportions used in the concrete being finished. Rubbing shall be continued until all form marks, projections, and irregularities have been removed, all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

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

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

(d) *Float Finish.* This finish, for horizontal surfaces, shall be achieved by placing an excess of material in the form and removing or striking-off the excess with a template, forcing the coarse aggregate below the mortar surface. Creation of a concave surface shall be avoided. After the concrete has been struck off, the surface shall be thoroughly worked and floated with a suitable wood, canvas, or cork floating tool. Before the finish has set, the surface cement film shall be removed with a fine brush in order to have a fine grained, smooth but sanded texture.

(e) *Special Surface Finish.* As an alternative to the rubbed surface finish, an acrylic or latex bonded mortar finish may be used when and where designated in the Plans and Special Provisions.

(f) *Tooled Finish.* A tooled finish shall be made on the surfaces previously spaded by cutting into the body of the concrete with a pointing tool or bush-hammer as indicated on the Plans.

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

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

When cotton mats, burlap, or earth or sand blankets are to be used to retain the moisture, the entire surface of the concrete shall be kept damp by applying water with a nozzle that so atomizes the flow that a mist and not a spray is formed, until the surface of the concrete is covered with the curing medium. The moisture from the nozzle shall not be applied under pressure directly upon the

concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or wash the surface. At the expiration of the curing period, the concrete surface shall be cleared of all curing mediums.

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

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

The surface shall be sealed with a single uniform coating of the specified type of curing compound applied at the rate of coverage recommended by the manufacturer or as directed by the Engineer, but not less than 0.27 L/m^2 of area.

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

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

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

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

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

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

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

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

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

(d) *Forms-In-Place Method.* Formed surfaces of concrete shall be cured by retaining the forms in place for a minimum period of seven days after the concrete has been placed.

If the Contractor elects to leave forms in place for a part of the curing period and use one of the other methods of curing included in this article for the remainder of the curing period, the concrete surfaces shall be kept wet during the time the curing methods are being changed.

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

Table 602-A

Minimum Requirements for Removal of Formwork, Placement of Superimposed Vertical Loads, and Placement of Backfill

Structural Element	Removal of Formwork		Placing Superimposed Vertical Dead Loads*		Placement of Backfill	
	Time (days)	Strength (%f '$_c$)	Time (days)	Strength (%f '$_c$)	Time (days)	Strength (%f '$_c$)
Arch (Span 20 m) (B.F.)	3	40	21	95	21	95
Arch (Span 20 m) (S.F.)	2	30				
Concrete Beam (B.F.)	7	60	12	80	n/a	n/a
Concrete Beam (S.F.)	2	30				
Slab (Span 3 m) and Diaphragms	2	30	14	85	n/a	n/a
Slab (Span > 3 m)	5	50				
Piers/Columns	2	30	5	50	n/a	n/a
Pile Cap and Pier Cap	5	50	7	60	5	50
Footing	2	30	3	40	2	30
Cast-In- Place Concrete Piles	n/a	n/a	5	50	n/a	n/a
Subfoundation Concrete	1	20	2	30	1	20
Retaining Wall, Headwall, and Wingwall	2	30	2	30	21	95
Parapet Wall, Curb, and Backwall	1	20	1	20	5	50
Abutment Wall, Rigid Frame Wall, and Box Culvert Wall	2	30	5	50	21	95

B.F. - Bottom Form

S.F. - Side Form

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 602-B

Requirements for the Removal of Formwork for Concrete in Contact with Sea Water or Brackish Water

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

602.20 Bridge Decks.

(a) *Permanent Steel Bridge Deck Formwork*. Permanent steel bridge deck forms for concrete deck slabs of bridges shall be used when shown on the Plans.

(1) *Design.* The steel forms shall be designed on the basis of dead load of the form, reinforcement, and plastic concrete plus 2.4 kPa for construction loads. The unit working stress in the steel sheet shall be not more than 72.5% of the specified minimum yield strength of the material furnished, but not to exceed 250 MPa.

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

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

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

All deck reinforcement shall have a minimum concrete cover

of 50 mm for the top mat of steel and 25 mm for the bottom mat unless otherwise specified on the Plans.

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

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

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

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

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

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

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

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

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

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

warranting additional inspection.

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

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

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

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

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

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

The placing of concrete in bridge decks will not be permitted until the Contractor has satisfied the Engineer that it has adequate personnel and equipment to deliver, place, spread, finish, and cure a minimum of 15 m^3 of concrete per hour, that experienced finishing machine operators and concrete finishers are employed to finish the deck, and that weather protective equipment and all necessary finishing tools and equipment are on hand at the site of the work and in satisfactory condition for use.

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

Supports for screeds or finishing machines shall be completely in place and firmly secured before placing of concrete will be permitted. Supports shall be set to elevations necessary to obtain a bridge deck true to the required grade and cross-section, with allowance being made for

anticipated settlement. Supports shall be of a type and shall be so installed that no springing or deflection will occur under the weight of the finishing equipment, and shall be so located that finishing equipment may operate without interruption over the entire bridge deck being furnished.

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

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

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

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

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

During the screeding operation, an adequate supply of concrete shall be kept ahead of the screed and a slight excess shall be maintained immediately in front of the screed. Workers will not be permitted to walk on

the concrete after screeding. The Contractor shall provide a sufficient number of work bridges or other suitable platforms to provide adequate access to the work, and so that screeding, finishing, and curing operations can progress without delay. The work bridge shall be supported outside the limits of the concreting.

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

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

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

The deck surface shall be tested using either a straightedge, a rolling straightedge, or a California-type profilograph. If surface testing using a California-type profilograph is required, testing will conform to the requirements of Subsection 501.17. If surface testing using a California-type profilograph is not required, testing shall be performed by the Contractor with a 3.048 m straightedge, and the Contractor shall rescreed the deck surface as many times as is necessary to ensure a smooth riding surface. The straightedge shall be held in successive positions at the edges, quarter points, and on the centerline, parallel thereto and in contact with the surface. Advancement along the deck shall be in successive stages of not more than one-half the length of the straightedge. The surface shall also be checked transversely at the ends, quarter points, and center of the span. Areas showing high spots or depressions of more than 3 mm in 3.048 m in the longitudinal direction and 6 mm in 3.048 m in the transverse direction shall be struck off or filled with freshly mixed concrete as the case may be. Special attention shall be given to ensure that the surface across joints meets the requirements for smoothness. Any cracking that occurs prior to opening to traffic shall be sealed or repaired in a manner approved by the Engineer at no cost to the Department. The deck shall also be sounded and any delaminated areas shall be removed and replaced in a manner approved by the Engineer at no cost to the Department.

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

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

saw uniformly pronounced grooves transverse to the centerlines.

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

For bridge lengths over 90 m, a randomly spaced groove pattern shall be used. The random spacing shall be from 35 mm centers to 40 mm centers, as determined by the Engineer.

Removal of all debris, including slurry, resulting from the grooving operations shall be continuous. Surfaces must be immediately left in a washed and clean condition, free of all slipperiness from the slurry. All debris and surplus material removed from the grooving operations shall be deposited in a truck, or other conveyance, and disposed.

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

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

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

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

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

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

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

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

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

(1) Accept the low strength concrete test results and all remedial action as described in the below categories or;

(2) Challenge the low strength concrete test result by coring the area that the test cylinders represent.

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

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

Category A:	0 to 1.66 MPa below 28-day Design Strength
	No repair required, full payment as specified in Subsection 602.27.
Category B:	1.67 to 3.33 MPa below 28-day Design Strength
	Prorated payment as specified in Subsection 602.27.
Category C:	3.34 to 6.66 MPa below 28-day Design Strength
	Prorated payment as specified in Subsection 602.27 plus the application of a protective waterproofing that is approved by the Department's Materials and Research Section. The coating shall be clear and shall only be applied to the pour area that the core represents.

Category D:	6.67 MPa or greater below 28-day Design Strength
	Strengthen area of low strength concrete as approved by the Engineer at no cost to the Department.

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

602.26 Method of Measurement. The quantity of Portland cement concrete will be measured as the number of cubic meters of concrete placed and accepted. The volume will be computed using the dimensions shown on the Plans, or as ordered in writing. The quantity of concrete in floor slabs will be computed from the dimensions shown on the Plans with no allowance for form deflection or stay-in-place form corrugations. No deduction in the computed volume of Portland cement concrete will be made for pipes with outside diameters of 300 mm or less, conduits, anchors, bolts, and scuppers. The quantity of concrete in deck slabs will be computed from design deck thickness. Floodlighting will not be measured.

The quantity of grooving will not be measured.

602.27 Basis of Payment.

(a) *General.* The quantity of Portland cement concrete will be paid for at the Contract unit price per cubic meter. Price and payment will constitute full compensation for furnishing all materials, forms, and falsework; for cold weather protection; for removal of bridge deck forms to allow visual inspection of areas of doubtful soundness and bonding of concrete; for construction of drainage openings and weepholes; for furnishing and placing pipes and conduits; for furnishing and placing anchors, bolts, and scuppers; for furnishing and maintaining light plants and lighting equipment; for grooving and removing all debris or for manual texturing; and for furnishing all equipment, tools, labor, and incidentals required to complete the work.

(b) *Price Adjustment for Low Strength Concrete.* Prorated payment for concrete as specified in Subsection 602.25 shall be calculated as shown in the following equation:

Prorated Payment = [*Low Compressive Strength Concrete/Specified Compressive Strength*] x (*Quantity of Concrete*[*]) x (*Bid Price*[**])

[*] The quantity for which the low compressive strength results represent.
[**] Item bid price; not material cost.

SECTION 603 BAR REINFORCEMENT

603.01 Description. This work consists of furnishing and placing bar reinforcement.

MATERIALS.

603.02 Bar Reinforcement. Bar reinforcement shall conform to the requirements of Section 824.

603.03 Working Drawings. Working drawings shall be submitted in accordance with Subsection 105.04. In addition, the Contractor shall submit complete, detailed bar lists and bending diagrams for all bar reinforcement to be furnished. The Contractor shall be responsible for checking all bar lists and details shown on the Plans for accuracy as to the quantity, size, length, and dimensions before ordering bars from its lists. Bar lists may be prepared on sheets of a size and type that are the supplier's standard.

CONSTRUCTION METHODS.

603.04 Storage. Bar reinforcement shall be stored on wooden platforms or other hard, clean surfaces, and shall be placed under cover. The Contractor shall not permit bar reinforcement to be in direct contact with soil.

603.05 Placing. All bar reinforcement shall be free from dirt, oil, paint, grease, mill scale, and loose or thick rust. When bending is required, it shall be accurately accomplished without the use of heat. Bar reinforcement with cracks or splits at the bends will be rejected.

All bar reinforcement shall be placed in the position shown on the Plans and shall be held in position by wiring at bar intersections. The bar reinforcement shall be securely held so that it will not be displaced during the placing and consolidating of the concrete. In bridge decks, bar reinforcement shall be tied at all intersections. For all other construction, bar reinforcement shall be tied at all intersections except where bar spacing is less than 300 mm in both directions, in which case alternate intersections shall be tied. The use of pebbles, bricks, broken stone, metal or wooden blocks, or other unapproved material for blocking is prohibited.

Chairs and metal supports in contact with the forms shall be plastic or rubber tipped. Epoxy or plastic coated chairs fabricated with turned-up legs are acceptable. Precast concrete may be used to provide the required vertical clearance between bar reinforcement and the ground in foundations.

603.06 Welding. Welding of bar reinforcement shall be performed only where detailed on the Plans or the approved working drawings, or if authorized in writing. Welding shall conform to ANSI/AWS D1.4. The workmanship shall not result in any burning or reduction in section of the bar reinforcement. The Contractor shall obtain the Engineer's approval for all welding methods and results.

603.07 Splicing Bar Reinforcement. All bar reinforcement shall be furnished in the full lengths indicated on the Plans unless otherwise permitted. Splicing of bars, except where shown on the Plans, will not be permitted without written approval. Splices shall be staggered as far as possible. Unless otherwise shown on the Plans, bars shall be spliced in accordance with the AASHTO Standard Specifications for Highway Bridges. In lapped splices, the bars shall be placed and wired in such a manner as to maintain the minimum distance to the surface of the concrete shown on the Plans. Lapped splices shall not be used for No. 43 and No. 57 bars. Connecting bars mechanically or by welding shall be done only if detailed on the Plans or authorized in writing by the Engineer.

603.08 Method of Measurement. The quantity of bar reinforcement will be measured by determining the theoretical weight, in kilograms, of the steel placed as shown on the Plans and accepted. For the purpose of computing the theoretical weight of bar reinforcement, the following table shall be used:

Table 603-A
Deformed Metric Bar Designation Numbers and Unit Weights

Bar Size Designation	Unit Weight (kg/m)
10	0.560
13	0.994
16	1.552
19	2.235
22	3.042
25	3.973
29	5.060
32	6.404
36	7.907
43	11.38
57	20.24

603.09 Basis of Payment. The quantity of bar reinforcement will be paid for at the Contract unit price per kilogram, based upon the metric designation. Price and payment will constitute full compensation for furnishing and placing all materials, including clips, wire, chairs, and other material used for fastening the bar reinforcement in place, for banding and splicing, and for all labor, equipment, tools, and incidentals required to complete the work.

SECTION 604 BAR REINFORCEMENT, EPOXY COATED

604.01 Description. This work consists of furnishing and placing epoxy coated bar reinforcement.

MATERIALS.

604.02 Bar Reinforcement. Epoxy coated bar reinforcement shall conform to the requirements of Section 824.

604.03 Repair Material. The Contractor shall furnish a certification from the coating manufacturer that the repair material is compatible with the coating material.

604.04 Working Drawings. Working drawings shall be submitted in accordance with Subsection 603.03. In addition, the working drawings shall indicate to the fabricator and coater that the spacing between bands around bundled bars shall not exceed 4 m.

CONSTRUCTION METHODS.

604.05 Storage and Protection. Epoxy coated bar reinforcement shall be stored on wooden or padded supports that will keep the steel above the ground, well drained, and protected against deformation and abrasion.
Epoxy coated bars that have been exposed to sunlight for 90 days shall be covered. This requirement includes partially embedded bars. The cover shall be opaque to block sunlight and shall be placed to allow air circulation around the bars.

In order to protect the coated bar reinforcement from damage during movement, the Contractor shall ensure that bands used to secure rebar in bundles are spaced no more than 4 m apart. The Contractor shall also use padded or non-metallic slings and padded straps to handle bundled bars. Bundles of epoxy coated bars shall be lifted by spreader bars or multiple supports from a platform bridge that will prevent bar-to-bar abrasion from sags. Bundles shall not be picked up by the banding material. Bars and bundles shall not be dropped, dragged, or driven over. The Contractor may propose alternate precautionary measures for the Engineer's approval.

604.06 Placing.

(a) *Bridge Decks.* The bottom layer of bar reinforcement in bridge decks shall be supported from the forms on continuous type bar supports placed parallel to the beams and spaced with the lines of supports, as measured between beam centers, at approximately the 1/4 and 3/4 points for beam spacing less than 2.7 m and at approximately the 1/6, 1/2, and 5/6 points for beam spacing 2.7 m and over. Additional individual chairs may be required outside the fascia beam to securely support the bar reinforcement along and near the fascia. The continuous type bar supports and individual chairs in contact with epoxy coated bars shall be either epoxy or plastic coated, as approved. The Contractor may propose other devices for the Engineer's approval. Coated chairs fabricated with straight legs shall also be equipped with plastic or rubber tips. Coated chairs fabricated with turned-up legs do not require tips.

The upper layer of bar reinforcement in bridge decks shall be supported with rows of approved, continuous, steel bar supports consisting of a minimum of three longitudinal wires acting as spacers at the proper height. The longitudinal wires shall be securely tied to the structural steel, stud shear developers, or other structural components at intervals not greater than 1.5 m along each beam or girder. Tie-downs shall consist of loops of 2.7 mm coated wire, or equivalent devices meeting the approval of the Engineer.

(b) *Other Structures.* The method of placement for structures other than bridge decks shall conform to the requirements of Subsection 603.05. The wire, chairs, and metal supports in contact with epoxy coated bars shall, at the Contractor's option, be either epoxy or plastic coated. Epoxy coated bar reinforcement shall not come in contact with any materials to be embedded in the concrete that are not epoxy or plastic coated.

604.07 Splicing Reinforcement. Splicing shall conform to the requirements of Subsection 603.07.

604.08 Repair of Epoxy Coating. If, in the opinion of the Engineer, the coating on bar reinforcement has been damaged, the damaged bar will be rejected and shall be properly repaired or replaced.
Repair material shall be compatible with the coating, inert in concrete, and supplied by the epoxy resin manufacturer. The material shall be suitable for repairing areas of the coating that have been damaged and shall be applied at the point of application, fabrication, or installation, as may be required. Sheared ends and other cut or exposed areas shall be repaired promptly before detrimental oxidation occurs. These areas shall be clean and free from all surface contaminants.

The sum of the damaged areas of coating in each 1 m of length of bar reinforcement shall not exceed 6% of the surface area in that 1 m length of bar. All visible damage of the epoxy coating shall be repaired. The total bar surface area covered by patching material shall not exceed 2%.

604.09 Method of Measurement. The quantity of epoxy coated bar reinforcement will be measured according to Subsection 603.08.

604.10 Basis of Payment. The quantity of epoxy coated bar reinforcement will be paid for at the Contract unit price per kilogram based upon metric designation as shown in the Table 603-A. Price and payment will constitute full compensation for furnishing and placing all materials, including the epoxy resin, clips, wire, chairs, and other material used for fastening the bar reinforcement in place; for preparing the bar reinforcement surfaces for epoxy coating; for applying the epoxy coating; for bending, splicing, and repairing; and for all labor, equipment, tools, and incidentals required to complete the work.

SECTION 605 STEEL STRUCTURES

605.01 Description. This work consists of furnishing, field fabricating, erecting, and painting structural steel for bolted and welded construction.

This work also consists of recoating a portion of or the entire existing steel structure.

605.02 Materials. Materials for steel structures shall conform to the following Subsections:

- Coatings 820.02
- Structural Steel 826.02
- Fasteners 826.03
- Shear Connectors 826.04
- Forgings and Castings 826.05
- Bearing Materials 826.06
- Galvanizing 826.07
- Sheet Zinc 826.08

605.03 Storage of Materials. Structural material shall be stored above the ground on platforms, skids, or other supports. It shall be kept free from dirt, grease, and other foreign matter, and shall be protected as far as practicable from corrosion.

FABRICATION.

605.04 Straightening Material. Rolled material, before being laid out or worked, must be straight. If straightening is necessary, it shall be done by methods that will not injure the metal. Sharp kinks and bends shall be cause for rejection of the material.

605.05 Finish. Portions of the work exposed to view shall be finished neatly. Shearing, flame cutting, and chipping shall be done carefully and accurately and result in square and true edges.

605.06 Bolt Holes.

(a) *High Strength Bolts.* All holes for high strength bolts shall be either punched or reamed or drilled. When there are more than five layers of metal to be bolted or when any of the material is thicker than 19 mm for carbon steel, or 16 mm for high-strength steel, all holes shall be either subpunched or subdrilled 5 mm smaller than the diameter of the bolts.

After preliminary assembling, the holes shall be reamed 2 mm larger or drilled from the solid to 2 mm larger than the diameter of the bolts.

Material forming parts of a member composed of not more than five layers of metal may be punched 2 mm larger than the diameter of the bolts whenever the thickness of the metal is not greater than 19 mm for structural steel or 16 mm for high-strength steel.

(b) Ribbed Bolts, Turned Bolts, or other Approved Bearing Type Bolts. All holes for ribbed bolts, turned bolts, or other approved bearing type bolts shall be either subpunched or subdrilled 5 mm smaller than the diameter of the bolt and reamed assembled to a steel template or, after assembling, drilled from the solid at the option of the fabricator. In any case the finished holes shall provide a driving fit as specified on the Plans or in the Special Provisions.

605.07 Punched Holes. The diameter of the die shall not exceed the diameter of the punch by more than 2 mm. All holes to be enlarged to admit the bolts must be reamed. Holes must be cut clean without torn or ragged edges. Poor matching of holes will be cause for rejection.

605.08 Reamed or Drilled Bolt Holes. Reamed or drilled holes shall be cylindrical and perpendicular to the member. Where practicable, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Poor matching of holes will be cause for rejection. Reaming and drilling shall be done with twist drills. If required by the Engineer, assembled members shall be taken apart for removal of burrs caused by drilling. Connecting members requiring reamed or drilled holes shall be assembled and securely held while being reamed or drilled and shall be match-marked before disassembling.

605.09 Subpunching or Subdrilling and Reaming Field Connections. Unless otherwise specified in the Special Provisions or on the Plans, holes in all field connections and field splices of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched or subdrilled and reamed while assembled to a steel template. Drilling full size holes, in lieu of assembly reaming or template reaming undersized holes, will be permitted upon approval of the procedures by the Engineer.

All holes for floor beam and stringer field end connections shall be subpunched or subdrilled and reamed to a steel template or reamed while assembled. Reaming or drilling full size field connection holes through a steel template shall be done after the template has been located with respect to position and angle and firmly bolted in place. Templates used for reaming matching members, or the opposite faces of a single member, shall be exact duplicates. Templates used for connections on like parts or members shall be located so that the parts or members are duplicates and require no match-marking.

If additional subpunching or subdrilling and reaming is required, it shall be specified in the Special Provisions or on the Plans.

605.10 Accuracy of Punched, Subpunched, and Drilled Holes. All holes punched full size, subpunched, or subdrilled shall be so accurately punched that after assembling and before any reaming is done, cylindrical pins 3 mm smaller in diameter than the size of the punched, subpunched, and subdrilled holes may be entered perpendicular to the face of the member without drifting, in at least 75% of the contiguous holes in the same plane. If this requirement is not fulfilled, the members will be rejected. If any hole will not pass a pin 5 mm smaller in diameter than the size of the punched hole, this will be cause for rejection.

605.11 Accuracy of Reamed and Drilled Holes. When holes are reamed or drilled, 85% of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 1 mm between adjacent thicknesses of metal.

All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centerlines of the connection as inscribed on the template. The centerlines shall be used in locating accurately the template from the milled or scribed ends of the members.

605.12 Fitting for Bolting. Surfaces of metal in contact shall be cleaned before assembling. The members shall be assembled, well pinned, and firmly drawn together with bolts before reaming is commenced. Assembled members shall be taken apart, if necessary, for the removal of burrs and shavings produced by the reaming operation. All members shall be free from twists, bends, and other deformations.

605.13 Drifting of Holes. The drifting during assembling shall only be to bring the members into position for bolting. The drifting shall not enlarge the holes or distort the metal. All holes to be enlarged must be reamed.

605.14 Connections Using Non-High-Strength Bolts. Non-high-strength bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A bolts of ASTM A 307. Bolted connections shall be used only as indicated by the Plans or Special Provisions. Bolts shall have single, self-locking nuts or double nuts unless otherwise shown on the Plans or in the Special Provisions. Beveled washers shall be used where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis.

(a) *Unfinished Bolts.* Unfinished bolts shall be furnished unless other types are specified.

(b) *Turned Bolts.* The surface finish of the body of turned bolts shall be 3.2 µm or better. Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of threads shall be equal to the body of the bolt or the nominal diameter of the bolt specified. Holes for turned bolts shall be carefully reamed for the bolts furnished to provide for a light driving fit. Threads shall be entirely outside of the holes. A washer shall be provided under the nut.

(c) *Ribbed Bolts.* The body of ribbed bolts shall be of any approved form with continuous longitudinal ribs. The diameter of the body measured on a circle through the points of the ribs shall be 2 mm greater than the nominal diameter specified for the bolts.

Ribbed bolts shall be furnished with round heads conforming to ANSI/ASME B18.5.2.2M unless otherwise specified. Nuts shall be hexagonal. The nuts shall be recessed or installed using washers of suitable thickness. Ribbed bolts shall make a driving fit with the holes. The hardness of the ribs shall be such that the ribs do not mash down enough to permit the bolts to turn in the holes during tightening. If for any reason the bolt twists before drawing tight, the holes shall be carefully reamed and an oversized bolt used as a replacement.

605.15 Connections Using High Strength Bolts. This Subsection covers the assembly of structural joints using ASTM A 325M high-strength carbon steel bolts and ASTM A 490M quenched and tempered alloy steel bolts or equivalent fasteners, tightened to a high tension. Holes for high-strength bolt connections shall conform to the requirements of Subsections 605.06, 605.07, and 605.08.

(a) *Bolts, Nuts, and Washers.* Bolts manufactured to ASTM A 325M shall be marked on the top of the head with three radial lines and the symbol **A 325M**.

All galvanized nuts shall be lubricated with a water soluble lubricant containing a visible dye so a visual check can be made for the lubricant at the time of field installation. Nuts shall be marked according to the requirements of ASTM A 563M.

Bolts, nuts, and washers shall be kept protected from the weather or any other adverse environments. Weathered or rusted fasteners or fasteners which have lost their lubricant or protective coating will be rejected for use.

Bolt and nut dimensions shall conform to the dimensions shown in Table 605-A.

Table 605-A

Bolt and Nut Dimensions

Nominal Bolt Diameter and Thread Pitch [1]	Heavy Hexagon Structural Bolt Dimensions [1] (mm)						Nut Dimensions [2] (mm)			
	Body Diameter (D)		Width Across Flats (S)		Head Height (K)		Width Across Flats (S)		Thickness (M)	
	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
M16 × 2	16.70	15.30	27.00	26.16	10.75	9.25	27.00	26.16	17.10	16.40
M20 × 2.5	20.84	19.16	34.00	33.00	13.40	11.60	34.00	33.00	20.70	19.40
M22 × 2.5	22.84	21.16	36.00	35.00	14.90	13.10	36.00	35.00	23.60	22.30
M24 × 3	24.84	23.16	41.00	40.00	15.90	14.10	41.00	40.00	24.20	22.90
M27 × 3	27.84	26.16	46.00	45.00	17.90	16.10	46.00	45.00	27.60	26.30
M30 × 3.5	30.84	29.16	50.00	49.00	19.75	17.65	50.00	49.00	30.70	29.10
M36 × 4	37.00	35.00	60.00	58.80	23.55	21.45	60.00	58.80	36.60	35.00

Note 1: From ANSI B18.2.3.7M - 1979. Pitch = the distance in millimeters from the crest of one thread to the crest of the next thread.

Note 2: From ANSI B18.2.4.6M - 1979.

(b) *Bolted Members.* The slope of surfaces of bolted members in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted members shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material.

When assembled, all faying surfaces including the outside surfaces adjacent to the bolt heads, nuts, or washers shall be free of scale, except for tight mill scale. The faying surfaces shall also be free of dirt, loose scale, burrs, other foreign material, and other defects that would prevent solid seating of the members.

(c) *Surface Preparation of Contact Surfaces.* Contact surfaces of high strength bolted connections which are considered within friction-type joints shall be free of oil, paint, lacquer, rust inhibitor, or galvanizing unless specifically modified by the Plans or Special Provisions.

(d) *Bolt Tension.* During installation each fastener shall be tightened to provide a tension which is greater than 70% of the tensile strength given in AASHTO M 164M for A 325M bolts and between 70% of the minimum and maximum tensile strength given in AASHTO M 253M for A 490M bolts.

Table 605-B Minimum Bolt Tension [1], kiloNewtons (kN)			
Nominal Bolt Diameter and Thread Pitch	AASHTO M 164M	AASHTO M 253M	
		min.	max.
M16 × 2	91	114	132
M20 × 2.5	142	179	206
M22 × 2.5	176	221	255
M24 × 3	205	257	297
M27 × 3	267	334	386
M30 × 3.5	326	408	471
M36 × 4	475	595	686
Note 1: Equal to 70% of specified minimum tensile strength of bolts.			

Threaded bolts shall be tightened by the turn-of-nut method. If required because of bolt-entering and wrench-operation clearances, tightening may be done by turning the bolt while the nut is prevented from rotating. Impact wrenches, if used, shall be of adequate capacity and supplied with sufficient air to perform the required tightening of each bolt in approximately ten seconds.

(e) *Washers.* All fasteners shall have a hardened washer under the element (nut or bolt head) turned in tightening. Hardened washers shall be used under both the head and nut regardless of the element turned when using AASHTO M 253M (ASTM A 490M) bolts, if the material against which it bears has a specified yield strength of less than 276 MPa.

Where an outer face of the bolted members has a slope of more than 1:20 with respect to a plane normal to the bolt axis, a smooth, beveled washer shall be used to compensate for the lack of parallelism.

(f) *Calibrated Wrench Testing.* To check the correct calibration of a wrench, the Skidmore-Wilhelm Bolt Tension Calibrator or equivalent tension measuring device shall be furnished.

(g) *Turn-of-Nut Tightening.* When the turn-of-nut method is used to provide the bolt tension specified under (d) above, there shall first be enough bolts brought to a "snug tight" condition to ensure that all members of the connection are brought into full contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a construction worker using an ordinary spud wrench. Following this initial operation, bolts shall be placed in all remaining holes in the connection and brought to snug tightness. All bolts in the connection shall then be tightened by the applicable amount of nut rotation specified in Table 605-C. Tightening shall progress systematically from the most rigid part of the connection to its free edges. During this operation there shall be no rotation of the element not turned by the wrench.

(h) *Tightening by Use of a Load Indicating Fastener System.* Tightening by

this means is permitted provided it can be demonstrated, by an accurate, direct measurement procedure, that the bolt has been tightened in accordance with Table 605-C. Tightening shall be by methods and procedures approved by the Engineer.

Table 605-C

Nut Rotation from Snug Tight Condition [1]

Bolt Length, measured from underside of head to extreme end of point	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters [2]	2/3 turn	5/6 turn	1 turn

Note 1: Nut rotation is relative to the bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be ±30 degrees; for bolts installed by 2/3 turn and more, the tolerance should be ±45 degrees.

Note 2: No research work has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedures when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

(i) *Inspection.*

(1) The Engineer will determine when the requirements of (3)b. and (3)c. below are met. When the calibrated-wrench method of tightening is used, the Engineer will have full opportunity to witness the calibration tests prescribed under (f) above.

(2) The Engineer will observe the installation and tightening of bolts to determine if the selected tightening procedure is properly used and will determine when all bolts are tightened.

(3) The following inspection procedure shall be used unless a more extensive or different inspection procedure is specified:

a. Either the Engineer will or the Contractor in the presence of the Engineer, at the Engineer's option, shall perform the inspection using an inspection wrench. The inspection wrench may be either a torque wrench or a power wrench that can be accurately adjusted in accordance with the requirements under (f) above.

b. Three bolts of the same grade, size*, and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. There shall be a washer under the element turned. (* Length

may be any length representative of bolts used in the structure.)

c. When the inspection wrench is a torque wrench, each of the three bolts shall be tightened in the calibration device by any convenient means to the minimum tension specified for its size under (d) above. The inspection wrench shall then be applied to the tightened bolt, and the torque necessary to turn the nut or head five degrees (approximately 25 mm at a 300 mm radius) in the tightening direction shall be determined. The average torque measured in the tests of the three bolts shall be taken as the job inspecting torque to be used as specified in (3)e. below.

d. When the inspection wrench is a power wrench, it shall be adjusted so that it tightens each of the three bolts to a tension at least 5% but not more than 10% greater than the minimum tension specified for its size under (d) above. This tension setting of the power wrench shall be taken as the job inspecting torque to be used in the manner specified in (3)e. below.

e. Bolts represented by the three-bolt sample that have been tightened in the structure shall be inspected by applying in the tightening direction, the inspection wrench to its job inspecting torque on 10% of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt is turned by this application of the job inspecting torque, the connection shall be accepted as properly tightened. If any nut or bolt head is turned by the application of the job inspecting torque, this torque shall be applied to all bolts in the connection. All bolts whose nut or head is turned by the job inspecting torque shall be tightened and reinspected. Alternatively, the Contractor has the option to retighten all of the bolts in the connection and then resubmit the connection for inspection.

605.16 Plate Cut Edges.

(a) *Edge Planing.* Sheared edges of plates more than 16 mm in thickness and carrying calculated stress shall be planed, milled, ground, or thermal cut to a depth of 6 mm. Re-entrant cuts shall be filleted to a minimum radius of 19 mm before cutting.

(b) *Visual Inspection and Repair of Plate Cut Edges.* In the repair and determination of limits of internal defects visually observed on sheared or flame-cut edges and caused by entrapping slag or refractory, deoxidization products, gas pockets, or blow holes, the amount of metal removed shall be the minimum necessary to remove the defect or to determine that the permissible unit is not exceeded. Plate edges may be at any angle with respect to the rolling direction. All repairs of defects made by welding shall conform to the applicable provisions of ANSI/AASHTO/AWS D1.5, *Bridge Welding Code* as modified in this Section.

The limits of acceptability and the repair of visually observed edge defects in plates 100 mm and under in thickness shall be in accordance with Table 605-D.

Table 605-D Required Repairs for Discontinuity	
Description of Discontinuity	Repair Required
Any discontinuity 25 mm in length or less and 3 mm maximum depth.	None; need not be explored.
Any discontinuity over 25 mm in length and 3 mm maximum depth.	None; depth should be explored by random spot grinding
Any discontinuity over 25 mm in length with depth over 3 mm but not greater than 6 mm.	Remove discontinuity; need not fill area with weld material.
Any discontinuity over 25 mm length with depth over 6 mm but not greater than 25 mm.	Completely remove and weld. Aggregate length of welding shall not exceed 20% of plate edge length being repaired.
Any discontinuity over 25 mm in length with depth greater than 25 mm.	Subject to approval by the Engineer. Repair to be made in accordance with Section 3.2 of the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges.
Note 1: The length of defect is the visible long dimension on the plate cut edge, and the depth is the distance that the defect extends into the plate from the cut edge. Note 2: This table does not apply to fracture critical members.	

Steel plate, bar, or shapes containing any discontinuity, regardless of length or depth, will not be permitted for use in any member or component in a tension area.

605.17 Welding and Oxygen Cutting. All welding and oxygen cutting shall conform to the requirements of Subsection 826.12.

605.18 Abutting Joints. Abutting joints in compression members and girder flanges, and in tension members where so specified on the drawings, shall be faced and brought to an even bearing. Wheel joints are not faced and the opening shall not exceed 6 mm.

605.19 End Connection Angles. Floorbeams, stringers, and girders having end connection angles shall be built to the exact length shown on the Plans measured between the heels of the connection angles with a permissible tolerance of +0 to -2 mm. Where continuity is required, end connections shall be faced. The thickness of the connection angles shall be not less than 10 mm and not less than that shown on the detail drawings, after facing.

605.20 Web Plates. For girders having no cover plates and not encased in concrete, the top edge of the web plate shall not extend above the backs of the flange angles and shall not be more than 3 mm below at any point. Any portion of the plate projecting beyond the angles shall be chipped flush with the backs of the angles.
At web splices, the clearance between the ends of the web plates shall not exceed 10 mm. The clearance at the top and bottom ends of the web splice plates shall not exceed 6 mm.

605.21 Bent Plates. Cold-bent, load-carrying, rolled-steel plates shall conform to the following:

(a) They shall be taken from the stock plates so that the bend-line will be at right angles to the direction of

rolling.

(b) The radius of bends shall be such that no cracking of the plate occurs. Generally accepted minimum radii, measured to the concave face of the metal, are shown in Table 605-E:

Table 605-E

Minimum Radii for Cold Bent Steel Plates

radii and t (thickness) in millimeters

All Grades of Structural Steel in this Section	Up to 13	Over 13 to 25	Over 25 to 38	Over 38 to 64	Over 64
Bend Radius	2t	2.5t	3t	3.5t	4t

Note: Low alloy steel in thickness over 13 mm may require hot bending for small radii. If a shorter radius is essential, the plates shall be bent hot at a temperature not greater than 620 C. Hot-bent plates shall conform to (a) above.

(c) Before bending, the corners of the plates shall be rounded to a radius of 2 mm throughout that portion of the plates at which the bending is to occur.

605.22 Eyebars. Pin holes may be flame-cut at least 50 mm smaller in diameter than the finished pin diameter. All eyebars that are to be placed side by side in the structure shall be securely fastened together so that they will be placed on the pin and bored at both ends while clamped. Eyebars shall be packed and match-marked for shipment and erection. All identifying marks shall be stamped with steel stencils on the edge of one head of each member after fabrication is completed so that the markings will be visible when the bars are nested in place on the structure. The eyebars shall be straight and free from twists, and the pin holes shall be accurately located on the centerline of the bar. The inclination of any bar to the plane of the truss shall not exceed 1 in 200 mm.

The edges of eyebars lying between the transverse centerline of their pin shall be cut simultaneously with two mechanically operated torches abreast of each other guided by a substantial template in such a manner as to prevent distortion of the plates.

605.23 Testing Requirements. Testing of fabricated structural members shall be according to Subsection 826.26.

FIELD ERECTION.

605.24 Erection of Structure. The Contractor shall set the steel according to the lines and elevations as provided in the Contract, remove the temporary construction, and do all the work required to complete the bridge or bridges as covered by the Contract, all in accordance with the Plans and this Section.

605.25 Erection Material. The Contractor shall provide the falsework and all tools, machinery, and appliances, including drift pins and fitting-up bolts, necessary to complete the work.

605.26 Handling and Storing Fabricated Materials. Stored material shall be placed on skids above the ground. It shall be kept clean and shall be properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent permanent deflections.

605.27 Falsework. The Contractor shall engage a Professional Engineer registered in Delaware to design the falsework separately for steel structures and for necessary changes in existing steel structures on the Project. The Professional Engineer’s signature and seal shall be affixed to the working drawings. Working falsework drawings shall be submitted in accordance with Subsection 105.04. The falsework shall be properly designed, constructed, and maintained for the loads that it will carry. It is the Contractor’s responsibility to obtain approval of the working drawings from the Department prior to the construction of the falsework. Approval of the Contractor’s plans shall not be considered as relieving the Contractor of any responsibility. After placement of the falsework, the Contractor’s Professional Engineer shall certify that the falsework system has been assembled according to the approved falsework drawing prior to placing loads on the falsework.

605.28 Methods and Equipment. Before starting the work of erection, the Contractor shall inform the Engineer as to the method of erection it proposes to follow and the number and type of equipment it proposes to use. The Contractor's methods and equipment shall be subject to the approval of the Engineer. The Engineer's approval does not relieve the Contractor of its responsibility for the safe performance of the work or from carrying out the work in full accordance with the Plans and the requirements of this Section. No work shall be done until the Engineer's approval has been obtained.

605.29 Bearings and Anchorages.

(a) *Bearings.* Bridge bearings shall be set level in the exact position indicated and shall have full and even bearing on the masonry. Prior to assembly in place, the steel surface bearing on the self-lubricating bearing plate shall be thoroughly lubricated with additional antioxidant lubricant furnished by the manufacturer.

The sliding surface shall be planed parallel to the movement of the spans.

(b) *Anchor Bolts.* Anchor bolts, when required, including hex nuts and washers, shall conform to the requirements of AASHTO M 314 unless otherwise specified on the Plans. The exposed portion of the anchor bolt shall be either galvanized or painted, unless otherwise specified.

When the anchor bolt passes through the sole plate, the nut is to be 6 mm clear. The threads shall be burred at face of nut. Anchor bolts shall be swedged and may be cast-in-place or grouted in preformed (sleeved or drilled) holes. If the Contractor elects to drill, it shall not cut through the bar reinforcement in the masonry. All slots and holes in the masonry plates surrounding the anchor bolts shall be filled with an approved, non-hardening caulking compound or elastic joint sealer.

605.30 Straightening Bent Material. The straightening of plates, angles, other shapes, and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fractures or other injuries. Distorted members shall be straightened using mechanical means or, if approved by the Engineer, using a limited amount of localized heat. The temperature of the heated area shall not exceed 620 C (a dull red) as monitored by temperature indicating crayons, liquids, or bimetal thermometers. Members to be heat-straightened shall be substantially free of stress and external forces, except stresses resulting from the mechanical means used in conjunction with the application of heat.

Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture.

605.31 Assembling Steel. The members shall be accurately assembled as shown on the Plans and all match-marks shall be followed. The material shall be carefully handled so that no members are bent, broken, or otherwise damaged. Hammering which injures or distorts the members shall not be done. Bearing surfaces and surfaces in permanent contact shall be cleaned before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking so to give the trusses proper camber. The blocking shall be left in place until the tension chord splices are fully bolted and all other truss connections are pinned and bolted. Permanent bolts in splices of butt joints of compression members and permanent bolts in railings shall not be tightened until the span has been swung. One-half of the holes in splices and field connections shall be filled with bolts and cylindrical erection pins (half bolts and half pins) before bolting with high-strength bolts. All splices and connections during erection shall have three-fourths of the holes filled.

Filling-up bolts shall be of the same nominal diameter as the high strength bolts. Cylindrical erection pins shall be 1 mm larger.

605.32 Pin Connections. Pilot and driving nuts shall be used for driving pins. They shall be furnished by the Contractor. Pins shall be driven so that the members take full bearing on them. Pin nuts shall be securely fastened, and the threads shall be burred at the face of the nut using a pointed tool.

605.33 Misfits. The correction of minor misfits involving harmless amounts of reaming, cutting, and chipping will be considered a legitimate part of the erection. However, all errors in the shop fabrication, or deformations resulting from handling and transportation, that prevent the proper assembly and fitting up of members by the moderate use of drift pins, or by a moderate amount of reaming and slight chipping or cutting, shall be reported immediately to the inspector to obtain approval of the proposed correction method. All corrections shall be made in the inspector's presence.

605.34 Cleaning and Restoration. Upon completion of the erection and before final acceptance, the Contractor shall remove all falsework, excavated or useless materials, rubbish, and temporary buildings. The Contractor shall also replace or renew any damaged fences, restore in an acceptable manner all property, both public and private, damaged during the prosecution of this work, and leave the structure site and adjacent highway in a neat and presentable condition satisfactory to the Engineer. All excavated material or falsework placed in the stream channel during construction shall be removed by the Contractor before final acceptance.

FIELD PAINTING.

605.35 Field Painting. All structural steel members, railings, fascia, downspouts, and other miscellaneous steel items that have been previously painted shall be cleaned, and primed and painted by applying two full coats of paint, the intermediate coat and the finish coat. The coating system to be used shall meet the requirements of moisture-cured urethane system as specified in Subsection 820.02.

605.36 Surface Preparation. Surfaces identified to be painted shall be cleaned in the following manner:

(1) Surfaces specified to be recoated shall be cleaned to bare metal in accordance with SSPC-SP 11.

The perimeter or edge of intact paint adjoining the cleaned surface shall be feathered back, and the adjoining paint shall be tightly adhered. Ragged edges on intact paint will not be allowed. Adherence will only be considered satisfactory if the adjoining remaining paint is smoothly feathered back and cannot be removed by lifting with a dull putty knife. After power tool cleaning operations are completed, all residue generated by the cleaning work shall be removed by vacuuming using HEPA filtered vacuums.

Surfaces shall be accepted by visual comparison to a prepared Project standard. The Contractor shall prepare the Project standard by power tool cleaning a representative area on the structure that is being prepared for painting. The prepared standard shall generally conform to SSPC-Vis 3, E SP 11, F SP 11, and G SP 11, as applicable, and shall be approved by the Engineer before the start of general cleaning work. At least one standard shall be prepared for each structure that is being specified for cleaning. More than one standard may be necessary if the cleaned steel differs significantly from the photographic standards due to surface conditions or other factors. Each standard shall be at least 300 by 300 mm in size and shall be located in an area of the structure that is accessible to and approved by the Engineer.

The Contractor shall protect the Project standard from corrosion and contamination throughout the duration of work. Protection shall be by applying a clear coat of polyurethane, or other means. At the completion of cleaning work, the Project standard shall be recleaned and painted in accordance with this Section. If in the opinion of the Engineer the Project standard becomes deteriorated, or otherwise ineffective, it shall be re-established in accordance with this Subsection.

(2) Surfaces specified to be overcoated shall be solvent cleaned after water blasting.

605.37 Painting.

(a) *Manufacturer's Instructions.* At least five working days prior to the start of work, the Contractor shall provide the Engineer with one copy of the paint manufacturer's current Technical Data and Material Safety Data Sheets for the paint materials being furnished. Instructions, suggestions, and precautions contained in the data sheets shall be followed to the extent that they do not contradict the provisions of this Section. In the case of a contradiction, the more stringent requirements shall be followed.

(b) *Specifications and Inspection Equipment.* Prior to the start of and throughout the duration of work, the Contractor shall supply the Engineer with the following:

(1) One bound copy each of the SSPC surface preparation

specifications, SSPC-SP 1 and SSPC-SP 11;

(2) One bound copy of the SSPC pictorial standard, SSPC-Vis 3;

(3) One bound copy of the SSPC paint application specification, SSPC-PA 2;

(4) One air thermometer, pocket type, ranging from -17 to 93 C;

(5) One surface thermometer, ranging from -18 to 149 C; and

(6) One magnetic dry film thickness gage, Type 2 (fixed probe);

(c) *Atmospheric Conditions.* Painting shall not be performed unless all of the following conditions are met:

(1) The receiving surface is clean and free of rust back, condensation, and visible moisture. Rustback occurs when freshly exposed bare steel is exposed to conditions of high humidity, moisture, or a corrosive atmosphere. The time interval from blast cleaning to rust back varies from minutes to weeks depending on the environment.

(2) The receiving surface and ambient air temperature are as recommended by the paint manufacturer, except that in no case shall painting work be performed when the surface and ambient temperatures are less than 2 or greater than 38 C.

(d) *Mixing Paint.* All paints shall be thoroughly mixed with mechanical mixers in accordance with the manufacturer's recommendations.

(e) *Solvent Restrictions.* The Contractor may thin the paint only with approved manufacturer's thinner. Thinning will be allowed only in strict accordance with manufacturer's recommendations and State VOC regulations. Unauthorized use of solvents shall result in recleaning and repainting of the surface in accordance with this Section.

(f) *Paint Application.* Paint coatings may be applied using brush, roller, or spray methods unless prohibited by the Contract. When spray painting is prohibited, paint shall be applied using brushes or rollers only.

Stripe painting with primer will be required on the following surfaces cleaned to bare metal. All welds, rivets, bolts, nuts, and edges of plates, angles, lattice, pieces, or other shapes, and corners and crevices shall be "striped" with primer before the general prime coat is applied. All stripe painting shall be performed using a brush only. No other method of paint application will be allowed for stripe painting.

Complete protection against paint spatter, spillage, overspray, wind blown paint, or similar releases of paint shall be provided. Covers, tarps, mesh, and similar materials shall be placed around the work area to protect public and private property; pedestrian, vehicular, marine, or other traffic; all portions of the bridge, highway appurtenances, waterways, and similar surrounding areas; and property upon, beneath, or adjacent to the structure.

(g) *Number of Coats.* Areas cleaned to bare metal and specified to be recoated shall be painted with one coat of primer. After the primer has dried, all surfaces shall be painted with two full coats of paint: the intermediate coat and the finish coat.

(h) *Film Thickness.* Paint shall be applied in sufficient quantity to produce the minimum dry film thickness specified in Section 820 for the type of paint specified.

(i) *Painting Schedule.* Primer shall be applied on the same day of the cleaning operation and before rust back occurs. Failure to apply primer to a cleaned surface within eight hours shall result in recleaning the surface in accordance with this Section.

The intermediate coat of paint shall be applied to the receiving surface within 14 days of the application of the previous coating (primer), or within the manufacturer's recommended schedule for recoating, whichever is less.

The finish coat of paint shall be applied to the receiving surface within 14 days of the application of the previous (intermediate) coating, or within the manufacturer's recommended schedule for recoating, whichever is less.

Areas failing to meet the specified minimum dry film thickness shall be recoated with the same type of paint to produce at least the total dry film thickness required. Paint applied containing thinners, paint applied to contaminated surfaces, and paint applied contrary to this Section shall result in recleaning and repainting the surface. The work of recleaning and repainting, if required, shall be done by the Contractor to the satisfaction of the Engineer.

(j) *Material Storage.* Paint in storage shall be protected from damage and maintained between 5 and 29 C. Paint not used before the expiration shall be immediately removed from the Project.

605.38 Painting of Galvanized Steel. All galvanized surfaces (downspouts, etc.) shall be painted with a moisture-cured aluminum paint that is designed to adhere to galvanized steel surfaces.

605.39 Stenciling Requirement. At the completion of the painting work, the completion date (month and year) and the bridge number, shall be stenciled on the structure in 75 mm high numbers. The paint used for this marking shall be the same as the topcoat except the color shall be black. The numbers shall be stenciled on the outside of each fascia beam at the approaching traffic end of the structure, on a location designated by the Engineer. The Contractor shall paint the month and year of the existing stenciling after the existing stenciling area is cleaned and painted if so required in case of partial painting of the structure.

605.40 Method of Measurement. The quantity of steel structures will not be measured if payment is on a lump sum basis. If payment is based on the Contract unit price per kilogram, then the quantity of steel structures will be measured in kilograms. Unless measurement by the scale weight is specified, the quantity of steel will be computed on the following basis:

(a) Unit weights, kg/m^3

- Aluminum, cast or wrought - 2770
- Bronze, cast - 8590
- Copper-alloy - 8590
- Copper sheet - 8940
- Iron, cast - 7130
- Iron, malleable - 7530
- Iron, wrought - 7800
- Lead, sheet - 11,330
- Steel, rolled, cast, copper bearings, silicon, nickel, and stainless - 7850
- Zinc - 7210

(b) The weights of rolled shapes shall be computed on the basis of their nominal weights per meter as shown on the drawings, or listed in the AISC Manual of Steel Construction.

The weights of plates shall be computed on the basis of the nominal weight of their width and thickness, as shown in the drawings, plus an estimated over-run computed as one-half the permissible variation in thickness and weight as tabulated in AASHTO M 160/M 160M.

(c) The weight of castings shall be computed from the dimensions shown on the approved shop drawings, deducting for open holes. To this weight shall be added 5% allowance for fillets and overruns. Scale weights may be substituted for computed weights in the case of castings or of small

complex parts for which accurate computations of weight would be difficult.

(d) The weight of temporary erection bolts; shop and field paint; boxes, crates, and other containers used for shipping; and materials used for supporting members during transportation and erection shall not be included.

(e) When computing the pay weight on the basis of computed net weight the following stipulations in addition to those in (a) through (d) above shall apply:

(1) The weight shall be computed on the basis of the net finished dimensions of the members as shown on the approved shop drawings, deducting for copes, cuts, clips, and all open holes.

(2) The aggregate weight of heads, nuts, single washers, and the threaded stick-through of all high strength shop bolts shall be included on the basis of the following weights:

Table 605-F
Weights of Metric High-Strength Structural Bolts [1]
approximate weight of 100 steel bolts in kilograms

Bolt Length (mm)	Nominal Bolt Diameter and Thread Pitch						
	M16 × 2	M20 × 2.5	M22 × 2.5	M24 × 3	M27 × 3	M30 × 3.5	M36 × 4
45	10.8	---	---	---	---	---	---
50	11.6	19.8	---	---	---	---	---
55	12.3	21.0	26.0	---	---	---	---
60	13.1	22.3	27.5	35.4	---	---	---
65	13.9	23.5	29.0	37.1	50.5	---	
70	14.7	24.7l>	30.5	38.9	52.7	64.0	
75	15.5	26.0	32.0	40.7	55.0	66.8	---
80	16.3	27.2	33.5	42.4	57.2	69.6	108
85	17.1	28.4	34.9	44.2	59.5	72.4	112
90	17.9	29.7	36.4	46.0	61.7	75.1	116
95	18.6	30.9	37.9	47.8	63.9	77.9	120
100	19.4	32.1	39.4	49.5	66.2	80.1	124
110	20.8	34.3	42.1	52.7	70.4	85.6	132
120	22.4	36.8	45.0	56.2	74.9	91.1	140
130	24.0	39.2	48.0	59.7	79.4	96.7	148
140	25.6	41.7	51.0	63.3	83.9	102	155

150	27.1	44.1	54.0	66.8	88.4	108	163
160	28.7	46.6	57.0	70.4	92.8	113	171
170	30.3	49.1	59.9	73.9	97.3	119	179
180	31.8	51.5	62.9	77.5	102	124	187
190	33.4	54.0	65.9	81.0	106	130	195
200	35.0	56.4	68.9	84.6	111	135	203
210	36.6	58.9	71.8	88.1	115	141	211
220	38.2	61.4	74.8	91.6	120	146	219
230	39.7	63.8	77.8	95.2	124	152	227
240	41.3	66.2	80.8	98.7	129	158	235
250	42.9	68.7	83.8	102	133	163	243
260	44.5	71.2	86.7	106	138	169	251
270	46.0	73.7	89.7	109	142	174	259
280	47.6	76.1	92.7	113	147	180	267
290	49.2	78.6	95.7	116	151	185	275
300	50.8	81.1	98.6	120	156	191	283
Note 1: From ANSI B18.2.3.7M, Table 3.							

(3) The weight of weld metal shall be computed on the basis of the theoretical volume from dimensions of the welds.

(f) When computing the pay weight on the basis of scale weight, the pay quantity of structural steel will be the shop scale weight of the fabricated members, weighed on satisfactory scales in the presence of the inspector. If the shop paint has been applied to the completed member when weighed, 0.4% of the weight of the member shall be deducted from the scale weight to compensate for the weight of shop paint.

The quantity of recoating will either be measured by the square meter of area recoated or will not be measured.

605.41 Basis of Payment.

(a) *Steel.* The quantity of steel structures will be paid for either at the Contract unit price per kilogram or on a lump sum basis. Price and payment will constitute full compensation for all labor, materials, equipment, and transportation required for furnishing, fabricating, transporting, erecting, and shop and field painting to complete the work. The quantity of recoating will be paid for either at the Contract unit price per square meter or at the Contract lump sum price.

The Contract price for steel structures shall also include, when applicable, taking field elevations along the tops of the existing beams; removal of existing blast plates; and modifications to existing beams for widening except those specifically paid for under the applicable Section. Also included are all additional costs for

stage construction for all the work on the Project. The cost of painting of all new structural steel includes all material, labor, tools and equipment, and surface preparation, spatter protection, and cleanup.

When tests of fabricated members are required by the Contract, the cost of testing, including equipment, handling, supervision, and incidentals including but not limited to temperature indicating crayons, liquids, or bimetal thermometers for making the test, will be included in the Contract unit price per kilogram of structural steel, unless otherwise specified.

All metal parts such as anchor bolts and nuts, shoes, rockers, rollers, bearing and slab plates, pins and pilot and driving nuts, expansion dams, roadway drains and scuppers, weld metal, bolts embedded in concrete, cradles and brackets, blast plates, and waterstops shall be paid for as structural steel unless otherwise stipulated. Steel reinforcement for concrete is not included in this Section and will be paid separately under the appropriate Section.

Payment will be made on a lump sum or price per kilogram basis as required by the terms of the Contract. When payment is to be based on price per kilogram, the finished work shall be weighed in the presence of the inspector, if practicable. The Contractor shall supply satisfactory scales and shall perform all work involved in handling and weighing the various members.

If payment is made on a lump sum basis the Contractor should note that the approximate weight of structural steel is stated in the proposal. It shall be the responsibility of the Contractor, however, to estimate and determine for itself the amount of metal work required as the quantity given is not guaranteed to be absolutely correct.

If payment is made on a price per kilogram basis, the payment shall be based on the computed net weight of metal in the fabricated and erected structures unless the Contract provides that payment shall be based on the scale weight. No payment will be made for any weight in excess of 1.5% above the computed net weight of the whole item.

(b) *Painting.* The quantity of recoating all existing structural steel, unless specified elsewhere, will be paid for at the Contract unit price per square meter or lump sum price. Price and payment will constitute full compensation for all material, labor, tools and equipment, surface preparation, spatter protection, and cleanup.

Price and payment for the moisture-cured urethane paint system will constitute full compensation for furnishing all materials; for providing protection against damage during paint application; for re-establishing Project standards, if necessary; for recleaning when primer is not applied within eight hours of initial cleaning; for recleaning and repainting surfaces when unauthorized solvents are used, when paint containing thinners is applied, when paint is applied to contaminated surfaces, and when paint is applied contrary to the requirements of this Section; and for all labor, equipment, tools, and incidentals required to complete the work.

Progress payments will be made based on the percentage of the structure primed and painted with two full coats of paint in accordance with the specification. The percentage will be computed as the ratio of the length of structure primed to the total length of structure. The percentage of payments to be paid to the Contractor will be 25%, 50%, 75%, and 100% after the completion of the work.

SECTION 606 METAL BRIDGE RAILING

606.01 Description. This work consists of furnishing, fabricating, and erecting either aluminum bridge railing or galvanized steel bridge railing.

606.02 Materials. Materials shall be as specified on the Plans. If galvanized steel is used, it shall be galvanized after fabrication.

606.03 Construction Methods. The type of rail and details shall be as shown on the Plans. Each post base shall be set on a preformed elastomeric pad, conforming to the requirements of Subsection 826.06. The outline of the pad shall conform to the base of the post or base plate. All posts shall be set normal to grade, and all rails shall be set parallel to

grade. Anchor bolts shall be set prior to pouring the concrete and shall be firmly held in place by a template. The portions of anchor bolts exposed above the concrete shall be given a protective coating of grease or oil before the concrete is poured.

All rough or sharp corners which, in the opinion of the Engineer, would endanger pedestrians shall be ground smooth either during fabrication or after erection. All anchor bolts and other connecting bolts and fasteners shall be burred to prevent loosening after erection is completed.

No paint will be required on the completed installation except for any touch up of damaged coating. Such damaged areas shall be coated with a material acceptable to the Engineer. Before acceptance of the installation, the railing shall be thoroughly cleaned of all dirt, grime, and stains. Cleaning methods and agents shall be used in accordance with the recommendations of the rail manufacturer.

606.04 Method of Measurement. The quantity of metal bridge railing will be measured as the actual number of linear meters of railing sections, installed and accepted.

606.05 Basis of Payment. The quantity of metal bridge railing will be paid for at the Contract unit price per linear meter. Price and payment will constitute full compensation for furnishing, fabricating, and installing all materials; for touch up of damaged coatings; and for all labor, equipment, tools, and incidentals required to complete the work.

SECTION 607 REMOVAL OF EXISTING CONCRETE AND MASONRY

607.01 Description. This work consists of the removal and acceptable disposal of existing rubble, concrete, and masonry that interferes with the completion of new construction except such objects as are designated to remain or are to be removed in accordance with other Sections of these Specifications.

607.02 Construction Methods. Care shall be used during the removal of existing concrete and masonry to avoid damage to existing concrete and masonry construction that is to remain in place.

607.03 Method of Measurement. The quantity of existing concrete and masonry removed will be measured by the cubic meter based on computations using field measurements of the concrete and masonry in place prior to removal.

607.04 Basis of Payment. The quantity of existing concrete and masonry removed will be paid for at the Contract unit price per cubic meter. Price and payment will constitute full compensation for the removal and disposal of the existing rubble, concrete, and masonry and for all labor, equipment, tools, and incidentals required to complete the work.

SECTION 608 COARSE AGGREGATE FOR FOUNDATION STABILIZATION AND SUBFOUNDATION BACKFILL

608.01 Description. This work consists of furnishing and placing coarse aggregate for foundation stabilization and subfoundation backfill. This Section is to be used only when specified and authorized by the Engineer.

608.02 Materials. Coarse aggregate shall conform to the provisions of Section 805 and to the grading requirements of Section 813, Delaware No. 57.

608.03 Construction Methods. The bedding areas on which the coarse aggregate is to be placed will be approved by the Engineer.

Coarse aggregate shall be carefully placed and tamped to form a solid, unyielding mass with the exposed surface conforming to the form and dimensions shown on the Plans. Coarse aggregate shall be placed in locations where the exposed soil conditions are of such a nature and composition as to require the use of this material to achieve a satisfactory load-bearing condition.

608.04 Method of Measurement. The quantity of coarse aggregate will be measured as the actual weight placed and accepted. The weight will be calculated as specified in Subsection 109.01.

608.05 Basis of Payment. The quantity of coarse aggregate will be paid for at the Contract unit price per metric ton. Price and payment will constitute full compensation for furnishing, hauling, and placing the material and for all equipment, tools, labor, and incidentals required to complete the work.

SECTION 609 SUBFOUNDATION CONCRETE

609.01 Description. This work consists of placing Portland cement concrete to level rock foundations, seal rock fissures, and for other similar purposes. This Section is to be used only when specified and authorized by the Engineer.

609.02 Materials. Portland cement concrete shall conform to the requirements of Section 812, Class C.

609.03 Construction Methods. Subfoundation concrete shall not be reinforced and need not be vibrated. Unless otherwise ordered, curing requirements for subfoundation concrete may be reduced to three days.

609.04 Method of Measurement. The quantity of subfoundation concrete will be measured as the number of cubic meters of subfoundation concrete placed and accepted. When limits are shown on the Plans, they shall govern for payment purposes. All costs for required forming will be included under this work. When the limits are not shown on the Plans, prior to the work the Engineer will take cross-sections of the spaces to be filled with subfoundation concrete and will compute the volume by the average end area method.

609.05 Basis of Payment. The quantity of subfoundation concrete will be paid for at the Contract unit price per cubic meter. Price and payment will constitute full compensation for furnishing and placing all materials; for required forming; and for all labor, tools, equipment, and incidentals required to complete the work.

SECTION 610 STONE MASONRY

610.01 Description. This work consists of furnishing all materials for and constructing stone masonry.

MATERIALS.

610.02 Portland Cement. Portland cement shall conform to the requirements of Section 801.

610.03 Fine Aggregate. Fine aggregate shall conform to the requirements of Section 818.

610.04 Water. Water shall conform to the requirements of Section 803.

610.05 Hydrated Lime. Hydrated lime shall conform to the requirements of Section 802

610.06 Stone. Stone shall be of the dimensions and type as detailed and specified on the Plans. The Contractor shall submit samples of stone for approval prior to starting in case of new masonry work. Materials for masonry repair/replacement shall match the existing stone and patterns.

610.07 Steel Wall Ties. All steel wall ties shall be hot-dipped galvanized.

CONSTRUCTION METHODS.

610.08 Excavation. Excavation shall be made to the required depth when necessary, to expose the foundation on which stone masonry is to be placed.

610.09 Mixing Mortar. Portland cement mortar shall be mixed in the proportion of one part Portland cement to three parts fine aggregate, to which shall be added hydrated lime not to exceed 10% of the cement by weight. The fine aggregate, Portland cement, and lime shall first be mixed dry in an approved manner until the mixture assumes a uniform color, after which water shall be added as the mixing continues until the mortar attains such consistency as can be easily handled and spread with a trowel. The mortar shall be so placed to form a firm bond. Mortar that is not used within 30 minutes after water has been added shall be wasted. Retempering of mortar will not be permitted.

610.10 Placing Stone. All masonry work shall be constructed by experienced stone masons. The stone shall be laid to the wall to form the pattern shown on the Plans, and shall be thoroughly wetted before laying in mortar. All joints shall be completely filled with mortar and shall be finished properly as work progresses. Mortar joints shall be 25 mm to 38 mm thick.

No masonry shall be laid in freezing weather.

610.11 Cleaning. After constructing the stone masonry, the entire area shall be thoroughly cleaned of all mortar, scars, or spots. Efflorescence may be partly removed by water, but where special treatment is necessary, the area shall be first washed down with water, then treated with a solution of three parts hydrochloric acid to 100 parts of water following washing with water again. The Contractor shall be watchful to notice for any deteriorating reaction to the stone masonry, and in such case the treatment shall stop, and the treated area shall be thoroughly washed down with water. However, it shall be the responsibility of the Contractor to clean the constructed masonry as to present a natural color.

610.12 Backfilling. The excavated areas that are not occupied by the stone masonry shall be backfilled to the required elevation with suitable material that shall be tamped in layers of not more than 150 mm, until firm and solid. No backfill shall be made prior to approval.

610.13 Method of Measurement. The quantity of stone masonry placed and accepted will be measured by the square meter.
610.14 Basis of Payment. The quantity of stone masonry will be paid for at the Contract unit price per square meter. Price and payment will constitute full compensation for excavating and backfilling; for furnishing and placing all materials; for the disposal of surplus materials, and for all labor, equipment, tools, and incidentals required to complete the work, including cleaning.

SECTION 611 BRICK MASONRY

611.01 Description. This work consists of constructing brick masonry.

MATERIALS.

611.02 Portland Cement. Portland cement shall conform to the requirements of Section 801.

611.03 Fine Aggregate. Fine aggregate shall conform to the requirements of Section 818.

611.04 Water. Water shall conform to the requirements of Section 803.

611.05 Hydrated Lime. Hydrated lime shall conform to the requirements of Section 802.

611.06 Brick. Brick shall be new, whole brick of best quality, of uniform and dense structure, free from lumps of lime, laminations, cracks, checks, soluble salt, or other defects that in any way impair their strength, durability, appearance, or usefulness for the purpose intended. All brick shall conform to requirements of AASHTO M 114 for Grade SW brick. The Contractor must submit samples for approval when the masonry is exposed to general view.

CONSTRUCTION METHODS.

611.07 Excavation. Excavation shall be made to the required depth when necessary, to expose the existing foundation on which the brick masonry is to be placed.

611.08 Mixing Mortar. Portland cement mortar shall be mixed in the proportion of one part Portland cement to three parts fine aggregate, to which shall be added hydrated lime not to exceed 10% of the cement by weight. The fine aggregate, Portland cement, and lime shall first be mixed dry in an approved manner until the mixture assumes a uniform color, after which water shall be added as the mixing continues until the mortar attains such consistency as can be easily handled and spread with a trowel. The mortar shall be so placed to form a firm bond. Mortar that is not used within 30 minutes after water has been added shall be wasted. Retempering of mortar will not be permitted.

611.09 Placing Bricks. Bricks shall be laid by means of the shove-joint method so as to thoroughly embed them into the mortar. Buttered or plastered joints will not be permitted. All brick headers and stretchers shall be so arranged as to thoroughly bond the mass with alternate courses breaking joints. All joints shall be completely filled with mortar and shall be finished properly as the work progresses. Joints shall be not less than 6 mm and not more than 13 mm in thickness. No spalls or bats shall be used except for shaping irregular openings or when unavoidable to finish out a course, in which case, full bricks shall be placed at the corners and bats shall be placed in the interior of the course. Competent bricklayers shall be employed on work of this class.

611.10 Cleaning. Brick masonry that is to be exposed after completion of the structure, shall be thoroughly cleaned of all mortar, scars, or spots, and shall present a surface showing the natural color of the bricks. Efflorescence may be

partly removed by water. The wall shall be first washed down with water, then treated with a solution of three parts hydrochloric acid to 100 parts of water, and finally washed thoroughly again with water.

611.11 Backfilling. The excavated areas which are not occupied by the brick masonry shall be backfilled to the required elevation with suitable material which shall be tamped in layers of not more than 150 mm, until firm and solid. No backfill shall be made prior to approval.

611.12 Method of Measurement. The quantity of brick masonry placed and accepted will be measured by the square meter.

611.13 Basis of Payment. The quantity of brick masonry will be paid for at the Contract per square meter. Price and payment will constitute full compensation for excavating and backfilling; for furnishing and placing all materials; for the disposal of surplus materials; and for all labor, equipment, tools, and incidentals required to complete the work, including cleaning.

SECTION 612 REINFORCED CONCRETE PIPE

612.01 Description. This work consists of furnishing and installing reinforced concrete round or elliptical pipe. This work also includes the construction of connections to existing drainage inlets and manholes as may be required to complete the work.

MATERIALS.

612.02 Reinforced Concrete Pipe.

(a) *Round Pipe.* Reinforced concrete round pipe shall conform to the requirements of AASHTO M 170M and shall be Class III unless otherwise noted.

(b) *Elliptical Pipe.* Pipe designed for placement with the major axis horizontal shall be designated as horizontal elliptical pipe (HE). Pipe designed for placement with the major axis vertical shall be designated as vertical elliptical pipe (VE).

Reinforced concrete elliptical pipe shall conform to the requirements of AASHTO M 207M and the following:

(1) Standard strength reinforcement concrete elliptical pipe (HE or VE) shall be Class III.

(2) Extra strength reinforced concrete elliptical pipe (HE or VE) shall be Class IV.

No pipe shall be shipped from the plant to the Project until the requirements of AASHTO M 170M or M 207M are met and the pipe is marked with the Department's inspection stamp. The manufacturer shall have clearly marked on the pipe the following information before inspection is made:

(1) Pipe class

(2) Pipe type, HE or VE, for elliptical pipe only

(3) Date of manufacture

(4) Name or trademark of the manufacturer

(5) One end of each section of elliptical pipe shall be clearly marked, during the process of manufacture or immediately thereafter, on the inside and the outside of the opposite walls along the minor axis.

All pipe inspected and approved at the manufacturing plant shall be subject to inspection at the site of the work, and no previous stamp or approval shall bar rejection if the pipe is found to be defective or damaged.

612.03 Joint Material. A rubber gasket conforming to the requirements of ASTM C 443M shall be used to seal the joints between successive sections of pipe.

612.04 Backfill Material. Backfill material shall conform to the requirements of Subsection 209.04, Borrow Type C. If the existing material meets these requirements, it shall be used for pipe backfill.

CONSTRUCTION METHODS.

612.05 Excavation. The trench in which the pipe is laid shall be excavated in accordance with Section 208 to the required depth. The bottom of the trench shall be shaped to provide the required class of bedding. Where rock is encountered, the trench shall be excavated in depth to the bottom of the earth cushion as shown on the Standard Construction Details for bedding in rock, and for a width of 300 mm on each side of the pipe. This depth and width shall be backfilled with approved material and thoroughly tamped.

612.06 Bedding of Pipe. Unless noted otherwise, all pipes shall receive a Class C bedding. Class C bedding shall consist of bedding the pipe in a trench carefully shaped to conform to the outside circumference of the pipe for a depth not less than 10% of the outside diameter of the pipe. Shaping of the bed to conform to the shape of the pipe at joints shall also be required.

612.07 Joints. Before laying the pipe in the trench, the rubber gasket shall be attached to the spigot end of each pipe joint and set firmly against the shoulder around the entire circumference of the pipe joint. A lubricant, specified by the gasket manufacturer, may be applied to the gasket for ease of installation.

Pipe handling after the gasket has been affixed shall be carefully controlled to avoid bumping the gasket and thus displacing it or covering it with dirt or other foreign material. Any gasket so disturbed shall be removed, replaced if damaged, and repositioned if displaced. Sufficient pressure shall be applied in making the joint to ensure that the joint is tight.

612.08 Laying Pipe. All pipe shall be laid in an upgrade direction unless otherwise directed. The pipe shall be laid with the lowest point of the inside diameter conforming to the flow line shown on the Plans.
All pipe shall be carefully laid with the bell ends upgrade, with the spigot ends fully entered into the adjoining bell, and true to the lines and grades shown on the Plans, or as directed.

Any pipe which is not in true alignment, or which shows any settlement after laying, shall be taken up and relaid. Unsuitable material encountered below the flow line of pipe shall be removed to a depth and replaced, as directed.

612.09 Backfill. Placement of backfill shall conform to Section 208. Where heavy construction equipment travels over the pipe, a cover of material shall be placed to a minimum depth of 1.2 m.

612.10 Method of Measurement. The quantity of reinforced concrete round or elliptical pipe will be measured as the actual number of linear meters of each type of pipe placed and accepted, measured from end to end of pipe, including structure wall thickness, but excluding structure interior.

612.11 Basis of Payment. The quantity of reinforced concrete round or elliptical pipe will be paid for at the Contract unit price per linear meter for each type of pipe. Price and payment will constitute full compensation for furnishing, hauling, and installing pipe; for all cribbing or foundation treatment necessary to prevent settlement; for all shoring and sheeting; for the replacement of any pipe which is not true in alignment or which shows any settlement after laying; and for all material, labor, equipment, tools, and incidentals required to complete the work.
For pipe under 600 mm nominal inside diameter, the excavation and backfill will be included in the price for this work. For pipe of nominal inside diameter 600 mm and over, payment for excavation and backfill will be in accordance with Section 208. Furnishing of Borrow Type C will be paid for under Section 210.

Payment for excavation and replacement of unsuitable material encountered below the flow line of pipe will be provided for under Section 208.

SECTION 613 RESERVED

SECTION 614 CORRUGATED PIPE

614.01 Description. This work consists of furnishing and installing corrugated steel or corrugated aluminum pipe. This work also includes the furnishing and construction of joints and connections to existing pipes, drainage inlets, and endwalls, as may be required to complete the work as indicated on the Plans, or as directed.

MATERIALS.

614.02 Pipe.

(a) *Corrugated Steel Pipe.* Corrugated steel pipe shall conform to the requirements of AASHTO M 36/M 36M.

(1) Zinc-coated (galvanized) corrugated steel pipe shall conform to AASHTO M 218.

(2) Aluminum-coated (Type 2) corrugated steel pipe shall conform to AASHTO M 274.

(b) *Corrugated Aluminum Pipe.* Corrugated aluminum pipe shall conform to the requirements of AASHTO M 196/M 196M.

(c) *Spiral Rib Pipe.* Spiral rib pipe (Type 1R) shall conform to the requirements of AASHTO M 36/M 36M for steel spiral rib and to AASHTO M 196/M 196M for aluminum spiral rib pipe.

614.03 Bituminous Coating. When bituminous coating is called for, it shall conform to the requirements of AASHTO M 190.

614.04 Bands. All corrugated steel or corrugated aluminum pipe shall be furnished in lengths specified on the Plans. If any specified length of pipe is divided into shorter sections for convenience, approved connecting bands shall be furnished for field joints. The coupling bands shall conform to AASHTO M 36/M 36M.

Bands shall be constructed so as to lap an equal portion of each of the pipe sections to be connected. Bands shall be fastened at the ends by galvanized angles having minimum dimensions of 50 by 50 by 4.75 mm. Other equally effective methods of fastening the bands may be used if approved. All bands shall include an approved rubber gasket to ensure a watertight joint.
Connecting bands used under this Section shall not be bituminous coated.

614.05 Defects. The following defects in corrugated steel or corrugated aluminum pipe constitute poor workmanship, and the presence of any of them in any individual pipe shall be sufficient cause for rejection:

(a) Uneven laps

(b) Elliptical shaping (circular pipe only)

(c) Variation from a straight centerline

(d) Ragged or diagonal sheared edges

(e) Loose, unevenly lined or spaced rivets

(f) Imperfectly formed rivet heads

(g) Unfinished ends

(h) Illegible brand

(i) Lack of rigidity

(j) Bruised, scaled, or broken protective coating

(k) Dents or bends in the metal

614.06 Field Inspection. Field inspections will be made and will include an examination of the pipe for deficiencies in lengths of sheet used, thickness of metal, nominal inside diameter, net length of finished pipe, and any evidence of poor workmanship as outlined in this Section. The inspection may include the taking of samples for chemical analysis and determination of coating thickness and quality.

614.07 Backfill Material. Backfill material shall conform to the requirements of Subsection 209.04, Borrow Type C. If the existing material meets these requirements, it shall be used for pipe backfill.

CONSTRUCTION METHODS.

614.08 Pipe Installation. All pipe shall be carefully handled during unloading and placing in position. Dragging the pipe over the ground or over timbers or planks will not be permitted. Utmost care shall be taken to prevent damage to the bituminous coating. Any exposed metal or damaged coating not exceeding 40 000 mm^2 shall be covered with an approved bituminous material properly built up, before placing the backfill. Pipe with damaged areas exceeding 40 000 mm^2 may be rejected.

The pipe shall be bedded according to Section 612.

Pipes of large diameter shall be strutted if shown on the Plans. The struts shall be placed before the embankment is placed and shall be removed when ordered.

Where the pipe sections are joined on the Project, the ends shall be joined with a standard band, bolted firmly in place. Any pipe which is not in true alignment or which shows any detrimental settlement after laying, shall be taken up and relaid.

614.09 Backfill. Placement of backfill shall conform to Section 208. Care shall be taken to avoid striking the pipe with tamping tools.

614.10 Method of Measurement. The quantity of corrugated steel or corrugated aluminum pipe will be measured as the number of linear meters of each type of pipe placed and accepted, measured from end to end of pipe, including structure wall thickness, but excluding structure interior.
In measuring lengths of special manufactured connections, exclusive of coupling bands, each actual linear meter placed will be doubled.

614.11 Basis of Payment. The quantity of corrugated steel or corrugated aluminum pipe will be paid for at the Contract unit price per linear meter for each type of pipe. Price and payment will constitute full compensation for furnishing, hauling, and installing pipe; for all cribbing or foundation treatment necessary to prevent settlement; for all shoring and sheeting; for the replacement of any pipe which is not in true alignment or which shows any detrimental settlement after laying; for coating if required; and for all material, labor, equipment, tools, and incidentals required to complete the work.

For pipe under 600 mm nominal inside diameter, the excavation and backfill will be included in the price for this work. For pipe of nominal inside diameter 600 mm and over, payment for excavation and backfill will be in accordance with Section 208. Furnishing of Borrow Type C will be paid for under Section 210.

Payment for excavation and replacement of unsuitable material encountered below the flow line of pipe will be provided for under Section 208.

SECTIONS 615 and 616 RESERVED

SECTION 617 FLARED END SECTION

617.01 Description. This work consists of furnishing and placing corrugated metal pipe and reinforced concrete flared end sections.

617.02 Materials. Materials shall conform to the requirements of Sections 612 and 614, as applicable.

617.03 Construction Methods. Flared end sections shall be placed in conformance with the details, dimensions, and notes shown on the standard sheet and at the locations shown on the Plans.

617.04 Method of Measurement. The quantity of flared end sections will be measured as the actual number placed and accepted.

617.05 Basis of Payment. The quantity of flared end sections will be paid for at the Contract unit price per each. Price and payment will constitute full compensation for furnishing, hauling, and installing materials, including bar reinforcement; for excavating, backfilling, and compacting; for cribbing, shoring, sheeting, coating, and paving; and for all labor, equipment, tools, and incidentals required to complete the work.

SECTION 618 PILE MATERIALS

618.01 Description. This work consists of furnishing treated and untreated timber piles and test piles, cast-in-place concrete piles and test piles, steel H pile and test piles, and precast, prestressed concrete piles and test piles.

TIMBER PILE MATERIALS.

618.02 Classification. Untreated timber piles that will be below water level at all times, may be of any species of wood that satisfactorily withstands driving.

Untreated timber piles for use in exposed work shall have a diameter of heartwood at the butt not less than 80% of the required diameter of the pile.

Treated timber piles shall be of southern yellow pine or Douglas fir, unless otherwise specified.

618.03 Requirements. The following requirements shall apply to both untreated and treated timber piles except that piles intended for treating shall be cleaned of all bark and shall be otherwise conditioned as outlined in Subsection 618.04.

All piling shall be cut from sound, live timber and shall contain no unsound knots. Sound knots will be allowed provided the diameter of the knot does not exceed the lesser of 100 mm or one-third the diameter of the pile at the point where the knot occurs. Any defect or combination of defects, which impairs the strength of the pile more than that of the maximum allowable knot, shall not be permitted. The butts shall be sawed square, and the tips shall be sawed square or tapered to a point not less than 100 mm square where soil conditions warrant pointing the tip. The slope of the spiral grain, if present, shall not exceed 25 mm in height for 300 mm in length.

Piles shall have a uniform taper from butt to tip. A line drawn from the center of the butt to the center of the tip shall not fall outside the center of the pile at any point more than 0.5% of the length of the pile. Bends that cause difficulty in driving are sufficient cause for rejection of the piling.

The piles shall be free from season checks that penetrate more than one-sixth of the diameter of the pile or are more than 6 mm in width. A check is defined as a lengthwise separation of the wood across the rings of normal growth, extending from the surface toward the pith, but not extending through the piece. Piles must meet the requirements of AASHTO M 168.

618.04 Preparation. Untreated piles shall have the outer bark removed.

Treated piles shall be peeled by removing all the outer bark and at least 80% of the inner bark. No strip of inner bark remaining on the pile shall be over 20 mm wide or over 200 mm long, and there shall be at least 25 mm of clean wood surface between any two such strips.

618.05 Dimensions. The diameter that designates the size of piles shall be measured 900 mm from the butt. The minimum tip diameter of piles shall be 200 mm for piles under 12 m in length and 175 mm for 12 m and longer piles. All measurements shall be made under the bark. The maximum diameter at butt of any pile shall not exceed 500 mm.

618.06 Preservation Treatment. Treated piles shall receive preservative treatment in accordance with AASHTO M 133 and the AWPA preservation standards specified therein. Unless otherwise specified, the preservative shall be either creosote oil-tar or CCA. The treatment shall be in accordance Table 618-A.

Table 618-A
Preservation Treatment of Timber Piles

Preservative	Process	Retention Rate, kg/m^3 (land, freshwater, and foundation piles)	
		Southern Pine	Douglas Fir
Creosote Oil-Tar	empty-cell	190	270
CCA	full-cell or modified full-cell	13	16
Preservative	Process	Retention Rate, kg/m^3 (marine piles)	
		Southern Pine	Douglas Fir
Creosote Oil-Tar	empty-cell	320	320
CCA	full-cell or modified full-cell	40	NR

NR - not recommended

618.07 Inspection. The timber, and the operation of treatment, will be inspected at the treating plant, both before and after treating, and all acceptable timber will be marked with the Department's standard hammer mark. All timber piles shall also be subject to inspection at the site of the work. If the pile is found defective, it shall be subject to rejection.

618.08 Storing and Handling. The methods of storing and handling shall be such as to avoid injury to the piles and shall be approved. Special care shall be taken to avoid breaking the surface of treated piles; canthooks, dogs, or pikepoles shall not be used. All cuts, holes, and injuries of the surface of treated material shall be field-protected by brushing, spraying, dipping, soaking, or coating. Care shall be taken to ensure that all injuries, such as abrasions and nail and spike holes, are thoroughly saturated with the field-treating solution. Treated piles shall not be cut or trimmed in any manner after they are driven other than to saw off the tops as hereinafter specified.

Holes bored in pressure treated material shall be poured full of preservative. Horizontal holes, such as those for sway brace bolts, may be filled by pouring the preservative into them with a bent funnel. All holes made for determining penetration and retention of preservatives shall be filled with tight fitting treated cylindrical plugs.

CAST-IN-PLACE CONCRETE PILE MATERIALS.

618.09 Shells (Steel Casings). The Contractor shall use fluted steel pile shells for cast-in-place concrete piles, unless steel pipe pile shells are specified on the Plans.

If steel pipe piles are used, the steel pipe pile shell shall conform to the requirements of ASTM A 252, Grade 2 with a minimum wall thickness of 6 mm. For welded pipe piles, all seams shall be straight or spiral-butt welded having full strength welded joints. Seamless steel pipe piles are also acceptable. All piles shall be equipped with cast steel, inside-flange, extra strong, ribbed 60 degree conical points. These conical points shall be securely fitted to the bottom of the pile shells by welding with a 30 degree beveled groove weld all around and in such a manner to minimize any extrusion beyond the outside surface of the steel casings. A maximum protrusion of 6 mm is permissible. If the protrusion exceeds 6 mm, the Contractor shall grind the protruding weld flush with the outside surface of the pile shell. If fluted steel pile shells are used, the tapered section shall have a tip diameter of 200 mm with a closed conical point and tapering at the rate of 33 mm/m. The fluted steel pile shall be closed or open ended as specified on the Plans. The Contractor shall accomplish splices by cutting the walls in a serrated pattern, inserting the added section, crimping back, and welding along the entire perimeter with a continuous 10 mm fillet weld. All welding shall be performed by AWS certified welders approved by the Department. Welding certifications shall be current and must show passing qualifications for the type of welding to be performed. The steel for the shells shall conform to SAE 1010 or 1015 and have a minimum yield point of 345 MPa and a minimum thickness of 4.55 mm.

All field splices shall have the full strength of the sections they connect and require approval of the Engineer. Generally the minimum distance between field splices on the pile shall be 12 m.

618.10 Protective Coating. When indicated on the Plans, the pile shells (steel casings) shall be protected with a coating consisting of either coal tar epoxy or fusion bonded epoxy.

If coal tar epoxy coating is specified, two coats of dark red coal tar epoxy shall be applied. The pile shell shall be thoroughly dry and commercially blast cleaned according to SSPC-SP 6 before coating. The two coat application, final drying time, touch-up, and inspection shall conform to the specifications of the SSPC. The dry film thickness of each coat shall be 200 µm minimum and 400 µm for the two-coat system.

If fusion bonded epoxy coating is specified, it shall be a one-part, heat curable, thermosetting powder coating meeting the following requirements:

Property	Test Method	Value
Gloss 60 degrees	ASTM D 523	25 to 90%
Impact (16 mm Top)	ASTM G 14	9 to 18 J
Taber Abrasion*	ASTM D 4060	70 mg/1000 cycles
Chemical Resistance	ASTM D 1308	10% CaCl No Effect10% NaOH No Effect Sat $Ca(OH)_2$ No Effect
Color	Red Standard (For other colors, consult coater.)	
* Taber Abrasion run CF 10 wheel, 1000 g load, 1000 cycles		

The fusion bonded epoxy coating shall be applied in an environmentally controlled plant that is fully enclosed. The blast cleaning apparatus and the coating application system shall be approved and prequalified by the Department. All surfaces to be coated shall be blast cleaned according to SSPC-SP 5 "White Metal Blast Cleaning" standards. The blast profile shall be 50 to 75 µm. The coating shall be applied within eight hours after blast cleaning. The coating shall be applied as an electrostatically charged dry powder sprayed onto the grounded pile. The coating shall be heated and cured in accordance with the manufacturers recommended procedures to provide a fully cured finish. The coating shall be applied to a cured thickness of 635 ± 50 µm as tested in accordance with ASTM G 12.

For both the coal tar and fusion bonded epoxy coatings, a compatible touch-up compound shall be provided for repairing areas damaged during driving. The touch-up compound shall be applied by the Contractor to all visible open areas in accordance with the manufacturers recommended procedures.

The length of each pile to be coated shall be in accordance with the requirements noted on the Plans. Test piles shall also be coated if a protective coating is specified for the production piles in the group.

618.11 Portland Cement Concrete. Portland cement concrete shall conform to the requirements of Section 812, Class B.

618.12 Bar Reinforcement. Bar reinforcement shall conform to the requirements of Section 824.

618.13 Storage and Handling. The pile casings or shells shall be carefully stored and protected to avoid dents, abrasions, and other injuries and shall be picked up in a manner that will avoid bending and distortion. If the pile shells are damaged due to improper storage or handling, they shall be rejected.

618.14 Inspection. Shells (steel casings) will be inspected by the Department at the point of shipment prior to applying any protective coating. If a protective coating is required, the application of the protective coating will be inspected at the plant. The pile shells shall also be subject to inspection at the Project site prior to driving. All defective piles will be rejected.

STEEL H PILE MATERIALS.

618.15 Materials. Unless otherwise indicated, all steel H piles shall conform to the requirements of AASHTO M 183/M 183M. Materials for splices or reinforced tips shall be the same as the H pile except that cast steel may be used for tips. All welding and welding materials shall be as specified under Subsection 826.12. Steel shall be straight and true with the camber and sweep within the permissible mill tolerances.

PRECAST, PRESTRESSED CONCRETE PILE MATERIALS.

618.16 Portland Cement Concrete. Portland cement concrete for square prestressed concrete piles shall conform to the requirements of Sections 623 and 812 as amended herein, and f'_c shall be 40 MPa, unless noted otherwise on the Plans. The Contractor shall develop its own concrete mix design, according to the requirements of ACI 211.1, which shall be submitted to the Engineer for approval. The cement content shall not be less than 390 kg/m^3. Portland cement shall conform to the requirements of ASTM C 150, Type II.

With the approval of the Engineer, a blend of Type I cement conforming to the requirements of ASTM C 150 and ground granulated blast-furnace slag cement conforming to the requirements of ASTM C 989, Grade 120 may be used in lieu of the specified minimum amount of Type II cement. The slag cement percentage shall be not less than 35% nor greater than 50% of the Type I-slag cement blend by weight.

618.17 Prestressing Strands. Prestressing strands shall be seven-wire stress relieved, strands conforming to the requirements of AASHTO M 203/M 203M, Grade 270, unless noted otherwise on the Plans. The prestressing strands shall be arranged and stressed as shown on the Plans.

618.18 Spiral Reinforcing. Spiral reinforcing shall conform to the requirements of AASHTO M 32/M 32M.

618.19 Bar Reinforcement. Bar reinforcement, if required, shall conform to the requirements of Section 824, Grade 420.

618.20 Fabrication. The prestressed concrete piles shall be manufactured in accordance with the requirements of Section 623.

Working drawings of the pile fabrication details shall be submitted in accordance with Subsection 105.04. Piles shall be furnished with flat tips as shown on the Plans. Pointed pile tips shall not be used, unless specifically called for on the Plans.

Tolerance for prestressed concrete piles shall be as follows:

Width: -6 mm to +25 mm

Head Out of Square: 6 mm per 300 mm of width, measured diagonally

Horizontal Alignment: 3 mm per 3 m of pile

(Deviation from straight line parallel to centerline of pile)

Position of Stirrup Bars and Spirals: +19 mm, maintain specified clearance

Position of Tendons: ±6 mm

Position of Handling Devices: ±150 mm

618.21 Storage and Handling. The piles shall be stored, protected, and handled properly to avoid damage. Slings or other appropriate rigging shall be used at the designated pick up points to avoid damage to the piles. If the piles are damaged due to improper storage or handling by the Contractor, the piles will be rejected and shall be replaced by the Contractor.

The Contractor shall submit working drawings to the Engineer for review showing the procedures for picking up, transporting, and handling the piles prior to handling the piles. Piles may be moved after transfer of the prestressing force. Piles may be driven after the concrete has aged at least seven days and the concrete compressive strength is equal to or greater than the specified 28-day compressive strength.

618.22 Method of Measurement. The quantity of permanent timber, cast-in-place concrete, steel H, and precast, prestressed concrete piles will be field measured as the total number of linear meters of material ordered as determined by the Department based on test pile driving. The quantity of timber, cast-in-place concrete, steel H, and precast, prestressed concrete test piles will be field measured as the total number of linear meters ordered by the Contractor after approval by the Engineer for each type of test pile. The quantity of pile material used in pile splices of all types of piles will be field measured as the total number of linear meters of material furnished to the site as agreed by the Department. Pay measurements will be taken, in every case, before actual driving has begun. The additional length of pile formed and constructed for the purposes of a pile build up for a Precast, Prestressed Concrete Pile will be field measured as the total number of linear meters formed and poured.

618.23 Basis of Payment. The quantity of permanent timber, cast-in-place concrete, steel H, and precast, prestressed concrete piles will be paid for at the Contract unit price per linear meter for each type of pile. The quantity of timber, cast-in-place concrete, steel H, and precast, prestressed concrete test piles will be paid for at the Contract unit price per linear meter for each type of test pile. The quantity of pile material used for pile splices will be paid for at the Contract unit price per linear meter for each type of pile. The quantity of pile build ups constructed will be paid at the Contract unit price per linear meter for precast, prestressed concrete piles.

Price and payment will constitute full compensation for furnishing all pile and test pile materials, including pile tip, preservatives for timber piles, metal pile shells, protective coating for piles, bar and spiral reinforcement, prestressing strands, dowels for precast piles, Portland cement concrete for cast-in-place piles, costs associated with construction of pile build ups, and for all labor, equipment, tools, and incidentals required to complete the work.

All piles that are damaged due to improper storage or handling by the Contractor shall be replaced by the Contractor at no expense to the Department.

No payment will be made for production piles and test piles not accepted, production piles and test piles improperly driven, or production piles and test piles damaged during driving.
The installation of timber, cast-in-place, steel H, and precast, prestressed concrete piles and test piles will be paid for under Section 619.

Labor costs associated with splicing precast, prestressed concrete piles to obtain proper length will be paid for under Section 619.

SECTION 619 INSTALLATION OF PILES

619.01 Description. This work consists of installing four types of production and test piles. The four types of piles are timber, cast-in-place concrete, steel H, and precast, prestressed concrete. This work also consists of extracting, removing, and disposing of any test pile where required.

619.02 General. All materials used in the installation of any production or test pile shall conform to the requirements of Section 618. The location of production and test piles shall be as shown on the Plans or as directed by the Engineer. No piles shall be driven until all excavating and backfilling necessary at any structural unit have been completed. No production piles shall be driven until the test pile or piles have been driven and the results have been evaluated by the Engineer.

Production and test piles shall be driven to one or a combination of the following criteria as directed by the Engineer:

- Driven Bearing
- Tip Elevation
- Practical Refusal
- Bearing Achieved by Freeze

EQUIPMENT.

619.03 Driving Hammers. All piles shall be driven with a steam, air, or diesel hammer. The minimum rated energy of the pile driving hammer per blow shall meet the following requirements:

- Timber production and test piles - 16.3 kJ
- Cast-in-place concrete production and test piles - 21.7 kJ
- Precast, prestressed concrete production and test piles - 40.0 kJ
- Steel H production and test piles - 30.4 kJ

For steel H production and test piles, a driving head, grooved to the cross-section of the pile, shall be used to prevent damage to the tops of piles.

For production and test piles, pile hammers shall be sized to ensure that stresses associated with hammer impact do not exceed allowable driving stresses specified in Subsection 619.09. In the case of batter piles, the wave equation analysis shall also consider the decrease in energy due to the inclination of the pile driving hammer.

The pile hammer shall be maintained in proper adjustment consistent with the manufacturer’s recommendations. The pile hammer shall be operated at the manufacturer’s rated number of blows per minute and at the rated steam or air pressure for steam and air hammers. For steam or air hammers, the Contractor shall furnish a boiler or air compressor with a capacity at least equal to that specified by the manufacturer of the hammer to be used, and the Contractor shall equip the boiler or compressor with an accurate pressure gage. Double acting diesel hammers shall be equipped with either a pressure gage or other device calibrated in a manner that enables the Engineer to determine hammer energy. The device and calibration curves shall be as recommended by the hammer manufacturer and shall be submitted to the Engineer for review and approval. Single acting hammers of all types shall be equipped to allow accurate visual

monitoring of the stroke height by the Engineer. The mechanism providing such stroke height monitoring shall be submitted to the Engineer for review and approved prior to driving the initial test pile on the Project.
The Contractor shall furnish to the Engineer for approval information regarding the proposed pile driving system on the form, "Pile and Pile Driving Equipment Data".

Pile and Pile Driving Equipment Data Contract No.: County: Project: Structure Name and/or No.: Pile Driving Contractor or Subcontractor: (Piles driven by)
Hammer Manufacturer: Model: Type: Serial No.: Rated Energy: @ Length of Stroke Modifications:
Capblock Material: Thickness: Area: Modulus of Elasticity - E: (MPa) Coefficient of Restitution - e:
Pile Cap Helmet Bonnet - Weight: Anvil Block Drivehead
Cushion Cushion Material: Thickness: Area: Modulus of Elasticity - E: (MPa) Coefficient of Restitution - e:
Pile Pile Type: Length (in Leads): Weight/meter: Wall Thickness: Taper: Cross-Sectional Area: (mm^2) Design Pile Capacity: (metric tons) Description of Splice: Tip Treatment Description:
Submitted By: Date:

Pile driving equipment shall not be transported to the Project site until such approval is granted.
The hammer, hammer cushion, and pile cushion used to drive the production and test piles shall be the same type and size as those used in the wave equation analysis. No modifications or substitutions will be permitted without the approval of the Engineer.

Approval of a pile hammer shall not relieve the Contractor of responsibility for achieving the required bearing, piles damaged because of misalignment of the leads, failure of capblock or cushion material, failure of splices, malfunctioning of the pile hammer, or other improper construction methods. Piles damaged for such reasons will be rejected and shall be replaced by the Contractor if the Engineer determines that the damage impairs the strength or the serviceability of the pile.

619.04 Driving Helmet and Pile Cushion. A driving helmet, including a pile cushion for concrete piles, shall be used between the top of the pile and the ram to prevent impact damage to the piles. The driving helmet, and pile cushion for

concrete piles, shall be capable of protecting the head of the pile, minimizing energy absorption and dissipation, and transferring hammer energy uniformly over the top of the pile. The driving helmet shall fit loosely around the top of the pile, so that the pile is not restrained by the driving helmet if the pile tends to rotate during driving. The pile cushion may be of solid wood or of laminated construction, shall completely cover the top surface of the pile, and shall be retained by the driving helmet. The minimum thickness of the pile cushion shall be 150 mm, and the thickness shall be increased so as to be suitable for the size and length of pile, character of subsurface materials to be encountered, and hammer characteristics. The exact size and characteristics of the pile cushion shall be determined from the wave equation analysis. Timber or timber product pile cushion if used shall be replaced if it becomes compressed to 50% of its original thickness, if it becomes charred or burned, or if it becomes deteriorated in any manner during driving. If the Contractor opts to use another type of pile cushion, its properties and replacement criteria shall be submitted for approval with the wave equation analysis.

619.05 Leads. All piles shall be supported in line and position with leads while being driven. Pile driver leads shall be constructed in a manner that affords freedom of movement of the hammer, while maintaining alignment of the hammer and the pile to ensure concentric impact for each blow. Leads may be either fixed or swing type. Swinging leads, when used, shall be fitted with a pile gate at the bottom of the lead, and in the case of batter piles, a horizontal brace shall be required between the crane and the leads. The leads shall be adequately embedded in the ground. Alternatively, for battered piles, the pile shall be constrained and the leads anchored in a structural frame such as a template, as approved by the Engineer, to maintain batter and alignment of the driven piles. The leads shall be of sufficient length to make the use of a follower unnecessary and shall be so designed as to permit proper placement of batter piles. The leads and crane shall have the ability to handle, as a minimum, piles of the length indicated on the Plans plus 3 m.

619.06 Followers. Followers shall only be used when approved in writing by the Engineer, or when specifically stated in the Contract. In cases where a follower is permitted, the first pile in each bent and every tenth pile driven thereafter shall be driven full length without the use of a follower to determine that the desired bearing capacity is being attained. The follower and pile shall be held and maintained in equal and proper alignment during driving. The follower shall be of such material and dimensions to permit the piles to be driven to the length determined necessary from the driving of the full length piles. The final position and alignment of the first two piles installed with followers in each substructure unit shall be verified to be in accordance with specified location tolerances before additional piles are installed.

619.07 Water Jets. Water jets will not be permitted unless approved in writing by the Engineer or when specifically stated in the Contract. Water jets will not be permitted when installing any steel H piles. The number of jets and the nozzle volume and pressure shall be sufficient to freely erode the material adjacent to the piling. The plant shall have sufficient capacity to deliver at all times a pressure equivalent to at least 700 kPa at two 19 mm jet nozzles. To determine driving resistance, all piles shall be driven the last meter without the aid of jets. The type and configuration of water jets shall be submitted and approved prior to driving the initial test pile on the Contract.

CONSTRUCTION METHODS.

619.08 Preparation for Driving. The heads of the timber production and test piles, when the nature of the driving is such as to injure them unduly, shall be protected by caps of approved design. Collars or bands to protect them against splitting or brooming shall be provided where necessary.

Steel H production and test piles shall be driven in unspliced lengths whenever possible. Splices will only be permitted when specifically approved by the Engineer and shall be held to the absolute minimum. Splicing together short pile cut-offs to form a pile will not be permitted. Splice details will be as shown on the Plans or as approved by the Engineer. When reinforced pile tips are required, they shall be as detailed on the Plans or as approved by the Engineer.

619.09 Bearing Values. The Engineer will determine the driving resistance, tip elevations, and safe bearing capacity as described in this Subsection.

Wave equation analysis will be required for all types of piles discussed in this Section, unless otherwise shown in the Contract.

The Contractor shall be responsible for performing the wave equation analysis, unless otherwise specified, to obtain the relationship between blow count and estimated ultimate capacity. As determined by the Schedule of Work, but no less than 30 calendar days prior to driving the initial test pile, the Contractor shall submit the wave equation analysis, certified by a Professional Engineer registered in Delaware, to the Engineer for review and approval. The wave equation analysis will be used to verify the adequacy of the pile driving system and to establish the necessary blow counts, stroke heights, pile cushions, and any other applicable information for use in driving initial test piles to the required bearing capacity and tip elevation. This criteria may be reevaluated during test pile driving and may or may not be revised for production pile driving.

Along with the wave equation analysis, the Contractor shall submit to the Engineer the necessary pile driving equipment information on the "Pile and Pile Driving Equipment Data" form shown in Subsection 619.03.

Included in the submittal shall be computer input and output sheets and suitable data plots displaying the Contractor's wave equation analysis for the pile driving throughout the various subsurface conditions of the site. The plots shall show ultimate resistance versus blow count as well as maximum tension and compression stresses versus ultimate resistance. Unless otherwise specified on the Plans, a safety factor of 2.5 shall be used to calculate the allowable bearing capacity and a safety factor of 2 shall be used for bridges with pile load tests.

The information relating to the pile driving equipment proposed by the Contractor for the Project must be used as input to perform the wave equation analysis. If the wave equation analysis shows that the pile may be damaged at any time during driving, or if it is not possible to drive the pile to the desired ultimate capacity due to the proposed equipment or methods, the Contractor shall modify its proposed methods or equipment until a subsequent wave equation analysis indicates that the piles can be driven to the desired ultimate capacity, without damage.

During pile driving operations, the Contractor must use the approved equipment. No variations in the driving system will be allowed, unless the Contractor performs a revised wave equation analysis that is approved in writing by the Engineer.

A wave equation analysis must be performed for test piles at each abutment and pier location unless otherwise specified on the Plans. The wave equation analysis should evaluate drivability of the pile to various depths of penetration using the proposed driving system. As a minimum, the driving conditions for 5% penetrations (or an alternate depth of penetration as determined by the Engineer), 70% penetration, 90% penetration, 100% penetration, and 110% penetration of the pile during initial driving and after set-up condition should be evaluated. One hundred percent penetration refers to penetration to the plan estimated tip elevation to achieve the designated ultimate driven capacity. If the Contractor's estimate of tip elevation for the ultimate driven capacity differs from the plan estimate by more than 10%, then the Contractor's estimate of penetration shall be used for 100% penetration in the wave equation analysis. If the Contractor's estimate is chosen as 100% penetration, then driving conditions for plan estimated depth shall also be shown in the analysis.

In the drivability analysis, the estimated friction and end bearing values obtained by static soil analysis along with soil layer specific quake and damping values and friction parameters for each level of penetration shall be used. Analysis output shall include, as a minimum, ultimate capacities, blow counts, compressive and tensile stresses, and transferred energy plotted as a function of depth of penetration. The static soil analysis must be submitted with the wave equation analysis.

If the Contractor's driving equipment consists of a varying energy or varying stroke type hammer, such as an open-ended diesel hammer, then an additional analysis that plots blow count versus stroke and/or energy for a fixed capacity equal to the ultimate driven capacity shall be performed.

The Contractor shall select a hammer that drives the pile to its required penetration to achieve required bearing or minimum tip elevation with a driving resistance not exceeding 120 blows per 300 mm. In no case shall the driving resistance exceed 20 blows per 25 mm in the last 150 mm of penetration

Unless buckling governs or unless otherwise noted in the Plans or Special Provisions, pile driving stress, due to hammer impact only, shall be limited to the values, in megapascals, specified below:

(1) *Timber Piles:*

Tension or Compression 3 $_{a}$ (where $_{a}$ = AASHTO allowable working stress for round timber piles)

(2) *Steel H Piles, Steel Pipe Piles, and Steel Shell Piles (Cast-In-Place Concrete Piles):*

Tension or Compression 0.9 f_{y}

(3) *Precast, Prestressed Concrete Piles:*

Tension 0.25 (square root of f'_{c}) + effective prestress

Compression 0.85 f'_{c} - effective prestress

If the test pile driving data or pile load test results indicate that a higher pile load capacity is possible, the Department reserves the right to redesign the pile layout, and footing if necessary, for the higher pile capacity as long as the capacity can be obtained by use of the same hammer.

For batter piles, the safe bearing capacity of the pile along its axis shall be equal to "U" times "P". The value of "U" for steam or air hammers and diesel hammers shall be determined as follows:

where: U = A coefficient, less than unity.

P = Safe allowable bearing capacity of piles, in kilograms, when driven vertically.

m = Tangent of the angle of batter.

If required by the Contract, the Engineer will perform dynamic monitoring of the driving of piles. This monitoring will provide information for determining the necessary production pile driving guidelines.

619.10 Pile Load Test. When required in the Special Provisions or when directed by the Engineer, safe bearing capacities of piles shall be determined by actual load tests. All requirements shall be in accordance with the Special Provision items indicated on the Plans.

619.11 Test Piles. When driving test piles, the following step-by-step procedures shall be followed:

(a) *Driving Test Piles to Bearing, Tip Elevation, Practical Refusal, or a Combination of These.*

(1) Perform the wave equation analysis based on the procedure outlined in Subsection 619.09.

(2) Ensure that test piles are the initial piles driven, are in general plumb piles, and that they meet the following requirements:

a. *Timber Test Piles.* Timber test piles shall be of the same material and size as the production piles, except that if treated timber production piles are specified, untreated test piles may be used if the Engineer gives written permission and if test piles are not to be driven in a permanent location or within any footing area.

Test piles driven outside permanent foundation locations shall, upon satisfactory completion of test driving, be either completely extracted and removed from their present locations or cut off in accordance with the requirements of Subsection 619.16.

b. *Cast-In-Place Concrete; Steel H; and Precast, Prestressed Concrete Test Piles.* Test piles shall be of the same material and size as that specified for production piles. The test piles shall be installed at locations indicated on the Plans. The test piles shall be driven in production pile locations so they can be used in the permanent structure if found satisfactory after testing. Bar reinforcement and concrete fill shall not be placed until conclusion of the testing and acceptance of the test pile for use as a production pile.

The Contractor shall furnish the Engineer with schedules of the proposed driving sequence. Driving of test piles shall not be started at any location until the schedule for that location has been approved by the Engineer. Departures from these schedules shall not be made without the Engineer’s approval.

The Contractor shall at all times conduct the test pile driving operations in close cooperation with the Engineer or the Engineer’s representative. The Engineer or the Engineer’s representative, without relieving the Contractor of any responsibility whatsoever, will be present when the test pile driving work is in progress. A complete driving log will be recorded by the Engineer or the Engineer’s representative for each test pile driven. The driving log will list all data that is essential for the determination of correct bearing capacity. The

Contractor shall conduct test pile driving operations so that all essential measurements and data can be accurately obtained.

(3) If one or more static load test is required, the Contractor shall perform at least one of the load tests in the first series of test piles driven.

(4) Lengths of test piles shall be as indicated on the Plans. However, should the Contractor's static analysis predict a need for alternate test pile lengths, then the lengths of test piles shall be clearly indicated in the wave equation analysis submittal. After evaluating the wave equation analysis, the Engineer will then issue an order length for test piles. A letter to the Contractor from the Engineer confirming test pile lengths must be received prior to the Contractor ordering any test piles.

(5) Furnish test piles in one length, and drive them continuously to the required bearing capacity and/or tip elevation.

(6) Assist the Engineer with dynamic pile testing in accordance with Special Provision 621502.

(7) The Engineer will advise the Contractor when test pile driving shall cease. However, in no case shall the pile be driven to exceed 240 blows per 300 mm or 20 blows per 25 mm of driving for a minimum of 75 mm.

(8) Any pile damaged by reason of internal defects or improper driving and any pile, as indicated below, driven out of its proper location or alignment shall be removed and replaced. Any driven timber pile that shows evidence of splitting, splintering, or brooming shall be removed and replaced. Any driven shell or casing that shows bends, kinks, or other deformations that are detrimental to its use as a production pile shall be removed and replaced. As an option, a second pile may be driven adjacent to the damaged or mislocated pile if the second pile can be driven without detriment to the structure and if approved by the Engineer.

The Contractor shall provide all facilities so that the required records will be kept of the pile lengths, hammer speeds, blows per meter, tip elevations, and other pertinent data for all piles driven. The Contractor shall also clearly mark the pile in 300 mm increments to assist in evaluating the driving. The mark shall be visible from a 17 m distance.

Piles shall be driven within an allowed variation of 3 mm per 300 mm of pile length from the vertical or batter shown on the Plans. The maximum allowable variation at the top of the pile shall be 75 mm in any direction from the location shown on the Plans.

No side pressure will be permitted for driving piles into the correct position.

(9) Following the driving of the test pile or series of initial test piles as agreed in the approved sequence of driving, the Engineer will review the driving records and make one of the following recommendations:

a. If load tests are not required, the Engineer will issue, within five working days after completion of the test pile driving, a list of production pile lengths to the Contractor for those piles governed by the test pile or group of test piles.

b. If the data and information obtained from driving any original test pile is conflicting, inconclusive, or unsatisfactory in any way, the Engineer will order, within two working days after completion of the initial driving, another test pile to be driven for additional information.

c. The Engineer will order, within two working days after completion of the initial driving, a test pile restrike to be performed in

accordance with Subsection 619.14.

d. The Engineer will order, within two working days after completion of the initial driving, a driving splice to be made on the test pile. The driving splice shall be made in accordance with the driving splice details shown on the Plans. After splicing is successfully completed, driving of the spliced pile shall be continued. When the driving of the spliced pile is completed, the Engineer will review the new driving records and make one of the recommendations listed under Step (9) above.

e. On jobs requiring static load testing, the Engineer may approve the driven test pile for load testing.

Recommendation (9)b., (9)c., or (9)d. above may be chosen prior to authorizing a load test to be performed. Also, recommendation (9)b., (9)c., or (9)d. above may be chosen if a load test is performed and found to be unsatisfactory. After a load test has been successfully completed, the Engineer will issue, within three working days after receipt of the Contractor's load test report, a list of production pile lengths to the Contractor for those piles governed by the test pile or group of test piles.

(10) On jobs requiring minimum tip elevation, the Engineer will evaluate the driving records, and in addition to recommendations (9)b. through (9)e. above, the Engineer may direct a revised tip elevation based on the test pile driving record. This revised tip elevation will be included in the issued production pile order list.

(11) If a pile reaches driving resistances exceeding 240 blows per 300 mm or 20 blows per 25 mm at a tip elevation significantly above the minimum tip elevation specified, the Contractor shall immediately inform the Engineer. The Engineer will analyze the pile group and direct the Contractor to perform corrective measures as required. At this point, the Contractor shall seek other methods, as approved by the Engineer, to drive the pile to the required minimum tip elevation.

(12) If any test pile build-ups (non-driving splices) are necessary, build-ups shall be constructed in accordance with the requirements of Subsection 619.15.

(13) Cut off the test pile, if necessary, in accordance with the requirements of Subsection 619.16.

(b) *Driving Test Piles to Bearing Achieved by Freeze.*

(1) Steps (1) through (8) under (a) above shall be followed.

(2) After successful driving of the test pile, the Engineer will order, within two working days after completion of the initial driving, a test pile restrike to be performed in accordance with the requirements of Subsection 619.14.

(3) On jobs requiring static load testing, test pile restrikes shall be performed in accordance with the requirements of Subsection 619.14.

(4) If any test pile build-ups (non-driving splices) are necessary, build-ups shall be constructed in accordance with the requirements of Subsection 619.15.

(5) The test pile shall be cut off, if necessary, in accordance with the requirements of Subsection 619.16.

619.12 Driving Production Piles. When driving production piles, the following step-by-step procedure shall be followed:

(1) The Engineer will establish the required blow count, stroke height, and tip elevation from the test pile results.

(2) The same hammer, cushioning, and other equipment that was used to drive the test piles must be used to drive the production piles. If the Contractor elects to change hammers, the Contractor must submit necessary wave equation analysis, drive additional test piles, and/or perform dynamic pile testing, as directed by the Engineer, before driving any production piles, even if the energy ratings of the hammers are identical.

(3) The pile driving sequence shall conform to the requirements established under Subsection 619.11. If necessary, additional detail shall be provided by the Contractor so that the Engineer is fully aware and in agreement with the proposed sequence of driving.

(4) Each production pile shall be driven continuously from the time that driving is started until the required bearing capacity and/or tip elevation is reached, except as may be required for splicing the pile.

(5) No production piles shall be driven to exceed 240 blows per 300 mm or 20 blows per 25 mm for a minimum of 75 mm.

Piles shall be driven to such depth that they develop at least the safe bearing capacities that are specified or until they reach practical refusal. The Engineer reserves the right, however, to establish the depth to which any or all piles are to be driven, depending on the actual conditions encountered.

(6) Any pile damaged by reason of internal defects or improper driving and any pile, as indicated below, driven out of its proper location or alignment shall be removed and replaced. Any driven timber pile that shows evidence of splitting, splintering, or brooming shall be removed and replaced. Any driven shell or casing that shows bends, kinks, or other deformations that are detrimental to its use as a production pile shall be removed and replaced. As an option, a second pile may be driven adjacent to the damaged or mislocated pile if the second pile can be driven without detriment to the structure and if approved by the Engineer.

The Contractor shall check piles for heave during driving of adjacent piles or by any other cause. All piles pushed up more than 6 mm shall be redriven to the minimum bearing capacity and at least to their original tip elevation, or as directed by the Engineer.

The Contractor shall provide all facilities so that the required records will be kept of the pile lengths, hammer speeds, blows per meter, tip elevations, and other pertinent data for all piles driven.

All piles shall be driven at locations shown on the Plans or as directed by the Engineer. Piles shall be driven within an allowed variation of 3 mm per 300 mm of pile length from the vertical or batter shown on the Plans. The maximum allowable variation at the top of the pile shall be 75 mm in any direction from the location shown on the Plans.

No side pressure will be permitted for driving piles into the correct position.

Any material forced up between the piles during driving shall be removed to the correct elevation before any concrete is placed for the foundation.

Piles shall be driven to secure the required bearing capacity and/or tip elevation specified herein, noted on the Plans, or specified by the Engineer. After driving of each pile group, the location and alignment of the piles shall be surveyed by the Contractor. The results of the survey shall be furnished to the Engineer. In the event that one or more of the piles are damaged by improper driving, or driven outside the allowable tolerance specified herein, the Engineer will analyze the pile group. If the analysis indicates that any pile is overstressed as a result of the damaged or out of tolerance piles, the Contractor shall remove the rejected pile or drive additional piles as directed by the Engineer. In addition, the Contractor shall modify the pile cap or abutment as required by the Engineer to accommodate the out of tolerance or added piles. All piles damaged by improper driving, or driven out of their proper location or alignment shall be rejected.

(7) Any driving splices determined necessary by the Engineer shall be made in accordance with the Plans or other details submitted by the Contractor to the Engineer for review and approval. Following the required curing time for the

splice, the spliced pile shall be driven to the required bearing capacity and/or tip elevation. If it becomes necessary to splice timber piles, the method for splicing and driving shall be submitted to the Engineer for written approval.

(8) Any build-ups (non-driving splices) shall be constructed in accordance with the requirements of Subsection 619.15.

(9) If the piles are driven to a tip elevation, as shown on the Plans or directed by the Engineer, and "Bearing Achieved by Freeze" is being used to achieve the desired bearing, the Engineer may direct the Contractor to restrike selected production piles in a particular footing, bent, or structural element. If this direction is given, the production pile restrikes shall be performed in accordance with the requirements of Subsection 619.14.

(10) Cut-offs, as necessary, shall be performed in accordance with the requirements of Subsection 619.16.

619.13 Auguring.

(a) *General.* When specifically indicated on the Plans or specifically approved by the Engineer, auguring shall be used to facilitate pile driving. The Contractor shall submit its proposed equipment and auguring procedures to the Engineer for approval prior to beginning pile driving operations.

When round piles are used, the auger diameter shall not be greater than 50 mm less than the pile diameter. The auger diameters listed below shall be used for square concrete piles unless otherwise shown on the Plans:

Hole Diameter	Pile Size
250 mm	300 by 300 mm
300 mm	350 by 350 mm
350 mm	450 by 450 mm
500 mm	600 by 600 mm
600 mm	750 by 750 mm
750 mm	900 by 900 mm

For other pile sizes, the diameter of the augers shall be as shown on the Plans, or approved by the Engineer. The pile holes shall be accurately augured with the hole centered over the plan location of the piling. The location and vertical alignment shall be maintained within the tolerances allowed for the piling.

For an augured hole that is required through rock material or a very dense layer that may damage the pile during driving, the augured hole diameter shall be approximately 50 mm larger than the largest dimensions across the pile’s cross-section. When required by the Plans or Project subsurface conditions, the Contractor shall maintain augured holes open both before and during pile driving operations. Bentonite slurry or an equivalent method shall be employed, if necessary, to maintain the holes in an open condition.

(b) *Auguring Through Compacted Fill.*

(1) When steel H or other low displacement piles are used, piles shall be driven through the compacted fill without auguring holes through the fill, except when the requirements for auguring are shown on the Plans. When concrete or other high displacement

piles are used, pile holes shall be augured through the fill to at least the elevation of the original ground surface.

(2) For an augured hole that is required through material that caves during driving, to the extent that the augured hole does not serve its intended purpose, the hole shall be cased from the embankment surface to the approximate elevation of the original ground surface. After the pile is driven, annular spaces between the casing and pile shall be filled with concrete sand or other approved clean sand in a manner approved by the Engineer. Unless otherwise shown on the Plans, the casing shall be removed after the pile is driven and accepted.

Any voids between the pile and soil remaining after driving through an augured hole, cased or uncased, shall be filled with concrete sand or other approved clean sand in an approved manner. The use of spuds (a spud is a short, strong driven member that is removed to make a hole for inserting a pile) will not be permitted in lieu of auguring.

619.14 Pile Restrike. After initial driving of production and/or test piles, the Engineer may order, within two working days after completion of the initial driving, a pile restrike. The restrike shall be performed within seven days of initial driving unless otherwise noted in the Contract. After the directed waiting time has elapsed, the pile restrike shall be performed as follows:

(1) Dynamic pile testing equipment shall be connected, if indicated on the Plans or directed by the Engineer, in accordance with Special Provision 621502.

(2) The pile hammer used during initial driving must be used for the Restrike.

(3) The hammer shall be warmed-up by striking another pile or pile cut-off at least 20 blows at full stoke.

(4) The elevation of the top of pile shall be established prior to performing the restrike.

(5) The hammer shall be carefully lowered and positioned on the pile. The hammer shall strike the pile 20 blows at the required stroke height.

(6) The hammer shall be removed from the pile, and the new top of pile elevation shall be established.

(7) After completion of the pile restrike, the Engineer will review the driving records and make a recommendation, within two working days, on how to proceed.

On contracts requiring dynamic pile testing, all piles to receive dynamic pile testing shall be subject to restrikes as described in Special Provision 621502.

On contracts requiring static load testing, test pile restrikes shall be performed, on each pile to be load tested, after a minimum of three but before five calendar days after completion of the pile load test. The pile load test shall be performed in accordance with Special Provision 620525, unless directed otherwise by the Engineer.

As directed by the Engineer, up to ten production piles driven shall be subject to pile restrikes. The Engineer will specify a waiting time of five days or less to perform the pile restrikes, unless noted otherwise on the Plans. The Engineer will attempt to schedule the pile restrikes so as to cause minimal, if any, delay to the overall pile driving operation. If the pile restrike results are satisfactory, the pile or representative group of piles shall be considered acceptable.

The pile restrikes described above shall be incidental to the price bid for the selected pile type. Under certain pile driving conditions it may become necessary to restrike various production piles and/or test piles, in addition to those described above, in order to verify the pile capacities. These additional restrikes may be a result of needing more than ten production pile restrikes or the restrike waiting time required may be greater than that specified above or in Special Provision 621502. Payment for additional pile restrikes will be as described in Special Provisions 620528 and 620529.

619.15 Pile Build-Ups. All build-ups shall be constructed as shown on the Plans or on other details submitted by the Contractor for review and approval by the Engineer.

619.16 Pile Cut Offs. Piles shall be cut to final cut-off elevation shown on the Plans or as directed by the Engineer. Cut-off sections of piles shall become the property of the Contractor at the end of the Project and shall be disposed of by the Contractor in a manner acceptable to the Engineer.

Pile shells or casings, after being driven, inspected, and approved, shall be cut off to a true plane using an acetylene or electric torch.

The tops of all timber production piles shall be sawed to a true plane at the elevation shown on the Plans, or as directed by the Engineer. Piles that support timber caps or grillage shall be sawed to conform to the plane of the bottom of the superimposed structure.

All exposed sawed surfaces of timber piles shall be thoroughly brush coated with three applications of preservative and covered with a thick layer of hot pitch or gum. Upon this shall be placed a metal covering of either a sheet of zinc or copper. Zinc sheet conforming to ASTM B 69 shall be at least 2 mm thick and shall be fastened with 24 mm long galvanized large-headed nails. Copper sheet conforming to ASTM B 152M shall be at least 8 mm thick and shall be fastened with 25 mm copper nails. The metal covering shall measure at least 100 mm more in each dimension than the diameter of the pile and shall be bent down over the sides of the pile, neatly trimmed, and securely nailed to the full satisfaction of the Engineer.

Test piles driven outside permanent foundation locations shall, upon satisfactory completion of test driving, be cut off at a point at least 600 mm below finished grade or final stream bed elevation at their respective locations.

619.17 Placing Bar Reinforcement for Cast-In-Place Concrete Piles. The longitudinal bar reinforcement and circular ties shall be assembled as a complete unit. The bars and ties shall be securely fastened together at all intersections in accordance with the details shown on the Plans. The complete unit shall be accurately placed in the driven casing or shell and held rigidly in place to prevent displacement during the placing of the concrete.
The Contractor shall submit a drawing or plan, showing the proposed method of holding the bar reinforcement in position during the placing of the concrete. Approval of the method submitted will not relieve the Contractor of its responsibility for ensuring that all bar reinforcement is properly located within the body of the finished piles.

619.18 Placing Concrete for Cast-In-Place Concrete Piles. No concrete shall be placed in any pile casing or shell until all driving within a radius of 5 m has been completed, or until all of the shells for that structure unit, such as a pier, bent, or abutment, have been driven to their final tip elevation and accepted. In the event that this limitation cannot be followed, all driving within the above limits shall be discontinued until the placed concrete has set for at least seven days.

After driving and completing the pile and other parts of the structure, the exposed part of the piling shall be cleaned of undue discoloration caused by methods of construction.

No concrete shall be deposited in a driven casing or shell until all water, dirt, and debris have been completely removed, and the Engineer has given approval.

Concrete for each shell or casing shall be placed in a continuous operation. An exception will be made if the bar reinforcement caging or dowels occupy only the upper section of the pile. In this case, no bar reinforcement shall be placed in the pile casing or shell until the concrete placed in the casing has reached the elevation of the lowest end of the bar reinforcement. The bar reinforcement shall then be rigidly set in the casing, and the placing of concrete shall be continued until the cut-off elevation has been reached. In no case shall an interruption in the sequence of placing concrete exceed 30 minutes. In the case where bar reinforcement caging or dowels occupy only the upper section of the pile, the Contractor may secure the reinforcement prior to placing any concrete if an "elephant trunk" is used to deposit concrete in the portion of the pile below the bottom elevation of the reinforcement. Concrete shall be consolidated as specified in Subsection 602.13 to a depth of at least 300 mm below the bottom of the rebar cage. The concrete shall be placed in such a manner as to ensure a dense, homogenous mass throughout the entire casing that is completely free from debris, oil, water, and other foreign matters to provide a permanent bond with all bar reinforcement embedded in the pile.

Piles with freshly placed concrete shall not be disturbed in any way until all concrete has set for at least 72 hours.

619.19 Method of Measurement. The installed quantity of test piles and production piles will be field measured as the total number of linear meters from final tip elevation to final cut-off elevation for each type of pile acceptably driven. The quantity of build-up lengths will not be measured and paid under this Section but will be measured and paid under Section 618.

The quantity of material used for driving splices on test piles and production piles will not be measured and paid under this Section but will be measured and paid under Section 618.

The cost of constructing driving splices for Precast, Prestressed Concrete Piles will be measured on an equivalent linear meter basis. The cost of constructing driving splices for all other pile types will not be measured and paid. The quantity of pile cut-offs for all pile types will not be measured for payment.

619.20 Basis of Payment. The installed quantity of timber, cast-in-place concrete, steel H, and precast, prestressed concrete test piles and production piles will be paid for at the Contract unit price per linear meter for each type of pile driven. Price and payment will constitute full compensation for driving and all work associated with the installation of piles, including auguring and jetting, unless noted otherwise, and restriking piles and test piles per Subsection 619.14; for conducting and submitting the wave equation analysis; for driving additional test piles; for performing dynamic pile testing if the Contractor elects to change hammers; for driving additional piles adjacent to rejected piles; for revising footings or abutments due to additional piles; and for all equipment, labor, tools, and incidentals required to complete the work.

The labor required to cut-off piles will be considered incidental to the cost of "Installation of Piles". Price and payment will constitute full compensation for acceptably performing a pile cut-off to the details and elevation shown on the Plans; for the disposal of cut-off piles; and for all equipment, labor, tools, and incidentals required to complete the work.

The quantity of driving splices constructed for Precast, Prestressed Concrete Piles will be paid for on an equivalent linear meter basis. Price and payment will constitute full compensation for all equipment and labor required to construct a driving splice in accordance with the Plans or details submitted by the Contractor for review and approved by the Engineer. Payment will be calculated based upon a fixed price of five hundred dollars per splice. This fixed price will be converted into an equivalent length, in linear meters, of pile for payment purposes. The equivalent length, in linear meters, will be based on the appropriate price bid for the piles. For example, if a driving splice is required on a production pile and the unit price bid for production piles is $165 per meter, then the equivalent length, in linear meters, to be added to that particular pile length for payment will be 3 m ($500÷$165/m = 3 m).

The cost of constructing splices for all other pile types will be considered incidental to the unit price bid for "Installation of Piles".

No payment will be made for falsework piles; for piles used in the construction of temporary wharves, platforms, and bridges, when built for the Contractor’s use; for removal and replacement of rejected piles; or for any other piles not definitely shown on the Plans or listed in the Proposal tabulations.

No payment will be made for production piles and test piles not accepted, production piles and test piles improperly driven, or production piles and test piles damaged during driving.

It is understood that driving additional test piles as required by the Engineer, due to conflicting, inconclusive, or unsatisfactory original test pile data and information, shall not serve as the basis for an increase in the original Contract unit price per linear meter for the type of pile, nor any other extra or increased compensation other than normal increase in payment due to the extra quantity of test piles to be paid for under this Section.

Payment for furnishing all pile materials, including preservation treatment, pile shell sections, pile material used to construct splices, material used to construct build-ups, protective coating, Portland cement concrete, bar reinforcement, prestressing strands, and spiral reinforcement will be made under Section 618.

SECTION 620 RESERVED

SECTION 621 TIMBER SHEET PILES

621.01 Description. This work consists of the furnishing and placing of either untreated timber sheet piles or creosoted timber sheet piles.

MATERIALS.

621.02 Timber. The timber, unless otherwise noted on the Plans, or in the Special Provisions, shall consist of any species that satisfactorily withstands driving without injury. It shall be sawed with square corners and shall be free from worm holes, loose knots, wind shakes, decayed or unsound portions, or other defects which might impair its strength or tightness.

621.03 Piles. The piles shall be of the type, width, and thickness specified, prepared from sound, solid materials. They shall be drift sharpened at their lower ends so as to wedge the adjacent piles tightly together.

621.04 Preservative Treatment of Sheet Piling. Preservative treatment shall be the same as specified for piles under Section 618.

621.05 Hardware. Hardware shall conform to the requirements of Subsection 601.07.

CONSTRUCTION METHODS.

621.06 Construction Materials. Timber sheet piles may be driven or jetted into place as directed. Sheet piles shall be so driven as to form a permanent, tight structure. After piles are in final position and have attained full bearing, the tops shall be cut off to a straight line at the elevation shown on the Plans, or as required.
Sheet pile cut-offs shall become the property of the Contractor, be removed from the Project site, and be disposed of in a manner that meets with the Engineer's approval.

Where shown on the Plans or directed, the tops of sheet pile walls shall be braced and aligned by means of timber wales. Wales shall be lapped and jointed at splices and corners and shall be solidly bolted or fastened together. The construction of wales shall conform, where applicable, to the provisions of Section 601.

621.07 Method of Measurement. The quantity of timber sheet piles will be measured as the actual cubic meters of sheet piles, driven and accepted. No measurement will be made for material cut off.

The cubic meters of timber wale construction will be measured in accordance with Section 601.

621.08 Basis of Payment. The quantity of timber sheet piles, including timber wales where required, will be paid for at the Contract unit price per cubic meter.

Price and payment will constitute full compensation for furnishing, driving, and cutting off the sheet piles; for timber wale construction, including hardware, where required; and for all labor, tools, equipment, and incidentals required to complete the work.

No payment or allowance will be made for sheet pile cut-offs.

SECTION 622 PERMANENT STEEL SHEET PILES

622.01 Description. This work consists of furnishing and placing untreated steel sheet piles.

622.02 Materials. Steel sheet piles shall be manufactured steel conforming to the requirements of AASHTO M 202/M 202M, except that steel shall meet the requirements to ASTM A 690/A 690M, unless otherwise shown on the Plans. All steel piles shall be straight and true at the time of driving. Pile camber and sweep shall be within the permissible mill tolerances.

622.03 Construction Methods. Construction shall not begin on the steel sheet pile bulkhead wall until all muck excavation in the immediate and adjacent area is completed and Borrow Type B is placed to the elevations shown on the Plans.

Sheet pile units shall be placed to full penetration and shall attain firm bearing in their final position. Jetting is prohibited. Sheet piles shall be placed to form a permanent tight structure and shall be cut off at, or driven to, the elevation shown on the Plans, or as directed. All pile cut-off material shall become the Contractor's property and shall be removed from the Project site.

622.04 Method of Measurement. The quantity of steel sheet piles will be measured in the field by determining the actual number of square meters of steel sheet piles placed and accepted, after cut-off. The cut-off portion of piles will not be measured for payment. The horizontal measurement of the completed installation shall be taken on a straight line between interlocks (the nominal or published width), not around the perimeter of the sheet pile units. The vertical measurement shall be taken from the tip elevation to the cut-off, or top elevation.

622.05 Basis of Payment. The quantity of steel sheet piles will be paid for at the Contract unit price per square meter. Price and payment will constitute full compensation for furnishing, placing, and cutting off the sheet piles; and for all labor, tools, equipment, and incidentals required to complete the work.

SECTION 623 PRESTRESSED REINFORCED CONCRETEMEMBERS

623.01 Description. This work consists of furnishing and erecting prestressed, precast, reinforced concrete members and accessories, on substructure units.

This work also includes furnishing and installing bearing pads and materials, dowels, tie rods, nuts, plates, joints and joint materials, scuppers, and all other parts and materials required to complete the work.

MATERIALS.

623.02 Strand. Strands shall be as shown on the Plans.

623.03 Wire. Wire shall be as shown on the Plans. The Contractor may propose the use of superior materials to the Department for approval.

623.04 Bar Reinforcement. Bar reinforcement shall conform to the requirements of Section 824.

623.05 Portland Cement Concrete. Portland cement concrete shall conform to the requirements of Section 812. The Contractor shall submit a mix design for the concrete to be used in prestressed members to the Department for approval. In addition, the total chloride content of the concrete mixture shall not exceed 0.06% by weight of cement. The mix design shall follow ACI design procedures and shall include the following:

Cement: Type I, II, or III, 9.2 bags/m^3

Air Content: 5 ± 2%

Admixtures: ASTM C 494

Required Strength, f_{cr}: Sufficient to ensure a minimum 28-day design strength of 35 MPa (ACI 214 evaluation)

The required test cylinder strength of the concrete at the time of transfer of the tensioning load from strand to concrete (release of prestress) shall be not less than 25 MPa.

Cylinders shall be initially cured under the same curing conditions as the members. A total of six test cylinders shall be cast for each member and tested as follows:

(a) Two cylinders (release cylinders) shall be tested to determine when transfer of the tensioning load may be permitted.

(b) Three cylinders shall be tested at 28 days.

(c) One cylinder shall be held in reserve or tested at the time of shipping, if necessary.

After the release cylinders have been tested, the remainder of the test cylinders shall be moist cured.

623.06 Bearing Materials. Elastomeric bearings shall include plain bearings, consisting of elastomer only, and laminated bearings consisting of layers of elastomer restrained at their interfaces by bonded laminates, each type being of the size indicated on the Plans.

The elastomer portion of the elastomeric compound shall be 100% virgin natural polyisoprene (natural rubber) conforming to the requirements of Table 623-A, or 100% virgin chloroprene (neoprene) conforming to the requirements of Table 623-B, as specified in the Contract. Compounds of nominal hardness between the values shown in the tables may be used and the test requirements interpolated. If test specimens are cut from the finished product, a 10% variation in "Physical Properties" will be allowed.

Laminates shall be rolled mild steel sheets conforming to AASHTO M 183/M 183M unless otherwise specified by the Engineer.

Bearings shall be manufactured according to the following requirements. Plain bearings may be molded individually, cut from previously molded strips or slabs, or extruded and cut to length. Cut edges shall be at least as smooth as specified for an ANSI 6.3 µm finish. Unless otherwise shown on the Plans, all components of a laminated bearing shall be molded together into an integral unit, and all edges of the nonelastic laminations shall be covered by a minimum of

3 mm of elastomer, except at laminate restraining devices and around holes that will be entirely closed on the finished structure.

Bearing tolerances shall conform to the following requirements. Flash tolerance, finish and appearance shall meet the requirements of the latest edition of the Rubber Handbook as published by the Rubber Manufacturers Association, Inc., RMA F3 and T.063 for molded bearings and RMA F2 for extruded bearings. For both plain and laminated bearings, the permissible variation from the dimensions and configuration required by the Plans and this Section shall be as follows:

(a) Overall Vertical Dimensions:

Average Total Thickness:

32 mm or less -0, +3 mm

Average Total Thickness

over 32 mm -0, +6 mm

(b) Overall Horizontal Dimension:

900 mm and less -0, +6 mm

over 900 mm -0, +13 mm

(c) Thickness of Individual Layers of Elastomer (laminated bearing only)

±3 mm

(d) Variation from a plane parallel to the theoretical surface (as determined by measurements at the edges of the bearings):

Top 3 mm

Sides 6 mm

Individual Non-Elastic Laminates 3 mm

(e) Position of Exposed Connection Members

3 mm

(f) Edge Cover of Embedded Laminates or Connection Members

-0, +3 mm

(g) Size of Holes, Slots, or Inserts

±3 mm

(h) Position of Holes, Slots, or Inserts

±3 mm

Whenever practical, the mechanical properties of the finished bearing shall be verified by laboratory test. The following values shall be met under laboratory testing conditions of full size bearings:

(a) Compressive strain of any layer of an elastomeric bearing shall not exceed 7% at 5.5 MPa average unit pressure or at the design dead load plus live load pressure if so indicated on the Plans.

(b) The shear resistance of the bearing shall not exceed: 205 kPa for 50 durometer, 275 kPa for 60 durometer, or 345 kPa for 70 durometer Table 623-A compounds; and shall not exceed 345 kPa for 50 durometer, 515 kPa for 60 durometer, or 760 kPa for 70 durometer Table 623-B compounds at 25% strain of the total effective rubber thickness after an extended four-day ambient temperature of -29 C.

Table 623-A				
ASTM Standard	Physical Properties	50 Durometer	60 Durometer	70 Durometer
D 2240 D 412	Hardness Tensile Strength, minimum MPa Ultimate elongation, minimum %	50 ± 5 17 450	60 ± 5 17 400	70 ± 5 17 300
	Heat Resistance			
D 573 70 hours at 70 C	Change in durometer hardness, maximum points Change in tensile strength, maximum % Change in ultimate elongation, max %	+10 -25 -25	+10 -25 -25	+10 -25 -25
	Compression Set			
D 395 Method B	22 hours at 70 C, maximum %	25	25	25
	Ozone			
D 1149	25 pphm ozone in air by volume, 20% strain, 38 ± 1 C, 48 hours mounting procedure D 518, Procedure A	No Cracks	No Cracks	No Cracks
	Adhesion			
D 429 B	Bond made during vulcanization, kN/m	7.0	7.0	7.0
	Low Temperature Test			
D 746 Procedure B	Brittleness at -40 C	No Failure	No Failure	No Failure

Table 623-B				
ASTM Standard	Physical Properties	50 Durometer	60 Durometer	70 Durometer
D 2240 D 412	Hardness Tensile Strength, minimum MPa Ultimate elongation, minimum %	50 ± 5 17 450	60 ± 5 17 350	70 ± 5 17 300
	Heat Resistance			
D 573 70 hours at 100 C	Change in durometer hardness, maximum points Change in tensile strength, maximum % Change in ultimate elongation, maximum %	+15 -15 -40	+15 -15 -40	+15 -15 -40
	Compression Set			
D 395 Method B	22 hours at 100 C, maximum %	35	35	35
	Ozone			
D 1149	100 pphm ozone in air by volume, 20% strain, 38 ± 1 C, 100 hours mounting procedure D 518, Procedure A	No Cracks	No Cracks	No Cracks
	Adhesion			
D 429 B	Bond made during vulcanization, kN/m	7.0	7.0	7.0
	Low Temperature Test			
D 746 Procedure B	Brittleness at -40 C	No Failure	No Failure	No Failure

623.07 Non-Shrink Grout. Non-shrink grout shall be composed of one sack of cement, 47.6 kg of sand, and 45.4 kg of approved non-shrink admixture.

623.08 Structural Steel. Structural steel shall conform to the requirements of Section 605, as applicable.

623.09 Protective Coating. The Contractor shall apply an epoxy coal-tar protection coating system to the surfaces indicated on the Plans. The epoxy coal-tar application shall consist of grinding and preparing the bridge deck surfaces, applying the epoxy coal-tar resin to the prepared surfaces, and coating the epoxy with sand as described herein or as directed by the Engineer.

DESIGN AND MANUFACTURE OF PRESTRESSED MEMBERS.

623.10 Plans and Alternate Designs. The Plans show general details and information, pertaining to the prestressed, precast, concrete members that serve as an indication of the type of construction acceptable. If the Contractor proposes an alternate design, a complete set of detailed shop drawings, with supporting design computations for the prestressed members to be furnished, shall be submitted in accordance with Subsection 105.04 for approval prior to any work.

The manufacture of prestressed members shall not proceed until the final shop drawings have been approved.

623.11 Design Criteria. The design of the prestressed, precast, reinforced concrete members shall meet the requirements of Section 6 of the AASHTO Standard Specifications for Highway Bridges.
The design load shall be HS 20-44.

For compressive strength of concrete at 28 days, f'_c shall be 35 MPa minimum.

For compressive strength of concrete at time of initial prestress, f'_c shall be 25 MPa minimum.

623.12 General Manufacturing Requirements. All plants manufacturing prestressed reinforced concrete members for work under this Contract shall be inspected and approved before manufacture of the members may be started. Only PCI certified plants, or plants which have been inspected and approved by the Department, will be permitted to manufacture prestressed primary load carrying members.

All materials, equipment, processes of manufacture, and the finished members, including handling, storage, and transportation, shall be subject to inspection and approval. Any defective construction, which may adversely affect the strength of a member or its performance in the bridge deck, shall be cause for rejection.

Permissible construction tolerances shall be in accordance with those recommended in the AASHTO publication, "Tentative Standards for Prestressed Concrete Pile, Slabs, I Beams and Box Beams for Bridges and an Interim Manual for Such Construction".

623.13 Forms. Forms and centering shall be made and maintained, during their use, true to the shapes and dimensions shown on the approved drawings.

Unless otherwise provided, only metal forms shall be used. The forms shall be well constructed, carefully aligned, substantial, firm, and securely braced and fastened together. The forms shall be sufficiently tight to prevent leakage of mortar and strong enough to withstand the action of mechanical vibrators.

Form ties shall be either the threaded type or the snap-off type. No form wires or metal pieces shall be left at the surface of the finished concrete. Corners and angles shall be mitered or rounded.

Joints between panel forms shall be made smooth and tight.

623.14 Reinforcement and Pretensioning Strands. Bar reinforcement and pretensioning strands shall be free of frost, dirt, oil, paint, mill scale, corrosion, or any foreign material that may prevent a bond between the steel and concrete. If an antibonding agent is used on the forms, every precaution shall be taken to protect the reinforcement and the pretensioning strands from being coated by the antibonding agent.

Pretensioning strands, reinforcement, and other embedded fixtures shall be accurately placed as indicated on the drawings and shall be maintained in their correct position during the manufacture of the members.

623.15 Pretensioning. The amount of stress to be given each cable or strand shall be shown on the approved working drawings.

All cables or strands to be prestressed in a group shall be brought to a uniform initial tension prior to being given their full pretensioning. This uniform initial tension shall be approximately 2.2 kN per strand and shall be measured by a dynomometer or other approved means so that the initial tension can be used as a check against elongation’s computed and measured. After this initial tensioning, the group of strands shall be stressed until the required elongation and jacking pressure is attained. The stress induced in the cables or strands shall be measured both by jacking gages and by elongations of the cables or strands. The calculated stress based on the elongation should closely match the gage reading.

All jacks shall be equipped with accurate and calibrated gages for registering jacking pressures. Means shall be provided for measuring the elongation of the prestressing strands to at least the nearest 1 mm.

The Contractor shall be required to furnish the Department with satisfactory, accredited proof that all jacking equipment and gages to be used in the manufacture of the prestressed members have been calibrated by a reputable testing laboratory.

The interpretations and analysis of the elongation's and jacking pressures shall consider and allow for all possible slippage or relaxation of the anchorage.

If there is a discrepancy of as much as 10% between the stresses determined by the jacking pressure and the elongation measurement, the entire operation shall be carefully checked and the source of error determined, before proceeding.

After the cables or strands are stressed in accordance with the plan requirements and this Subsection, and all other reinforcing is in place, the concrete shall be placed in the form. The temperature of the concrete shall be between 10 and 29 C. Cable or strand stresses shall be maintained between anchorages until the concrete has reached a minimum compressive strength of 25 MPa and the process of transferring the prestress to the member has begun. Members shall be steam cured under a suitable enclosure to contain the live steam and minimize moisture and heat losses. The initial application of the steam shall be from four to six hours after the final placement of concrete to allow the initial set of the concrete to take place. The steam shall be at 100% relative humidity to prevent loss of moisture and to provide excess moisture for proper hydration of the cement. Application of the steam shall not be directly on the concrete. During application of the steam, the ambient air temperature shall increase at a rate not to exceed 22 C per hour until a maximum temperature of from 60 to 71 C is reached. The maximum temperature shall be held until the concrete has reached the desired release strength. In discontinuing the steam, the ambient air temperature shall not decrease at a rate exceeding 22 C per hour until a temperature has been reached that is about 11 C above the temperature of the air to which the concrete will be exposed. The concrete shall not be exposed to temperatures below freezing for six days after casting. Recording charts of steam temperature shall be maintained.
The detensioning shall be done immediately following the curing period while the concrete is still warm and moist. If allowed to dry and/or cool prior to detensioning, dimensional changes take place that may cause cracking or undesirable stresses in the concrete.

In all detensioning operations, the prestressing forces must be kept nearly symmetrical about the vertical axis of the member. The detensioning must be applied in a manner that will minimize sudden or shock loading. Maximum eccentricity about the vertical axis shall be limited to one strand.

Forms, ties, inserts, holddowns, or other devices that would restrict longitudinal movement of the members along the bed shall be removed or loosened. Alternate detensioning shall be performed in such manner and sequence that longitudinal movement is precluded.

After completing the release of the prestresses, the strands shall be cut flush with the ends of the member and painted with either an approved bitumastic compound or waterproofing compound.

623.16 Production. The manufacturing process shall provide uniform production of dense, high grade concrete for all parts of the prestressed members under all working and weather conditions. The operations of mixing, placing, finishing, and curing shall be subject to inspection and approval.

623.17 Handling, Storage, and Shipping. Prestressed members may be handled immediately after curing and detensioning of the of strands or cables. Members shall not be shipped until at least the minimum 28-day compressive strength has been attained but in no case less than three days after the placing of concrete in the forms. Members shall be handled using the pick-up points provided especially for this purpose. The members shall be maintained in a horizontal position (as when formed on the casting bed) at all times during handling, moving, storing, and shipping. Members damaged by improper storing, handling, transporting, or erecting shall become the property of and be replaced by the Contractor.

Members will be inspected at the Project site for possible shipping damage and for verification that the member meets all dimensional requirements required by the Contract.

The Contractor shall follow the manufacturers recommended procedures for handling and placing the precast members during the entire process of transporting, unloading, and installing the members.

623.18 Grouting Between Prestressed Members. After the deck members have been placed and fastened together with tie rods and the end anchor dowels have been placed, the longitudinal joints between adjacent members shall be filled with a non-shrink grout.

Immediately prior to filling the joints, the keyways shall be cleaned of all debris, oil, grease, and other material that may prevent effective bonding. After cleaning, the keyways shall be thoroughly soaked with water and tightly caulked with an approved material, below the bottom of the shear key to avoid grout leaks. The caulking material shall not project more than 13 mm into the shear key area. In cold weather, the concrete against which the grout will be placed must be frost-free.

The grout shall be mixed to a consistency necessary to place the material. Traffic, or other loading, shall not be permitted on the bridge deck for at least 24 hours after the grout has been placed or, preferably, not until the end of the curing period.

The joints shall be covered with wet burlap, kept wet, and cured for three days.

623.19 Scuppers. The Contractor shall furnish and install scuppers of the material and at the locations shown on the Plans or as directed.

623.20 Method of Measurement. The quantity of prestressed, precast, reinforced concrete members, placed and accepted, will not be measured.

623.21 Basis of Payment. The quantity of prestressed reinforced concrete members placed will be paid for at the Contract lump sum price. Price and payment will constitute full compensation for furnishing and placing all materials, including the removal and replacement of all prestressed members rejected due to defective construction or improper storing, handling, or transporting; and for all equipment, tools, labor, and incidentals required to complete the work.