DIVISION 500. STRUCTURES

BRIDGES

SECTION 501. REMOVAL OF EXISTING STRUCTURES

501.01 Description. This work shall consist of the removal of existing traffic and drainage structures or portions thereof.

CONSTRUCTION REQUIREMENTS

501.02 General. Materials that are to be salvaged under the contract and which the Engineer deems fit for reuse shall be carefully removed in transportable sections and stockpiled near the site at a location designated by the Engineer. If the material for reuse is unfit, through no fault of the Contractor, the material shall be disposed of according to Article 202.03. When the Contractor damages or destroys such material, the Contractor shall repair or replace the material in a manner satisfactory to the Engineer. Materials that are not to be salvaged shall be removed and disposed of according to Article 202.03.

When a superstructure is specified to be salvaged for reerection, all members and loose parts shall be properly matchmarked, all machined steel surfaces treated with an approved anti-rust compound, and all loose parts wired to adjacent members or packed in marked boxes.

501.03 Protective Shield System. When required, a protective shield system shall be erected and maintained to protect pedestrian, vehicular, or railroad traffic from falling objects. The system shall protect the area shown on the plans. The protective shield system shall be designed and constructed to sustain loads of 200 lb/sq ft (9.5 kPa) in addition to its own weight. Protective shield systems comprised of wood members shall be designed for a minimum loading duration of seven days. The system may be either fixed or mobile. The existing vertical clearances above roadways and/or railroad tracks shall be maintained. The Contractor shall coordinate the installation with municipalities and/or utilities to insure protection of their facilities during the removal process.

The Contractor shall submit working drawings and calculations prepared and sealed by an Illinois Licensed Structural Engineer to the Engineer for the protective shield system. The drawings shall provide full details, dimensions, and types of materials proposed for use. The protective shield system shall not be installed until authorization to proceed is given by the Engineer.

Concrete removal shall not commence until the protective shield system is in place and in conformity with the sealed working drawings.

Upon completion of the work or when directed by the Engineer, the protective shield system shall be removed.

501.04 Complete Removal of Structures. Existing structures shall be removed to at least 1 ft (300 mm) below the proposed elevation of subgrade or ground surface. Portions of existing structures below this elevation that interfere with the proposed construction shall also be removed.

When slope wall is specified to be removed, it shall be the responsibility of the Contractor to determine the thickness of the slope wall to be removed and the extent to which it is reinforced. No additional compensation will be allowed because of variations from the assumed thickness or from the thickness shown on the plans, or for variations in the amount of reinforcement.

Removal of existing pipe culverts shall include any headwalls, wingwalls, or aprons attached to the culvert.

501.05 Partial Removal of Structures. Where portions of existing structures are to remain in service, portions to be removed shall be removed in such a manner as to leave the remaining structure undamaged and in proper condition for the use contemplated. Any damage to the portions remaining in service shall be repaired. Repairs shall be made as directed by the Engineer. The removed portions shall be disposed of according to Article 202.03.

Prior to partial removal of any concrete structure, a 3/4 in. (20 mm) deep saw cut shall be made along all boundaries of removal areas adjacent to areas to remain in place.

Where existing bars are to extend from the remaining portions of existing structures into new construction, the concrete shall be removed so as to leave the projecting bars clean and undamaged. All newly exposed concrete and exposed reinforcement bars to be incorporated into new concrete shall be blast-cleaned; epoxy coated reinforcement bars shall be cleaned and repaired according to Article 508.04. Where projecting bars are not to extend into the new construction, they shall be cut off flush with the surface to which the old concrete has been removed.

Additional requirements for the partial removal of specific structures shall be as follows.

(a) Bridge Decks, Partial Removal. When utilizing hammers to perform partial removal within 1 ft (300 mm) of the saw cut boundaries or portions of the existing bridge deck to remain in service, the hammers shall be limited to 15 lb (7 kg) chipping hammers or hand tools. Particular care shall be exercised at the bottom of the slab to avoid breakage beyond the designated removal line. When jack hammers are utilized to remove the remaining concrete, the hammers shall not be heavier than the nominal 45 lb (20 kg) class. More powerful hydraulic impact equipment will not be allowed to perform this removal. The surfaces presented as a result of this removal shall be reasonably true and even, with sharp straight corners that will permit a neat and workmanlike joint with the new construction.

Upon removal of the formwork, the bottom surfaces of new concrete, adjacent to remaining portions of existing concrete, shall be inspected with hammer sounding to detect loose and delaminated areas. Those areas

shall be removed as directed by the Engineer. All removed areas 1 in. (25 mm) or deeper shall be repaired with an approved method.

(b) Bridge Decks, Complete Removal. The concrete within 1 ft (300 mm) of partial depth saw cut boundaries, stage removal lines, or attached to and/or supported by portions of the structure to remain in service shall be removed according to Article 501.05(a). When jackhammers or hydraulic impact equipment are utilized to remove the remainder of the concrete, the equipment shall have a maximum rated striking energy of 1200 ft lb (1600 J). When saw cutting of the deck is utilized for deck removal, the top flanges of all beams or girders shall be marked on the deck surface. Saw cutting directly over the top of the beam or girder flanges will not be permitted.

(c) Culverts. At locations designated by the Engineer, all earth and debris shall be removed from the invert of the portions of existing culverts which are to remain in service.

(d) Substructures. When piers, abutments, or retaining walls, etc. or portions thereof are to be removed adjacent to structures or property to remain in use, even if that use is only temporary, the removal shall be done in such a manner as to not transmit damaging energy in to the remaining structure. The maximum rated impact energy shall be limited to 1200 ft lb (1600 J) unless the remaining portion of the structure can be fully isolated from the portion being removed. The removal shall be completed so as to maintain adequate structural and foundation support of the remaining elements.

At the Contractor's option, hydrodemolition equipment meeting the requirements of Article 1101.11 may be used. Operation of the hydrodemolition equipment shall be performed and supervised by qualified personnel certified by the equipment manufacturer. Evidence of certification shall be presented to the Engineer. When partial-depth removal is required, the equipment shall be calibrated and set to remove sound concrete to the required depth. If sound concrete is being removed below the required depth, the Engineer will require the equipment to be recalibrated and reset.

The Contractor shall control the runoff water generated by the various construction activities in such a manner as to minimize, to the maximum extent practicable, the discharge of construction debris into adjacent waters, and shall properly dispose of the solids generated according to Article 202.03. Runoff water shall not be allowed to constitute a hazard on adjacent or underlying roadways, waterways, drainage areas, or railroads, nor be allowed to erode existing slopes.

501.06 Method of Measurement. When paid for as a separate item, removal of existing structures, removal of existing superstructures, removal of existing concrete deck, and removal of existing concrete headwall for pipe culverts will be measured for payment in units of each at the location designated on the plans.

The protective shield system will be measured for payment in place and the area computed in square yards (square meters). The length will be measured along the centerline of the structure. The width will be measured perpendicular to the centerline of the structure.

When paid for as a separate item, slope wall removal will be measured for payment in place and the area computed in square yards (square meters).

Removal of existing culverts will be measured for payment in place, in feet (meters) along the invert of the culvert.

When paid for as a separate item, removal of existing bridge rail will be measured in place in feet (meters). The length measured will be the overall length along the top longitudinal rail element through all posts and gaps. Removal and disposal of all posts and connecting hardware associated with the bridge rail will not be measured for payment.

When paid for as a separate item, the removal of concrete or masonry for partial removal of structures will be measured for payment in place and the volume computed in cubic yards (cubic meters).

Excavation of earth necessary to perform the removal of existing structures will not be measured for payment.

Rock excavation will be measured for payment according to Article 502.12.

501.07 Basis of Payment. When the contract contains a separate item for the removal of a structure, the work will be paid for at the contract unit price per each for REMOVAL OF EXISTING STRUCTURES, REMOVAL OF EXISTING SUPERSTRUCTURES, or REMOVAL OF EXISTING CONCRETE DECK at the location designated on the plans.

When the contract contains a separate item for the partial removal of concrete or masonry structures the work will be paid for at the contract unit price per cubic yard (cubic meter) for CONCRETE REMOVAL or MASONRY REMOVAL.

Disposal of materials specified for salvage but deemed unfit for further use through no fault of the Contractor will be paid for according to Article 109.04.

The protective shield system will be paid for at the contract unit price per square yard (square meter) for PROTECTIVE SHIELD.

Removal of existing pipe culvert concrete headwalls will be paid for at the contract unit price per each for CONCRETE HEADWALL REMOVAL.

Removal of existing pipe culverts will be paid for at the contract unit price per foot (meter) for PIPE CULVERT REMOVAL.

When a pay item is provided in the contract, removal of existing slope wall will be paid for at the contract unit price per square yard (square meter) for SLOPE WALL REMOVAL.

When a pay item is provided in the contract, removal of existing bridge rail will be paid for at the contract unit price per foot (meter) for BRIDGE RAIL REMOVAL.

When the Engineer directs that earth and debris be removed from culvert inverts, such removal will be paid for according to Article 109.04.

When existing structures or portions of existing structures are encountered which cannot be removed by normal excavation procedures and are not shown on the plans or are not evident in the field and are required to be removed, the cost of such removal will be paid for according to Article 109.04.

Rock excavation will be paid for according to Article 502.13.

SECTION 502. EXCAVATION FOR STRUCTURES

502.01 Description. This work shall consist of the excavation required for the construction of structures including bailing, draining, pumping, sheeting; the construction of cofferdams, or temporary cribs if found necessary, and their subsequent removal; and backfilling to the level of the ground surface as it existed before any excavation was made.

CONSTRUCTION REQUIREMENTS

502.02 Clearing, Tree Removal, and Protection of Existing Plant Material. Prior to starting excavation operations in any area, all clearing, tree removal, and protection of existing plant material in that area shall be performed as specified in Section 201.

502.03 General. Excavation for structures shall include all materials encountered, regardless of their nature.

Structure excavation shall include all excavation, except rock excavation or excavation within a cofferdam.

Cofferdam excavation shall include all excavation within the limits of a cofferdam, except rock excavation.

Rock excavation for structures shall consist of the excavation of boulders 1/2 cu yd (0.4 cu m) in volume or greater and all rock in ledges, bedded deposits, and conglomerate deposits exhibiting the physical characteristics and difficulty of rock removal as determined by the Engineer. After the Engineer has made the determination that the material qualifies as rock excavation, the Contractor may use any method, approved by the Engineer, to remove the rock. Rock excavation for structures shall also include existing concrete, masonry, timber grillages, foundation piles, and similar materials which are not exposed to view, are not shown on the plans, and for which payment is not otherwise provided.

502.04 Sequence of Operations. The elevations of the bottoms of footings, as shown on the plans, shall be considered as approximate and the Engineer may order such changes in dimensions or elevations of footings as may be necessary to secure a satisfactory foundation. Where foundation piles are used, the excavation of each footing, as shown on the plans, shall be completed before the piles are driven. After the piles are driven, all loose and displaced material shall be removed to the bottom of the footing elevation.

502.05 Excavation in Rock. Where the footing excavation is in rock, the rock shall be excavated to the plan dimensions of the footing or seal coat. No rock shall project inside of such dimension more than 2 in. (50 mm). Other rock excavation shall be as necessary for the construction of the structure, subject to the limitations for measurement for payment specified in Article 502.12. All cracks, voids, seams, or other irregularities in the excavation shall be cleaned and filled with concrete.

502.06 Cofferdams. Cofferdams shall consist of watertight enclosures surrounding excavations. When cofferdams are not specified in the contract documents and conditions are encountered where the excavation for the structure cannot be kept free of water for prosecuting the work by pumping and/or diverting water by the use of sheeting or dikes, the Contractor, with the written permission of the Engineer, will be permitted to construct a cofferdam.

The cofferdams shall be designed, constructed, and removed with the Engineer's approval. Cofferdams shall consist of engineered structural components consisting of timber, standard steel sheet pile sections, structural steel sections, cylindrical metal shells, or a combination of the above. Earthen embankments or dikes will not be classified as cofferdams.

The Contractor shall submit drawings and design calculations showing the proposed design, method of construction, removal, as well as other details left open to choice or not fully detailed on the plans. The design and method of construction shall provide, within the measurement limits specified in Article 502.12, necessary clearance for forms, inspection of exterior of the forms, pumping, protection of fresh concrete from rising water, and protection of the footing from erosion. No component of the cofferdam shall extend into the substructure concrete without written permission of the Engineer. These drawings shall be prepared and sealed by an Illinois Licensed Structural Engineer and submitted to the Engineer and approved prior to the start of construction.

(a) Seal Coat. Seal coats shall be constructed according to Article 503.14. When a cofferdam and seal coat are added to the contract by written permission of the Engineer, the design of the seal coat, including design calculations, shall be included in the overall design of the cofferdam when submitted to the Engineer for review and approval. When the excavation within the cofferdam has been completed and piles have been driven, the elevation of the bottom of the cofferdam shall be determined by soundings. The equipment and methods used to conduct the soundings shall meet the approval of the Engineer. Any material higher than the plan elevation of the bottom of the seal coat shall be removed.

(b) Removal. Removal shall be according to the previously approved procedure. Unless otherwise approved in writing by the Engineer, all components of the cofferdam shall be removed.

502.07 Excavation Other Than Rock. When the structure excavation occurs in material other than rock, the limits of the excavation shall not exceed the dimensions specified in Article 502.12. These limits may be exceeded only with the permission of the Engineer and subject to the limitations for measurement for payment specified in Article 502.12. The depth of the excavation shall be carried to the plan bottom of the footing elevation. If the material encountered at the plan

bottom elevation of spread footings is soft, muddy, or otherwise unsuitable, the material shall be removed to an additional depth as directed by the Engineer and replaced with crushed stone, gravel or other material approved by the Engineer.

502.08 Pumping. Pumping from the interior of a foundation enclosure shall be done in a manner approved by the Engineer. Pumping will not be allowed during placement of the concrete or for a period of 24 hours after completion of the placement, unless the pumping is accomplished from a watertight sump separated from the concrete being placed. Pumping to dewater a sealed cofferdam shall not begin until the seal coat has attained the design strength.

502.09 Inspection. After each excavation is completed, the Contractor shall notify the Engineer. No concrete shall be placed until after the Engineer has approved the depth of the excavation and the character and condition of the foundation material. When ordered in writing by the Engineer, the bottom of the excavated space within any cofferdam in which a seal coat is to be constructed shall be inspected by a qualified diver.

502.10 Backfilling. Backfilling shall consist of placing and compacting the necessary fill within the space excavated for a structure below the ground surface as it existed before any excavation was made. Fill required above the ground surface as it existed prior to excavation for the structure shall be considered as embankment. Bracing, forms, and rubbish shall be removed from the excavation before the backfill is placed. Unless sheeting is to remain in place, it shall be removed at such time as directed by the Engineer to prevent loosening unexcavated material and facilitate placing and compacting the backfill. Sloping sides of the excavation shall be stepped or serrated to prevent wedging action of the backfill against the structure.

Where the original ground surface is higher than the proposed elevation of roadway surface, stream banks or channels, the backfill shall be constructed up to the elevation designated as the proposed ground surface.

Backfill which is to serve as a roadbed, or upon which embankment is to be placed, shall be constructed by materials satisfactory to the Engineer. No sod, frozen material, or any material which, by decay or otherwise, might cause settlement, shall be placed or allowed to remain in the backfill at such locations. Whenever the material obtained from the excavation is suitable, it may be used in constructing the backfill. Excavated material that is unsuitable for backfill because it is in excess of 110 percent of the optimum moisture content shall be allowed to dry before being used as backfill. Excavated material unsuitable for backfill shall be disposed of according to Article 502.11. If the amount of suitable excavated material is insufficient, suitable material shall be obtained and used for making or completing the backfill.

In placing backfill or embankment, the material shall be placed simultaneously insofar as possible to approximately the same elevation on both sides of a wall, pier, or column. If conditions require placing backfill or embankment appreciably higher on one side of a wall, pier, or column than on the opposite side, the additional material on the higher side shall not be placed until test specimens show that the concrete has attained the required flexural strength and the curing period is completed. In the absence of tests to determine the flexural strength, the additional material on the higher side shall not be placed until at least 14 days have elapsed after the placing of

the concrete, exclusive of days on which the temperature of the air surrounding the concrete falls below 45 ºF (7 ºC).

Backfill or embankment shall not be placed behind the walls of concrete culverts until the top slab is placed and cured. Backfill and embankment behind the sidewalls of culverts having a clear height of more than 5 ft (1.5 m), shall be carried up simultaneously, and at no time shall the fill be more than 2 ft (600 mm) higher than behind the opposite sidewall.

Backfill shall not be placed in water at closed abutments, culverts, or retaining walls. The excavated area around these structures shall be pumped dry, and any mud or loose material within the excavated area shall be removed before placing backfill. At piers, backfill may be placed in water, providing no roadway embankment or slope wall is to be supported by the backfill and provided that both the water level and backfill are kept at approximately the same elevation on opposite sides of the pier. A time interval, approved by the Engineer, shall elapse before placing additional fill on one side of the pier, above the water surface.

Mechanical compaction of backfill will not be required around piers upon which no roadway embankment, slope wall, or other highway appurtenance is to be placed; and at those locations that are not adjacent to a highway, railroad, or other improvement beneath the structure.

Except as specified, the procedures for placing and compacting the backfill shall be according to Articles 205.04, 205.05, and 205.06. Except as described above, all backfill shall be placed in continuous horizontal layers not more than 8 in. (200 mm) in thickness, loose measurement, and each layer shall be compacted with a mechanical tamper of a type approved by the Engineer before the next layer is placed, and the backfill shall be compacted to the density specified in Article 205.06. If the moisture content of the backfill material exceeds 110 percent of the optimum moisture content determined for this material, no additional material shall be placed without the permission of the Engineer.

A deposit of gravel or crushed stone, CA 5, CA 7, or CA 11, according to the gradation requirements of Article 1004.01, at least 2 ft (600 mm) in each direction shall be placed at the back of each drain hole in abutments, wingwalls, retaining walls, and culvert sidewalls. The bottom of this deposit shall be 2 in. (50 mm) below the drain hole. All form boards or other obstructions shall be removed from the drains before such deposit is placed. The cubical deposit of coarse aggregate shall be completely enclosed in a fabric envelope. The fabric shall be according to the requirements of the applicable portions of Section 1080 and Section 282 with either the 6 or 8 oz/sq yd (200 or 270 g/sq m) material allowed. Free edges shall overlap by 12 in. (300 mm).

502.11 Disposal of Excess Excavation and Unsuitable Material. Unsuitable material and suitable material in excess of that required for backfilling shall be disposed of according to Article 202.03.

502.12 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of contract quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Structure excavation, when specified, will be measured for payment in its original position and the volume computed in cubic yards (cubic meters). Horizontal dimensions will not extend beyond vertical planes 2 ft (600 mm) outside of the edges of footings of bridges, walls, and corrugated steel plate arches. The vertical dimension for structure excavation will be the average depth from the surface of the material to be excavated to the bottom of the footing or seal coat as shown on the plans or ordered in writing by the Engineer.

Rock excavation for structures will be measured for payment as follows.

(1) General. Rock excavation will be measured for payment in its original position and the volume in cubic yards (cubic meters) computed by the method of average end areas.

(2) Footings and Seal Coats. Rock excavation for footings and seal coats will be measured for payment in its original position and the volume computed in cubic yards (cubic meters). Measurements will be taken vertically from the top of the rock to the elevation of the bottom of the rock or bottom of the structure, whichever occurs first, and horizontally within the perimeter of the structure to be placed.

(3) Pipe Structures. Rock excavation for pipe structures will be measured for payment in its original position and the volume computed in cubic yards (cubic meters). Measurements will be taken vertically from the elevation of the top of the rock to the specified elevation below the bottom of the pipe and horizontally for the width of the trench specified for placing the pipe. When the depth of rock removal below the bottom of a pipe structure is not otherwise specified, the rock shall be removed to 8 in. (200 mm) below the bottom of the pipe; except for water service lines and pipe underdrains, the depth of removal shall be 3 in. (75 mm) below the bottom of the pipe.

Rock excavation for storm sewers which are jacked in place will be measured as the volume actually moved, except that the horizontal dimension will not be greater than the external diameter of the pipe plus 12 in. (300 mm) and the vertical dimension will not be greater than the external diameter of the pipe plus 12 in. (300 mm) above the pipe and 8 in. (200 mm) below the pipe, unless the total vertical dimension is less than 4 ft (1.2 m), in which case 4 ft (1.2 m) may be used.

(4) Boulders, Concrete, or Timber. Boulders, concrete, or timber, 1/2 cu yd (0.4 cu m) or more in volume, will be measured for payment individually and the volume in cubic yards (cubic meters) computed from average dimensions taken in three directions. The quantity of concrete or timber to be paid for will be the volume of such material actually removed within the limits of the excavation as specified.

(5) Sumps in Rock. Where it is necessary to construct sumps in rock, measurements shall include the areas and depths required for such sumps.

Cofferdam excavation will be measured for payment in cubic yards (cubic meters) in its original position within the cofferdam sheeting. The horizontal dimensions used in computing the volume will not extend beyond vertical planes 2 ft (600 mm) outside of the edges of the pier footings or 4 ft (1.2 m) outside of the faces of the pier wall whichever is greater. The vertical dimensions will be the average depth from the surface of the material to be excavated to the elevation shown on the plans for bottom of the footing or seal coat, or as otherwise determined by the Engineer as the bottom of the excavation.

502.13 Basis of Payment. Except as provided, the work specified in this Section will not be paid for as a separate item. Where excavation for structures is not specified, the cost of the excavation shall be considered as included in the contract unit price for the class of concrete involved, or other unit price item of the work for which it is required. Structure excavation, when specified, will be paid for at the contract unit price per cubic yard (cubic meter) for STRUCTURE EXCAVATION.

Cofferdam excavation will be paid for at the contract unit price per cubic yard (cubic meter) for COFFERDAM EXCAVATION. When the contract does not contain a pay item for cofferdam excavation and this item is required, it will be paid for according to Article 109.04.

Rock excavation for structures will be paid for at the contract unit price per cubic yard (cubic meter) for ROCK EXCAVATION FOR STRUCTURES. When the contract does not contain a pay item for rock excavation for structures and this item is required, it will be paid for according to Article 109.04.

Removal and disposal of unstable and/or unsuitable material will be paid for according to Article 202.08.

Where it is necessary to excavate below the plan bottom of footing elevation, the excavation will be paid for at the contract unit prices for the class of excavation involved. Furnishing and placing the crushed stone, gravel, or other material will be paid for according to Article 109.04.

Cofferdams, when specified, will be paid for at the contract unit price per each for COFFERDAMS, at the locations specified. When added to the contract, cofferdams will be paid for according to Article 109.04.

Tree removal and protection of existing plant material will be paid for according to Section 201.

Additional suitable material required for backfilling within the roadbed, will be paid for according to Article 109.04.

When ordered by the Engineer in writing, cofferdam inspection by a certified diver will be paid for according to Article 109.04.

SECTION 503. CONCRETE STRUCTURES

503.01 Description. This work shall consist of constructing cast-in-place concrete structures.

503.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Portland Cement Concrete	1020
(b) Protective Coat	1023
(c) Preformed Expansion Joint Fillers	1051
(d) Waterproofing Materials	1060.01 - 1060.08
(e) Nonmetallic Water Seals	1054
(f) Reinforcement Bars	508

503.03 Equipment. Equipment shall be according to the following.

Item	Article/Section
(a) Hand Vibrator	1103.17(a)
(b) Vibrating Screed	1103.17(g)
(c) Finishing Machine	1103.13(a)
(d) Fogging Equipment	1103.17(k)

CONSTRUCTION REQUIREMENTS

503.04 Excavation and Backfill. Excavation and backfill shall be according to Section 502. Substructures, foundations, and footings shall be constructed in open excavation wherever practicable.

503.05 Falsework. The Contractor shall submit detailed plans for falsework, prepared and sealed by an Illinois Licensed Structural Engineer, for examination by the Engineer. If such plans are not satisfactory to the Engineer, the Contractor shall make such changes in them as may be required.

For continuous concrete slab and girder bridges, falsework shall be provided for the full length of each continuous unit and the full width of the structure.

For calculating the strength of falsework, a weight (mass) of 150 lb/cu ft (2400 kg/cu m) shall be assumed for the concrete. The design of the falsework shall take into account the weight of the concrete and also other loads incidental to the construction operations. All falsework shall be designed and constructed to provide the necessary rigidity and to support the imposed loads without appreciable settlement or deformation. The Contractor shall make allowance for the deflection, shrinkage, and settlement of falsework, in addition to the allowance for the amount of dead load deflection and camber shown on the plans. A method satisfactory to the Engineer shall be used to detect any settlement that may occur during the placing of the concrete.

Falsework bents shall be founded upon piling driven to a capacity sufficient to support the load without appreciable settlement. If the soil is firm and well

compacted, the Contractor may, as an alternate, place falsework bents upon concrete footing or mud sills of sufficient size that the pressure on the soil will not exceed 1 1/2 tons/sq ft (145 kPa) or the Contractor may support falsework from the piers or abutments, provided sleeves for any tie bolts can be cast into the concrete. Sleeves or other appurtenances cast into the concrete shall be constructed so as to permit their removal to a depth of at least 1 1/2 in. (40 mm) from the face without injury to the concrete. Drilling into existing piers or abutments that are to remain as a part of the final structure will not be permitted for the support of falsework. The Engineer may require the Contractor to use screw jacks or hardwood wedges to take up any settlement in the form work, either before or during the placing of the concrete.

Falsework supporting forms for cast-in-place concrete shall remain in place until tests show that the concrete has attained the required flexural strength and the curing period is completed. In the absence of tests to determine the flexural strength, the falsework shall remain in place until at least 14 days have elapsed after the placing of the concrete, exclusive of days in which the temperature falls below 45 ºF (7 ºC). When either fly ash or ground granulated blast-furnace slag has been used in the concrete mixture, falsework shall remain in place a minimum of 28 days from the time of concrete placement in the absence of strength tests.

No superimposed load, either dead or live, will be allowed upon the bridge during the period the falsework is required to remain in place. If longitudinal construction joints are provided in the roadway of any superstructure, the falsework shall not be released under one portion adjacent to such a joint until the concrete in that portion has attained the required strength and the concrete has been placed in the portion on the opposite side of such joint. The falsework shall not be removed from either side of such joint until all the concrete has attained the required flexural strength and the curing period is completed.

A compressive strength established through field testing to be equivalent to the required flexural strength may be used if approved by the Engineer.

Falsework shall be removed in such a manner as to permit the concrete to take uniformly and gradually the stress due to its weight (mass).

503.06 Forms. Forms shall be set and maintained to the lines and grades shown on the plans.

For continuous concrete slab and girder bridges, forms shall be provided for the full length and width of each continuous unit formed. The Contractor shall submit detailed plans for forms for review and approval by the Engineer.

A weight (mass) of 150 lb/cu ft (2400 kg/cu m) shall be assumed for the concrete in the design of the forms. The design of the forms shall provide for accommodation of incidental loads, settlement, deadload deflection, shrinkage, and deformation of the form components. The forms shall provide the structural capacity required to produce finished concrete to the lines and grades specified on the plans. Forms shall be constructed of wood or metal. Supporting or attaching forms by welding to or drilling or cutting holes in beams will not be allowed.

Wood forms for exposed surfaces shall be made of dressed lumber or plywood. Except for curved and special surfaces, wood forms shall be surfaced on both sides and both edges and shall be sized to uniform thickness.

Metal forms shall be of such thickness that they will remain true to shape. All bolts and rivet heads in contact with concrete shall be countersunk. Clamps, pins, and other connecting devices shall be designed to hold the forms rigidly in place and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or line up properly shall not be used. Metal forms shall be free from rust, grease, or other foreign matter.

Forms shall be filleted at all sharp corners. Triangular moldings used for fillets or V-shaped notches shall have two equal sides. Where the size of the molding is specified, the dimension stated shall be the width of each of the equal sides.

Moldings for fillets and notches shall be 3/4 in. (20 mm). The moldings for corners on handrails and handrail posts shall be 1/2 in. (13 mm). All moldings shall be cut with true edges, surfaced on all sides, and not warped, cracked, or frayed. Forms shall be given a bevel or draft in case of all projections, such as girders and copings.

When directed by the Engineer, temporary openings shall be provided in the bottom of forms for cleaning out all extraneous material immediately prior to placing concrete.

Tie rods, bolts and anchorages within the forms shall be constructed so as to permit their removal to a depth of at least 1 1/2 in. (40 mm) from the face without injury to the concrete. Wire ties, when used, shall be cut back at least 1/2 in. (13 mm) from the face of the concrete upon removal of the forms, except on surfaces not exposed to view, they may be cut flush. All fittings for metal ties shall be of such design that, upon their removal, the cavities which are left will be of the smallest practicable size.

Prior to reinforcement bar placement, forms shall be coated with form oil. When the surfaces are not exposed to view, wood forms may be saturated with water, in lieu of form oil, immediately prior to placement of the concrete.

Forms shall remain in place until permission is obtained from the Engineer for their removal. For Class SI concrete substructure components that will be self-supporting after the forms are removed, and for Class BS concrete components, except those defined in Article 503.16(b), the forms shall remain in place until the concrete has attained the required flexural strength and the curing period is completed. For the remainder of cast-in-place concrete components the forms shall remain in place at least 24 hours.

In the absence of tests to determine the flexural strength, the forms shall remain in place until at least 14 days have elapsed after placing the concrete, exclusive of days the temperature falls below 45 ºF (7 ºC). When either fly ash or ground granulated blast-furnace slag has been used in the concrete mixture, forms shall remain in place a minimum of 28 days from the time of concrete placement in the absence of strength tests.

A compressive strength established through field testing to be equivalent to the required flexural strength may be used if approved by the Engineer.

The method of form removal shall not result in damage to the concrete. If forms are removed prior to the completion of the required curing period, curing shall be resumed with an approved curing method for the remainder of the curing period.

Additional requirements for form liners and bridge deck forms shall be as follows.

(a) Form Liners. When form liners are specified, the Contractor shall submit plans for the form liner pattern along with an installation procedure for approval by the Engineer.

All form liner joints and tie holes shall be sealed.

Form release agents shall be according to the recommendations of the form liner manufacturer. The form release agent shall be compatible with all curing agents and admixtures.

The temperature differential between the form liner and concrete shall not be greater than 9 ºF (5 ºC) for normal ambient conditions. During cold weather, the form liner shall be applied in the same ambient conditions as concrete placement is to take place. In ambient conditions above 90 ºF (32 ºC), form liner attachment shall allow for thermal expansion.

Variations in dimensions for the cast-in-place concrete with a textured surface shall be within the following tolerances: the width and depth of textured joints shall be within ± 1/8 in. (± 3 mm); the location of the joints shall be within ± 1/2 in. (± 13 mm); and the maximum variation of a joint from a straight line shall be ± 1/4 in. (± 6 mm) in 10 ft (3 m).

A 2 x 2 ft (600 x 600 mm) test sample that includes the proposed textured surface shall be cast and supplied to the Engineer for his/her approval 30 days prior to pouring the cast-in-place concrete.

(b) Bridge Deck Forms. Forms used in casting concrete bridge decks will not be allowed to remain in place permanently. All tie rods, bolts, anchorages, brackets, and other forming hardware which is incorporated into the bridge deck shall be either epoxy coated or galvanized. Areas of epoxy coating which have been damaged shall be repaired.

When the Contractor uses cantilever forming brackets on the exterior beams or girders, the following procedures will be required.

(1) Bracket Placement. The resulting force of the leg brace of the cantilever bracket shall bear on the web within 6 in. (150 mm) of the bottom flange of the beam or girder.

(2) Beam Ties. The exterior beams or girders, supporting cantilever forming brackets, shall be tied together. On stage construction where cantilever brackets are supported on one exterior line of beams or girders, this line shall be tied to the furthest opposite interior line.

The ties shall be spaced at 4 to 8 ft (1.2 to 2.4 m) centers; except, when steel beams or girders are used and the finishing machine rails are located outside of the exterior beam or girder, the tie spacing shall be 4 ft (1.2 m) maximum. Cross frames on steel girders which do not have a top strut shall not be considered a tie.

Ties shall be a minimum of No. 4 (No. 13) epoxy coated reinforcement bars with threaded ends. Each tie bar shall be furnished with an approved tie bar stabilizing system consisting of adjustable end clips, lag studs, and turnbuckles. The tie clips shall mechanically attach to the outside fascia girder or interior girders as required for stage construction and the individual tie bar. The tie bars shall be placed parallel to and have the same clearance from the deck form work as required for the bottom transverse reinforcement. No welding will be permitted to the structural steel or stud shear connectors, or reinforcement bars for concrete beams, for the installation of the tie bar stabilizing system. After installation, the tie bar shall be tensioned with the turnbuckles until the bar does not vary from a straight line from center of end clip to center of opposite end clip.

(3) Beam Blocks. Hardwood 4 x 4 in. (100 x 100 mm) blocks, or material of an equivalent strength, shall be wedged between the webs of exterior and first interior beams within 6 in. (150 mm) of the bottom flanges at each location where the top of the beams are tied together.

If the Contractor elects to use cantilever brackets with an alternate procedure, the Contractor shall submit design calculations and detailed plans for approval by the Engineer.

503.07 Placing and Consolidating. No concrete shall be placed on ice, snow, or frozen foundation material.

The method and manner of placing concrete shall be such as to avoid segregation or separation of the aggregates or the displacement of the reinforcement. The external surface of all concrete shall be thoroughly worked during the operations of placing in such a manner as to work the mortar against the forms to produce a smooth finish free of honeycomb and with a minimum of water and air pockets.

Open troughs and chutes shall extend as nearly as practicable to the point of deposit. Dropping the concrete a distance of more than 5 ft (1.5 m) or depositing a large quantity at any point and running or working it along the forms will not be permitted. The concrete for walls with an average thickness of 12 in. (300 mm) or less shall be placed with tubes so that the drop is not greater than 5 ft (1.5 m).

When concrete is pumped, the equipment shall be suitable in kind and adequate in capacity for the work and arranged so that vibrations will not damage freshly placed concrete. Aluminum pipe or conduit will not be permitted in pumping or placing concrete. Mixed concrete shall be supplied so that the pumping equipment will be in continuous operation.

When placing Class BS concrete with a pump, the discharge end of the pump shall have an “S” shaped flexible or rigid conduit, a 90 degree elbow with a minimum of 10 ft (3 m) of flexible conduit placed parallel to the deck, or a similar configuration approved by the Engineer.

Placing of concrete shall be regulated so that the pressures caused by the wet concrete will not exceed those used in the design of the forms. Special care shall be taken to fill each part of the forms by depositing the concrete as near its final position as possible, to work the coarser aggregates back from the face, and to force the concrete under and around the reinforcement bars without displacing them. Leakage through forms onto beams or girders shall not be allowed to harden and shall be removed while in a plastic state.

The concrete shall be consolidated by internal vibration, except in thin sections or inaccessible locations where consolidation by internal vibration is not practicable.

The Contractor shall provide and use a sufficient number of vibrators to ensure that consolidation can be started immediately after the concrete has been deposited in the forms.

The vibrators shall be inserted into the concrete immediately after it is deposited and shall be moved throughout the mass so as to thoroughly work the concrete around the reinforcement, embedded fixtures, and into the corners and angles of the forms. Vibrators shall not be attached to the forms, reinforcement bars, or the surface of the concrete.

Application of vibrators shall be at points uniformly spaced and not farther apart than twice the radius over which the vibration is visibly effective. The duration of the vibration at the points of insertion shall be sufficient to thoroughly consolidate the concrete into place but shall not be continued so as to cause segregation. When consolidating concrete in bridge decks, the vibrator shall be vertically inserted into the concrete for 3 - 5 seconds or for a period of time determined by the Engineer. Vibration shall be supplemented by spading when required by the Engineer. In addition to the internal vibration required herein, formed surfaces which will be exposed to view after completion of the work shall be spaded with a spading tool approved by the Engineer.

Concrete shall be placed in continuous horizontal layers. When it is necessary by reason of an emergency to place less than a complete horizontal layer in one operation, such layer shall terminate in a vertical bulkhead. Separate batches shall follow each other closely and in no case shall the interval of time between the placing of successive batches be greater than 20 minutes.

After the concrete has taken its initial set, care shall be exercised to avoid jarring the forms or placing any strain on the ends of projecting reinforcement.

503.08 Depositing Concrete Underwater. Concrete shall not be exposed to the action of water before setting, or deposited in water, except with the approval of the Engineer and under his/her immediate supervision.

When concrete is deposited underwater, it shall be carefully placed in its final position by means of a tremie and shall not be disturbed after being deposited. Still

water shall be maintained at the point of deposit and all form work designed to retain concrete underwater shall be watertight. The consistency of the concrete shall be carefully regulated and segregation of the materials shall be prevented. The method of depositing concrete shall produce approximately horizontal surfaces.

The tremie shall consist of a tube having a diameter of not less than 10 in. (250 mm) and constructed in sections having flanged couplings fitted with gaskets. The means of supporting the tremie shall permit the free movement of the discharge end over the entire top surface of the work and shall permit it to be rapidly lowered when necessary to choke off or retard the flow. The discharge end shall be entirely sealed at all times and the tremie tube kept full to the bottom of the hopper. When a batch is dumped into the hopper, the tremie shall be raised slightly to induce the flow of concrete but the lower end shall be kept below the top of the deposited concrete until the batch is discharged. The flow shall then be stopped by lowering the tremie.

At the Contractor's option, pumping equipment may be used in lieu of a tremie to deposit concrete underwater. The Engineer will approve the concrete pumping equipment and its piping before the work is started.

503.09 Construction Joints. Construction joints shall be made only at locations shown on the plans or approved by the Engineer, except in cases of breakdowns or other unforeseen and unavoidable delays.

All construction joints shall be bonded unless noted otherwise. When not shown on the plans, their location shall be confined, as far as possible, to regions of low shearing stress and to locations that will be hidden from view. When possible, the location of construction joints shall be planned in advance and the concrete placed continuously from joint to joint. The reinforcing steel shall extend through such joints. If a construction joint is necessary in the sloped portion of a wingwall or similar location where a featheredge would result, the joint shall be constructed so as to produce an edge thickness of not less than 6 in. (150 mm) in the succeeding layer. No construction joint shall be placed within 18 in. (450 mm) of the top of any wall or pier unless the details of the work provide for a coping having a thickness of less than 18 in. (450 mm), in which case, at the option of the Engineer, a construction joint may be made at the underside of the coping.

The face edges of all joints which are exposed to view shall be carefully finished true to line and elevation. Shear keys, formed into or out from the surface of the previously placed concrete or steel dowels, shall be used where required. Shear keys formed into the concrete shall be formed by the insertion and subsequent removal of beveled wood strips which shall be thoroughly saturated with water prior to insertion. Steel dowels may, at the discretion of the Engineer, be used in lieu of keys. The size and spacing of the keys and dowels will be as determined by the Engineer.

Between adjacent sections of retaining walls and abutment walls, a V-shaped groove shall be formed in the exposed face of the walls by the use of 1/2 in. (13 mm) triangular molding on each side of the joint.

Care shall be exercised not to injure the concrete or break the concrete-steel bond at any time. In constructing bridge decks where longitudinal joints are specified, a platform shall be constructed outside the longitudinal joints and supported on the

lower form, and personnel will not be permitted to stand or walk on the projecting reinforcement bars until the concrete has hardened.

The Contractor, subject to approval of the Engineer, may pour a bridge deck full width with horizontal bonded construction joints between the deck and curbs, parapets, or sidewalks.

(a) Unbonded Construction Joints. Unbonded construction joints shall be made by forming or striking off the initial concrete placed to a true and even surface and allowing it to set. Loose material shall be removed. The new concrete shall be thoroughly consolidated against the existing concrete.

(b) Bonded Construction Joints. For bonding to hardened concrete, the existing cement paste shall be removed to create a prepared surface. The surface shall be prepared by washing with water under pressure or by sandblasting to expose clean, well bonded aggregate.

To facilitate the removal of the cement paste, the form in contact with the first pour or the exposed surface of the first pour, may be thoroughly covered with a surface retarder. When the surface retarder is applied directly to the fresh concrete surface, its application shall be completed within 30 minutes after concrete placement.

The surface retarder shall be a ready-to-use liquid compound that delays the set of a concrete surface, and shall be approved by the Engineer in advance of beginning the work. It shall produce results satisfactory to the Engineer and will be evaluated on the tests performed by the Engineer, and on the manufacturer's data recommendations.

The prepared surface of the existing concrete shall be wetted a minimum of one hour before application of the new concrete. The surface shall be maintained in a dampened condition during that period. Immediately before placing the new concrete, any excess water shall be removed.

503.10 Expansion Joints. Expansion joints shall be constructed to permit freedom of movement. After all other work is completed, all thin shells of mortar and projections of the concrete into and around the joint space that are likely to spall under movement or prevent the proper operation of the joint shall be carefully removed. Expansion joint devices shall be furnished and installed according to Section 520.

(a) Open Joints. Reinforcement shall not extend across or into an open joint. Open joints in railings or under projecting portions of rail posts shall be formed with square corners unless beveled corners are specified. When not protected by metal expansion guards, open joints in decks and sidewalks shall be finished with an edging tool satisfactory to the Engineer.

(b) Filled Joints. When preformed joint filler is specified, the material may be any one of the types specified in Section 1051. The preformed joint filler shall be placed in correct position before the adjacent concrete on one side of the joint is poured. The joint filler shall be cut from the least practicable number of pieces to fit exactly and completely fill the space shown on the

plans. Loose fitting or open points between sections of filler or between filler and forms will not be permitted.

(c) Edge Supports. The plates, angles, or other structural shapes provided as edge supports at open joints between adjacent spans shall be furnished and installed according to Article 520.03.

503.11 Drainage Openings. When specified, drain holes shall be constructed in abutment walls, wingwalls, retaining walls, and culvert sidewalls. A cubical deposit of gravel or broken stone shall be placed behind each drain hole according to Article 502.10.

The locations of drains on all concrete superstructures shall be adjusted so as to prevent the discharge of drainage water against any portion of the structure, or directly onto any railroad, highway or unprotected embankment beneath the structure.

Drains consisting only of openings formed in the deck and curbs shall be provided with a surrounding drip notch in the bottom surface of the slab.

Deck drains shall be placed and securely fastened in position before the concrete is placed.

503.12 Nonmetallic Water Seals. Nonmetallic water seals shall be installed as shown on the plans. Provisions shall be made to adequately support the water seal during construction. The projecting edges and ends of partially embedded water seals shall be protected from damage.

When splices are required, they shall be made by heating or vulcanizing to form continuous watertight joints. For the polyvinylchloride water seal, the heat shall be sufficient to melt but not char the plastic.

503.13 Foundations and Footings. When concrete footings are constructed in excavation other than rock, forms shall be used for all vertical surfaces, except when the excavation can be made and will remain true to the required lines and grades until the concrete is placed in the excavated space, the Engineer may permit forms to be omitted. When forms are omitted, the entire excavated space shall be filled with concrete to the elevation of the top of the footing.

When concrete footings are constructed in rock, forms shall be omitted and the entire space shall be filled with concrete up to the top of the footing, or to the top of the rock if the latter is lower.

In all cases, where sumps are required for the disposal of water, they shall be constructed outside the footing areas and forms shall be used for the footings at each sump.

The concrete footing for each substructure unit shall be placed monolithically, except when joints are specified. Vertical construction and expansion joints shown on the plans in abutments and wing walls shall not extend through the footing. In retaining walls or other structures, where joints extend through the footing, the water seal required in the joints between adjacent sections of wall need not extend below the top of the footing.

When concrete encasement is specified, this work shall include the furnishing and placing of the reinforcement required for encasement and any excavation necessary to construct it.

503.14 Seal Coats in Cofferdams. When conditions are encountered which render it impractical to dewater a cofferdam before placing concrete, the Contractor will be permitted to construct a concrete seal coat. Seal coats will not be authorized, except where properly constructed cofferdams cannot be dewatered satisfactorily by ordinary means.

The seal coat shall be constructed below the elevation of the footing and will not be considered a part of the footing. Seal coats shall be designed to withstand the hydrostatic pressure taking into account the resistance afforded by the cofferdam and foundation piles. Seal coats shall be constructed of Class SC concrete. Seal coat concrete shall be placed in one continuous operation according to Article 503.08.

503.15 Surface Finish. Depressions resulting from the removal of ties, and holes left by attachments to rod or bolt anchorages, shall be neatly pointed with a mortar of sand and cement mixed in the proportions of, and color matched to, the concrete being treated.

Air pockets or rough places larger than 1/2 in. (13 mm) diameter shall be pointed as specified in the foregoing paragraph. Honeycombed areas shall be chipped out by the Contractor and inspected by the Engineer before being pointed.

After being pointed, form liners and all other surfaces that will be exposed to view after completion of the work, except those surfaces specified in Articles 503.16(a) and (b)(1), shall be given a normal finish.

(a) Normal Finish. A normal finish shall consist of the removal of fins, rough spots, stains, hardened mortar or grout, and form lines by rubbing with a No. 16 carborundum stone or an abrasive of equal quality without materially changing the texture of the surface. The rubbing shall be continued sufficiently to produce a surface matching the surrounding surface.

When the surface of concrete shows a film of oil left from an excess of oil on the forms, or the concrete is oil-stained, or is otherwise not of uniform color, the Engineer may require the Contractor to employ the following cleaning method. Mix one part portland cement and 1 1/2 parts fine sand with sufficient water to produce a grout having the consistency of thick paint. Portland cement from the source of the cement used in the concrete shall be used in the grout. Wet the surface of the concrete sufficiently to prevent absorption of water from the grout and apply the grout uniformly with brushes, completely filling air bubbles and holes. Immediately after applying the grout, float the surface with a suitable float, scouring the wall vigorously. While the grout is still plastic, the surface shall be finished with a sponge rubber float removing all excess grout. This finishing shall be done at the time when grout will not be pulled from holes or depressions. Next, allow the surface to dry thoroughly, then rub it vigorously with dry burlap to completely remove any dried grout. There shall be no visible film of grout remaining after this rubbing. The entire cleaning operation for any area

must be completed the day it is started. No grout shall be left on the wall overnight. No cleaning operations shall be undertaken until all patching and filling of tie holes has been done.

(b) Rubbed Finish. Surfaces to receive a rubbed finish will be designated on the plans.

The surfaces shall be thoroughly wet with a brush and rubbed with a No. 16 carborundum stone, or an abrasive of equal quality, bringing the surface to a paste. The rubbing shall be continued sufficiently to remove all roughness and projections, producing a smooth dense surface free from pits and irregularities. The material which has been ground to a paste in the above process shall be carefully spread or brushed uniformly over the rubbed surface and permitted to reset. The final finish shall be obtained by a thorough rubbing with a No. 30 carborundum stone, or an abrasive of equal quality, first wetting with a brush as for the initial rubbing. The finish rubbing shall continue until the entire surface is of a smooth texture and uniform in color.

(c) Bearing Seats. Seats for bridge bearings shall be finished smooth at the proper plane and elevation with a steel trowel within 1/8 in. (3 mm) of the specified elevation before the bearings are placed. After the water sheen has disappeared, the surface shall be given a final finish by brushing with a whitewash brush. The brush shall be drawn across the seat longitudinally with the bridge deck, with adjacent strokes slightly overlapping, producing a uniform, slightly roughened surface with parallel brush marks.

503.16 Concrete Superstructures. The concrete in bridge decks, slab bridges or other monolithic superstructures shall be placed in one continuous operation between expansion or construction joints specified. Sidewalks, curbs, and medians shall be placed monolithically with the superstructure unless a construction joint is specified.

When falsework is utilized to support steel or precast concrete beams during erection, the falsework shall be removed prior to pouring the deck. The concrete bridge deck or top riding surface of the superstructure shall be constructed so that the top of the finished surface shall be at the final plan elevation after taking into account any anticipated deflection of the supporting members due to the weight of the deck, median, and parapets.

Fogging equipment shall be in operation unless the evaporation rate is less than 0.1 lb/sq ft/hour (0.5 kg/sq m/hour) and the Engineer gives permission to turn off the equipment. The evaporation rate shall be determined according to the figure in the Portland Cement Association's publication "Design and Control of Concrete Mixtures" (refer to the section on plastic shrinkage cracking). The Contractor shall provide temperature, relative humidity, and wind speed measuring equipment. The fogging equipment shall be adjusted to adequately cover the entire width of the pour.

If there is a delay of more than ten minutes during concrete placement, wet burlap shall be used to protect the concrete until operations resume. Concrete placement operations shall be coordinated to limit the distance between the point of concrete placement and concrete covered with cotton mats for curing. The distance

shall not exceed 35 ft (10.7 m). For pour widths greater than 50 ft (15 m), the distance shall not exceed 25 ft (7.6 m).

(a) Riding Surfaces of Superstructures. Superstructure riding surfaces shall be finished and textured as follows.

(1) Initial Finishing. After the concrete is placed and consolidated, it shall be struck off and finished with a power driven finishing machine.

The finishing machine will not be required for that portion of the surface outside of the outer construction joints shown on the plans when the distance from the construction joint to the parapet flow line is less than 6 ft (2 m). The concrete surface in these areas shall be finished with a hand operated float.

At the Contractor's option, a vibrating screed may be used in lieu of a finishing machine for superstructures with a pour width less than 16 ft (5 m). After the concrete is placed and consolidated, it shall be struck off with a vibrating screed allowing for camber, if required. The vibrating screed shall be of a type approved by the Engineer. A slight excess of concrete shall be kept in front of the cutting edge at all times during the striking off operation. After screeding, the entire surface shall be finished with long handled floats.

Long handled floats having blades not less than 3 ft (1 m) in length and 6 in. (150 mm) in width may be used to smooth and fill occasional porous or open-textured areas in the concrete surface, but shall not be used to float the entire surface. The Contractor shall take immediate corrective action to eliminate the causes of the porous or open-textured areas as they occur.

The Contractor may, at their option, transversely float the entire surface with a hand-operated float having blades not less than 10 ft (3 m) in length and 6 in. (150 mm) in width. If the Contractor chooses to transversely float the entire surface with the 10 ft (3 m) hand float and surface corrections are made, straightedge testing while finishing will not be required.

Water will not be permitted to be applied to the bridge deck surface unless it can be demonstrated to the Engineer that workability cannot be obtained. If water is permitted by the Engineer, it shall be applied in a fine mist by means of a sprayer, at a distance not to exceed 12 in. (300 mm) from the surface. Application by brushes or any other method that concentrates water will not be permitted.

Excess concrete, mortar, or paste produced by the finishing process shall not be discarded into areas of the bridge deck that will be covered by sidewalks, medians, curbs, or parapets or otherwise incorporated into the work but shall be removed and disposed of properly.

(2) Straightedge Testing and Surface Correction. After the finishing has been completed and while the concrete is still plastic, the surface shall

be tested for trueness with a 10 ft (3 m) straightedge. The Contractor shall furnish and use an accurate 10 ft (3 m) straightedge which has a handle not less than 3 ft (1 m) longer than 1/2 the pour width. The straightedge shall be held in contact with the surface and passed gradually from one side of the superstructure to the other. Advance along the surface shall be in successive stages of not more than 1/2 the length of the straightedge. Any depressions found shall be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished. High areas shall be cut down and refinished. The straightedge may be used to finish and seal the bridge deck surface when approved by the Engineer.

(3) Texture. All riding surfaces shall be textured in the plastic state and subsequently saw cut grooved after the concrete has cured.

a. Plastic Texture. The texture shall be formed into the plastic concrete with a burlap or artificial turf carpet drag. The burlap or artificial turf shall be attached to a work bridge riding on rails, or other approved device that will permit control of the time and rate of texturing. The burlap or artificial turf carpet shall have a length equal to the width of the pour or from face-to-face of curbs, as applicable. The burlap or carpet shall be laid on the concrete surface and dragged, parallel to the centerline of the roadway, in the direction that the superstructure is being poured with approximately 2 ft (600 mm) of its width in contact with the concrete surface. The drag shall be operated so as to produce a uniform finish. The burlap shall be double thickness and shall be kept saturated with water while in use. The artificial turf carpet may be weighted, if necessary, for maintaining intimate contact with the concrete surface.

b. Saw Cut Grooving. The grooving operation shall not be started until after the expiration of the required curing or protection period and after correcting excessive variations by grinding or cutting has been completed.

The grooves shall be cut into the hardened concrete, perpendicular to the centerline, using a mechanical saw device equipped with diamond blades that will leave grooves 1/8 in. wide and 3/16 in. ± 1/16 in. deep (3 mm wide and 5 mm ± 1.5 mm deep). The Contractor shall have the option of constructing the grooves at either a random spacing of 5/8 to 1 1/4 in. (15 to 30 mm) centers with an average spacing of 7/8 in. (22 mm) or a uniform spacing of 3/4 in. (20 mm) centers. The grooving shall be stopped 1 ft (300 mm) from the faces of curbs or parapets and 2 in. ± 1 in. (50 mm ± 25 mm) from deck drains and expansion joints. If grooving must be performed as part of stage construction, the grooving may be deferred until at least two adjacent lanes have been poured.

The removal of slurry shall be continuous throughout the grooving operations. The grooving equipment shall be equipped with

vacuum slurry pickup equipment which shall continuously pick up water and sawing dust, and pump the slurry to a collection tank. The slurry shall be disposed of off site according to Article 202.03.

Cleanup shall be continuous throughout the grooving operation. All grooved areas of the deck shall be flushed with water as soon as possible to remove any slurry material not collected by the vacuum pickup. Flushing shall be continued until all surfaces are clean.

(4) Surface Smoothness. All riding surfaces shall be tested for trueness at the expiration of the required curing or protection period. The entire surface shall be tested by means of a 16 ft (5 m) straightedge placed parallel to the grade line and touching the surface. Variations measured from the face of the straightedge to the surface of the superstructure shall not exceed 3/16 in. (5 mm). Variations greater than 3/16 in. (5 mm) shall be removed by grinding or cutting. Bushhammering or any method involving impact shall not be used.

(b) Concrete Superstructures Other Than Decks. Concrete parapets and railings, and those concrete curbs, sidewalks, and medians not placed monolithically with the deck shall be placed after the deck has been completed and the forms removed.

(1) Curbs, Sidewalks, and Medians. Forms for concrete sidewalks, curbs, and medians shall be adjusted to correct elevation, camber, and alignment after the deck or superstructure has been placed. After the concreting has been completed, they shall be struck off and finished with floats and trowels.

The edge of curbs, or walks not more than 2 ft (600 mm) in width, shall be either beveled by the use of 3/4 in. (20 mm) triangular molding at the top of the face forms or edged with an edging tool. The edge of walks over 2 ft (600 mm) in width shall be finished with an edging tool. Transverse construction joints shall not be edged and transverse grooves shall not be provided.

The top surface of sidewalks shall be finished according to Article 424.06, except the surface shall not be divided by grooves.

(2) Parapets and Railings. Forms for concrete parapets and railings shall be held rigidly to line and grade and removed without injury to the concrete. Special care shall be exercised to secure smooth, tight fitting forms. All moldings, panel work, and bevel strips shall be straight and true with neatly mitered joints and all corners in the finished work shall be true, sharp, and clean cut. Alignment of forms and grade of top chamfer strips shall be checked immediately after the placing of concrete in the forms. Rail posts, openings, and panels shall be constructed with vertical lines, regardless of the grade on which the railing is constructed.

503.17 Curing. Concrete shall be cured according to Article 1020.13.

503.18 Waterproofing. The surfaces of concrete structures designated on the plans shall be waterproofed as follows.

(a) Surfaces Below Ground. Surfaces below the ground which are to be waterproofed shall be given either one coat of asphalt primer and two mop coats of petroleum asphalt Type I; or two mop coats of asphalt emulsion.

(b) Surfaces Above Ground. Surfaces above the ground line which are to be waterproofed shall be given one coat of asphalt primer and two mop coats of petroleum asphalt Type II.

With the approval of the Engineer, spraying will be permitted in lieu of mopping.

The surfaces to be waterproofed shall be smooth and free from projections or porous places. The surfaces shall be cleaned of dust, dirt, grease, and loose particles and shall be dry at the time the waterproofing is applied. Petroleum asphalt shall not be applied until at least seven days have elapsed after placing of the concrete. Asphalt emulsion may be applied as soon as the forms are removed. No waterproofing shall be done in wet weather, or if local conditions indicate that rain is imminent, or when the temperature of the air in the shade is below 50 ºF (10 ºC), without the written permission of the Engineer, except as specified for asphalt emulsion below.

When waterproofing with petroleum asphalt, the primer shall be applied to the surface of the concrete in a uniform coating and may be applied without heating. The primer shall be applied at least 24 hours before applying the first mopping of hot asphalt. The two mop coats shall be heated to a temperature which will permit uniform application. Asphalt shall not be heated above 350 ºF (175 ºC). The amount applied in the two moppings shall be approximately 8 gal/100 sq ft (3 L/sq m) of finished work. If any imperfections appear in the waterproofing, additional coats will be required.

When waterproofing with asphalt emulsion, two uniform coats, free from holes or holidays, shall be applied. The second coat shall be applied as soon as the first coat has dried. The minimum total quantity applied in the two coats shall be 3 gal/100 sq ft (1 L/sq m). When the temperature of air in the shade is below 45 ºF (7 ºC), and the requirements of Article 1020.13(d) have been complied with, asphalt emulsion waterproofing may be applied down to a temperature of 32 ºF (0 ºC). Regardless of the temperature during application the material shall be kept at a temperature above 50 ºF (10 ºC). A minimum drying time of 24 hours is required before backfilling, but no backfilling shall commence until the requirements of Article 502.10 are met.

503.19 Protective Coat Application. A protective coat shall be applied to the entire top surface of bridge decks, hubguards, and the top and inside vertical faces of sidewalk, parapets, end posts, and wings when the concrete is at least 14 days old. This work shall be performed after saw cut grooving, and before the bridge deck is marked and opened to traffic.

Before the protective coat is applied, the concrete surface shall have at least a 48-hour drying period since the last rain and shall be cleaned to remove all oil, grime, and loose particles which would prevent the mixture from penetrating the concrete.

Immediately prior to application of the protective coat, the surface shall be blown with oil-free compressed air.

The protective coat shall consist of two applications of the mixture and each application shall be at a rate of 50 sq yd/gal (11 sq m/L) or less.

The protective coat shall be sprayed on the surface using hand methods or with a mechanical spraying machine which will perform the work in a satisfactory manner. The spray nozzle(s) shall be within 18 in. (450 mm) of the concrete or as directed by the Engineer. The interior of the distributor tank shall be thoroughly cleaned prior to placing the protective coat therein. Unless otherwise directed by the Engineer, the temperature of the concrete and air shall be 40 ºF (4 ºC) or higher at the time of application.

The second application of the protective coat shall be made when, in the opinion of the Engineer, the concrete has regained its dry appearance.

Traffic shall be prohibited from the area until the concrete has regained its dry appearance.

If an application of sand is required by the Engineer for blotter material, it will be paid for according to Article 109.04.

CAUTION: Linseed oil – petroleum spirits mixture has a low flash point and is readily flammable.

503.20 Opening Structures to Traffic. Concrete structures shall be opened to traffic according to Articles 503.05, 503.06, and 1020.13.

503.21 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. This work will be measured for payment in place and the volume computed in cubic yards (cubic meters). The dimensions used will not exceed those shown on the plans or ordered in writing by the Engineer. Increased quantities from the omission of forms for footings will not be measured for payment. Deductions will be made for the volume of piling, except for steel H pile, encased in the concrete. No deduction will be made for the volume of concrete displaced by steel reinforcement, drain holes, floor drains, and expansion joint material. The reduction in quantity of concrete involved in scoring and chamfers 2 sq in. (1300 sq mm) or less in cross sectional areas will be neglected in all measurements for payment.

When shown on the plans or ordered in writing by the Engineer, concrete for seal coats will be measured for payment within the cofferdam sheeting. The vertical dimension used in computing the volume will be the average thickness of the seal between the top of the seal not to exceed the elevation shown on the plans for the bottom of the footing and the bottom of the excavation, but in no case lower than the elevation shown on the plans for

the bottom of the seal coat. The horizontal dimensions used will be the average measurement from center to center of the interlocks of the sheet piling in opposite walls of the cofferdam, but in no case will these dimensions be taken as more than 2 ft (600 mm) beyond the neat lines of the footing in any direction, except that provision may be made for a sump at one end of the cofferdam if necessary.

Reinforcement bars will be measured for payment according to Article 508.07.

Bridge deck grooving will be measured for payment in place and the area computed in square yards (square meters). No deductions will be made for grooving omissions at deck drains, expansion joints, longitudinal joints, or lane lines.

Protective coat will be measured for payment in place and the area computed in square yards (square meters).

Form liner textured surfaces will be measured for payment in place and the area computed in square feet (square meters).

Joint fillers, water seals, drain holes, floor drains and welded wire fabric reinforcement, except when specified, will not be measured for payment.

Rubbed finish will be measured for payment in place and the area computed in square feet (square meters).

503.22 Basis of Payment. This work will be paid for at the contract unit price per cubic yard (cubic meter) for CONCRETE STRUCTURES and CONCRETE SUPERSTRUCTURE.

Other cast-in-place concrete for structures will be paid for at the contract unit price per cubic yard (cubic meter) for CONCRETE HANDRAIL, CLASS MS CONCRETE, CONCRETE ENCASEMENT, and SEAL COAT CONCRETE.

Reinforcement bars will be paid for according to Article 508.08.

Expansion bolts, when specified, will be paid for according to Article 540.08.

Rubbed finish will be paid for at the contract unit price per square foot (square meter) for RUBBED FINISH.

Form liner textured surfaces will be paid for at the contract unit price per square feet (square meter) for FORM LINER TEXTURED SURFACE.

Floor drains, other than frames and grates, will be paid for at the contract unit price per each for FLOOR DRAINS.

Texturing of bridge decks by saw cut grooving will be paid for at the contract unit price per square yard (square meter) for BRIDGE DECK GROOVING.

Protective coat will be paid for at the contract unit price per square yard (square meter) for PROTECTIVE COAT.

Concrete protected according to Article 1020.13(d) may be paid for at the adjusted unit prices which will be the following percentages of the contract unit price for the classes of concrete involved. These adjustments will be made only when they are authorized in writing by the Engineer. No adjustment will be made in the contract unit prices for any concrete if winter work is necessary to meet the required completion dates specified in the contract.

UNIT PRICE ADJUSTMENTS	
Type of Construction	Percent Adjustment in Unit Price
For concrete in substructures, culverts (having a waterway opening of more than 10 sq ft (1 sq m)), pump houses, and retaining walls (except concrete pilings, footings, and seal coats):	
When protected by:	
Protection Method II	115 %
Protection Method I	110 %
For concrete in superstructures:	
When protected by:	
Protection Method II	123 %
Protection Method I	115 %
For concrete in footings:	
When protected by Method I, II or III	107 %
For concrete in slope walls:	
When protected by Method I	107 %

SECTION 504. PRECAST CONCRETE STRUCTURES

504.01 Description. This work shall consist of the construction of structures or portions thereof, with precast concrete or precast, prestressed concrete structural members.

504.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Portland Cement Concrete	1020
(b) Reinforcement Bars	1006.10
(c) Prestressing Steel	1006.10
(d) Welded Wire Fabric	1006.10
(e) Transverse Tie Rods and Dowel Rods	1006.06
(f) Nonshrink Grout (Note 1)	1024
(g) Epoxy Bonding Compound	1025.01
(h) Precast Concrete Products	1042
(i) Preformed Bearing Pads	1082

Note 1. Nonshrink grout shall be mixed and placed according to the manufacturer's instructions, except the use of aggregate in the nonshrink grout will not be permitted. Water shall not exceed the minimum amount required for placement and finishing of the grout.

504.03 Equipment. Equipment shall be according to the following.

Item	Article/Section
(a) Hand Vibrator	1103.17(a)
(b) Vibrating Screed	1103.17(g)

CONSTRUCTION REQUIREMENTS

504.04 General. This work shall be according to Section 503, and the following.

504.05 Precast Concrete Members. Tie bolts, anchor dowels, bearing pads, inserts, nonshrink grout, and other items required for the erection of the units shall be furnished with the member.

Erection of precast bridge slabs shall commence at the centerline and proceed, one slab at a time, working out to the curb. As each slab is placed, the transverse tie bars shall be inserted and secured. Any shifting of the beams must be done while they are held free of the supports by the hoisting device or crane. The use of a steel pinch bar will not be permitted.

The abutting edges of each unit shall be carefully cleaned of any concrete or extraneous matter in order that the slabs can be bolted tightly together.

Care shall be exercised to keep the bearing seat areas free of foreign material when placing the slabs. After the units have been placed and fastened together and the end anchor dowels are placed, the longitudinal keyways between the units shall be filled with nonshrink grout according to Article 504.06(e).

Pile caps shall be carefully lowered into their proper position over the piles and to the specified elevation. After the units have been placed, the recess holes shall be filled with nonshrink grout according to Article 504.06(e).

504.06 Precast, Prestressed Concrete Members. Deck beams, I-beams, Bulb T-beams, and other prestressed concrete structural members shall be fabricated according to the Department's "Manual for Fabrication of Precast Prestressed Concrete Products" in effect on the date of invitation for bids.

(a) Damage Inspection. The completed members shall not be placed until they are inspected for damage at the jobsite by the Engineer. The members shall be inspected for damage again after placing and before decking begins.

(b) Deck Beam Erection Tolerances. The tolerance for the total width of the deck shall be the theoretical width plus 1/2 in. (13 mm) per joint. The maximum distance between beams, measured below the keyway, shall be 3/4 in. (20 mm). The deviation from the specified width for the transverse

joints shall be - 1/4 in. (6 mm) to + 1/2 in. (13 mm) at expansion joints, and 0 to + 1/2 in. (13 mm) at fixed joints.

The beams individually may comply with the dimensional tolerances and still not place satisfactorily in the structure. Acceptance of the beams, therefore, will be conditioned upon satisfactory placement.

(c) Handling, Storing and Transporting. The members shall be maintained in upright position at all times and shall be supported only at the ends. During lifting, they shall be supported only by the inserts provided for that purpose. During transportation, the ends of I-beams shall not extend a distance of more than the depth of the beam and, in no case, more than 3.5 ft (1.1 m) beyond the bolsters or other supports on the transporting vehicle. The ends of Bulb T-beams shall not extend more than 6 ft (1.8 m) beyond the supports. The ends of deck beams shall not extend a distance of more than 1 1/2 times their depth, and in no case more than 3 ft (0.9 m), beyond the supports. Trucks with double bolsters will be permitted, provided that the beams are fully seated on the outer bolsters and that the inner bolsters are not more than 8 ft (2.5 m) from the ends of the beams.

(d) Erection. Beams shall be placed on clean bridge seats and tops of bearing devices. Any shifting of beams shall be done while they are held free of the supports.

Precast members shall be handled with a suitable hoisting device or crane provided with a spreader sling of sufficient capacity to handle the members. The spreader shall be of sufficient length to prevent horizontal forces in the member due to lifting, and shall be equipped with leads and hooks at each end. For the purpose of engaging the threaded inserts provided in the member, the manufacturer shall provide a sufficient number of eye bolts of proper size.

Before lifting the member, all lifting inserts in each end shall be fully engaged with the spreader lead hooks. In the event that raising by alternate lifting and blocking of opposite ends is performed, the lifted end shall not be rotated unless a proper pivoting device for the opposite end has been provided.

Erection of deck beams shall begin at the expansion end. During the initial placement of the beams, every effort shall be made by the Contractor to achieve optimum match between beams. The Contractor may be required to shift or interchange interior beams, or pairs of beams on skewed bridges, to achieve a better fit when directed by the Engineer. As the beams are placed in their final position, and prior to securing transverse ties and drilling and grouting dowels, the beams shall be brought to firm even bearing on the seats through the use of the bearing pads and fabric shims furnished with the beams, and/or grinding of the concrete seats as required.

After deck beams are properly placed and firm even bearing assured, the beams, either in pairs for skewed structures or all beams for right angle structures, shall be secured in lateral position by placing and tightening of the transverse tie assemblies. Dowels at the fixed ends of the deck beams

shall be installed and nonshrink grout placed. In addition, the cast-in-place concrete at the expansion end of the deck beams shall be placed and cured.

In stage construction with deck beams, the first stage shall be constructed as a complete deck including grouting according to Article 504.06(e) and the placement of the wearing surface if one is specified. The transverse ties for the first stage of construction shall not be released during construction of the next stage. Threaded sleeves shall be used to secure the deck beams to the previous stage and at no time shall the transverse tie nuts for the previous stage be loosened or removed.

The next stage of construction shall proceed as specified above, except the keyway along the stage construction line shall be aligned with clamping devices. This keyway shall be the last keyway to be grouted.

The Contractor shall furnish all material for the clamping devices, including sufficient 1/16 in. (2 mm) and 1/8 in. (3 mm) steel shims to adjust for differential elevations between the two deck beams.

The 1 1/4 in. (30 mm) holes for the clamping devices shall be drilled at the locations shown on the plans. Care shall be taken to drill the holes perpendicular to the beams. The clamping devices shall be installed and pulled up tight so that a full, firm bearing is obtained between the clamping plates and the deck beam concrete.

(e) Grouting. After the erection is completed, the longitudinal keyways between beams shall be filled with nonshrink grout. The Contractor shall also place nonshrink grout between the ends of the deck beams at fixed piers and for the transverse tie assembly pockets. During the curing period, no vehicular traffic, including the Contractor's equipment, will be permitted on the beams. Grouting of the keyway at the staged construction line shall be done after the shear key clamping devices are fully secured. The clamping devices shall not be loosened or removed until the nonshrink grout has fully cured. After the clamping devices are removed the drilled holes and unfilled area of adjacent key shall be flushed out with water and then completely filled with grout.

The temperature of the grout at time of placement shall be a minimum of 50 ºF (10 ºC) and a maximum of 90 ºF (32 ºC).

Surfaces to which the grout is applied shall be wetted a minimum of one hour before placement of grout. The surface shall be maintained in a dampened condition during that period. Prior to placement of grout, all excess water shall be removed and all openings between beam edges at the base of the longitudinal keyways shall be caulked or sealed with a suitable compressible material to prevent leakage. Keyways shall be clean and free of all oil, grease, laitance and other foreign substances.

During placement, the grout shall be worked into the area with a trowel blade or a pencil vibrator. The surface shall be troweled to a smooth finish. The nonshrink grout shall be cured with burlap or cotton mats according to

Article 1020.13 for a minimum of three days. Curing shall commence as soon as practicable after finishing.

The nonshrink grout for the longitudinal keyways and between the ends of deck beams at fixed piers will be inspected by the Engineer for cracks. When deck beams are used as the final driving surface, any cracks 0.007 in. (0.2 mm) or wider shall be sealed according to Section 590.

If cracks propagate along the keyway from the ends of beams, it could indicate one or more beams are not firmly seated. Prior to sealing, the Contractor shall check for beam wobble and shim any beams not firmly seated.

504.07 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Precast concrete bridge slabs and precast, prestressed concrete deck beams will be measured by the square foot (square meter) of horizontal surface area of the individual slabs or beams, as shown on the plans. In determining the total number of square feet (square meters) to be paid for, the overall horizontal surface area of all the slabs or beams specified will be used.

Precast, prestressed concrete I-beams, or Bulb T-beams will be measured by the foot (meter). In determining the total length of beams to be paid for, the specified overall length of the individual beams will be used.

Precast concrete pile caps will be measured for payment in place as each precast concrete cap.

504.08 Basis of Payment. This work will be paid for at the contract unit price per square foot (square meter) for PRECAST CONCRETE BRIDGE SLAB and PRECAST, PRESTRESSED CONCRETE DECK BEAMS, of the depth specified, or per foot (meter) for FURNISHING AND ERECTING PRECAST PRESTRESSED CONCRETE I-BEAMS, of the depth specified, or FURNISHING AND ERECTING PRECAST PRESTRESSED CONCRETE BULB T-BEAMS, of the depth specified.

Precast concrete pile caps will be paid for at the contract unit price per each for PRECAST CONCRETE CAPS.

SECTION 505. STEEL STRUCTURES

505.01 Description. This work shall consist of furnishing, erecting, and painting steel structures or portions thereof.

505.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Structural Steel	1006.04
(b) Turned and Ribbed Bolts	1006.07
(c) High-Strength Steel Bolts, Nuts and Washers	1006.08(a)
(d) Anchor Bolts and Rods	1006.09
(e) Steel Forgings	1006.12
(f) Gray Iron Castings	1006.14
(g) Malleable Castings	1006.16
(h) Paint Materials and Mixed Paints	1008.01, 1008.02
(i) Stud Shear Connectors	1006.32

Materials for structures that will carry railroad traffic shall satisfy AREMA Specifications.

505.03 Drawings. Before steel fabrication begins, the Contractor shall submit duplicate prints of shop drawings to the Engineer for review and preliminary approval. These drawings shall be on 11 x 17 in. (275 x 425 mm) sheets. Each sheet shall provide adequate space for review and approval stamps at the lower right corner, and both lettering and details must insure legibility for review and reproduction after microfilming. Each drawing shall be completely titled according to the contract plans, including structure number, state contract number, route, section, and county, and shall pertain to only one structure. If the submitted shop drawings have significant discrepancies, revised sets must be submitted until details comply with the contract requirements. After all review comments have been addressed and preliminary approval is given, the Contractor shall furnish six or more prints of the drawings as directed by the Engineer, and these shall be distributed and become a part of the contract. Changes to previously approved shop drawings shall be subject to the approval of the Engineer, and the Engineer shall be supplied with a record of all such changes.

After the Engineer's preliminary approval and prior to distribution, prints of shop drawings for structures that will carry railroad traffic shall also be submitted for the approval of the Railroad Engineer. Upon request, the Contractor shall also furnish full size reproducibles, 22 x 34 in. (550 x 850 mm), including margins. The margin at the left end shall be 1 1/2 in. (40 mm) and the others 1/2 in. (13 mm) wide. These reproducibles shall become the property of, and shall be delivered to, the Railroad upon completion of the contract.

During the preparation of shop drawings, the Contractor shall check all general dimensions of the steel work and shall report any discrepancies discovered to the Engineer for revision and correction before fabrication is begun. Allowance will be made to the Contractor for additional material fabricated to correct reported contract plan errors.

505.04 Fabrication. Structural steel shall be fabricated and stored according to the following requirements, except for structures carrying railroad traffic. The AREMA Specifications shall govern fabrication of structures carrying railroad traffic, except the requirements of this section shall govern when they are more demanding. Fabrication shall be performed by structural steel fabricators meeting the certification requirements of Article 106.08.

(a) Workmanship and Finish. The workmanship and finish shall satisfy applicable Specification and Code requirements.

(b) Storage of Materials. Structural material, either plain or fabricated, shall be stored above the ground upon platforms, skids, or other supports. It shall be kept free from dirt, grease, or other foreign matter, and shall be protected as far as practicable from corrosion.

(c) Straightening or Curving Material. Straightening shall be done by methods which will not injure the metal. Sharp kinks and bends may be cause for rejection of the material. Heat straightening of AASHTO M 270 Grade 100 and 100W material shall be done only when approved by the Engineer and then only under rigidly controlled procedures.

The Contractor may fabricate curved welded girders by cutting the flanges to the required curvature prior to welding the web. Curved welded girders or rolled beams may be fabricated as a straight unit, and through the application of heat to induce the required curvature. Heat-curving will not be permitted on beams or girders fabricated of AASHTO M 270 Grade HPS 485W (HPS 70W) or 690 & 690W (100 and 100W) steels. Cold bending of beams or girders to the required curvature will be permitted provided the proposed detailed procedures receive the Engineer's approval and the finished member approximates a smooth curve without kinks or twist. When beams or girders are to be heat curved, the Contractor shall satisfy the following requirements.

(1) Type of Heating. Beams or girders may be curved by either continuous or V-type heating. For both types of heating, the flange areas to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is mandatory when the flange thickness is 1 1/4 in. (30 mm) or greater, and the two surfaces shall be heated concurrently. The heating shall progress along the top and bottom flange at approximately the same rate. Heating shall be performed using multiorfice (rosebud) heating torches manipulated to avoid overheating. Torches shall use air-propane or air-natural gas unless other methods are approved by the Engineer for the specific girder configuration.

For the continuous method, strips centered approximately 2 in. (50 mm) inside the edge of the top and bottom flanges shall be heated simultaneously. The strips shall be of sufficient width and temperature to obtain the required curvature.

For the V-type heating, the top and bottom flanges shall be heated in truncated triangular areas spaced at regular intervals along each flange.

The heat patterns applied to the inside flange surface shall terminate just before reaching the juncture of the web and the flange. For curvature radii greater than 1000 ft (300 m), heating patterns on the outside flange surfaces shall have their apex coincide with the plane of the web centerline, and for smaller radii, the outside patterns shall extend past the web centerline a distance of 1/8 of the flange width or 3 in. (75 mm), whichever is less.

Beginning at the truncated end of each heating pattern, heating shall progress toward the base of the pattern, spreading with an included angle of 15 to 30 degrees. The base of the pattern shall not exceed 10 in. (250 mm) regardless of flange width and thickness. The heating torch progresses toward the base of the heating pattern after the truncated end of the truncated pattern reaches the specified temperature. Once heating begins to progress towards the base at the pattern, the heating torch(es) shall not be returned to the apex of the heating triangle. Heat pattern spacing and size shall be as required to obtain the required curvature.

The maximum temperature shall be prescribed below. If chording or twisting occurs in the member that is unsatisfactory to the Engineer, the Contractor shall correct the situation using Engineer-approved methods to obtain acceptable results.

(2) Temperature Control. Heat curving shall be conducted so that the internal temperature of the steel does not exceed 1150 ºF (620 ºC). "Internal steel temperature" shall be represented by the surface temperature approximately five seconds after passage of the torch. Heating shall be confined to the planned patterns or areas, and shall bring the steel within the pattern to the desired temperature as rapidly as possible without overheating. The temperature range shall be documented, based on frequent monitoring with appropriate temperature indicating crayons or other calibrated equipment during the heating and cooling of the member. Any procedure which causes the internal steel temperature to exceed 1150 ºF (620 ºC) will be considered destructive heating and be cause for rejection of the member. Steel rejected for overheating may be investigated for reacceptance or repair by tests acceptable to the Engineer. The costs of such tests shall be borne by the Contractor.

After completing a planned set of heat patterns along the member's length, additional heat shall not be applied until the entire member has cooled below 160 ºF (70 ºC) and the net displacement has been verified. Accelerated cooling with water or water mist will not be permitted. Cooling with dry compressed air will be permitted after the steel has cooled to 600 ºF (315 ºC).

(3) Position for Heating. Members may be heat-curved with the web either vertical or horizontal. When curved in the web-vertical position, the member shall be braced or supported so that the lateral deflection will not cause instability. When curved in the web horizontal position, the member shall be supported near its ends and have limiting blocks at

intermediate points as to obtain the desired curvature. Restraints or preloads may be used to facilitate heat-induced steel movements, but additional external loads shall not be applied to heated steel. Preloads, including the member's self-weight, shall not cause stresses exceeding 50 percent of the material's nominal yield at ambient temperature.

(4) Sequence of Operations. Members shall be heat-curved before they are painted. The heat curving may be conducted either before or after transverse intermediate stiffeners are installed. Unless provisions are made for girder shrinkage, connection and bearing plates shall be located and attached after heat-curving. If longitudinal stiffeners or cover plates are required, they shall be curved separately and then welded to the previously curved girder.

Girders shall be fabricated to specified cambers by cutting web plates to the required geometries before attaching flanges. Heating may be used for small camber corrections if the method and points of application are approved by the Engineer. The prescribed camber shall be obtained before heat-curving and the Contractor shall make allowance for any anticipated losses during fabrication. Rolled shapes shall not be shop cambered, unless otherwise specified. If the contract requires cambering rolled shapes or if straightening as received material is necessary, proposed procedures must be submitted for the Engineer's approval.

Horizontal curvature and vertical camber will not be measured for final acceptance until all heating and welding operations are completed and the flanges have cooled to a uniform temperature. Horizontal curvature will be checked with the beam or girder in upright position. For beams or girders curved after reaming or drilling field splices, at least 20 percent of the girder or beam lines shall be check assembled after curving to verify final geometry. If problems are discovered, additional lines shall be checked until the Engineer is satisfied that the problems have been corrected.

(d) Fastener Holes. All fastener holes shall be either punched or drilled. In all cases hereafter, drilling may be substituted for punching of full-size holes; subdrilling may be substituted for subpunching; and holes may be drilled in assembly ("from the solid") instead of being subpunched or subdrilled and reamed. Drilling in assembly shall be done with the material in the same configuration required for reaming. Holes punched or drilled full-size shall be 1/16 in. (2 mm) larger than the nominal diameter of the fasteners. Subpunched holes for fastener diameters greater than 5/8 in. (16 mm) shall be 3/16 in. (5 mm) smaller than the nominal diameter of the fasteners and for smaller fasteners, the holes shall be subpunched to the fastener's nominal diameter. Subpunched or subdrilled holes shall be reamed to 1/16 in. (2 mm) larger than the nominal diameter of the fasteners.

Holes in carbon steel thicker than 3/4 in. (20 mm) or alloy steel thicker than 5/8 in. (16 mm) shall be drilled or subdrilled and reamed. Punching or subpunching shall not be permitted.

Where reaming is not required, holes in carbon steel up to 3/4 in. (20 mm) thick or in alloy steel up to 5/8 in. (16 mm) thick may be punched to their final specified size.

Holes for field connections of beams, girders, main truss or arch connections, skewed portals, and rigid frames carrying design loads shall be subpunched and reamed with the members assembled in the shop and supported against deadload deflection.

The accuracy of the assembly, including camber, alignment of subpunched holes, and finished-to-bear joints shall be approved by the Engineer before reaming is commenced.

Holes may be punched or drilled to their final specified size for field connections of secondary items including: lateral bracing for girders, truss cords, and arch ribs; hanger supports for laterals and utilities; portal and sway bracing; and cross frames or diaphragms that do not require reamed holes. All holes for end field connections of floor beams shall be subpunched or subdrilled and then reamed to a template, and all corresponding holes in the members to which they connect shall be reamed to the same template, or these connections may be reamed with the members assembled. Stringer connections to floor beams may have holes punched or drilled to their final specified size. Reaming templates shall have hardened steel bushings and reference lines inscribed to locate the template on the members.

Computer-numerically-controlled (CNC) equipment may be used to produce full-sized holes in components otherwise requiring reamed, sub-sized holes, subject to the Engineer's approval and the demonstrated accuracy of the CNC system. Accuracy must be verified by periodic check assemblies of components, and the Contractor's quality control plan for the system must be acceptable to the Engineer. Errors detected by check assemblies will require additional assemblies to define the extent of problems and subsequent CNC work may be restricted or prohibited until system corrections are accepted by the Engineer.

(1) Punched Holes. The diameter of the die shall not exceed the diameter of the punch by more than 1/16 in. (2 mm). Holes shall be cleanly cut, without torn or ragged edges.

(2) Accuracy of Unreamed Holes. All subdrilled or subpunched holes shall be so accurate that after steel is assembled and before reaming, a cylindrical pin 1/8 in. (3 mm) smaller in diameter than the punched hole may be inserted perpendicular to the face of the member, without drifting, through at least 75 percent of the holes in the connection or the pieces will be rejected. Holes punched or drilled to their final specified size without assembly shall be so accurate that fasteners may be installed without reaming or additional drilling.

(3) Reamed or Drilled Holes. Reaming and drilling shall be perpendicular to the faying (contact) surface of the connection. Drilling shall be done with twist drills and reaming with fluted or adjustable reamers. Where

practical, reaming shall be directed by mechanical means, and done after all the components are assembled and firmly secured. Unless otherwise approved by the Engineer, assembled parts shall be taken apart for removal of cutting oil, shavings, and burrs caused by drilling and reaming.

(4) Accuracy of Reamed and Drilled Holes. Where full-size holes are reamed, drilled from the solid, or made by CNC equipment, 85 percent of the holes in any group shall show no offset greater than 1/32 in. (1 mm) between adjacent thickness of metal.

(5) The Contractor shall be responsible for the accuracy of all holes, regardless of tolerance in dimensions of rolled sections or fabricated members. If the required accuracy cannot be obtained otherwise, holes shall be drilled with the members assembled.

(e) Connections. All shop and field connections of structural elements shall be bolted using high-strength steel bolts.

(f) Bolts and Bolted Connections. Bolts and connections shall be as follows.

(1) Turned Bolts. Turned bolts shall have a finishing cut. Holes for turned bolts shall be reamed or drilled 1/32 in. (1 mm) larger in diameter than the bolt. The threads of each turned bolt shall be entirely outside the grip of the metal. A washer 1/4 in. (6 mm) thick shall be used under each nut.

(2) High-Strength Steel Bolts. Bolted parts shall fit solidly together when assembled. Contact surfaces, including those adjacent to bolt heads, nuts, or washers, shall be free of all mill scale, dirt, burrs, and other defects that would prevent solid seating of all parts. Methods of installation and tightening shall be according to the "Specification for Structural Joints Using ASTM A 325 (A 325M) or A 490 (A 490M) Bolts", for slip-critical connections as issued by the Research Council on Structural Connections Joints of the Engineering Foundation, except as follows.

To insure solid seating of all parts of a slip-critical connection, no visible gap shall remain between the faying surfaces when all bolts are tightened to the snug tight condition, producing a bolt tension of approximately 10,000 lb (45 kN). All high-strength bolts shall have a hardened washer under the element (nut or bolt head) turned in tightening, regardless of the method used in tightening.

Inspection will be according to the requirements of the latest issue of the "Specifications for Structural Joints using ASTM A 325 (A 325M) or A 490 (A 490M) Bolts" for slip-critical connections. The Contractor shall provide a calibration device capable of indicating bolt tension. The calibration device shall be capable of testing the shortest bolt length encountered on the structure down to the following minimum lengths.

Bolt Diameter	Minimum Length
5/8 and 3/4 in. (M16 and M20)	2 in. (50 mm)
7/8 in. (M22)	2.25 in. (60 mm)
1 in. (M26)	2.5 in. (65 mm)

The following fastening systems and installation methods will be allowed as options for all high-strength bolted connections: load indicating washer system, twist-off type fastener system, lock-pin and collar type fastener system, and turn-of-the-nut method. The Calibrated Wrench method will not be permitted.

The Contractor shall furnish a calibrated dial inspection torque wrench for use by the Engineer.

In addition to the field Rotation Capacity tests required in Article 505.04(f)(3)g.1., prior to its actual installation, a representative sample of not less than three fasteners of each diameter, length, and grade will be tested at the job site in the calibration device for approval. This field test will be performed according to the Procedure for Installation and Tightening for the particular fastening system as set forth in the Department's Construction Manual. Each powered tool to be used in the actual field installation will be used for at least one of the samples tested. Each worker who is to perform actual field installation will be required to perform and pass at least one of the sample tests, using the same equipment and methods that will be used for the actual field installation. Any worker who undertightens or overtightens the fastener during the test will not be allowed to perform actual field installation unless they perform a successful retest. If any fastener fails to meet the required minimum tension, the lot it was taken from will be rejected.

After all erection pins are removed, the fasteners in all holes of the connection shall be initially brought to a snug tight condition, approximately 10,000 lb (45 kN), progressing systematically from the most rigid part of the connection to the free edges in a manner minimizing relaxation of previously tightened fasteners. When testing for acceptance, the torque corresponding to the snug tight condition may be verified on the calibration device prior to failure.

After all fasteners in the connection are snug tight, they shall be fully tightened progressing systematically from the center most rigid part of the connection to its free edges.

For the twist-off or lock-pin and collar type fastener systems, the fractured end of the fastener, where the splined or pintailed end broke away, shall be cleaned with a wire brush or power tool prior to painting. After cleaning, the exposed end shall be given one coat of an approved high-build aluminum epoxy mastic and then painted with the paint specified for field painting the structure. The minimum dry film thickness of the aluminum epoxy mastic coating shall be 5.0 mils (125 microns).

The fastening systems shall meet the following requirements.

a. Load Indicating Washer System. The direct tension indicator shall be according to ASTM F 959, except the average gap for giving the required minimum bolt tension shall be 0.005 in. (125 micron) for galvanized bolts.

1. Testing. The calibration device shall have an adapter for checking the direct tension indicator when placed under the bolt head. The bolts shall be assembled with the direct tension indicator as they are to be installed in the field, including lubrication. Both the turn required by the impact wrench and the tension in lb (kN) shall be determined at snug tight, 0.015 and 0.005 in. (380 and 125 micron) gaps. This calibration test shall demonstrate that each bolt develops a tension not less than five percent greater than the tension required when the direct tension indicator average gap is 0.005 in. (125 micron). Average gap shall be measured according to Table 4 of ASTM F 959. If the bolt does not develop the minimum required tension at 0.005 in. (125 micron) gap with the direct tension indicator, the lot represented by the direct tension indicator will be rejected.

2. Installation. The galvanized direct tension indicator shall be assembled under the bolt head with the protrusions bearing against the underside of the bolt head and shall not be placed under the element turned for tightening. A galvanized hardened washer shall be provided under the nut. For plain finished bolts the direct tension indicator may be placed under either the bolt head or the nut. A hardened washer shall be used between the direct tension indicator and the turned element with the protrusions bearing against the hardened washer.

The Engineer will check the gap with gap gauges. The Contractor shall supply a sufficient number of 0.001, 0.005 and 0.015 in. (25, 125 and 380 micron) gauges for inspection purposes.

Torque wrenches shall only be used as needed for verification purposes. Overtightening may produce total zero gaps. Total zero gap occurs when a 0.001 in. (25 micron) feeler gauge cannot enter any gap in the direct indicating washer. No more than ten percent of the bolts with total zero gap in any one connection will be allowed. If the number of total zero gap bolts exceeds ten percent of the bolts in the connection, a sufficient number of these bolts shall be removed and replaced to bring the percent within the ten percent allowed. No more than ten percent of the galvanized bolts will be allowed per connection with gaps between 0.005 and 0.015 in. (125 and 380 micron) or over 0.015 in. (380 micron) for plain finish bolts.

If there are more than ten percent of these bolts per connection, additional tightening will be required to reduce the number of excessive gaps to less than ten percent of the total number of bolts. The Engineer will check 100 percent of the gaps of the first two connections with feeler gauges for each bolting crew. Testing at 100 percent will continue if the bolt tightening does not meet the above requirements. Once the above bolting requirements are met, a minimum of 20 percent but not less than ten bolts of each connection, and only one bolt of each cross frame or diaphragm connection will be tested with feeler gauges. The remainder of the bolts will be visually inspected. If ten percent of this sampling is total zero gap or ten percent greater than 0.005 in. (125 micron) gap, the entire connection will be tested.

b. Twist-Off Type Fastener System. This method of joint assembly and tightening of connections shall be achieved by the use of a twist-off type fastener system meeting the requirements of section 2(d) of the "Specifications for Structural Joints using ASTM A 325 (A 325M) or A 490 (A 490M) Bolts". The twist-off bolts shall consist of a threaded bolt with a splined end extension that shears off at a given torque.

c. Lock-Pin and Collar Type Fastener System. This method of joint assembly and tightening of connections shall be achieved by the use of a lock-pin and collar type fastener system meeting the requirements of section 2(d) of the "Specifications for Structural Joints using ASTM A 325 (A 325M) or A 490 (A 490M) Bolts". The lock-pin shall be round headed with a pintail that yields at a given load, and the collars shall be of the flanged type and equipped with tablocks to prevent slipping during installation.

A galvanized hardened washer according to AASHTO M 293 may be used under the bolt head for joint thickness adjustment, provided the installed fastener conforms to the maximum permissible dimensions "A" and "B" from inspection charts provided by the supplier. Loose or relaxed fasteners shall be removed and replaced with new fasteners. Each fastener will be visually inspected according to the inspection charts provided by the supplier.

The "A" dimension from inspection charts provided by the supplier may be increased to 1/8 in. (3 mm) and still meet all published values, provided there is no requirement to meet ASTM specifications pertaining to locking grooves (threads) in the shear plane.

A properly installed high-tensile fastener shall possess the dimensional characteristics from inspection charts provided by the supplier. Should the dimensions "A" or "B" exceed the indicated values, the fastener is being used out-of-grip. A "C" dimension of less than the values specified is an indication of incomplete swage.

A “D” dimension exceeding the tabulated values is an indication of an incorrect or worn anvil on the installation tool. Fasteners falling outside of these ranges shall be removed and replaced.

d. Turn-of-the-Nut Method. This method of joint assembly shall be according to Section 8(d)(1) of the “Specifications for Structural Joints using ASTM A 325 (A 325M) or A 490 (A 490M) Bolts”, except as follows.

1. Installation. After all bolts in a connection are brought to a “snug tight” condition, the outer face of the nut, the turning element shall be match-marked with the protruding portion of the bolt to visually determine the relative rotation occurring between the bolt and the nut during the process of final tightening. If the element to be turned is the bolt head, it shall be match-marked with the plate. The wrench operator shall make marks with a permanent ink type marker or other approved means.

   For connections with individual plates 1 in. (25 mm) and thicker, a minimum of two cycles of systematic snug tightening will be required to minimize relaxation of previously tightened fasteners prior to final tightening.

2. Inspection. Bolts tightened by the Turn-of-the Nut Method may be accepted by the Engineer on the basis of a visual inspection of the match-marks on the bolts.

(3) Rotational Capacity tests for High-Strength Steel Bolts. Rotational Capacity tests are required for the Turn-of-the-Nut Method, Load Indicating washer, and Twist-Off type fastener Systems.

a. Manufacturing. Hardness for bolt diameters 1/2 in. to 1 in. (M16 to M36) inclusive shall be as follows.

Bolt Size (Inclusive)	Hardness Number			
	Brinell		Rockwell C	
	Min.	Max.	Min.	Max.
1/2 to 1 in.	248	311	24	33
	Vickers		Rockwell	
	Min.	Max.	Min.	Max.
M16 to M36	255	336	C23	C34

b. Testing. For galvanized washers, hardness testing shall be performed after galvanizing. The coating shall be removed prior to taking hardness measurements.

Rotational-capacity tests shall be required and will be performed on all black or galvanized (after galvanizing) bolt, nut, and washer

assemblies by the manufacturer or distributor, and the following requirements shall be met prior to shipping.

1. The rotational-capacity test shall be performed according to AASHTO M 164 (M 164M).

2. Each combination of bolt production lot, nut lot, and washer lot shall be tested as an assembly.

3. A rotational-capacity lot number shall be assigned to each combination of lots tested.

4. The minimum frequency of testing shall be two assemblies per rotational-capacity lot.

5. The bolt, nut, and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device.

   Bolts too short to test in a tension calibrating device shall be tested in a steel joint. The tension requirement specified in Article 505.04(f)(3)b.7. need not apply. The maximum torque requirement specified in Article 505.04(f)(3)b.8. shall be computed using a value of P equal to the turn test tension shown in the table in Article 505.04(f)(3)b.7.

6. The minimum rotation, from an initially tightened condition (ten percent of the installation tension), shall be as follows.

Bolt Length	Minimum Rotation
≤ 4 bolt diameters	240° (2/3 turn)
>4 and ≤ 8 bolt diameters	360° (1 turn)
> 8 bolt diameters	480° (1 1/3 turn)

7. The tension reached at the above rotation shall be equal to or greater than 1.15 times the required installation tension. The installation tension and the tension for the turn test for ASTM A 325 (A 325M) bolts shall be as follows.

Diameter (in.)	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
Installation Tension (kips)	12	19	28	39	51	56	71	85	104
Turn Test Tension (kips)	14	22	32	45	59	64	82	98	120

Diameter (mm)	16	20	22	24	27	30	36
Installation Tension (kN)	94	147	182	212	275	337	490
Turn Test Tension (kN)	108	169	209	244	316	388	564

8. After the required installation tension listed above has been exceeded, one reading of tension and torque shall be taken and recorded. The torque value shall conform to the following.

   Torque shall be less than or equal to 0.25 PD.

   Where: Torque = measured torque ft lb (kN m)
   P = measured bolt tension lb (kN)
   D = bolt diameter ft (m)

c. Reporting. Reporting of tests shall be as follows.

   1. The results of all tests specified including zinc coating thickness and the appropriate AASHTO tests shall be documented.

   2. Location where tests are performed and data of tests shall be documented.

d. Witnessing. The tests need not be witnessed by an inspection agency. The manufacturer or distributor that performs the tests shall certify the results recorded as accurate.

e. Documentation. Documentation of tests shall be as follows.

   1. Mill Test Report(s) (MTR).

      (a.) MTR shall be furnished for all mill steel used in the manufacture of bolts, nuts, or washers.

      (b.) MTR shall indicate where the material was melted and manufactured.

   2. Manufacturer Certified Test Report(s) (MCTR).

      (a.) The manufacturer of the bolts, nuts, and washers shall furnish MCTR for the item furnished.

      (b.) Each MCTR shall show the relevant information according to the reporting of the testing required.

      (c.) The manufacturer performing the rotational-capacity test shall include on the MCTR the following information.

         (1.) The lot number of each of the items tested.

         (2.) The rotational-capacity lot number according to Article 505.04(f)(3)b.3.

         (3.) The results of the tests required in Article 505.04(f)(3)b.

(4.) The information required in Article 505.04(f)(3)c.

(5.) A statement that MCTR for the items are according to this specification and the appropriate AASHTO specifications.

(6.) The location where the bolt assembly components were manufactured.

3. Distributor Certified Test Report(s) (DCTR). The DCTR shall include the following.

(a.) Include MCTR above for the various bolt assembly components.

(b.) Include rotational-capacity tests by either the manufacturer or the distributor.

(c.) Show the results of the tests required in Article 505.04(f)(3)b.

(d.) Show the pertinent information required in Article 505.04(f)(3)c.

(e.) Show the rotational-capacity lot number as required in Article 505.04(f)(3)b.3.

(f.) Shall certify that the MCTR are in conformance to this specification and the appropriate AASHTO specifications.

f. Shipping. Shipping shall be as follows.

1. Bolts, nuts, and washers from each rotational-capacity lot shall be shipped in the same container. When there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. Each container shall be permanently marked with the rotational-capacity lot number such that identification will be possible at any stage prior to installation. The rotational-capacity lot number shall be placed on both the container itself and the lid.

2. The appropriate MTR, MCTR, or DCTR shall be supplied to the Engineer.

g. Installation. The following requirements for installation shall apply prior to the installation of high-strength bolts.

1. The rotational-capacity test described in Article 505.04(f)(3)b. above shall be performed on each rotational-capacity lot at each job site prior to the start of bolt installation. If any bolt

fails to meet the required minimum tension, the lot from which it was taken will be rejected.

2. Lubrication.

   (a.) Galvanized nuts shall be checked to verify that a visible lubricant is on the threads.

   (b.) Black bolts shall be “oily” to the touch when delivered and installed.

   (c.) Slightly weathered or lightly rusted bolts or nuts that fail to meet the above requirements shall be cleaned and relubricated prior to testing. Recleaned or relubricated bolt, nut, and washer assemblies shall be retested according to the rotational-capacity test, prior to final installation.

3. Bolt, nut, and washer combinations as installed shall be from the same rotational-capacity lot.

(g) Shop Assembling. Flange splice plates shall be fabricated with the primary rolling direction parallel to the member’s longitudinal centerline. Web splice plates, connecting plates, gusset plates, and stiffeners may have their primary rolling direction in either direction. Parts of a member shall be assembled, well pinned and/or firmly drawn together with bolts before reaming or tightening of fasteners is commenced. The member shall be free from twists, bends, and other deformations that would prevent the solid seating required under Article 505.04(f)(2). A 1/8 in. (3 mm) or greater difference in plate thickness or member depths across a bolted splice shall be rectified with shims included during reaming, match marked, and shipped with member.

Parts not completely fastened in the shop shall be secured insofar as practicable to prevent damage in shipment and handling. Members assembled in the shop for reaming of field connections shall remain assembled until shop inspection by the Department has been made.

Fitting-up and shipping bolts, templates, jigs, shipping or shop assembly braces, and other items provided by the shop for fabrication or shipping but not incorporated in the final structure are considered incidental to the fabrication of the steel and will not be paid for as structural steel.

(h) Drifting of Holes. The drifting done during shop assembly shall bring parts into position, but shall neither enlarge the full-size holes nor induce permanent distortion in any portions of the final structure.

(i) Match Making. All parts of connections reamed or drilled in assembly shall be individually match marked while assembled and a diagram showing such marks shall be included in the shop detail drawings. Individually match marked items shall not be interchanged.

(j) Stamping of Members for Identification. Any metal die stamping of steel members shall be done using low or mini-stress dies. Letters and numbers shall be 3/8 or 1/2 in. (10 or 13 mm) tall. When used, the dies shall be lightly struck to produce an impression that can be clearly seen in the absence of paint and mill scale.

(k) Thermal Cutting. Structural steel or wrought iron may be thermally cut, provided that a smooth, accurate profile, free from cracks and notches, is obtained by the use of a mechanical guide. Hand cutting of material remaining in the final structure shall be done only where approved by the Engineer, and shall be followed by grinding.

Reentrant cuts shall have a radius of not less than 3/4 in. (20 mm) and be finished to an ANSI surface roughness not exceeding 500 µ in. (13 µm).

Surface roughness exceeding the applicable limits of Article 505.04(l)(2) or the BWC and gouges not more than 3/16 in. (5 mm) deep on thermal cut edges (TCEs) shall be removed by machining or grinding and be faired to the surface with a slope of 1 to 10 or less. Material surface defects and gouges due to thermal cutting or handling damage that are more than 3/16 in. (5 mm) deep may be repaired according to the BWC using a procedure approved by the Engineer for the material type and thickness involved. The completed weld shall be ground to match the adjacent surface and nondestructively inspected by magnetic particle or ultrasonic testing, as approved by the Engineer.

(l) Finishing.

(1) Edge Planing. Sheared edges of material more than 5/8 in. (16 mm) thick and carrying calculated stress shall be planed to a depth of 1/4 in. (6 mm). Sheared edges of material up to 5/8 in. (16 mm) thick which carry calculated stress shall be planed to a depth of not less than 1/8 in. (3 mm) unless enclosed by welds. Sheared edges of material not carrying calculated stress and exposed after fabrication shall be ground or planed to remove evidence of tearing and sharp corners.

(2) Facing of Bearing Surfaces. The top and bottom surfaces of steel pedestals, bolsters, column cap and base plates, and masonry (base) plates shall be planed or otherwise finished as necessary to be within 1/16 in. (2 mm) of planar. Cast pedestals shall be planed on surfaces that are to be in contact with steel and shall be finished to a maximum of ANSI roughness not exceeding 2000 µ in. (50 µm) on surfaces in contact with masonry, leveling plates, or pads.

The surface finish of bearing and base plates and other bearing surfaces that come in contact shall meet the following requirements as defined in ANSI B 46.1, Surface Roughness, Waviness and Lay, Part 1.

Steel slabs	ANSI 2000 µ in.	50 µm
Heavy plates in contact in shoes to be welded	ANSI 1000 µ in.	25 µm
Milled or faced ends of compression members, milled or ground ends of stiffeners	ANSI 500 µ in.	13 µm
Bridge rollers and rockers	ANSI 250 µ in.	6 µm
Pin holes	ANSI 125 µ in.	3 µm
Sliding self-lubricating bearings	ANSI 125 µ in.	3 µm

Bronze or copper-alloy bearing plates shall be self-lubricated by special graphited and metallic inserts. The manufacturer's proposed materials and methods for producing the bearing plate shall meet with the approval of the Engineer.

(3) Abutting Joints. Abutting joints in compression members shall be faced and brought into uniform bearing, with no gaps exceeding 1/32 in. (1 mm), before welding or producing full-size holes during shop assembly. Abutting joints in tension members and at beam or girder splices need not be faced but the clearance within field bolted connections shall be from 1/16 to 1/4 in. (2 to 6 mm).

(4) End Connection Angles. End connection angles of floor beams and stringers shall be coplanar and positioned for the length of the member with such accuracy that milling to the exact member length will not reduce their thickness by more than 1/8 in. (3 mm).

(5) Corner Grinding. All outside corners remaining after shop fabrication shall be free of abrupt irregularities and dull to the touch. Fins, burrs, cutting slag, significant deformities, gouges, sharpness (corner more acute than 1/32 in. (1 mm)) radius, and other hazards to handling or impediments to proper coating application and performance shall be corrected by grinding and/or other Engineer-approved methods. When painting is required, it shall be done according to Section 506.

(6) Fit of Stiffeners. For bolted construction, end stiffener angles of girders and stiffener angles intended as supports for concentrated loads shall be milled or ground to secure an even bearing against the flange angles or beam flanges with no gaps exceeding 1/32 in. (1 mm).

For welded construction, bearing stiffeners shall be milled or ground to bear at the bearing ends and a tight fit provided at the other ends.

(m) Links. Links for pin and link hanger assemblies or bearings experiencing uplift shall be fabricated from rolled plate. The primary plate rolling direction shall be along the length (vertical axis) of the link. The material shall have a minimum Charpy V-Notch toughness of 35 ft lb at 20 ºF (48 J at –7 ºC) and a minimum elongation of 22 percent in 2 in. (50 mm). Nominal yield strength

of the link material shall not exceed 70 ksi (480,000 kPa). The links shall be straight and parallel. Holes in links and webs for pins or bushings shall have a maximum roughness equivalent to 125 µ in. (3 µm) finish.

(n) Rollers and Pins. Rollers and pins shall be straight and turned to the dimensions shown on the drawings. The final surface shall be produced by a finishing cut, except expansion rollers made from cold finished steel bars having a smooth, true surface, need not be turned. Pins for pin and link assemblies or bearings with uplift shall have a ground finish equivalent to a 32 µ in. (0.8 µm) maximum roughness and shall be 100 percent inspected by magnetic particle or dye penetrant testing after grinding. Any cracks or other flaws detected shall be reported to the Engineer and will be cause for rejection. After testing, unpainted carbon steel pins shall be coated for corrosion protection according to Article 506.04(h). Rollers shall be shop primed after testing.

(o) Boring Pin Holes. Pin holes shall be bored at right angles with the axis of the member and parallel to each other, unless otherwise required. The actual distance from center to center of pins at link connections shall not vary from that specified by more than 1/8 in. (3 mm). The boring shall be done after the member is fabricated. If metallic pin bushings are required, they shall be shrunk fit and their internal diameters shall be ground to 32 µ in. (0.8 µm) maximum roughness.

(p) Pin Clearances. For steel-on-steel contact, the fit between a hole and a pin shall be according to ANSI Standard B4, Class RC8, loose running fit. For pins bearing on metallic shrink fit bushings, the fit shall be ANSI Standard B4, Class RC7. For pins bearing on Teflon Impregnated fiber reinforced bushings, the bushing manufacturer's recommended tolerances for fit shall be followed for the hole and pin diameters. Tolerances for all pin diameters and pin holes shall satisfy the following.

Nominal Diameter	Range of Clearance	Tolerance from Nominal Sizes	
		Hole	Pin
in.	in. x 10^{-6}	µ in.	µ in.
1.97-3.15	6.0-13.5	$\frac{+4.5}{0}$	$\frac{-6.0}{-9.0}$
3.15-4.73	7.0-15.5	$\frac{+5.0}{0}$	$\frac{-7.0}{-10.5}$
4.73-7.09	8.0-18.0	$\frac{+6.0}{0}$	$\frac{-8.0}{-12.0}$
7.09-9.85	10.0-21.5	$\frac{+7.0}{0}$	$\frac{-10.0}{-14.5}$
9.85-12.41	12.0-25.0	$\frac{+8.0}{0}$	$\frac{-12.0}{-17.0}$
12.41-15.75	14.0-29.0	$\frac{+9.0}{0}$	$\frac{-14.0}{-20.0}$

Nominal Diameter	Range of Clearance	Tolerance from Nominal Sizes	
		Hole	Pin
(mm)	(μm)	μm	μm
50-80	152-343	+114 0	-152 -229
80-120	178-394	+127 0	-178 -267
120-180	203-457	+152 0	-203 -305
180-250	254-546	+178 0	-254 -368
250-315	305-635	+203 0	-305 -432
315-400	356-737	+229 0	-356 -508

(q) Welding. Welding shall be done according to the requirements of the ANSI/AASHTO/AWS D-1.5, except steel tubular structures shall be covered by the AWS D1.1 Structural Welding Code. Steel shall only be shop welded to remedy minor defects or according to details shown on shop drawings approved by the Engineer. Proposed details and procedures for field welding of structural steel shall be approved by the Engineer before welding begins.

Shop and field welding shall be performed using Welding Procedure Specifications approved by the Engineer with shielded metal arc welding (SMAW), submerged arc welding (SAW), gas metal arc welding (GMAW), or flux cored arc welding (FCAW) consumables permitted by the BWC. Other processes or consumables shall be specifically authorized by the Engineer on a project by project basis. Welders shall be qualified according to the BWC or Structural Welding Code.

(1) Modifications by Code. The following modifications to the specified sections of BWC shall apply.

a. In sections 4 and 5 of the BWC, including tables 4.1, 4.2, 4.3, and 4.4, the base metals shown in each row of the following list shall be considered equivalent for the purposes of fabrication and weld procedure qualifications.

English

Row	ASTM Specification		AASHTO Specification	
	Previous	Current	Previous	Current
1	A 36	A 709 Gr. 36	M 183	M 270 Gr. 36
2	A 572 Gr. 50	A 709 Gr. 50	M 223 Gr. 50	M 270 Gr. 50
3	A588	A 709 Gr. 50W	M 233	M270 Gr. 50W

Row	ASTM Specification		AASHTO Specification	
	Previous	Current	Previous	Current
4	Note 1	A 709 Gr. HPS 70W	Note 1	M 270 Gr. HPS 70W
5	A 514	A 709 Gr. 100W	Note 1	M 270 Gr. 100
6	A 517	A 709 Gr. 100	M 244	M 270 Gr. 100

Note 1. Previous specification deleted.

(Metric)

Row	ASTM Specification		AASHTO Specification	
	Previous	Current	Previous	Current
1	A 36M	A 709M Gr. 250	M 183M	M 270M Gr. 250
2	A 572M Gr. 345	A 709M Gr. 345	M 223M Gr. 345	M 270M Gr. 345W
3	A 588M	A 709M Gr. 345W	M 222M	M 270M Gr. 345W
4	Note 1	A 709M Gr. HPS 485W	Note 1	M 270M Gr. HPS 485W
5	A 514M	A 709M Gr. 690W	Note 1	M 270M Gr. 690W
6	A 517M	A 709M Gr. 690W	M 244M	M 270 M Gr. 690

Note 1. Previous specification deleted.

Charpy-V-notch (CVN) Testing: All CVN testing shall be for Zone 2.

b. In Section 5 of the BWC, 5.2 requires the Contractor to perform Qualification or Verification testing. The Department will consider each fabrication organization as a separate Contractor for this requirement of the BWC. For fabricators operating in multiple locations, either with a group of buildings or at geographically separates facilities, weld procedures for the same type of equipment, used under similar operating conditions may be based on a common set of Procedure Qualification Reports (PQRs). If routine nondestructive testing reveals significant disparities in production quality that may be attributed to equipment variation then separate qualification tests shall be done at each location or machine involved. Non-FCM PQRs based on qualification tests, pretests, and/or verification tests shall remain valid as long as no significant changes occur in electrode/flux components or properties, subject to evidence of the shop's successful use of the process on equal or greater strength material at least every six months. If more than six months elapse without documented successful use of the process, the Engineer may require requalification of the PQR used to prepare the Weld Procedure

Specification (WPS) proposed. Evidence of satisfactory use shall include Fracture Critical procedure tests, nondestructive examination of production welds, or welder/weld operator qualification tests. The Engineer will accept evidence of prior testing provided the PQR is complete and shows compliance with these specifications, and both the witnesses and the facility performing testing are satisfactory.

c. Ancillary products described by subparagraph 1.3.6 of the BWC shall include: cross frames and diaphragms for non-curved structures and not designed to convey liveload stresses, expansion seal joints, pedestals and bolsters, retainer angles, walkway grating, and other items specifically identified by the Engineer.

(2) Electrodes and Flux. Welding electrodes and flux for submerged arc welding shall bear the manufacturer's marking showing the material to be of the proper class. The equipment and consumables to be used shall be submitted to the Engineer for approval, together with evidence of the manufacturer's PQR and the Contractor's verification test(s) or the Contractor's PQR, except as exempted.

For flux cored electrodes, only E7XT-6 or E7XT-8 may be used in areas susceptible to drafts or wind exceeding 5 mph (8 km/hr). Other flux cored, metal cored, or solid electrodes utilizing gas shielding and satisfying the BWC may be used in enclosed, protected environments with air movement of less than 5 mph (8 km/hr). Welds made with E7XT-6 or E7XT-8 shall not be covered by or incorporated into welds made with other electrodes.

Electrodes and flux used for welding tubular steel structures and which satisfy prequalification requirements in the AWS D1.1 shall not require qualification testing.

When PQR, Pretests, and/or Verification Tests are not required, variables affecting heat input shall be within ranges specified by consumable manufacturers, and supported by manufacturers' compliance reports, not more than 12 months old, which shall be in a file maintained by the Contractor and furnished to the Engineer or Inspector upon request. Any parameters (including gas flow, current limits, E.S.O., and polarity) not within the manufacturer's guidelines shall require qualification testing for the WPS. The Quality Assurance (QA) Inspector representing the Department and Contractor's Quality Control (QC) Inspector shall ensure the Procedure Qualification Test weld parameter variables are being accurately monitored and recorded for each pass, and that specimen identity is constantly maintained. Similarly, the QA Inspector and QC Inspector shall assure the critical weld parameters (preheat, travel speed, wire feed speed, current, etc.), consumable condition, and weld quality are adequately monitored throughout production.

When repetitive welding deficiencies persist even after adjustments are made, the QA Inspector shall have authority to prohibit use of the WPS,

consumables involved, welding equipment and/or welding personnel, as applicable, for Department projects, until abnormalities are corrected to the QA Inspector's satisfaction. Such deficiencies may include: lack of fusion or penetration, overlap, large or frequent slag inclusions, poor deslagging and interpass cleaning, ropiness, convexity or concavity of bead, gross porosity, and non-uniform weld size. If more serious deficiencies are noted, such as weld or underbead cracking, extensive lack of fusion, wet flux, contaminated weld zone, or not conforming to an approved WPS, the QA Inspector may require either removal of questionable welds or additional NDT. If deficiencies are attributable to the WPS or a specific electrode-flux combination, the Engineer will have authority to require the Contractor to either repeat Qualification Testing or to use another approved WPS.

(3) Procedures. Complete Weld Procedure Specifications (WPSs) shall be submitted to the Engineer with fully documented and accepted PQRs (if applicable) for approval. The WPS submitted may be either generic for common situations on multiple projects or be tailored to suit the particular fabrication project.

The WPS shall include the following items: general instructions for fit-up, techniques and welding sequences; types of steel; joint description and preparations; welding position; polarity; amperage, voltage, and linear welding speed; electrode size and type; flux designation and consumable manufacturer's trade name(s); approximate number of passes, maximum width and thickness of weld layers, and any procedure change between passes in the same weld; preheat-interpass temperatures, maximum and minimum; post heat temperature and duration; and other data necessary to fully describe the welding procedure. A copy of the WPS shall be available at the welding operation.

(4) Welder Qualification. All welders, welding operators, and tackers shall be qualified by test according to the applicable welding code. Testing shall be administered and certified by a Certified Welding Inspector (CWI) or equivalent acceptable to the Engineer. The Engineer may accept evidence of previous qualification for welders under the applicable welding specifications.

(5) Fabrication. Shop welded butt splices, not detailed on Contract plans but required by limiting lengths of material, may be used if they are detailed for the full strength of the member and are placed at locations approved by the Engineer. Complete joint penetration welds shall not have more than three repair welds made at a common location. Complete removal of the weld and adjacent base metal shall be required after the third repair.

Flange-to-web welds and shop welded splices in flanges or webs shall use the automatic submerged arc welding process. All fillet welding of stiffeners and connection plates to webs shall utilize automatic submerged arc welding, unless otherwise approved by the Engineer for specific situations.

If the applicable code permits welding on areas with tight mill scale present, WPSs utilizing consumables with sufficient deoxidizing capacity shall be employed to avoid porosity or lack of fusion. Tack welds shall start a minimum of 3 in. (75 mm) from the end and shall be a minimum of 1 1/2 in. (40 mm).

Ends of fillet welds shall have full throat and no unfilled craters. Fillet welds on stiffeners, connecting plates, gussets, and other assemblies (except for flange-to-web welds) shall terminate approximately 1/4 in. (6 mm) from the end of plate intersects to avoid undercut and other defects.

Special precautions shall be taken when welding during cold weather to avoid extreme thermal gradients and to avoid adversely effecting the manual functions of the welder or welding operator. In certain cases, the BWC minimum preheat and interpass temperatures may be insufficient for steels with nominal yield strengths exceeding 50 ksi (345,000 kPa) and thickness above 3/4 in. (20 mm). Preheat for these steels shall be calculated if the nominal welding electrode strength exceeds 80 ksi (550,000 kPa) and the plate sulfur content exceeds 0.01 percent, or if either plate's carbon equivalent exceed 0.4 percent.

Tolerances for welded components shall be according to the applicable welding code, except the maximum deviation from specified camber for a span (abutment to-pier or pier-to-pier) or girder segment (abutment-to-splice or splice-to splice) shall be ±3/4 in. (±20 mm).

Shop butt welds in flanges and webs shall be completed, tested, and accepted before the flanges are assembled on the web. Where possible, extension blocks (run on/run-off tabs) matching the joint's cross section are to be used for all complete penetration welds and flange-to-web welds, unless additional material is provided to ensure full size welds the full length of the member.

(6) Inspection. The inspection of welds and workmanship will be performed according to the BWC, except as modified.

Prior to the start of fabrication of their first project for the Department, within the previous 24 months, the Contractor's QC and production supervisors and the Engineer shall have a conference to ensure agreement regarding the details of the project, standard shop procedures, advance notifications to the Inspector, specific items for QC/QA acceptance, material documentation, cleaning and painting requirements, the sequence of fabrication to be followed, the status of qualifications for welders and welding operators, and approval of electrodes, wire, flux, other welding materials, and equipment.

The welding and testing of all Procedure Qualification Test specimens shall be witnessed by personnel from two separate agencies, independent of the fabricator and acceptable to the Engineer. These may include the Inspector, Inspectors from other state DOTs, and/or

qualified individuals from independent testing agencies which meet the approval of the Engineer.

Butt welds shall be radiographically (RT) or ultrasonically (UT) inspected according to the BWC, except: top and bottom 1/3 of each vertical web joint shall receive RT, and the remainder of that joint shall receive RT if unacceptable discontinuities are found in those areas; 50 percent of longitudinal web joints shall receive RT; and, except for webs, joints shall be considered "subject to tension or reversal of stress" if either plate joined requires Charpy V-notch (CVN) testing. In addition, butt welds in which the thickness of the thinner plate equals or exceeds 3 in. (75 mm) shall also receive UT. All joints to be inspected shall be free of paint, scale oil, and grease.

All radiographs shall be taken and interpreted by qualified technicians acceptable to the Engineer. The original film and a complete report describing the procedure and the technicians interpretation, properly identified as to piece and location of the weld, shall be submitted to the QA Inspector for approval prior to acceptance of the weld. If the original film is found to be unacceptable by review by the QA Inspector, another radiograph of the joint shall be taken. In the event the Contractor questions the QA Inspector's interpretation of the radiographic films, a joint review of the film will be made. The Engineer's final interpretation will govern.

When areas to be radiographed are too large for one film, overlapping exposures shall be made to cover the area. The limits for one film shall be 15 in. (375 mm) for web shots and 16 in. (400 mm) for flange shots 1 1/4 in. (30 mm) and thicker the limits shall be 15 in. (375 mm).

If radiographic inspections disclose rejectable defects, they shall be repaired and additional radiographs shall be taken for each repaired weld and submitted to the QA Inspector for approval.

The Contractor shall furnish the Engineer a shop drawing with the weld identification and showing assembly of the steel into final members or pieces. Lettering on radiographs of repairs shall show an "R" and the number of the repair shot. This additional identification shall be placed next to the film number and be included on the weld identification shop drawing.

Location marks shall be stamped in the steel by the Contractor prior to radiographing, using a prick punch with a dull tip. These will be located by lead arrows, but only the "floating" mark must be visible on the film. The location marks shall consist of center punch marks 1 1/2 in. (40 mm) from the centerline of the weld for plates up to 3 in. (75 mm) thick or 2 in. (50 mm) from the centerline on thicker plates, and 2 1/4 in. (60 mm) in from each edge of the plate. In addition, there shall be one randomly placed, "floating" punch mark within each exposure at the same distance from the centerline. The punch marks shall be placed in the thinner plate. In a series of overlapping exposures, the location marks shall be placed at approximately every 15 in. (375 mm).

Complete penetration tee and corner joints of primary members shall be ultrasonically inspected. Complete penetration tee and corner joints in compression or shear shall have at least 1 ft (300 mm) of every 4 ft (1.2 m) and 1 ft (300 mm) of each joint less than 4 ft (1.2 m) ultrasonically inspected. This shall include flange-to-web welds in bending members and welds joining material that does not require Charpy V-notch (CVN) testing. If unacceptable defects are found in any test length, the full length of the weld or 3 ft (900 mm) either side of the test length, whichever is less, shall be ultrasonically inspected. If unacceptable defects are found in more than 20 percent of the 1 ft (300 mm) increment lengths tested, the full length of the joint shall be ultrasonically inspected. Complete penetration tee and corner joints subject to tension or stress reversal shall be ultrasonically inspected the full length of the joint. This shall include welds joining plates requiring CVN testing other than web-to-flange joints in bending members. Welds within 1 ft (300 mm) of repairs shall be retested after the repairs are made.

Partial magnetic particle inspection will be required of each fillet weld on nonfracture critical girders, floor beams, stringers and truss members, fabricated items subjected to tensile stress or reversal of stress, including fingerplate stools, and for root and final passes of partial penetration groove welds in primary members, unless specifically exempted by the Engineer. At least 1 ft (300 mm) of every 10 ft (3 m) of weld length or 1 ft (300 mm) of each weld less than 10 ft (3 m) in length, plus welds within 1 ft (300 mm) of all starts and stops shall be tested, except bearing assembly to flange and diaphragm seat angle to web welds shall only be tested when visual inspection indicates possible flaws. The test shall be located at random in the members so as to be typical of the welding. Random locations are subject to selection by the Engineer. If unacceptable defects are found in any test length of a fillet weld, the full length of the weld, or 5 ft (1.5 m) on either side of the test length, which ever is lesser, shall be magnetic particle tested.

For Fracture Critical Members (FCM), fillet welds on flanges and webs that may be in tension areas shall receive 100 percent magnetic particle inspection.

The magnetic inspection procedure and techniques shall be according to ASTM E 709. The QA Inspector will examine the magnetic test reports and give approval before the members will be accepted. Welds within 1 ft (300 mm) of repairs shall be retested after the repairs are made.

Welded or cast steel bearing assemblies weighing more than 350 lb (160 kg) each shall be nondestructively examined by visual, magnetic particle and/or ultrasonic methods, as directed by the Engineer to insure no critical flaws exist.

Surface porosity in all welds shall not exceed 3/16 in. in 1 in. (5 mm in 25 mm) of weld nor 3/8 in. in 1 ft (10 mm in 300 mm) of weld. Cluster

porosity size shall be determined by describing a circle around the cluster of holes. If the circle diameter is 3/16 in. (5 mm) or greater, the porosity must be ground out and rewelded. For linear porosity, a line connecting three or more adjacent pores shall be drawn. Adjacent pores are defined as pores separated by less than 1/4 in. (5 mm). If the line drawn exceeds 3/8 in. in 1 ft (10 mm in 300 mm), the porosity shall be ground out and rewelded. The maximum diameter for a single pore shall not exceed 3/32 in. (2 mm). The maximum frequency shall not exceed 1 porosity episode in 4 in. (100 mm) nor 5 (6) episodes for every 4 ft (1.2 m) of weld. The above criteria shall also apply to all subsurface welds which are critical or heavily stressed welds that are subjected to various nondestructive tests.

The Contractor shall give the Engineer sufficient advance notice of the date on which the material will receive radiographic, ultrasonic, or magnetic particle inspection so that the Engineer may be present.

(r) Bent Material. Material that must be bent, shall be produced by techniques approved by the Engineer.

(s) Fillers. Fills less than 1/4 in. (6 mm) thick may employ sheet steel material such as ASTM A 570 or A 606 satisfying the physical and weathering or coating requirements of the material joined. Fills shall not be tack welded.

(t) Screw Threads. Threads for all bolts and pins for structural steel construction shall be according to the Unified Standard Series UNC-ANSI B 1.1, Class 2A for external threads and Class 2B for internal threads, except pins ends having a diameter of 1 3/8 in. (35 mm) or more shall have a thread pitch of 6 threads to the 1 in. (4.2 mm).

(u) Anchor Bolts. Anchor bolts shall be according to Article 521.06.

505.05 Inspection. All material and workmanship will be subject to QA inspection by the Engineer. The cost of inspection, both at mill and shop, will be borne by the Department, except whenever any inspection is conducted outside the Continental United States, the Contractor shall bear the actual costs of travel and subsistence for the Department's QA inspection.

(a) Shop Inspection. The Contractor shall give the Engineer at least a one week notice prior to the beginning of work for shops within Illinois, and at least two weeks notice for work outside state boundaries. The Contractor shall arrange members or units to be inspected so that identification marks are visible and each member or unit is accessible for measurements the QA Inspector may deem necessary. Upon the QA Inspector's request, the Contractor shall reposition the steel to permit full examination. Prior to shop inspection of an item, the Contractor shall furnish the QA Inspector with a list of its main stress carrying material, correlating the piece mark and heat numbers. The heat number, established by the rolling mill, shall be preserved on material through fabrication until the element is joined into a member with a permanent piece mark.

(b) Shop Assembly. All trusses and arches shall be completely, geometrically, or sequentially assembled at the fabricating plant, subject to the Engineer's approval of the fabricator's proposed system. Continuous beams or girders and connections requiring reamed field connection holes shall be assembled, unless otherwise noted or approved by the Engineer before reaming is commenced. For girder or beam lines with more than three elements, at least three pieces shall be included in each assembly. Unless approved by the Engineer, assemblies made for reaming or drilling holes shall not be disassembled until after shop QA inspection has been made. Shop assembly of curved girders shall meet the additional requirements of Article 505.04(c)(4).

(c) Waiving Shop Inspection. The Engineer may partially or completely waive shop QA inspection and complete the inspection of fabricated material when it is delivered at the job site. The Contractor shall remain responsible for the fabricated items until job site acceptance is given.

505.06 Cleaning and Shop Painting. Fabricated steel shall be cleaned and shop painted according to Articles 506.03 and 506.04.

505.07 Marking and Shipping. Each member shall receive an erection mark for identification, and an erection diagram showing member locations shall be included in the shop drawings. If paint is used to locate (circle) metal stamped marks or to enhance their legibility (copy) on unpainted structures, the marks shall be placed in areas not highly visible after construction. Paint marks on outside faces of unpainted fascia members or on the underside of their bottom flanges shall be removed prior to shipping.

Pins, small parts, and small packages of bolts, washers, and nuts may be combined for shipment in boxes, crates, kegs, or barrels, but they shall be protected from damage and the gross weight of any container shall not exceed 300 lb (135 kg). A list and description of the contents shall be attached to the outside of each container. The loading, transportation, unloading, and storing of structural material shall be conducted so that the items will be kept clean and not be excessively stressed, deformed or otherwise damaged. For handling long steel members or large assemblies, lifting points, temporary supports and sequences, based on the Contractor's calculations, shall insure member stresses do not exceed 80 percent of the material's minimum yield strength. These calculations shall be submitted to the Engineer for review. In storing and shipping members, blocking, bracing, and shoring shall be sized and placed as necessary to prevent excessive deflection or motion. Fabricated beams and girders shall be handled, stored, and shipped in an upright and final erection position unless otherwise approved by the Engineer.

Steel lifting lugs on members will not be permitted if their installation and removal could possibly be detrimental to the structure. The following requirements shall also be met.

(a) One Contract for Fabrication and Erection. When fabrication and erection are accomplished under one contract and lifting lugs are used, the lugs shall be placed during fabrication. When no longer required, the lugs shall be removed.

The location, attachment, and removal method for the lugs shall be detailed on the shop drawings approved by the Engineer.

(b) Separate Contracts for Fabrication and Erection. When fabrication and erection are accomplished under separate contracts and lifting lugs are desired by the erector but not shown on the contract plans, the erection Contractor shall be responsible for submittal of shop drawings to the Engineer for approval and for having the lugs furnished, installed and removed. When lifting lugs are detailed on the contract plans, the fabrication Contractor shall be responsible for furnishing and installing the lugs and the erection Contractor shall remove them when no longer required. The location, attachment, and removal method for the lugs shall be detailed on the shop drawings and approved by the Engineer.

505.08 Erection. The Contractor shall erect the structural steel, remove the temporary construction associated with the steel erection and do all work required to complete the structure as covered by the contract. The following requirements shall govern.

(a) Concrete Work. If the substructure and superstructure are built under separate contracts, the Department will provide the substructure is within allowable tolerances for lines and elevations, and properly finished, and will establish the locations and elevations required for setting the steel.

(b) Plant. The Contractor shall provide the falsework and all tools, machinery and appliances, including pilot and driving nuts, cylindrical erection pins, and fitting-up bolts, necessary for the expeditious handling of the work. These items will be considered as equipment and shall remain the property of the Contractor.

(c) Handling and Storing. The loading, transporting, unloading, storing, and handling of structural steel shall be according to Article 505.07 and shall be conducted so that the members will be kept clean and free from injury. When unloaded, the materials shall be placed on skids and braced to prevent excessive deflection, to keep the member off the ground and to provide adequate stability.

If the contract covering the erection of the steel does not include the fabrication, the erection Contractor shall check the material received and report promptly, in writing to the Engineer, any shortage or injury discovered. The erection Contractor shall be responsible for the loss of any material furnished by the Department or another Contractor after delivery and acceptance at the job-site, or for any damage to such material during job-site storage or erection.

(d) Falsework. The falsework shall be properly designed, constructed, and maintained for the required loads and site conditions. The Contractor shall prepare and submit falsework plans for the Engineer's review unless waived by the Engineer.

(e) Methods and Equipment. Before starting work, the Contractor shall submit an erection plan to the Engineer for approval detailing the proposed

methods of erection and the amount, location(s), and type(s) of equipment to be used.

(f) Fixed Bearings. Fixed bearings on concrete shall be set level and not be placed upon areas that are improperly finished, damaged, or irregular.

Leveling plates, pads, and/or adjustment shims shall be placed beneath the bottom bearing plates or castings.

Anchor bolts shall be installed according to Article 521.06.

(g) Straightening Bent Material. The straightening of plates, angles, and other shapes and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fracture or additional injury. Distorted members shall be straightened by mechanical means or, if approved by the Engineer, by the careful planned and supervised application of a limited amount of localized heat, under rigidly controlled procedures. Procedures using heat, with or without external restraints (jacks, come-alongs), shall be detailed to include heat patterns and locations, maximum temperatures, monitoring methods, restraint locations, and calculations of restraint forces.

Before beginning any work, these shall be submitted and received for the approval of the Engineer. For AASHTO M 270 (M 270M) Grades 70W, 100, or 100W (485W, 690 or 690W) steels, the temperature shall not exceed 1050 ºF (565 ºC), and for other steels, the temperature of the heated area shall not exceed 1150 ºF (620 ºC) as verified by temperature indicating crayons, infrared or bimetal thermometers. Parts to be heat straightened shall be substantially free of stress from external forces, except the preplanned restraints in the Engineer-approved proposal. Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected, and any evidence of fracture shall be immediately reported to the Engineer.

(h) Assembling Steel. Match marks shall be followed and beams or girders supported to provide the top of beam/web elevations shown on contract plans (without steel dead load deflection) until field splices are pinned and partially bolted.

Bearing surfaces and surfaces to be in permanent contact shall be cleaned of foreign material before the members are assembled. Detailed truss spans erection procedures shall be submitted for the Engineer's approval. These shall include blocking and falsework plans, assembly sequence and bolting methods for chords, floor beams, stringers and bracing installation.

Bolted field splices in continuous beams or girders shall not be torqued until the entire continuous length is in place on the substructure. During erection, splices and field connections shall have 1/4 of the holes filled with finger-tight bolts and 1/4 with cylindrical erection pins. Bolt tightening shall not commence until all erection pins at a splice have been removed and all holes are filled with finger-tight bolts. Bolt tightening shall be according to Article 505.04(f). Temporary fitting-up bolts shall be the same diameter as

the specified bolts, and cylindrical erection pins shall be 1/32 in. (1 mm) smaller than the hole.

(i) Field Bolting. High-strength bolts shall be tested and installed according to Article 505.04(f). Drifting shall draw the parts into position but not enlarge the holes or distort the metal.

(j) Other Bolted Connections. In connections, where bolts or turned bolts are used, the bolts shall be brought to snug tight and loosening shall be prevented by either burring the threads at the face of the nut with a pointed tool or other mechanical means, including lockwashers and self locking nuts.

(k) Pin Connections. Pilot and driving nuts shall be used if required for driving pins. Pins shall be installed so that the members will take full bearing on them. Pin nuts shall be tightened sufficiently to limit lateral separation of material to 1/8 in. (3 mm) or that detailed by the contract plans, but not enough to clamp material and restrict rotation. Pins shall be double nutted with jam nuts or have other provisions to prevent loosening of single nuts under normal service conditions, subject to approval by the Engineer.

(l) Misfits. The correction of misfits involving minor field corrections will be considered a part of the erection. Minor field corrections include grinding corners, burrs, or other small areas, removing less than 1/8 mm (3 mm) of material, or reaming of less than five percent of holes. Plates shall either be held tightly together during reaming or disassembled for cleaning. Any error in the shop fabrication or permanent deformation resulting from handling and transportation, which prevents the proper assembling and fitting up of parts by the use of cylindrical erection pins, or by minor field corrections, shall be reported immediately to the Engineer. Any proposed method of correction must be approved by the Engineer, and the correction shall be made in the Engineer's presence. If the contract provides for complete fabrication and erection, the Contractor shall be responsible for all misfits, errors, and juries, and shall make the necessary corrections and replacements. If the contract provides for complete fabrication of the steel, the Contractor performing the fabrication shall be responsible for all errors in fabrication. The Engineer will determine: what corrections are considered to be of a minor nature and are included as part of the erection work; what damage or loss is the responsibility of the erection Contractor; and which problems are to be considered errors is fabrication, to be remedied at the expense of the Contractor responsible for the fabrication. Damage occurring during transportation shall be corrected at the expense of the responsible Contractor.

(m) Stud Shear Connectors. Stud shear connectors shall be furnished as a single unit and of a design suitable for end-welding to steel with automatically timed stud welding equipment. Stud shear connectors that are to be welded to the top flanges of beams or girders shall be placed after the steel has been erected and suitable scaffolding or the deck forming has been provided so the hazard due to stud projections is at a minimum. Studs that are to be welded to expansion guards, bearing plates, or other locations not posing a hazard, may be placed in the shop.

If flux-retaining caps are used, the steel for the caps shall be of a low carbon grade suitable for welding and shall comply with ASTM A 109 (A 109M). Finished studs shall be of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other injurious defects.

Finish shall be as produced by cold drawing, cold rolling, or machining. The manufacturer shall certify that the studs satisfy the requirements of this Section. Certified copies of in-plant quality control test reports shall be furnished to the Engineer upon request. An arc shield (ferrule) of heat-resistant ceramic or other suitable material shall be furnished with each stud. The material shall not be detrimental to the welds or cause excessive slag and shall have sufficient strength so as not to crumble or break due to thermal structural shock before the weld is completed. Flux for welding shall be furnished with each stud, either attached to the end of the stud or combined with the arc shield for automatic application in the welding operation.

(1) Power Source. Stud shear connections shall be end welded with automatically timed stud welding equipment connected to a suitable power source. If two or more stud welding guns are to be operated from the same power source, they shall be interlocked so that only one gun can operate at a time and so that the power source has fully recovered from making one weld before another weld is started.

Studs may be welded using two or more welding generators in parallel or by use of a battery operated source to supply the necessary amperage.

(2) Preparation and Welding. At the time of welding, the studs shall be free of any rust, rust pits, scale oil, or deleterious matter. The surface to receive the stud shall be free from mill scale and heavy rust. Paint, galvanizing and oil are contaminants and shall be removed.

Welding shall not be done when the base metal temperature is below 0 ºF (-17 ºC), or when the surface is wet. If it becomes necessary to weld the studs when the temperature of the base metal is below 0 ºF (–17 ºC), base metal shall be preheated and maintained above 32 ºF (0 ºC) during the welding operation.

While in operation, the welding gun shall be held in position without movement until the weld has solidified.

Longitudinal and lateral spacings of studs with respect to each other and to edges of beam or girder flanges shall not vary more than 1/2 in. (13 mm) from the dimensions shown on the plans, except that a variation of 1 in. (25 mm) will be permitted where required to avoid obstruction with other attachments on the beam. The minimum distance from the edge of a stud shank to the edge of a beam or plate shall be 1 in. (25 mm).

(3) Inspection and Field Bend Tests. The first two studs welded on each beam or girder, after being allowed to cool, shall be bent 45 degrees by

striking the stud with a hammer. If failure occurs in the weld of either stud, the procedure shall be corrected and 2 successive studs shall be successfully welded and tested before any more studs are welded to the beam or girder. This bend check shall also be made at the start of each day of the work, when the welding has been interrupted for an hour or more, when changing grounds, when changing weld settings or when changing cable loop due to arc blow (arc not going vertically from center stud to flange). In any case, no more than 500 studs shall be welded to a beam or girder without the welds being field bend tested according to the foregoing procedure. These bend tests shall be made by the operator and left in the bent position for inspection by the Engineer. All such studs that show no sign of failure as determined by the Engineer shall be left in the bent position. When 7/8 in. (22 mm) studs are welded, bend tests will be performed after every 250 studs. If due to low temperatures, preheating of the base metal has been utilized in preparation for automatic welding of studs to the beams or girders, the operator shall hammer bend to 45 degrees from the vertical two studs in each 100 welded in addition to the first two studs welded on each beam or girder. The studs shall be left in the bent position for examination by the Engineer.

Studs on which a full 360 degrees weld has not been obtained may, at the option of the Contractor, be repaired by adding a 5/16 in. (8 mm) fillet weld in place of the lack of weld, using the shielded metal-arc (SMAW) process with low hydrogen welding electrodes. The repair weld shall extend at least 3/8 in. (10 mm) beyond each end of the discontinuity being repaired. The minimum preheat (flange and stud temperature) for SMAW repair welds is 70 ºF (20 ºC). The Engineer will bend test questionable studs as follows: Using a heavy hammer the Engineer will strike the stud to bend in the direction opposite to the weld deficiency until the shank is bent 15 degrees from the vertical (about 1 in. (25 mm) deflection). Then reversing, direction, the stud will be driven back into the vertical position. If there is no visual distress evident in the weld, it will be considered satisfactory.

In addition to the bend tests accomplished by the operator to the satisfaction of the Engineer and the bend tests made by the Engineer, the Engineer will check approximately one percent of the studs at random by striking the stud and bending to an angle of 45 degrees with the vertical. The studs shall be left in the bent position.

If a stud fails or it becomes necessary to remove a stud with a defective weld, the vacated area of the beam or girder flange shall be ground smooth and flush, or in case of a pullout of metal, the pocket shall be welded according to Article 505.04(q) using the shielded metal-arc process with low-hydrogen electrodes and then ground flush. The new stud shall be placed in the dimensional location as the defective stud it replaces.

If the Engineer notes a reduction of the height of the studs as they are welded, the work shall be stopped immediately and not resumed until the cause has been corrected. If the Engineer determines that the

shear connectors are not satisfactory by inspection and testing during the progress of the work, the Contractor shall replace all defective studs and make necessary changes in the welding procedure or welding equipment to secure satisfactory results.

(n) Field Welding and Cutting. Field welding shall be according to Article 505.04(q) and all field thermal (flame or plasma) cutting shall be according to Article 505.04(k). No field welding shall be done on main, load carrying members unless specified by the contract plans or with the written permission of the Engineer. The use of thermal cutting in other areas will be permitted only when specified by the contract plans or authorized by the Engineer, and shall be subject to the Engineer's inspection. No thermal cutting equipment shall be permitted on the structure, except when in use according to the above requirements.

(o) Construction Loads. Equipment for pulling falsework or other piles, for erecting adjacent structures, or for other tasks not directly related to construction of the structure shall not be operated upon or attached to any portion of the new structure without the written approval of the Engineer.

505.09 Work Under Separate Contracts. When the fabrication, erection, and painting of structural steel, construction of concrete decks, and other collateral work on a structure are accomplished under separate contracts, the following shall apply.

(a) Storing and Protection of Structural Steel. When the fabrication, erection and painting of structural steel is accomplished under separate contracts, the fabrication Contractor shall be responsible for storing and protecting all fabricated structural steel up to 45 calendar days after completion dates, delivery dates or number of working days specified in the fabrication contract. All storage costs incurred by the fabrication Contractor during this 45 day period shall be borne by the fabrication Contractor.

(b) Shipping of Structural Steel to Jobsite. The erection Contractor shall provide the fabrication Contractor and the Engineer with a schedule for shipping the structural steel to the jobsite within 30 calendar days after the execution of the erection contract. This schedule shall specify the order items are to be received and their orientation for delivery, and must meet the approval of the Engineer. The erection Contractor will be responsible for receiving, unloading storing and protecting the structural steel in accordance with this schedule. If the erection Contractor elects to change this schedule, the erection Contractor shall be responsible for coordinating the change with the fabrication Contractor and for all costs and time delays associated with such changes.

Delivery of the structural steel to the jobsite shall be the responsibility of the fabrication Contractor. The mode of delivery shall be the option of the fabrication Contractor. Delivery shall be limited to the hours between 8:00 a.m. and 5:00 p.m. on weekdays only, excluding any observed holidays, unless otherwise approved by the Engineer. The erection Contractor shall be responsible for coordination of movement of the structural steel within the contract limits and shall be responsible for all

demurrage charges. At the erection Contractor's option and expense, steel may be requested at times other than the stated time.

(c) Installation of Minor Items. Minor items of fabricated steel that cannot be completely installed until either final adjustments are made or the completion of subsequent contracts, shall be delivered and partially erected or stored as directed by the Engineer. These items shall be installed or adjusted, as required, by the Contractor performing the subsequent work.

505.10 Field Painting. Steel structures shall be cleaned and field painted according to Articles 506.03 and 506.05.

505.11 Reserved.

505.12 Method of Measurement. All structural steel shown on the plans will be included for payment unless it is specifically included with a separate pay item. All other structure items, unless they are included with separate pay items or specified as included into other items, will be included as structural steel, and the weight will be calculated based upon their actual density (mass).

The Contractor performing the erection shall furnish the erection bolts and pins, and also pilot and driving nuts when required. The Contractor performing the fabrication shall furnish all fasteners, washers, shipping bolt, and fitting-up diaphragms when required.

When minor items of structural steel are specified for payment by weight, the weight used will be the measured weight (mass) of the fabricated structural steel furnished. No measurement will be made or allowed for the weight (mass) of field weld material. The structural steel will be measured in pounds (kilograms) using the approved shipping weight (mass) or by measuring on approved platform scales. When the plan quantities of minor items of structural steel, such as expansion dams on concrete bridges or miscellaneous steel for the repair of existing structures, is approximately 10,000 lb (4500 kg) or less, the method of measurement for payment will be according to Article 202.07(a) unless a weigh ticket is provided.

505.13 Basis of Payment. Structural steel furnished and erected in place will be paid for at the lump sum price for FURNISHING AND ERECTING STRUCTURAL STEEL.

Fabricated structural steel furnished and delivered will be paid for at the lump sum price for FURNISHING STRUCTURAL STEEL.

Storage and care of the fabricated steel by the fabrication Contractor beyond the specified storage period, will be paid for at the contract unit price per calendar day for STORAGE OF STRUCTURAL STEEL if a pay item is provided for in the contract, or will be paid for according to Article 109.04 if a pay item is not provided in the contract.

Erected structural steel and other materials fabricated under this item will be paid for at the lump sum price for ERECTING STRUCTURAL STEEL.

If alterations or deductions to the work specified in the aforementioned lump sum items are ordered by the Engineer, the Contractor shall accept payment for any

increase or decrease in the amount of structural steel and other materials according to Article 104.02(a). The unit price used for the adjusted work will be determined by dividing the lump sum price bid for the item by the Engineer's calculated weight as shown on the contract plans. No adjustment in this plan weight will be allowed in calculation of the unit price for the adjusted work. If the weight (Mass) in pounds (kilograms) for the increased or decreased amounts of structural metals ordered by the Engineer amounts to a change exceeding 0.5 percent of the Engineer's calculated weight as shown on the contract plans or 3000 lb (1360 kg), whichever is larger, the unit price used for the increased or decreased amount of structural steel shall be agreed upon by the Contractor and Engineer.

When specified, minor items of structural steel furnished and erected complete in-place will be paid for at the contract unit price per pound (kilogram) for FURNISHING AND ERECTING STRUCTURAL STEEL.

Stud shear connectors that are to be field welded to the top flanges of beams or girders will be paid for at the contract unit price per each for STUD SHEAR CONNECTORS.

SECTION 506. CLEANING AND PAINTING METAL STRUCTURES

506.01 Description. This work shall consist of the cleaning and preparation of steel surfaces; the furnishing, application and protection of the paint coatings; and incidental work on new and existing steel structures.

506.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Structural Steel Coatings	1008
(b) High Strength Steel Bolts, Nuts and Washers	1006.08(a)

CONSTRUCTION REQUIREMENTS

506.03 Cleaning New Structures. After fabrication, accessible surfaces of all steel, except bolts, stainless steel, sliding surfaces, and items to be hot dip galvanized, shall be blast cleaned in the shop after removal of dirt, oil or grease, and other foreign substances according to the requirements of the Steel Structures Paining Council (SSPC) Surface Preparation Specification SP 1 for Solvent Cleaning. All outside corners to be shop painted shall be free of abrupt irregularities and dull to the touch prior to blast cleaning. Small areas may be cleaned according to SSPC Surface Preparation Specification SP 11 for Power Tool Cleaning to Bare Metal. Fins, burrs, thermal cutting residue, abrupt deformities, sharpness (corner more acute than a 1/32 in. (1 mm) radius), and other impediments to safe handling or a uniform coating application and performance shall be corrected by grinding and/or other Engineer-approved methods before final blasting or galvanizing. Blast cleaning of areas to be shop painted shall be accomplished according to the requirements of the SSPC Surface Preparation Specification SP 10 for Near White Blast Cleaning. Areas to be blast cleaned but not shop primed shall satisfy the requirements of SSPC Surface Preparation Specification SP 6 for Commercial Blast Cleaning. Diaphragms

and/or cross frames shall be cleaned as required for the main members at the same location.

All surfaces to be shop primed shall have an anchor profile of 1 to 2.5 mils (25 to 65 µm).

506.04 Shop Painting New Structures. Before painting, all blast products shall be removed from the surfaces, and the cleaning shall be approved by the Engineer. The blast-cleaned surfaces to be painted shall be given a prime coat within 24 hours after cleaning, unless otherwise authorized by the Engineer. The surface shall be primed before any rust forms.

At the Contractor's option, hot-dip galvanizing may be substituted for shop priming of bearings, typical cross frames or diaphragms on non-curved structures, expansion joint assemblies, and other elements not carrying calculated stress. Galvanized surfaces which shall have concrete poured against them shall be chemically passivated or otherwise protected by a method approved by the Engineer. Galvanized bearings for exterior members and elements readily visible after erection shall be prepared for field painting, but galvanized items obscured from public view will not require field painting. The Contractor shall submit a proposal for substituting galvanizing to the Engineer, showing items to be field painted, applicable provisions of AASHTO M 111 (ASTM A 123), drain/vent holes and any other necessary modifications.

The fabricated steel shall not be loaded for shipment to the job-site until: the shop paint is cured, the steel and coating has been inspected and approved by the Engineer, and at least 24 hours after application of paint. No painting shall be done after the material has been loaded for shipment.

The shop painting of steel structures shall be according to the following requirements.

(a) Paint. The paint for the shop coat shall be the inorganic zinc-rich primer according to Article 1008.02. The paint shall be stored at temperatures between 40 and 110 ºF (5 and 43 ºC) or the manufacturer's recommended limits, whichever are more restrictive. A permanent, automated record of storage temperatures shall be maintained and be available for the Engineer's review. Coatings stored at temperatures outside the above limits will be rejected.

(b) Mixing of Paint. The paint shall be thoroughly mixed with a power mixer before being applied and the pigments shall be kept in suspension. Records shall be maintained for every batch or kit of primer, showing when the activator was added to the primer, when the last of the primer was either applied or discarded, and what items were coated with primer. The manufacturer's recommended pot life times shall not be exceeded, and primer applied after that limit shall be removed. Inorganic zinc-rich primer, after initial mixing, shall be strained through a metal screen not coarser than 30 mesh (600 µm) or finer than 60 mesh (250 µm), before application. Small quantities may be withdrawn from the mixed primer and applied by brush or dauber for minor touch-up of thin primer, stiffener snipes and other

areas inaccessible for spraying. Pot life and dry film thickness limits shall apply to brush or dauber application.

Thinning will be permitted when required for proper application. The type of thinner used and the amount used shall be as recommended by the paint manufacturer for the ambient conditions. Any thinner additions (quantity and time) shall be documented on the record for each batch of primer.

(c) Weather Conditions. Primer shall be applied when the temperature of the metal and the air are above 32 ºF (0 ºC) and within the limits specified by the coating manufacturer's product data sheet, and when conditions are otherwise satisfactory for such work, including an air speed less than 5 mph (8 km/hr), a temperature more than 5 ºF (3 ºC) above dew point, and adequate light and ventilation. The surface of the steel shall be dry when the paint is applied. The relative humidity and ambient temperature ranges specified by the coating manufacturer for primer application shall be maintained in the paint area and areas where steel is stored for at least ten hours after painting is complete. If the relative humidity cannot be maintained above the manufacturer's recommended lower limit due to ambient conditions, alternate methods of ensuring proper cure may be proposed by the Contractor, accompanied by supporting recommendations from the coating manufacturer, for the Engineer's consideration. Documented records correlating the items primed, temperatures of paint and material during application, and the ambient temperature and relative humidity for painting and storage areas shall be maintained by the painting facility.

(d) Application. Paints shall be applied by either airless or conventional spray methods, except areas inaccessible to spray and small touch-up areas may be painted by brush or dauber. When inorganic zinc-rich primer is being spray applied, the material shall be kept under constant agitation with a power mixer to avoid settling. The applicable recommendations of the coating and spray equipment manufacturers as well as those of the Steel Structures Painting Council for Good Painting Practice shall be followed for all shop painting.

The coating shall be applied to produce a smooth, uniform coating with an average dry-film thickness of at least 3.0 mils (75 µm) at any location. The minimum dry-film thickness of an inorganic zinc-rich prime coat measured at any spot shall be at least 2.5 mils (65 µm), except as otherwise specified for contact surfaces of high-strength bolted connections. If the paint coating is too thin or if portions of the steel are not coated completely, the deficient portions shall be prepared and repainted according to the coating manufacturer's recommendations for surface preparation, thinning and technique. The maximum dry film thickness (DFT) shall be 6.0 mils (150 µm) for a single coat and 8.0 mils (200 µm) for multiple coats. DFT in excess of these limits may be reduced by methods approved by the Engineer or the coating may be removed and replaced. Alternatively, the Contractor and coating manufacturer may propose verification tests that prove the integrity and acceptability of the heavier DFT to the Engineer. If the Engineer accepts the evaluation methods and the areas of excessive DFT satisfy testing, they may remain. All such testing shall be at the

Contractor's expense, and the Contractor remains responsible for the performance of the primer until final acceptance of the field coats on those areas.

(e) Removal of Unsatisfactory Paint. If all or a portion of the paint coat shows significant or widespread defects, evidence of having been applied under unfavorable conditions, or poor workmanship, the Engineer may order it removed and steel cleaned and repainted. Where "mud cracking" occurs in inorganic zinc-rich primer, it shall be removed to soundly bonded paint and re-coated if necessary for adequate DFT. Areas adjacent to the removal of unsatisfactory paint shall be feathered to provide a smooth transition between originally and re-applied paint.

(f) Contact and Inaccessible Surfaces. Surfaces in contact at shop-welded or shop-bolted joints need not be painted unless specified, but shall be free of heavy or loose rust and scale, non-adherent paint, and other foreign material. Unpainted shop bolted connections joining elements which each require Charpy V-notch (CVN) tested material shall be cleaned to the requirements of SSPC SP6, Commercial Blast Cleaning. Surfaces not in contact, but which will be inaccessible after assembly and erection, shall be shop primed.

For painted areas, contact surfaces of field bolted connections joining elements which each require CVN tested material shall receive one shop coat of primer with a dry-film thickness from 1.0 to 5.0 mils (25 to 125 µm).

(g) Surfaces in Contact with Concrete. Top surfaces of painted beams and girders shall be given one shop coat of primer, except that portions where stud shear connectors are field installed shall not be painted. Unless hot dip galvanized, all portions of expansion guards (except anchor studs or bars), that are to be in contact with or partially embedded in concrete, shall be shop primed. Steel that is to be completely embedded in concrete shall not require painting, except when specified.

(h) Machine-finished Surfaces. Machine-filled surfaces of pins, pin holes, or other sliding surfaces, except stainless steel, shall be coated as soon as practicable after being approved, with lacquer or an anti-rust compound. When anti-rust compound is used, it shall be removed at the time of erection and a coating of a suitable lubricant approved by the Engineer shall be provided and applied by the erection Contractor before installation.

(i) Bearing Surfaces. All surfaces of rockers, bolsters, masonry (base) plates, and shims of fills placed under masonry plates shall be given one coat of primer. Sole (top bearing) plates welded or bolted to members shall receive the same treatment as the member at that location.

(j) Connectors. For areas that will be shop and/or field painted, all high-strength bolts and other connectors, including nuts and washers, installed in the shop or field shall be zinc-coated according to Article 1006.08(a).

(k) Erection Marks. Erection match marks and member piece marks shall be legible when delivered to the jobsite. Contrasting paint may be used on

areas that have received shop primer to identify locations of stamped marks or to duplicate their information. The paint used shall be the same as, or compatible with, the field topcoat. Paint marks used on unpainted steel shall not be in locations readily visible on the finished structure, such as the outside face of exterior members or the underside of bottom flanges. Marks in areas readily visible after erection shall be removed.

506.05 Field Painting New Structures. The requirements of Article 506.04, paragraphs (b) to (e), inclusive, shall also pertain when applying intermediate and final coats of paint on new steel, hereinafter referred to as "field painting" whether in a field or shop environment.

The Contractor shall protect pedestrian, vehicular, watercraft, or other traffic upon or underneath the structure, and also all portions of the structure against damage or disfigurement by paint. When painting over waterways, the Contractor shall implement such controls as are necessary to avoid paint spills into the water or depositing paint films on the water during spraying operations.

Field painting shall consist of spot painting and application of paint coatings required. Paint may be applied by spray or with brushes as specified in Article 506.04(d). Airless equipment shall be used when spray painting is done in the field. In addition, the use of rollers will be permitted in the application of paint coatings to flat surfaces, provided satisfactory results are obtained. Only brushes or rollers shall be used when spray painting is prohibited by the Special Provisions. If the structure includes a concrete deck, field painting at the job site shall be done after the deck is poured and the forms have been removed.

Before the application of the first field coat, the prime coat shall be cleaned of all dirt, oil, and other foreign substances by high pressure water. Adherent foreign material remaining after high pressure water washing shall be removed in a manner subject to the approval of the Engineer such that damage to the primer and base metal is minimized. Rust staining due to unpainted top flanges need not be removed. Also prior to the first field coat, prime coat damage, field welds, bare steel that must be field painted, or any rust that has developed in shop primed areas shall be power tool cleaned to SP 11 or blast cleaned to SP 6, and surfaces shall be dry.

When a structure has been cleaned to the satisfaction of the Engineer, it shall be spot painted in areas specified to receive field paint and/or where the hot-dip galvanizing coating has been damaged. The spot painting shall consist of the application of one coat of high build aluminum epoxy mastic paint applied on the exposed portions of field bolts, damaged galvanizing, and all areas noted in the last sentence of the preceding paragraph. A compatible coating produced by the manufacturer may be used in lieu of the aluminum epoxy mastic if approved by the Engineer. Stainless steel surfaces shall not be painted.

The dry film thickness of the aluminum epoxy mastic shall be 5.0 to 7.0 mils (125 to 175 µm) and it shall be applied when the surface is dry and both the steel and coating temperatures are within the manufacturer's recommended range. The spot painted areas shall be kept within the manufacturer's recommended temperature range and protected from moisture and contaminants until full cure has been verified. Spot painting shall be done when dirt or other material from the cleaning operations will not fall or blow on the spot coat.

The sequence of the work shall permit the prime coat and/or the intermediate coat to fully cure to satisfy recoating requirements before the next coat is applied. In no case shall paint be applied until the previous coat has been inspected by the Engineer and its condition has been verified by the appropriate tests.

Except as provided herein, field painting shall be done after the erection is completed. Surfaces that require field paint but would be inaccessible after the erection is completed shall be painted as approved by the Engineer during either fabrication or erection or at the job site prior to installation.

Surfaces that will have concrete poured against them or that shall be in contact within high-strength bolted connections shall receive no field paint.

(a) The number of coats, colors, and types shall be as specified in the contract.

(b) Machine-finished Surfaces. Except for stainless steel which shall not be painted, machine-finished surfaces, and the ends, threaded parts, and nuts of pins exposed after erection shall be cleaned according to SSPC SP 1, Solvent Cleaning, be painted with one coat of the paint used for spot painting, and then be painted with the paint specified for field painting the structure.

(c) Work Under Separate Contracts. All field cleaning and field painting of new work shall be included as part of the contract that includes the erection of the steel. When complete field painting is not included in the contract that includes the erection, the spot cleaning and painting of damaged coatings on newly erected work and applying one coat of the field paint to applicable surfaces that will be inaccessible after erection shall be included under the contract that included the erection. Field painting under a contract that does not include the erection shall include the cleaning and spot preparation necessary at the time the work is performed, and the additional spot and field paint coatings required.

(d) Inspection. The Contractor shall provide the Engineer adequate access for the inspection during all stages of work performed. The Contractor shall use a compatible paint with contrasting color to stencil the date of painting and the paint type code from the Structural Information and Procedure Manual on the surface of the final field coat. The letters shall be capitals, not less than 2 in. (50 mm) and not more than 3 in. (75 mm) in height. The stencil shall contain the word “Painted” and shall show the month and year in which the painting was completed followed by the proper paint type code. This shall be stenciled on the top surface of a truss end post or arch rib near the top of the right side railing, or on the outside face of the left-side fascia member near each ends of the bridge (at the right end of the structure when viewed from below), or at some equally visible surface designed by the Engineer.

506.06 Method of Measurement. Shop cleaning and painting new structures will not be measured for payment. Field cleaning and painting will not be measured for payment, except when performed under a contract that contains a separate pay item for this work.

506.07 Basis of Payment. Cleaning and painting in connection with the fabrication and erection of steel structures will not be paid for separately but shall be considered as included in the contract unit price or prices for furnishing, fabricating and erecting, or installing the material.

The field cleaning and painting of newly erected structural steel under a contract separate from the fabrication and erection will be paid for at the lump sum price for CLEANING AND PAINTING STRUCTURAL STEEL, at the location specified and the field cleaning and painting of steel railings which are fabricated and erected at the contract unit price per foot (meter) will be paid for at the contract unit price per foot (meter) for PAINTING STEEL RAILING when performed under a contract separate from the erection.

SECTION 507. TIMBER STRUCTURES

507.01 Description. This work shall consist of timber construction required for bridges and appurtenances, where the timber is incorporated in the completed structure. All lumber and timber for erection purposes, such as falsework, forms, sheeting, bracing, etc., are not subject to the requirements of this Section.

507.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Structural Timber	1007.03
(b) Preservative Treatment	1007.12
(c) Fastenings for Timber Structures	1006.17
(d) Structural Steel	1006.04
(e) Asphalt Binder, Grade PG52-28, PG58-28 or PG58-22	1032.01 - 1032.05
(f) Fine Aggregate	1003.03
(g) Structural Steel Coatings	1008.01 - 1008.02

Structural steel and other metals requiring fabrication shall be fabricated according to Section 505.

CONSTRUCTION REQUIREMENTS

507.03 Storage of Materials. Untreated lumber at the site of the work shall be open-stacked on supports at least 12 in. (300 mm) above the ground and shall be so stacked and stripped as to permit free circulation of air between the tiers and courses. When required by the Engineer, it shall be protected from the weather by suitable covering. Treated timber shall be close-stacked according to Article 1007.13.

507.04 Workmanship. All timber shall be accurately cut and framed to a close fit in such manner that the joints will have even bearing over the entire contact surfaces. Nails and spikes shall be driven just sufficiently to set the heads flush with the surface of the wood. Deep hammer marks in wood surfaces shall be considered evidence of poor workmanship.

507.05 Treated Timber. All cutting, framing and boring of treated timber shall be done before treatment insofar as is practicable.

(a) Handling. Treated timber shall be handled carefully without sudden dropping, bruising, breaking of outer fibers or penetrating the surface with tools. It shall be handled with rope slings. Cant hooks, peaveys, pikes, or hooks shall not be used.

(b) Cuts, Abrasions, and Holes. All cuts, abrasions, and holes made after treatment shall be repaired according to Article 1007.13. Each coat shall be allowed to dry before the next coat is applied. Any unfilled holes, after being treated with preservative, shall be plugged with treated plugs.

(c) Temporary Attachments. Forms or temporary braces may be attached to treated timber with nails or spikes only when approved by the Engineer. Upon their removal, the holes shall be filled by driving galvanized nails or spikes flush with the surface, or by plugging as required for holes.

507.06 Countersinking. Countersinking shall be done wherever smooth faces are required. Recesses formed in treated timber for countersinking shall be treated as required for cuts and abrasions, except as specified for plank floors.

507.07 Hardware. The term hardware shall include all metal fastenings required for timber connections or for connecting timber to concrete or steel work. The following items will be considered as hardware: bolts, tie rods, turnbuckles, washers, nuts, drift bolts, steel dowels, nails, spikes, and lag screws for timber connections; steel plates used as washers or between timber caps and the tops of piles or timbers; metal timber connectors of various designs; metal shear developers for composite timber and concrete floors; and anchor plates or clips for plank floors and sidewalks. Sheet metal pile coverings and steel traffic treads and their fastenings are not considered hardware.

All hardware for treated timber construction, except cast iron ogee washers, malleable iron washers and timber connectors, shall be stainless steel or galvanized.

(a) Rods. Rods connecting only sawed timbers shall be threaded sufficiently at each end to provide tight connections, allowing for permissible variations in dimensions of material. All rods shall extend entirely through the nut at each end and, after being drawn tight, all ends that project more than 1 in. (25 mm) beyond the nut shall be cut off about 1/2 in. (13 mm) beyond the nut.

(b) Bolts. The length specified shall be the length measured under the head. Bolts may be substituted for rods for timber connections where the length of threaded portion provided by the bolt is sufficient. Bolt ends projecting more than 1 in. (25 mm) beyond the nut shall be cut off as specified for rods. Special flat head bolts, or carriage bolts, shall be used for connections horizontally through railings and wheel guard timbers, with the head at the roadway face of the timbers. Machine bolts with square heads and nuts shall be used for other connections.

(c) Lag Screws. Lag screws shall be installed by turning them into place. They may be driven sufficiently to start them into the holes and hold them firmly in place for turning, but shall not be driven beyond the depth that will be occupied by the shank.

(d) Nuts and Washers. Washers shall be used under all nuts and bolt heads that would otherwise come in contact with wood, except under large diameter heads of specially designed flat head bolts. Ogee or malleable iron washers shall be used for all tie rods except where plate washers are called for by the plans, and for all rods and bolts passing through piles except bolts connecting railing plank to wing piles. Standard wrought washers shall be used at all locations, except where washers of other types are required. All nuts shall be standard square nuts. They shall be tightened sufficiently to prevent the rods or bolts from becoming loose during service and, after being tightened, they shall be effectively secured against backing off by burring of the rod or bolt threads.

(e) Nails and Spikes. Nails shall not extend through all material into which they pass. The size of nails and spikes, when not otherwise shown, shall be according to the following.

Size of Nails and Spikes				
Actual Thickness of Piece Nailed in.	(mm)	Actual Thickness of Piece Nailed to in. (mm)	Size of Nails and Spikes
1 5/8	(41)	1 5/8 (41)	10d
1 5/8	(41)	2 (50)	16d
1 5/8	(41)	2 5/8 (66) or more	20d
2	(50)	2 (50)	16d
2	(50)	2 5/8 (66) or more	20d
2 5/8	(66)	2 5/8 or 3 (66 or 75)	40d
2 5/8	(66)	3 5/8 (92) or more	60d
3	(75)	3 (75)	50d
3	(75)	3 5/8 (92) or more	60d
3 5/8	(92)	3 5/8 (92) Spikes	
4	(100)	3 5/8 (92) or more	7 in. (178 mm) spikes

507.08 Holes for Bolts, Dowels, Rods, and Lag Screws. Holes for round drift bolts and dowels shall be bored with a bit 1/16 in. (2 mm) less in diameter than the bolt or dowel to be used. The diameter of holes for square drift bolts or dowels shall be equal to the least dimension of the bolt or dowels. Holes for bolts shall be bored with a bit of the same diameter as the bolt. Holes for rods shall be bored with a bit 1/16 in. (2 mm) greater in diameter than the rod. Holes for lag screws shall be bored with a bit not larger than the body of the screw at the root of the thread. If required to prevent splitting, the hole for the shank shall be bored the same diameter as the shank. The depth of holes for lag screws shall be a minimum of 1 in. (25 mm) less than the length under the head.

507.09 Pile Bents and Abutments. All work involving piles shall be according to Section 512. Cut-offs shall be made accurately to ensure complete bearing between the cap and piles, or good alignment of the tops of wing piles. No shimming between pile tops and caps will be permitted, except to provide for adjustment of not more than 1 in. (25 mm) required on account of errors in cut-off. The shim for this purpose shall consist of a single square steel plate of the proper thickness, having the same width as the cap, punched 1/16 in. (2 mm) larger than the drift bolt. The piles for any one bent or line shall be selected carefully as to size, to avoid undue bending or distortion of the bracing or backing timbers. Care shall be exercised in the distribution of piles of varying sizes to secure the required strength and rigidity throughout the structure.

507.10 Caps. Timber caps shall be placed, with ends aligned, in a manner to secure an even and uniform bearing on the tops of the supporting posts or piles. They shall be secured by a drift bolt not less than 3/4 in. (20 mm) in diameter, extending at least 9 in. (225 mm) into each post or pile. The drift bolt shall be as near the center of the post or pile as possible without interfering with rods passing through the post or pile near the cap. Caps shall not be spliced, except as provided by the plans.

507.11 Backing Plank. Backing plank shall be placed so that exposed ends form a straight line. They shall be fastened to each pile and nailing strip with at least two nails or spikes. Splices in backing plank shall be made at the center of a pile and splices in adjoining lines or plank shall be staggered. Backing plank for wings shall be placed so that the top of the top plank will be at the proper elevation.

507.12 Stringers. Timber stringers shall be placed in position so that the floor will have an even bearing on all stringers and so that any knots near edges will be in the top portions of the stringers. Outside stringers may have butt joints, centered over caps or floor beams, but interior stringers shall be lapped to take bearing over the full width of the cap or floor beams at each end. Stringers shall be toenailed to caps and intermediate stringers of adjoining spans shall be spiked together where they lap.

Cross-bridging between stringers shall be neatly and accurately framed, and securely toenailed with at least two nails in each end. All cross-bridging members shall have full bearing at each end against the sides of stringers. 2 in. (50 mm) by 4 in. (100 mm) cross-bridging shall be placed at the center of each span.

507.13 Plank Floors. The floor planks shall be laid at right angles to centerline of roadway. The planks shall be carefully graded as to thickness and laid so that no two adjacent planks will vary in thickness by more than 1/16 in. (2 mm). When more than one length of plank is required, joints between abutting ends shall be staggered at least 3 ft (1 m) in any two adjacent lines of plank. Ends of planks at the edges of the roadway shall be cut on a straight line parallel with the centerline of the roadway.

When plank floors on steel stringers are to be fastened to nailing strips bolted to the sides of the steel stringers, the top of each nailing strip shall be flush with the top of the beam or channel. A recess of the proper width and depth shall be provided in the top surface of the nailing strip to fit neatly around the projecting flange of the

beam or channel. Nailing strips for treated plank floors shall be so recessed before treatment.

In constructing floors of untreated material, the planks shall be laid heart side down with 1/4 in. (6 mm) joints between them for seasoned material and with tight joints for unseasoned material. Treated plank floors shall be laid with tight joints, except when the planks are separated by anchor clips used for fastening the planks to steel stringers.

Standard wrought washers shall be used under the heads of all lag screws and the heads or nuts of all machine bolts used for fastening the floor plank. Where machine bolts are used for fastening the floor plank, all nuts used shall be locknuts. Heads of all lag screws and bolts in the surface of the floor shall be countersunk so that the tops will be flush with the surface of the plank. Recesses formed for countersinking shall be just large enough to admit the washers and, after the lag screw or bolt is in place, shall be filled with hot pitch.

For laminated or strip floors, the strips shall be placed on edge and each strip shall be nailed to the preceding strip at each end with two nails and approximately at 18 in. (450 mm) intervals with nails driven alternately near the top and bottom edges. The nails shall be long enough to pass through two strips and at least halfway through the third strip. If timber stringers or nailing strips are used, every other strip shall be toenailed to every other support. Care shall be taken to have each strip vertical and tight against the preceding one, and bearing evenly on all supports.

507.14 Bituminous Surface Coat. When required, plank floors shall be given a bituminous surface coat. The floor shall be cleaned of foreign materials and the asphalt cement shall be applied at a temperature of from 275 to 350 ºF (135 to 175 ºC) and at a rate of approximately 1/4 gal/sq yd (1 L/sq m) of surface. The plank shall be dry at the time of this application. The entire surface shall then be covered with a thin coating of fine aggregate, sufficient in quantity to take up any free bitumen.

507.15 Steel Traffic Treads. Steel traffic treads shall be not less than 3/16 in. (5 mm) thick, exclusive of the raised portions, not less than 24 in. (600 mm) wide, and the individual sections not more than 15 ft (4.5 m) long. Treads shall have a non-skid surface with alternate projections at right angles to each other. The raised portions shall be formed in the rolling and not by punching or pressing from the under side. Treads shall be punched 7/16 in. (11 mm) for lag screws or bolts. The holes shall be placed not less than 1 1/4 in. (30 mm) nor more than 1 1/2 in. (40 mm) from the edge of the tread. The spacing of holes on both sides of the tread shall be not more than 15 in. (375 mm) and on both ends of each section not more than 6 in. (150 mm). The unit weight of the treads shall be approximately 8 3/4 lb/sq ft (43 kg/sq m).

Before the treads are laid, all high spots and rough spots in the plank floor shall be removed so that the treads will be in contact with the floor for their full length and width. Treads shall be laid in a heavy mop coat of hot asphalt according to Article 1032.11, PAF-3. Treads shall be laid with a space of 1/4 in. (5 mm) between adjacent ends and shall be fastened by means of 3/8 in. (M10) galvanized bolts. Where bolts cannot be installed, 3/8 in. by 3 in. (M10 by 75 mm) galvanized screws shall be used.

507.16 Wheel Guards and Railings. Wheel guards and railings shall be accurately framed so that they will be true to line and grade. Wheel guards shall be laid in sections not less than 12 ft (3.6 m) long with each splice located approximately over the center of a scupper block. Railing plank shall be untreated timber and shall be painted with two coats of white paint. Surfaces in contact with rail posts or piles shall be painted with one coat before the railing planks are erected.

507.17 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. The quantity of timber will be computed in foot board measure (cubic meters). Computations of quantity will be based on the nominal commercial widths and thicknesses of the material. The length will be the actual lengths of the various pieces required, measured to the nearest 1 in. (25 mm). The length of each piece with a beveled end will be taken as the overall length of the piece, except that when two or more pieces with beveled ends may be cut economically from a single commercial length, the sum of the lengths will not exceed the commercial length required. The quantity computed for payment will include all splices required by the plans but will not include any allowance for additional splices or waste.

Hardware will be measured for payment in pounds (kilograms). The weight (mass) of rods and plates will be computed from the weights (masses) shown in the current edition of the American Institute of Steel Construction Manual, with no deduction for holes and no allowance for overrun. Weights (masses) computed from dimensions of material will be based upon a weight (mass) of 490 lb/cu ft (7850 kg/cu m) for steel, 485 lb/cu ft (7770 kg/cu m) for wrought iron, and 450 lb/cu ft (7200 kg/cu m) for cast iron. No additional allowance for loss or waste will be added to the computed weights (masses), but an additional allowance of 3 1/2 percent for galvanizing will be added to weights (masses) of all galvanized material computed on the basis of ungalvanized material.

Bituminous surface coat for plank floors will be measured for payment in square yards (square meters).

Steel traffic treads will be measured for payment in square feet (square meters).

507.18 Basis of Payment. Treated timber will be paid for at the contract unit price per foot board measure (cubic meter) for TREATED TIMBER. Untreated timber will be paid for at the contract unit price per foot board measure (cubic meter) for UNTREATED TIMBER. All items classed as hardware will be paid for at the contract unit price per pound (kilogram) for HARDWARE. Bituminous surface coat for plank floors will be paid for at the contract unit price per square yard (square meter) for BITUMINOUS SURFACE COAT. Steel traffic treads, including bolts, lag screws, or other fastenings, will be paid for at the contract unit price per square foot (square meter) for STEEL TRAFFIC TREADS.

SECTION 508. REINFORCEMENT BARS

508.01 Description. This work shall consist of furnishing and placing reinforcement bars.

508.02 Materials. Materials shall be according to Article 1006.10.

CONSTRUCTION REQUIREMENTS

508.03 Storage and Protection. The reinforcement bars, when delivered on the job, shall be stored above the surface of the ground upon platforms, skids, or other supports, and shall be protected from mechanical injury and from deterioration by exposure. When placed in the work, they shall be free from dirt, detrimental scale, paint, oil, or other foreign substances. A light coating of rust will not be considered objectionable on black bars. For epoxy-coated reinforcement bars, all systems for handling shall have padded contact areas. The bars or bundles shall not be dropped or dragged. Coated bars shall be stored on wooden or padded steel cribbing.

508.04 Cutting and Bending. Reinforcement bars shall be cut and bent at the mill or shop to the shapes shown on the plans before shipment to the work. Bending in the field will not be permitted, except to correct errors, damage by handling and shipping, and minor omissions in shop bending.

Epoxy-coated reinforcement bars on skewed bridges and in other locations that are specified to be cut in the field shall be either sawed or sheared but shall not be flame cut. Patching of the bar cuts shall be according to ASTM D 3963.

508.05 Placing and Securing. All reinforcement bars shall be placed and tied securely at the locations and in the configuration shown on the plans prior to the placement of concrete. Reinforcement bars shall not be placed by sticking or floating into place during or immediately after placement of the concrete.

Bars shall be tied at all intersections, except where the center to center dimension is less than 1 ft (300 mm) in each direction, in which case alternate intersections shall be tied. The number of ties as specified shall be doubled for lap splices at the stage construction line of concrete bridge decks when traffic is allowed on the first completed stage during the pouring of the second stage.

Prior to the placement of any concrete, all mortar or other foreign material shall be removed from the reinforcement. Placement of the concrete shall not commence until the Engineer has inspected and approved the reinforcement placement. The Contractor shall correct any misalignment of the reinforcement bars occurring during the placement of the concrete.

The clearances from the face of the form shall be maintained by the use of chairs or other supports approved by the Engineer. Clearance from the bottom of footing shall be maintained by concrete blocks, cement bricks, suspended in place, or other support system approved by the Engineer. Pebbles, stones, building bricks, and wood blocks shall not be used for bar supports. Bars in the bottom of beams and

girders shall be supported by chairs placed on the forms. In beams and girders having two or more layers of bars, the chairs for the upper layer shall rest on the immediate lower layer, top bars in beams and girders shall be supported from the adjacent slab or from the stirrups.

Supports shall be metal or plastic. Metal bar supports shall be made of cold-drawn wire, or other approved material and shall be either epoxy coated, galvanized or plastic tipped. When the reinforcement bars are epoxy coated, the metal supports shall be epoxy coated. The supports may be recycled plastic. Supports shall be provided in sufficient number and spaced to provide the required clearances. All supports shall meet the approval of the Engineer.

Bars in the bottom of concrete bridge decks shall be supported from the forms on continuous type bar supports placed transversely to the bottom bars at a maximum spacing of 3 ft 3 in. (1 m). Bars in the top of concrete bridge decks shall be supported on continuous high chairs placed transverse to the bottom bars of the top mat at a maximum spacing of 3 ft (900 mm). Individual high chairs may be used to support the bars in the top of concrete bridge decks in lieu of continuous high chairs. If individual high chairs are used, they shall be spaced at a maximum of 2 ft (600 mm) by 3 ft (900 mm) centers, or equivalent. The requirements, as herein specified, for supporting bars in concrete bridge decks are minimum requirements only and the Contractor is in no way relieved of the responsibility of providing additional supports as may be required to support the bars firmly in their correct position. When working loads on the bars prior to and during concrete placement includes chutes, pipes, or tubes for pumping concrete, or other unusual material or equipment, special consideration shall be given to the need for supplementary bar supports.

In addition to the requirements for tying bars at intersections, as herein specified, the bars in the tops of slabs shall be securely held in place by No. 9 (3.8 mm) wire ties, or other devices fastened to the structural steel, falsework, or other structural component at a maximum of 25 ft (7.6 m) longitudinal and 15 ft (4.5 m) transverse spaces. Welding to the structural steel will not be permitted.

Epoxy coated reinforcement bars shall be tied with plastic or epoxy coated wires or acceptable molded plastic clips. After the bars are in place and immediately before placement of the concrete, the coated bars will be inspected for damage to the coating. Damage caused during shipment of epoxy bars or by installation procedures or both need not be repaired in cases where the damaged area is 1/4 x 1/4 in. (6 x 6 mm) or smaller, and the sum of all damaged areas in each 1 ft (300 mm) length of bar does not exceed two percent of the bar surface area. All damaged areas larger than 1/16 sq in. (40 sq mm) shall be repaired and all bars with total damage greater than two percent of bar surface area in any 1 ft (300 mm) length of bar shall be rejected and removed. The total bar surface area covered by patching material shall not exceed five percent. Epoxy-coated bars at bonded deck construction joints shall be protected from coating damage during preparation of the joint surfacing for bonding. If sandblasting is used in preparation of the joint area, as allowed in Article 503.09(b), the Contractor shall be required to wrap or otherwise protect the bar coating during the blasting operation.

Prior to the placement of concrete for bridge decks, the clearance for the top mat of reinforcement bars shall be checked. A template shall be attached to the finishing machine or vibrating screed and a dry run shall be made over the entire area of the

deck. The template shall be set to 1/4 in. (6 mm) less than the specified clearance to allow for tie wires. Any reinforcement exceeding the allowable tolerance shall be corrected before the start of concrete placement.

508.06 Splicing. Reinforcement bars shall be furnished in their full lengths and splicing will only be permitted where shown on the plans or by written approval of the Engineer. All splicing shall be performed as specified herein; splicing by welding will not be allowed.

(a) Lap Splicing. Lap Splicing shall be performed as follows.

(1) Contact Lap Splice. Bars to be spliced along a continuous line of reinforcement shall be lapped the specified length, placed in direct contact, and wired together.

(2) Non-Contact Lap Splice. Bars to be spliced, which are not along a continuous line of reinforcement and not specified to be contact spliced, shall be lapped the specified length and either spaced transversely a clear distance apart or contact spliced as described in (1) above, whichever requires the least adjustment to the bar spacing. The clear distance apart shall be from a minimum of 2 1/2 in. (65 mm) to a maximum of either 1/5 the lap length or 6 in. (150 mm), whichever is least.

(b) Bar Splicer Assemblies. When specified on the plans, the splicing of bars shall be performed with bar splicer assemblies. The assemblies shall be of an approved type and shall develop, in tension, at least 125 percent of the yield strength of the lapped reinforcement bars.

508.07 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Reinforcement bars and epoxy coated reinforcement bars incorporated in special reinforced pavement designs and in structures will be measured in pounds (kilograms) as computed for the sizes and lengths of bars shown on the plans or authorized by the Engineer. In computing the quantity to be paid for, the quantity of the bars of the cross section shown on the plans, or authorized, will be used. These weights (masses) are given in the following table.

Bar Size (English)	Weight, lb/ft
No. 3	0.376
No. 4	0.668
No. 5	1.043
No. 6	1.502
No. 7	2.044
No. 8	2.670
No. 9	3.400

Bar Size (English)	Weight, lb/ft
No. 10	4.303
No. 11	5.313
No. 14	7.650
No. 18	13.600

Bar Size (metric)	Mass, kg/m
No. 10	0.785
No. 13	0.994
No. 16	1.552
No. 19	2.235
No. 22	3.042
No. 25	3.973
No. 29	5.060
No. 32	6.404
No. 36	7.907
No. 43	11.380
No. 57	20.240

The computed weight (mass) will not include the extra metal used when bars larger than those specified are substituted by the Contractor with the permission of the Engineer, the extra metal necessary for splices when bars shorter than those specified are substituted with the permission of the Engineer, the weight (mass) of any devices used to support or fasten the steel in correct position, the weight (mass) of the epoxy coating, or the weight (mass) of specified test bars.

Tie bars in pavement or between pavement and other new and/or existing portland cement concrete appurtenances, including all labor and materials required for installation and testing, will not be paid for separately, but shall be considered as included in the unit bid price for the portland cement concrete item involved. Dowel bars in load transmission devices for pavement, and marginal bars in pavement, when required, will not be measured for payment. Reinforcement bars required for concrete piles or other reinforced concrete work in structures, where the concrete is not measured for payment in cubic yards (cubic meters), will not be measured for payment, but shall be considered as part of the piles or other complete units that are to be paid for as such. If the weight (mass) of the reinforcement per unit of measurement is increased from that shown on the plans, by authority of the Engineer, the additional weight (mass) of the steel will be measured for payment.

508.08 Basis of Payment. Reinforcement bars in special reinforced pavement designs and in reinforced concrete structures where the concrete is paid for at a unit price per cubic yard (cubic meter), will be paid for at the contract unit price per pound (kilogram) for REINFORCEMENT BARS or REINFORCEMENT BARS, EPOXY COATED.

Bar splicer assemblies will be paid for at the contract unit price per each for BAR SPLICERS.

SECTION 509. METAL RAILINGS

509.01 Description. This work shall consist of furnishing and erecting metal railings, and furnishing, erecting, maintaining, and removing temporary steel railings.

509.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Structural Steel	1006.04
(b) Structural Steel Coatings	1008
(c) Steel Pipe	1006.18
(d) Aluminum for Railings	1006.30
(e) Stainless Steel Hardware	1006.31
(f) Fabric Reinforced Elastomeric	1028
(g) Steel Posts for Railings	1006.34(a)
(h) Tubular Steel Rail for Railings	1006.34(b)
(i) Steel Shapes and Plates for Railing	1006.34(c)
(j) High-Strength Steel Bolts, Nuts, and Washers	1006.08(b)
(k) Malleable Castings	1006.16
(l) Chemical Adhesive Resin System	1027.01
(m) Hardware for Railings	1006.29(d)
(n) Threaded Anchor Rods	1006.09
(o) Chain Link Fabric (Note 1)	1006.27

Note 1. When galvanized fencing is specified, the chain link fabric shall be according to Article 1006.27(a)(1)a., b., or c. When painting is specified for posts and/or frames, the chain link fabric, ties and tensioning components shall be vinyl coated according to Article 1006.27(a)(1)d.

CONSTRUCTION REQUIREMENTS

509.03 General. Work shall be according to the details shown on the plans, and lines and grades shall not follow any defects in the structure. When the structure is on a grade, rail posts shall be vertical, except posts for metal railings on concrete parapets and welded frames carrying chain link fencing shall be normal to the theoretical grade. Top of railings shall be parallel to grade line. High spots shall be ground and low spots shimmed.

All welds facing pedestrian areas shall be ground smooth in the shop. The rails shall be straight and true to line, without kinks, bends, or warps, and straightened as necessary before shipment.

509.04 Shop Drawings. Before beginning fabrication, the Contractor shall submit shop drawings to the Engineer according to Article 505.03. For railings constructed according to standard Department details, the drawings will not be formally reviewed, but will be included in the project record. When special non-standard details are required by the plans or proposed by the Contractor, the drawings shall be submitted for approval.

509.05 Steel Railings. Fabrication, inspection, storage, and erection of steel railings shall be according to Section 505, except that galvanized railing and accessories shall be stored according to Article 1006.34(d).

(a) Type T-1, TP-1, S-1, SM, WT, and Type 2399 Steel Railings. For top mounted posts, three galvanized or ASTM A 304 stainless steel shims per post, one at 1/8 in. (3 mm) and two at 1/16 in. (2 mm), shall be provided for 25 percent of the posts. Shims shall be similar to base plate in size and holes.

For side mounted posts, a 1/8 in. (3 mm) thick fabric reinforced elastomeric pad shall be placed between the post and the concrete.

For side mounted rails on multi-span bridges, sufficient galvanized steel shims shall be provided to align rails between adjacent spans. Various thicknesses may be used, with no more than three shims per post.

The 3/4 in. (M20) diameter high strength bolts used to connect the angles to the post shall be tightened according to Article 505.04(f)(2). The 1 in. (M24) diameter high strength bolts connecting steel to the concrete shall be brought to a snug tight condition and given an additional 1/8 turn. The 5/8 in. (M16) cap screws in the bottom of the posts shall be brought to a snug tight condition only.

(b) Tubular Thrie Beam Retrofit Rail. In addition to the requirements of Article 509.04, the tubular thrie beam rail section shall be fabricated by welding two thrie beam rail elements according to the details shown on the plans. The thrie beam rail section shall be according to the requirements of AASHTO M 180, Type 1, of the class specified.

All structural steel shapes and plates shall be galvanized.

Posts shall be attached to the concrete by drilling and setting anchor rods according to Article 509.06.

The standard length for a tubular thrie beam section is 25 ft 0 in. (7.5 m). Posts shall be provided at standard 8 ft 4 in. (2.5 m) centers whenever practical.

Posts shall not be located closer than 1 ft 3 in. (375 mm) to an existing bridge expansion joint or end of bridge.

In the event that standard lengths of tubular thrie beam cannot be longitudinally positioned to meet the requirements, shorter custom fabricated section(s) will be specified with a minimum length of 2 ft 6 in. (750 mm) and hole spacing for joints the same as full length sections.

All splice bolts shall be 5/8 in. (M16) diameter, unless otherwise noted.

Tubular thrie beam expansion joint shall be provided between any two posts which span a bridge expansion joint. Bolts located at expansion joints shall

be provided with locknuts or double nuts and shall not be tightened beyond a point that prevents thermal expansion and contraction of the rail.

The expansion joint width shall be 2 1/2 in. (65 mm) at 50 ºF (10 ºC) and shall be adjusted for other temperatures according to the requirements of Article 520.04.

(c) Pedestrian Railings, Bicycle Railings, and Bridge Fence Railings. The furnishing and installing of the chain link fabric, when specified, shall be according to Section 664. Stretcher bars shall be used on all four sides of each panel. The chain link fabric shall be placed along the pedestrian side as detailed on the plans. The maximum post spacing shall be 10 feet (3 m).

At the Contractor option, either cast in place anchor devices or drilled and set anchor rods may be used to attach the posts to the concrete. Drilling and setting of anchor rods shall be according to Article 509.06.

(d) Pipe Handrail. The railings shall be standard (Schedule 40) pipe and the posts shall be extra strong (Schedule 80) pipe. Either welded or seamless pipe may be used. Rail panel lengths shall not exceed 7 ft (2.1 m) center-to-center of posts for 1 1/2 in. (40 mm) pipe and 8 ft (2.4 m) for larger diameter pipe. No railing shall be continuous for more than 40 ft (12 m) without expansion joints. Provision for expansion shall also be made in any panel crossing an expansion joint in the structure.

Connection of railings to posts shall be by the use of fittings or welding. One type of connection shall be used for railings throughout a structure. Welded joints shall be continuous, and weld surfaces shall be ground smooth. The use of couplings or unions will not be permitted.

When connections are made with fittings, rails shall be continuous through fittings at intermediate posts where expansion is not provided, and pinned, or welded to the fittings. Rails shall be threaded or welded into fittings at end and corner posts and shall have slip connections at points where expansion is provided.

The pipe handrail shall be fastened to the concrete or other support by means of standard flange plates with four anchors each. Anchors for this purpose shall have a diameter of not less than 5/8 in. (16 mm).

Whenever practicable, anchors shall be cast-in-place bolts, otherwise, they shall be anchor rods drilled and set according to Article 509.06.

When painted rail is specified, the cleaning and painting shall be according to Section 506, using the paint system specified for structural steel.

When galvanizing is specified, all posts, rails, splices, anchorage devices and plates shall be galvanized according to AASHTO M 111. Vent holes for galvanizing shall be placed in the posts and rails at locations that will not allow the accumulation of moisture in the members. Field drilled holes shall be spot painted with of one coat of aluminum epoxy mastic paint before erection. All bolts, nuts, and anchors shall be

galvanized according to AASHTO M 232, except stainless steel hardware shall be uncoated.

509.06 Setting Anchor Rods. Drilled holes in concrete for anchor rods shall be to the diameter and depth required by the adhesive manufacturer for the size and type of anchor rod specified. The anchor rods shall be set with capsule or cartridge type adhesive systems that have been previously tested and approved by the Department. The sealed capsule or cartridge shall contain pre-measured amounts of adhesive chemicals and be installed according to the manufacturer's written instructions.

509.07 Temporary Steel Railing. The 1 in. (M24) diameter high strength bolts or threaded anchor rods used to connect the posts to the deck shall be tightened according to Article 505.04(f)(2), except the nut shall only be rotated 1/8 turn beyond snug tight.

When required or allowed by the Engineer anchor rods may be drilled and set according to Article 509.06.

Contact surfaces between the post flange, rail, and inside face of the brackets for the alternate rail connection detail shall be free of all lubricants. The nuts for 5/8 in. (M16) high strength studs used to connect the bracket to the post shall be tightened to snug tight and given an additional 1/8 turn.

After the removal of bolts and anchorage devices, all holes in the permanent deck shall be filled flush with the deck surface using a nonshrink grout according to Section 1024 placed according to the manufacturer's recommendations. Anchors drilled and set in a permanent deck shall be cut flush with the deck surface after removal of the temporary steel railing.

509.08 Aluminum Railings. During manufacture, transport, and erection, railing shall be protected from scratching, denting or other defects that may affect its durability or appearance.

Rail elements shall be extruded in modular lengths of 30 ft (9 m), except for end/terminal sections, over expansion joints, or sections curved to a radius of 2300 ft (700 m) or less. Each rail element shall be attached to no less than two posts. All joints in rails shall be spliced as detailed.

Three aluminum shims per post, one at 1/8 in. (3 mm) and two at 1/16 in. (2 mm), shall be provided for 25 percent of the posts. Shims shall be similar to base plate in size and holes.

509.09 Method of Measurement. This work will be measured for payment in place in feet (meters). The length measured will be the overall length along the top longitudinal railing member through all posts and gaps.

509.10 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for STEEL RAILING, or ALUMINUM RAILING, of the type specified; STEEL RAILING (TEMPORARY); TUBULAR THRIE BEAM RETROFIT RAIL FOR BRIDGES; PEDESTRIAN RAILING; BICYCLE RAILING; BRIDGE FENCE RAILING; BRIDGE FENCE RAILING (SIDEWALK); PARAPET RAILING; and PIPE HANDRAIL.

SECTION 510. RESERVED

SECTION 511. SLOPE WALL

511.01 Description. This work shall consist of constructing a slope wall on a prepared earth bed.

511.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Portland Cement Concrete	1020
(b) Fabric Reinforcement	1006.10

511.03 Equipment. Equipment shall be according to the following.

Item	Article/Section
(a) Membrane Curing Equipment	1101.09

CONSTRUCTION REQUIREMENTS

511.04 General. This work shall consist of the preparation of the earth bed, excavation, backfilling, disposal of surplus material according to Section 502, and the construction of concrete slope walls according to Section 503. Preferably, the slope wall shall be constructed in alternate sections each approximately 9 ft (2.7 m) in width.

The fabric reinforcement shall be supported 2 in. (50 mm) below the upper surface of the slope wall by concrete blocks. A clear distance of 2 in. (50 mm) shall be maintained between the fabric reinforcement and the outside face of any vertical or inclined toe or cutoff wall. The fabric reinforcement shall be continuous across all construction joints and shall extend into each section a minimum of 6 in. (150 mm) from any adjacent previously placed section. Adjacent sections of fabric reinforcement shall be lapped a minimum of 6 in. (150 mm) in all cases.

511.05 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements of the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. This work will be measured for payment in place and the area computed in square yards (square meters). In computing the quantity for payment, the dimensions used will be those established by the Engineer to conform to the elevations of the natural ground line or stream bed. The area for measurement will include the upper, sloped surface of the wall. Anchor and cut-off walls will not be measured for payment.

511.06 Basis of Payment. This work will be paid for at the contract unit price per square yard (square meter) for SLOPE WALL of the thickness specified.

SECTION 512. PILING

512.01 Description. This work shall consist of furnishing and driving piles.

512.02 Materials. Materials shall be according to the following.

	Item	Article/Section
(a)	Timber Piling	1007.08
(b)	Preservative Treatment	1007.12
(c)	Portland Cement Concrete	1020
(d)	Reinforcement Bars and Fabric	1006.10
(e)	Structural Steel	1006.04
(f)	Structural Steel Coatings	1008
(g)	Metal Shell Piling	1006.05(a)
(h)	Steel Piling	1006.05(b)
(i)	Pile Shoes	1006.05(e)
(j)	Fastenings for Timber Structures	1006.17
(k)	Precast Concrete Products	1042

CONSTRUCTION REQUIREMENTS

512.03 Precast Concrete and Precast, Prestressed Concrete Piles. Precast concrete piles shall be manufactured according to Section 1042 and precast, prestressed concrete piles shall be manufactured according to the Department's "Manual for Fabrication of Precast, Prestressed Concrete Products" in effect on the date of invitation for bids.

(a) Splicing. Splicing of precast concrete or precast, prestressed concrete piles for the purpose of driving additional length will not be allowed.

(b) Extensions. Extensions on precast concrete or precast, prestressed concrete piles shall be avoided; but when necessary, they shall be made as shown on the plans.

512.04 Metal Shell Piles. Metal shell piles shall consist of a steel shell which is driven into place and filled with concrete. The walls of all shells shall be of sufficient thickness, but not less than the minimum specified, to permit driving without distortion or damage.

(a) Splicing. Splicing of metal shell piles shall be as follows.

(1) Planned Splices. Planned field or shop splices may be used provided the minimum length of each segment is at least 20 ft (6 m).

(2) Unplanned Splices. Unplanned field splices shall be used as required to furnish lengths beyond those specified in Article 512.16. The length

of additional segments shall be a minimum of 10 ft (3 m) unless otherwise specified by the Engineer.

All splices shall be accomplished by a complete joint penetration (CJP) weld or a commercial drive splice with Department approved commercial splicer welding detail. Welder qualification and certification will be required for all splicing according to Article 512.07.

(b) Driving. Whenever practicable, all piles for any one bent, pier, or abutment shall be completely driven before any concrete is placed in the shells. If this is impracticable, driving of additional piles within 15 ft (4.5 m) shall be deferred until the concrete in all shells within this zone has been in place for at least 24 hours from the time placing is completed.

(c) Inspection. The Contractor shall have a suitable light available at all times for illuminating the entire interior length of the shells. Driven shells shall be watertight and free of bends, kinks, or other deformations that would impair the strength or efficiency of the completed pile.

If the shells are not filled with concrete shortly after being driven, the tops of the shells shall be temporarily sealed.

(d) Reinforcement. Reinforcement shall be used inside the shells as shown on the plans. Reinforcement shall be rigidly fastened together and lowered into the shell before the concrete is placed. Spurs or spacers shall be used to ensure the specified clearance for the bars.

(e) Filling. Prior to filling with concrete, the metal shells shall be again inspected. Any water or foreign substances found within shall be removed. During filling, the top 10 ft (3 m) of concrete in the piles shall be consolidated by internal vibration.

512.05 Steel Piles. Steel piles shall consist of structural steel shapes such as H-piles or other sections indicated on the plans.

(a) Splicing. Splicing of steel piles shall be as follows.

(1) Planned Splices. Planned field or shop splices may be used provided the minimum length of each segment is at least 20 ft (6 m).

(2) Unplanned Splices. Unplanned field splices shall be used as required to furnish lengths beyond those specified in Article 512.16. The length of additional segments shall be a minimum of 10 ft (3 m) unless otherwise specified by the Engineer.

All splices shall be accomplished by a complete joint penetration (CJP) weld of the entire cross-section, or by the Department's standard steel pile field splice, or by the use of a commercial splicer with a Department approved commercial splicer welding detail. Welder qualification and certification will be required for all splices according to Article 512.07.

(b) Painting and Field Connections for Trestle Bents. Before being driven or placed, all steel piles, caps, splices, and bracing members in trestle bents shall be shop painted with inorganic zinc-rich primer. When specified, after the piles are driven and all bracing members, concrete caps, and encasement are in place, all exposed steel shall be given one complete coat of field paint. All painting shall be according to Section 506.

When piles are not driven sufficiently exact to line up with bracing members, fills or shims shall be furnished and placed to secure proper attachment of the bracing.

(c) Pile Shoes. When specified, steel piles shall be fitted with pile shoes. The pile shoes shall be fastened to the piles using a 5/16 in. (8 mm) continuous fillet weld along the flange contact areas.

512.06 Timber Piles. Full length piles shall be used and no planned splices will be allowed. When unplanned splices are required to furnish lengths beyond those specified in Article 512.16, they shall be of the butt joint type and the added piece shall conform closely in diameter to the main pile at the point of splice. The pile shall be sawed square and the butt joints shall bear evenly over the entire surface. The splices shall be made by the use of at least four steel plates or a metal pipe sleeve. The plates shall be at least 4 ft (1.2 m) long, 3 1/2 in. (90 mm) wide and 3/8 in. (10 mm) thick and each plate shall be bolted to the pile with not less than two 3/4 in. (M20) bolts both above and below the joint. Pipe sleeves shall be standard steel pipe, at least 3 ft (900 mm) long and shall be fastened with not less than three 5/8 in. (M16) lag screws, 5 in. (125 mm) long, both above and below the joint. All metal used for splicing piles shall be galvanized according to Article 1006.17.

Before the splice is assembled, if the joint is to be above low ground water line, all sawed surfaces and holes in piles shall be treated according to Article 1007.13.

512.07 Welding. Welding shall be according to the applicable requirements of Article 505.04(q), except for the following.

Welders shall be qualified according to either AWS D1.1 or D1.5 Code, except the macroetch specimen requirement of the "Qualification Test for Fillet Welds Only (Option 1)" will be waived. Welding procedures are considered prequalified if consumables in Table 4.1 of the D1.5 BWC and low hydrogen practices of Section 4 in the BWC are employed. Submittal of weld procedure specifications (WPSs) for the Engineer's approval is not required, but the welder must have written WPSs for the procedures employed, showing consumables, variables (amps, volts, etc.), joint configuration, surface preparation, and preheat. Submerged arc welding (SAW) is not mandatory for CJP welds in flanges and/or webs of steel piles. Non-destructive testing of pile splices by the Contractor will not be required unless visual inspection by the Engineer indicates significant anomalies.

512.08 Storage and Handling of Piles. The method of storing and handling piles shall protect them from damage.

(a) Treated Timber Piles. Treated timber piles shall be stored at the site of the work according to Article 1007.13 and handled according to Articles 507.05 and 1007.13.

(b) Precast Concrete and Precast, Prestressed Concrete Piles. Precast concrete piles shall be lifted by suitable devices attached to the pile at not less than two points for piles up to 45 ft (14 m) long, and not less than three points for piles over 45 ft (14 m) long. Precast, prestressed concrete piles shall be lifted by suitable devices and supported during storage or transportation at not less than two points for piles up to 65 ft (20 m) long and not less than three points for piles over 65 ft (20 m) long. The locations of the points of support shall be as shown on the precast shop plans.

The piles shall be lifted by a bridle attached to the pile or special embedded or attached lifting devices. Unless special lifting devices are attached for lifting, the pickup points shall be plainly marked on all piles before removal from the casting bed and all lifting shall be done at these points. The method of handling precast concrete piles shall not induce stresses in the reinforcement in excess of 12,000 psi (83,000 kPa), using a factor of safety of two to account for impact and shock. The method of handling precast prestressed concrete piles shall not induce tensile stresses in the concrete in excess of 210 psi (1400 kPa), using a factor of safety of two to account for impact and shock.

(c) Steel Piles. The handling and storing of steel piles shall be according to Article 505.08(c).

(d) Metal Shell Piles. Metal shell piles shall be stored off the ground with sufficient cribbing to prevent bending or distortion of the pile and to prevent dirt, water, or other foreign material from entering the metal shell.

512.09 Preparation for Driving. Piles shall not be driven until after the excavation or embankment near piles for the footings, abutments, piers, or channel construction is completed. Any material forced up between the piles shall be removed to the correct elevation before concrete in the foundation is placed.

(a) Pointing Timber Piles. When shown on the plans, the piles shall be shod with metal shoes of a design satisfactory to the Engineer. The points of the piles shall be shaped to secure an even and uniform bearing on the shoes.

(b) Precast and Precast, Prestressed Concrete Piles. All piles shall be saturated with water, for the entire length of the pile, at least six hours prior to driving.

(c) Precoring Through Embankment or Dense Soils. When shown on the plans, holes as detailed shall be precored for piles which are to be driven through new embankment or dense soils. If oversize holes are drilled, the void space outside of the pile shall be filled with dry, loose sand.

512.10 Driving Equipment. The equipment for driving piles shall be according to the following.

(a) Hammers. Piles shall be driven with an impact hammer such as a drop, steam/air, hydraulic, or diesel. The driving system selected by the Contractor shall not result in damage to the pile. The impact hammer shall

be capable of being operated at an energy which will maintain a pile penetration rate between 2 and 10 blows per 1 in. (25 mm) when the nominal driven bearing of the pile approaches the nominal required bearing.

For hammer selection purposes, the minimum and maximum hammer energy necessary to achieve these penetration rates may be estimated as follows.

$E \geq 0.082 \times [R_N + 100]^2$ (English)

$E \leq 0.193 \times [R_N + 100]^2$ (English)

$E \geq 0.005 \times [R_N + 550]^2$ (metric)

$E \leq 0.012 \times [R_N + 550]^2$ (metric)

Where:

R_N = Nominal required bearing in kips (kN)
E = Energy developed by the hammer per blow in ft lb (J)

When steel piles are driven to hard rock, the penetration resistance and hammer energy may both abruptly increase, making it difficult to calculate the penetration rate and increase concern for pile tip damage. Under these conditions, the Contractor shall reduce hammer energy and/or calculate the penetration rate over a reduced penetration increment (less than 1 in. (25 mm)) to assure that the pile has obtained the nominal required bearing and has not sustained damage.

Air/Steam hammers may be single or double acting but must have a total weight of striking parts of not less than one-third of the weight (mass) of the pile and drive cap and in no case shall the striking part have a weight (mass) less than 1.4 tons (1.3 metric tons). The equipment supplied with the hammer shall maintain the pressure at the hammer that is specified by the manufacturer. The Contractor shall provide the Engineer with the hammer specifications so that the energy developed by the hammer with each blow may be determined.

Diesel hammers may be open-ended or closed-ended. Open-end single acting diesel hammers shall be equipped with either a device to measure ram impact velocity or speed of operation (with the necessary correlation charts) unless the stroke height can be directly observed to determine the energy developed by the hammer with each blow. Closed-end double acting diesel hammers shall be equipped with a bounce chamber pressure gauge that is easily readable and the Contractor shall provide a correlation chart and hammer data to determine the energy developed by the hammer with each blow.

Drop hammers shall not be used for driving precast piles or piles with a nominal required bearing exceeding 60 tons (533 kN). The hammer data shall be provided to the Engineer and the minimum ram weight (mass) of the hammer ram is 1 ton (0.9 metric tons). The fall of the ram shall be regulated so as to avoid injury to the piles, but shall in no case exceed 15 ft (4.6 m). In

no case shall the ram weight (mass) be less than the combined weight (mass) of the pile and drive cap.

Hydraulic hammers shall be equipped with an energy readout device and the Contractor shall furnish wave equation analysis to aid in the determination of the adequacy of the hammer and indicate the nominal driven bearing of the pile. The formula provided in Article 512.14 may not be used for these calculations.

Vibratory hammers may only be used to install piles when approved by the Engineer. Piles installed with vibratory hammers shall be further driven with an impact hammer until the nominal driven bearing is verified to be equal to or greater than the nominal required bearing.

(b) Drive Heads. The heads of all piles shall be protected by a pile drive head also referred to as a helmet or cap during driving. The drive head shall consist of a cast or structural steel helmet capable of holding the axis of the pile in line with the axis of the hammer.

The heads of metal shell piles shall be protected by a combination driving head and pilot capable of distributing the hammer blow uniformly across the metal shell cross section and maintaining the alignment of the pile.

(c) Hammer and Pile Cushions. The heads of timber, precast concrete, and precast, prestressed concrete piles shall be protected by a pile cushion between the pile and driving head during driving to prevent damage to the pile. The minimum pile cushion thickness prior to driving shall be 3 in. (75 mm). A new cushion shall be provided if, during driving, the cushion is either compressed to less than 60 percent of the original thickness or it begins to burn. Hammers which require a hammer cushion shall be inspected prior to driving and after each 50 hours of operation thereafter. The hammer cushion shall be replaced when there is a reduction in thickness exceeding 25 percent; or for air/steam hammers, when the reduction in thickness exceeds the manufacturer's limitations.

(d) Leads. Pile leads shall be used to maintain the alignment of the pile and hammer to assure concentric impact for each blow. Swinging leads shall be set or toed in the ground prior to the start of driving. The design of the leads shall accommodate the length of pile segments, the hammer, and other required equipment, and shall be capable of maintaining the alignment of the pile during driving within the tolerances specified.

(e) Followers. The driving of piles with followers shall be done only with the written permission of the Engineer. Followers shall be fabricated to bear evenly and concentrically on the pile as well as maintain proper alignment with the pile to efficiently deliver the energy from the hammer to the pile. The first pile in every group of ten shall be driven without a follower, by using a longer pile if necessary, and shall be used, to determine the average nominal driven bearing of the other piles in the group.

(f) Jets. Water and air jets may be used when approved by the Engineer. The jets shall have the capacity to erode the material adjacent to the pile without

causing damage to the site or affecting vertical or lateral capacity of adjacent piles. After the use of jets has been discontinued within the substructure area, the piles shall be further driven with an impact hammer until the nominal driven bearing is verified to be equal to or greater than the nominal required bearing.

512.11 Penetration of Piles. Piles shall be installed to a penetration that satisfies all of the following.

(a) The nominal driven bearing, as determined by the formula in Article 512.14, is not less than the nominal required bearing shown on the plans.

(b) The pile tip elevation is at or below the minimum tip elevation shown on the plans. In cases where no minimum tip elevation is provided, the piles shall be driven to a penetration of at least 10 ft (3 m) below the bottom of footing or below undisturbed earth, whichever is greater.

When piles fail to achieve nominal driven bearings in excess of the nominal required bearing after driving the full furnished lengths, but are within 85 percent of nominal required bearing, these piles shall be left for a minimum of 24 hours to allow for soil setup and retesting before splicing and driving additional length. After the waiting period has passed, the pile shall be redriven to check the gain in nominal driven bearing upon soil setup. The soil setup nominal driven bearing shall be based on the number of redriving blows necessary to drive the pile an additional 3 in. (75 mm) using a hammer that has been warmed up by applying at least 20 blows to another pile. These piles will be accepted if they exhibit a nominal driven bearing larger than nominal required bearing.

512.12 Tolerances in Driving. Piles shall be driven with a variation from the vertical or required batter alignment of not more than 1/4 in./ft (20 mm/m). Piles shall be driven to an accuracy where no portion of the visible pile is out of plan position by more than 6 in. (150 mm) in any direction, provided that no design modification is required to accommodate the pile location, and where forcing them into tolerance after driving would not result in injury to the piles.

512.13 Cutoffs. After driving piles, they shall be cut off perpendicular to their longitudinal axis at the elevations shown on the plans. The remaining portion of the piles shall be free of damage or bruising. All debris shall be removed and disposed of from around the piles.

The heads of all treated timber piles, when not encased in concrete, shall be field treated after cutoff according to Article 1007.13. Each pile head shall then be covered with a sheet of galvanized steel, not lighter than 24 gauge (0.701 mm) and of sufficient area to project at least 4 in. (100 mm) outside the pile at any point, which shall be bent down over the pile to fit neatly and exclude water in the best possible manner. The edges shall be trimmed neatly and fastened to the pile face with large headed galvanized roofing nails.

The cutoff portions of all piles, including test piles, shall be retained and made available for use in splicing or extending piles, if required, until the pile driving is complete. Upon completion of the work, the cutoffs shall become the property of the Contractor and shall be disposed of.

512.14 Determination of Nominal Driven Bearing. The nominal driven bearing of each pile will be determined by the FHWA modified Gates formula as follows.

$$R_{NDB} = 1.75\sqrt{E}\ Log\left(10N_b\right) - 100 \quad \text{(English)}$$

$$R_{NDB} = 7\sqrt{E}\ Log\left(10N_b\right) - 550 \quad \text{(metric)}$$

Where:

R_{NDB} = Nominal driven bearing of the pile in kips (kN)
N_b = Number of hammer blows per inch (25 mm) of pile penetration
E = Energy developed by the hammer per blow in ft lb (J)

For piles driven on a batter, the value of "E" will be multiplied by the hammer energy reduction coefficient, "U" will be determined as follows.

$$U = \frac{0.25\left(4 - m\right)}{\left(1 + m^2\right)^{0.5}} \quad \text{for drop hammers}$$

$$U = \frac{0.1\left(10 - m\right)}{\left(1 + m^2\right)^{0.5}} \quad \text{for all other hammers}$$

Where:

U = Hammer energy reduction coefficient, less than unity
m = Tangent of the angle of batter (i.e. m = .25 = 3/12 for 3H:12V batter)

The Engineer will determine the value of "E". For drop, single acting air/steam hammers, and open type diesel hammers, the kinetic energy will be used by measuring ram velocity. When measuring ram velocity is not possible, it may be approximated by the potential energy calculated by multiplying the weight (mass) of hammer striking parts by the observed fall or stroke height. For double acting air/steam hammers and closed type diesel hammers, the energy will be calculated by using ram weight (mass) and bounce chamber pressure. The Contractor shall submit hammer literature and correlation charts to aid in determining hammer energy of each blow. In either case, the calculated value of "E" will be further reduced by the hammer energy reduction coefficient "U" prior to being used in the formula to calculate "R_{NDB}" or "N_b".

The preceding formula for piles driven with a drop hammer is applicable only when: the hammer has an unrestricted free fall; the pile head is not broomed, crushed or splintered; there is no appreciable bounce of the hammer after striking the pile; and the penetration is at a uniform or uniformly decreasing rate.

When specified in the contract or when a hydraulic hammer is used, the nominal driven bearing of the piles will be determined by the results of a wave equation analysis. The analysis will take into account the hammer driving system, site specific subsurface data, and project pile geometry to develop driving criteria which will not overstress the pile and correctly indicate its nominal driven bearing.

When specified in the contract, a static pile load test shall be performed on the specified piles of a group to determine their nominal driven bearing. The pile load test shall be performed according to ASTM D 1143. Shop drawings for the design of the load test frame shall be submitted to the Engineer.

512.15 Test Piles. Test piles shall be of the same material and size, satisfy all splicing requirements, and contain any pile shoes as specified for the production piles. Test piles shall be driven with the same equipment as will be used for driving the production piles. The furnished length for test piles shall be at least 10 ft (3 m) longer than the estimated length shown on the plans.

Before driving test piles, the excavation or embankment near piles shall be within 2 ft (600 mm) of the proposed grade of the footing, pier, abutment, or channel.

Test piles shall be driven to a nominal driven bearing 50 percent greater than the nominal required bearing shown on the plans. The Engineer may stop the driving of any test pile at tip penetrations exceeding 10 ft (3 m) beyond the estimated length to check for pile setup according to Article 512.11. After any retesting, the Contractor shall recommence test pile driving, providing piling, splices, and any retests until the nominal driven bearing during driving reaches 50 percent more than the nominal required bearing or the Engineer stops the driving due to having sufficient data to provide the itemized list of furnished lengths.

Test piles driven in production pile locations that are incorporated into the structure shall be cut off as permanent piles. Test piles not driven in a production location shall be cut off or pulled, as directed by the Engineer.

512.16 Length of Piles. The Contractor shall furnish pile lengths according to a written itemized list provided by the Engineer. Should the Contractor elect to preorder piles prior to being provided with the itemized list, it shall be done at his/her own risk. The itemized list of furnished lengths will be based on the Engineer's evaluation of the test pile results, the soil boring data, and the estimated pile lengths on the plans. If the plans do not require a test pile, the itemized list of furnished lengths shall be as estimated on the plans. The length of test piles shall be according to Article 512.15.

512.17 Method of Measurement. Furnishing piles will be measured for payment in feet (meters). Measurement will include the total length of piles delivered to the site of the work, according to the itemized list furnished by the Engineer, and any additional lengths delivered for splicing as ordered by the Engineer. Measurements will be made to the nearest 0.1 ft (0.03 m).

Driving piles will be measured for payment in feet (meters). Measurement will include the total length of piles subtracting cutoffs. For precast concrete and precast, prestressed concrete piles, this length will not include extensions or the portion of the

pile cutoff to make the extension. Measurements will be made to the nearest 0.1 ft (0.03 m).

512.18 Basis of Payment. This work will be paid for as follows.

(a) Furnishing Piles. This work will be paid for at the contract unit price per foot (meter) for FURNISHING UNTREATED PILES and FURNISHING TREATED PILES, of the length specified; or FURNISHING PRECAST CONCRETE PILES, FURNISHING PRECAST PRESTRESSED CONCRETE PILES, FURNISHING METAL SHELL PILES, and FURNISHING STEEL PILES, of the size specified.

(b) Driving Piles. This work will be paid for at the contract unit price per foot (meter) for DRIVING PILES.

(c) Extensions. Extensions for precast concrete and precast, prestressed concrete piles will be paid for according to Article 109.04.

(d) Unplanned Splices. Unplanned splices for metal shell, steel, and timber piles will be paid for according to Article 109.04.

(e) Test Piles. Furnishing and driving test piles will be paid for at the contract unit price per each for TEST PILE, of the type specified. Driving test piles beyond the furnished test pile length will be paid for according to Article 109.04.

(f) Static Pile Load Tests. This work will be paid for at the contract unit price per each for PILE LOAD TEST.

(g) Pile Shoes. The furnishing and installing of pile shoes, including those for test piles driven in production locations, will be paid for at the contract unit price per each for PILE SHOES.

SECTION 513. TEMPORARY BRIDGES

513.01 Description. This work shall consist of the construction of temporary bridges, their maintenance in a safe condition for traffic, and their removal and disposal.

513.02 Design. If complete plans are not furnished by the Department, the details of design, materials to be used, sizes, spacing, and arrangement of members shall be determined by the Contractor. The highway loading, roadway width and overall length or waterway opening shall be as specified on the plans. The temporary bridge shall be designed according to the AASHTO Standard Specifications for Highway Bridges. Temporary bridge plans furnished by the Contractor shall be sealed by an Illinois licensed Structural Engineer.

513.03 Materials. All materials shall be according to Division 1000, except as modified herein. Used materials, except for anchor bolts, reinforcement bars, hardware for timber construction, and high strength bolts may be incorporated into the construction of temporary bridges provided those materials are in sound condition

and suitable for the purpose intended. All materials shall meet the approval of the Engineer as to quality and suitability for the use intended.

The outer bark shall be removed from piles in temporary bridges at points where bracing or backing is attached; otherwise, the requirements of Article 1007.08(c) concerning the removal of bark shall not apply. Galvanizing of high strength bolts, anchor bolts, and hardware for timber construction will not be required. Epoxy coating for reinforcement bars for cast-in-place construction will not be required.

CONSTRUCTION REQUIREMENTS

513.04 Excavation and Backfill. Excavation and backfill shall be according to Section 502.

513.05 Piling and Timber. Except as modified herein, all work involving timber piles shall be according to the applicable portions of Sections 507 and 512. The requirements for treatment of piling, treatment of holes and pile tops, and metal coverings for piles shall not apply.

Timber construction shall be according to the applicable portions of Section 507. The requirements regarding the use of treated timber shall not apply. Timber shall be either rough or surfaced. Countersinking will not be required, except in the vertical roadway face of wheel guards and under longitudinal floor planks.

513.06 Other Construction. Cast-in-place concrete shall be according to Section 503. New precast concrete members shall be according to the applicable portions of Section 504. The use of used precast concrete members shall be limited to the configuration and intent contemplated for the original design of the member. No cutting or splicing of used precast members will be allowed. The furnishing and erecting of structural steel shall be according to Section 505, except no painting of structural steel will be required. Reinforcement bars shall be according to Section 508. Metal railings shall be according to Section 509.

513.07 Maintenance. The Contractor shall maintain such temporary bridge in good condition. All labor and materials required for such maintenance, including the repair of any damage caused by traffic, shall be furnished by the Contractor.

513.08 Removal. After the need to maintain traffic on the temporary bridge has ceased to exist, it shall be removed and disposed of according to Article 501.04. No excavation or other material will be allowed to remain in the stream channel.

513.09 Method of Measurement. Rock excavation will be measured for payment according to Article 502.12.

513.10 Basis of Payment. This work will be paid for at the contract unit price per each for TEMPORARY BRIDGE COMPLETE.

Rock excavation will be paid for according to Article 502.13.

SECTION 514. RESERVED

SECTION 515. NAME PLATES

515.01 Description. This work shall consist of the furnishing and installing of name plates.

515.02 Materials. Name plates shall be made of brass, bronze, or other material as provided by the plans.

CONSTRUCTION REQUIREMENTS

515.03 General. The general features of design; the type, size, and spacing of letters and figures; the items of information to be shown on all name plates for structures constructed under a given contract; and the arrangement of these items shall be as shown on the plans. The surface of the name plate shall be polished.

515.04 Installation. Installation of name plates shall be as follows.

(a) Concrete Structures. On concrete structures, the name plate shall be embedded in the concrete and fastened by means of four brass or bronze bolts with countersunk heads, or four lugs cast integral with the plate. The bolts or lugs shall project at least 3 in. (75 mm) into the concrete beyond the back of the plate.

(b) Steel Truss. On steel truss spans, the plate shall be fastened on the steel member at the fabricating shop by brazing around the entire perimeter of the plate.

(c) Steel Rails. On steel rails, the plate shall be bolted on with four, 3/8 x 1 in. (M10 x 25 mm) stainless steel or brass cap screws that are self tapping or drilled and tapped in the field.

515.05 Basis of Payment. This work will be paid for at the contract unit price per each for NAME PLATES.

SECTION 516. DRILLED SHAFTS

516.01 Description. This work shall consist of constructing drilled shaft foundations.

516.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Portland Cement Concrete	1020
(b) Reinforcement Bars	1006.10
(c) Sand Cement Grout (Note 1)	1001, 1002, 1003
(d) Permanent Steel Casing	1006.05(d)

Note 1. The sand-cement grout mix shall be according to Section 1020 and shall be a 1:1 blend of sand and cement comprised of a Type I or II cement at 185 lb/cu yd (110 kg/cu m). The maximum water cement ratio shall be sufficient to provide a flowable mixture with a typical slump of 10 in. (250 mm). When soil and ground water sulfate contaminates exceed 500 parts per million, a Type V cement will be required.

516.03 Equipment. Equipment shall be according to the following.

	Item	Article/Section
(a)	Concrete Equipment	1020.03
(b)	Drilling Equipment (Note 1)	
(c)	Hand Vibrator	1103.17(a)

Note 1. The drilling equipment shall have adequate capacity, including power, torque and down thrust, to create a shaft excavation of the maximum diameter specified to a depth of 20 percent beyond the depths shown on the plans.

516.04 Submittals. The following shall be submitted.

(a) Qualifications. At the time of the preconstruction conference, the Contractor shall provide the following documentation.

(1) References. A list containing at least three projects completed within the three years prior to this project's bid date which the Contractor performing this work has installed drilled shafts of similar diameter, length, and site conditions to those shown in the plans. The list of projects shall contain names and phone numbers of owner's representatives who can verify the Contractor's participation on those projects.

(2) Experience. Name and experience record of the drilled shaft supervisor, responsible for all facets of the shaft installation, and the drill operator(s) who will be assigned to this project. The supervisor and operator(s) shall each have a minimum of three years experience in the construction of drilled shafts.

(b) Installation Procedure. A detailed installation procedure shall be submitted to the Engineer for acceptance at least 45 days prior to drilled shaft construction and shall address each of the following items unless otherwise directed by the Engineer in writing.

(1) Equipment List. List of proposed equipment to be used including cranes, drill rigs, augers, belling tools, casing, core barrels, bailing buckets, final cleaning equipment, slurry equipment, tremies, or concrete pumps, etc. Standby equipment shall be available to assure there is no delay in placing concrete once drillingpouring operations have started.

(2) General Sequence. Details of the overall construction operation sequence, equipment access, and the sequence of individual shaft

construction within each substructure bent or footing group. The submittal shall address the Contractor's proposed time delay and/or the minimum concrete strength necessary before initiating a shaft excavation adjacent to a recently installed drilled shaft.

(3) Shaft Excavation. A site specific step by step description of how the Contractor anticipates the shaft excavation to be advanced based on their evaluation of the subsurface data and conditions expected to be encountered. This sequence shall note the method of casing advancement, anticipated casing lengths, tip elevations and diameters, the excavation tools used and drilled diameters created. The Contractor shall indicate whether wet or dry drilling conditions are expected or if the water table will be sealed from the excavation.

(4) Slurry Quality Control. When the use of slurry is proposed, details covering the measurement and control of the hardness of the mixing water, agitation, circulation, de-sanding, sampling, testing, and chemical properties of the slurry shall be submitted.

(5) Shaft Cleaning and Inspection. Method(s) and sequence proposed for the shaft cleaning operation as well as recommendations on how the shaft excavation will be inspected under the installation conditions anticipated.

(6) Reinforcement Placement. Details of reinforcement placement including cage centralization devices to be used and method to maintain proper elevation and plan location of cage within the shaft excavation during concrete placement. The method(s) of adjusting the cage length if rock is encountered at an elevation other than as shown on the plans.

(7) Concrete Placement. Details of concrete placement including proposed operational procedures for free fall, tremie or pumping methods. The sequence and method of casing removal shall also be stated along with the top of pour elevation, and method of forming through water above streambed.

(8) Mix Design. The proposed concrete mix design(s).

The Engineer will evaluate the drilled shaft installation procedure and notify the Contractor of acceptance, need for additional information, or concerns with the installation's effect on the existing or proposed structure(s).

CONSTRUCTION REQUIREMENTS

516.05 General. Excavation for drilled shaft(s) shall not proceed until written authorization is received from the Engineer. The Contractor shall furnish an installation log for each shaft installed. The Contractor shall be responsible for verification of the dimensions and alignment of each shaft excavation as directed by the Engineer.

Unless otherwise approved in the Contractor's installation procedure, no shaft excavation shall be made within four shaft diameters center to center of a shaft with concrete that has a compressive strength less than 1500 psi (10,300 kPa). The site-specific soil strengths and installation methods selected will determine the actual required minimum spacing, if any, to address vibration and blow out concerns.

516.06 Construction Methods. The construction of drilled shafts may involve the use of one or more of the following methods to support the excavation during the various phases of shaft drilling, cleaning, and concrete placement dependent on the site conditions encountered. Surface water shall not be permitted to enter the hole.

The following are general descriptions indicating the conditions when these methods may be used.

(a) Dry Method. The dry method consists of drilling the shaft excavation, removing accumulated water and loose material from the excavation, and placing the reinforcing cage and concrete in a predominately dry excavation. This method shall be used only at sites where the groundwater and soil conditions are suitable to permit the drilling and dewatering of the excavation without causing excessive water infiltration, boiling, squeezing, or caving of the shaft side walls. This method allows the concrete placement by tremie or concrete pumps, or if the excavation can be dewatered, the concrete can be placed by free fall within the limits specified for concrete placement according to Article 516.12.

(b) Wet Method. The wet construction method may be used at sites where dewatering the excavation would cause collapse of the shaft sidewalls or when the volume and head of water flowing into the shaft is likely to contaminate the concrete during placement resulting in a shaft defect. This method uses water or slurry to maintain stability of the shaft perimeter while advancing the excavation. After the excavation is completed, the water level in the shaft is allowed to seek equilibrium, the base is cleaned, the reinforcing cage is set, and the concrete is discharged at the base using a tremie pipe or concrete pump, displacing the drilling fluid upwards.

(c) Temporary Casing Method. Temporary casing shall be used when either the wet or dry methods provide inadequate support to prevent sidewall caving or ensure excessive deformation of the hole. Temporary casing may also be used to reduce the flow of water into the excavation to allow dewatering, adequate cleaning, and inspection, or to insure proper concrete placement. Temporary casing left in place may constitute a shaft defect; no temporary casing will be allowed to remain permanently in place without the specific approval of the Engineer.

Before the temporary casing is broken loose, the level of concrete in the casing shall be a minimum of 5 ft (1.5 m) above the bottom of the casing. The casing shall not be broken loose by any method which may cause separation of the concrete. After being broken loose and as the casing is withdrawn, additional concrete shall be added to maintain sufficient head so that water and soil trapped behind the casing can be displaced upward and discharged at the ground surface without contaminating the concrete in the shaft or at the finished construction joint.

(d) Permanent Casing Method. When called for on the plans or proposed as part of the Contractor's accepted installation procedure, the Contractor shall install a permanent casing of the diameter, length, thickness, and strength specified. When permanent casings are used, the lateral loading design requires intimate contact between the casing and the surrounding soils. If the installation procedure used to set the permanent casing results in annular voids between the permanent casing and the drilled excavation, the voids shall be filled with a sand-cement grout to maintain the lateral load capacity of the surrounding soil, as assumed in the design. No permanent casing will be allowed to remain in place beyond the limits shown on the plans without the specific approval of the Engineer. A sand-cement grout mix shall be used to fill any visible gaps, which may exist between the permanent casing and either the drilled excavation or temporary casing.

(e) Removable Forms. When the shaft extends above the streambed through a body of water and permanent casing is not shown, the portion above the streambed shall be formed with removable casings, column forms, or other forming systems as approved by the Engineer. The forming system shall not scar or spall the finished concrete or leave in place any forms or casing within the removable form limits as shown on the plans unless approved as part of the installation procedure. The forming system shall not be removed until the concrete has attained a minimum compressive strength of 2500 psi (17,200 kPa) and cured for a minimum of 72 hours. For shafts extending through water, the concrete shall be protected from water action after placement for a minimum of seven days.

516.07 Slurry. If the Contractor proposes to use a method of slurry construction, it shall be submitted with the installation plan. Measures for preventing anomalies from sand fallout shall be included in the plan. During construction, the level of the slurry shall be maintained at a height sufficient to prevent caving of the hole. In the event of a sudden or significant loss of slurry to the hole, the construction of that foundation shall be stopped and the shaft excavation backfilled or supported by temporary casing, until a method to stop slurry loss, or an alternate construction procedure has been approved by the Engineer.

516.08 Excavation Cleaning and Inspection. Materials removed or generated from the shaft excavations shall be disposed of according to Article 202.03.

After excavation, each shaft shall be cleaned. The cleaning operation shall result in at least of 50 percent of the base of each shaft having less than 1/2 in. (13 mm) of sediment or debris at the time of concrete placement. The depth of sediment or debris at any place on the base of the shaft shall be a maximum of 1 1/2 in. (38 mm).

Shaft cleanliness shall be determined using the methods as submittedaccepted in the installation procedure.

A shaft excavation shall be overreamed when, in the opinion of the Engineer, the sidewall has softened, swelled, or has a buildup of slurry cake. Overreaming may also be required to correct a shaft excavation which has been drilled out of tolerance. Overreaming may be accomplished with a grooving tool, overreaming bucket, or

other approved equipment. Overreaming thickness shall be a minimum of 1/2 in. (13 mm).

516.09 Top of Rock. The top of rock will be considered as the point where rock, defined as bedded deposits and conglomerate deposits exhibiting the physical characteristics and difficulty of rock removal as determined by the Engineer, is encountered which cannot be drilled with earth augers and/or underreaming tools configured to be effective in the soils indicated in the contract documents, and requires the use of special rock augers, core barrels, air tools, blasting, or other methods of hand excavation.

516.10 Design Modifications. If the top of rock elevation differs from that shown on the plans by more than 10 percent of the length of the shaft above the rock, the Engineer shall be contacted to determine if any drilled shaft design changes may be required. In addition, if the type of soil or rock encountered is not similar to that shown in the subsurface exploration data, the Contractor may be required to extend the drilled shaft length(s) beyond those specified in the plans. In either case, the Engineer will determine if revisions are necessary and the extent of the modifications required.

516.11 Reinforcement. This work shall be according to Section 508 and the following.

The shaft excavation shall be cleaned and inspected prior to placing the reinforcement cage. The reinforcement cage shall be completely assembled prior to drilling and be ready for adjustment in length as required by the conditions encountered. The cage shall be lifted using multiple point sling straps or other approved methods to avoid cage distortion or stress. Additional cross frame stiffeners may also be required for lifting or to keep the cage in proper position during lifting and concrete placement.

The Contractor shall attach suitable cage centralizers to keep the cage away from the sides of the shaft excavation during placement and to ensure that at no point will the finished shaft have less than the minimum concrete cover(s) shown on the plans. The cage centralizers or other approved non-corrosive spacing devices shall be used at sufficient intervals (near the bottom and at intervals not exceeding 10 ft (3 m) throughout the length of the shaft) to ensure proper cage alignment and clearance for the entire shaft.

If the conditions differ such that the length of the shaft is increased, additional longitudinal bars shall be either mechanically spliced or lap spliced to the lower end of the cage and confined with either hoop ties or spirals. The Contractor shall have additional reinforcement available or fabricate the cages with additional length as necessary to make the required adjustments in a timely manner as dictated by the encountered conditions. The additional reinforcement may be non-epoxy coated. Any reinforcement fabricated in advance but not incorporated into the shaft(s) shall remain the property of the Contractor.

516.12 Concrete Placement. Concrete work shall be performed according to Section 503 and the following.

Concrete shall be placed as soon as possible after reinforcing steel is set and secured in proper position. The pour shall be made in a continuous manner from the bottom to the top elevation of the shaft as shown on the contract plan or as approved in the Contractor's installation procedure. Concrete placement shall continue after the shaft excavation is full and until good quality, uncontaminated concrete is evident at the top of shaft. The elapsed time from the beginning of concrete placement in the shaft to the completion of the placement shall not exceed two hours. At no time during construction shall the slump loss result in a slump below the minimum specified. The Contractor may request a longer placement time provided the concrete mix maintains the minimum specified slump requirements over the longer placement time as demonstrated by trial mix and slump loss tests. Vibration of the concrete will not be allowed when the concrete is displacing drilling fluid or water. In dry excavations, the concrete in the top 10 ft (3 m) of the shaft shall be vibrated.

When the top of the shaft is at the finished elevation and no further concrete placement above the finished elevation is specified, the top of the shaft shall be level and finished according to Article 503.15(a).

Concrete shall be placed by free fall, tremie, or concrete pump subject to the following conditions.

(a) Free Fall Placement. The free fall placement shall only be permitted in shafts that can be dewatered to ensure less than 3 in. (75 mm) of standing water exist at the time of placement without causing side wall instability. The height of free fall placement shall be a maximum of 60 ft (18.3 m). Concrete placed by free fall shall fall directly to the base without contacting either the rebar cage or shaft sidewall. Drop chutes may be used to direct concrete to the base during free fall placement.

Drop chutes used to direct placement of free fall concrete shall consist of a smooth tube of either one continuous section or multiple pieces that can be added and removed. Concrete may be placed through either a hopper at the top of the tube or side openings as the drop chute is retrieved during concrete placement. The drop chute shall be supported so that the free fall does not exceed 60 ft (18.3 m) at all times and to ensure the concrete does not strike the rebar cage. If placement cannot be satisfactorily accomplished by free fall in the opinion of the Engineer, either a tremie or pumping shall be used to accomplish the pour.

(b) Tremies and Concrete Pumps. Tremies shall consist of a tube of sufficient length, weight, and diameter to discharge the initial concrete at the base of the shaft. The tremie shall be according to Article 503.08 and contain no aluminum parts that may have contact with the concrete. The inside and outside surfaces of the tremie shall be clean and smooth to permit both flow of concrete and unimpeded withdrawal during concrete placement.

Pumps and lines may be used for concrete placement and shall have a minimum 4 in. (100 mm) diameter.

Tremies and pump lines shall be pre-lubricated with a cement/water mixture, and the excess material wasted before concrete placement begins.

The tremie or pump lines used for wet method concrete placement shall be watertight and not begin discharge until placed within 10 in. (250 mm) of the shaft base. Valves, bottom plates, or plugs may be used only when they can be removed from the excavation or be of a material approved by the Engineer that will not cause a defect in the shaft if not removed. The discharge end shall be immersed at least 5 ft (1.5 m) in concrete at all times after starting the pour. Sufficient concrete head shall be maintained in the tremie at all times to prevent water or slurry intrusion in the shaft concrete.

516.13 Construction Tolerances. The following construction tolerances shall apply to all drilled shafts.

(a) Center of Shaft. The center of the drilled shaft shall be within 3 in. (75 mm) of the plan station and offset at the top of the shaft.

(b) Center of Reinforcement Cage. The center of the reinforcement cage shall be within 1 1/2 in. (40 mm) of plan station and offset at the top of the shaft.

(c) Vertical Plumbness of Shaft. The out of vertical plumbness of the shaft shall not exceed 1.5 percent.

(d) Vertical Plumbness of Reinforcement Cage. The out of vertical plumbness of the shaft reinforcement cage shall not exceed 0.83 percent.

(e) Top of Shaft. The top of the shaft shall be no more than 1 in. (25 mm) above and no more than 3 in. (75 mm) below the plan elevation.

(f) Top of Reinforcement Cage. The top of the reinforcing steel cage shall be no more than 1 in. (25 mm) above and no more than 3 in. (75 mm) below the plan elevation.

(g) Excavation Equipment. Excavation equipment and methods used to complete the shaft excavation shall have a nearly planar bottom. The cutting edges of excavation equipment used to create the bottom of shafts in rock shall be normal to the vertical axis of the shaft within a tolerance of 6.25 percent.

516.14 Obstructions. Obstructions shall be defined as any object that cannot be removed with normal earth drilling procedures, but requires special augers, tooling, core barrels, or rock augers to remove the obstruction. When obstructions are encountered, the Contractor shall notify the Engineer and upon concurrence of the Engineer, the Contractor shall begin working to core, break up, push aside, or remove the obstruction.

516.15 Method of Measurement. This work will be measured for payment in place and the volume computed in cubic yards (cubic meters). The volume will be computed using the plan diameter of the shaft multiplied by the measured length of the shaft. The length of shaft in soil will be computed as the difference in elevation between the top of the drilled shaft shown on the plans, or as installed as part of the Contractor's installation procedure, and the bottom of the shaft or the top of rock (when present) whichever is higher. The length of shaft in rock will be computed as

the difference in elevation between the measured top of rock and the bottom of the shaft.

When permanent casing is specified, it will be measured for payment in place, in feet (meters). Permanent casing installed at the Contractor's option will not be measured for payment.

Reinforcement furnished and installed will be measured for payment according to Article 508.07.

516.16 Basis of Payment. This work will be paid for at the contract unit price per cubic yard (cubic meter) for DRILLED SHAFT IN SOIL, and/or DRILLED SHAFT IN ROCK.

Permanent casing will be paid for at the contract unit price per foot (meter) for PERMANENT CASING.

Reinforcement furnished and installed will be paid for according to Article 508.08.

Obstruction mitigation will be paid for according to Article 109.04.

SECTION 520. BRIDGE EXPANSION JOINTS

520.01 Description. This work shall consist of constructing bridge expansion joints.

520.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Preformed Elastomeric Joint Seals for Bridge Decks	1053.02
(b) Preformed Elastomeric Strip Seals for Bridge Decks	1053.03
(c) Structural Steel	1006.04
(d) Neoprene Expansion Joint	1052
(e) Stud Shear Connectors	1006.32
(f) Fabric Reinforced Elastomeric	1028
(g) Stainless Steel Hardware	1006.29(d)
(h) Chemical Adhesive Resin System	1027.021

CONSTRUCTION REQUIREMENTS

520.03 Steel Fabrication. The plates, angles, and other structural shapes supporting joint seals shall be fabricated to satisfy shop drawing details and conform to the configuration of the concrete deck or sidewalk. The fabrication shall be according to Articles 505.04 through 505.10. The anchor studs shall be welded prior to painting or galvanizing.

For finger plate expansion joints the fabricator shall be certified according to Article 106.08(b) and shop drawings shall be submitted according to Article 505.03. For other joints, shop drawings need not be submitted for approval before fabrication,

but the manufacturer shall supply them with the completed joint to the Contractor and Engineer.

The manufacturer shall have current, pre-approved shop standards detailing the various standard components for the joint system(s) supplied on file with the Department prior to installation. The pre-approved shop standards shall be included with the shop drawings.

After fabrication, the steel plates or locking edge rail supports shall receive one shop coat of paint according to Section 506. At the manufacturer's option, the steel components may be hot dip galvanized according to AASHTO M 111 and ASTM A 385 in lieu of shop painting.

520.04 Joint Opening. The components of the joint system shall be properly aligned and set prior to casting them into the deck or anchorage material. The joint opening shall be adjusted according to the temperature at the time of placing so that the specified opening will be secured at a temperature of 50 ºF (10 ºC). The opening for each 100 ft (10 m) of bridge between the nearest fixed bearings each way from the joint shall be reduced 1/8 in. (1 mm) from the amount specified, for each 15 ºF (8 ºC) the temperature at the time of placing exceeds 50 ºF (10 ºC) and increased 1/8 in. (1 mm) from the amount specified, for each 15 ºF (8 ºC) the temperature at the time of placing is below 50 ºF (10 ºC).

520.05 Joint Preparation. Prior to installation of the joint seal, all thin shells of mortar and projections of concrete into and around the joint space likely to spall under movement or prevent the proper operation of the joint shall be carefully removed and all forms and debris shall be removed from the joint opening.

520.06 Preformed Elastomeric Joint Seals. Joints shall be clean immediately prior to application of the adhesive. Temperature limitations of the adhesive, as specified by the manufacturer, shall be observed. The seal shall be installed in a compressed condition and secured in place with adhesive covering both sides of the seal over the full area in contact with the sides of the joint. The seal shall be in one continuous piece for the full length of the joint. The continuous piece for installation shall not have more than one manufacturer's butt splice within its length. If the splice is torn or damaged, the seal shall be replaced.

520.07 Neoprene Expansion Seals. The neoprene expansion seals shall be installed according to the manufacturer's specifications, shop drawings, and as specified herein. The shop drawings, along with joint details, shall include details of the concrete blockout, if required for the installation, a layout plan of the joint units to be used, and the spacing and location of the anchor bolts or studs.

Anchors shall be properly positioned by the use of a suitable template and shall be cast-in-place bolts or by drilling and setting anchor rods according to Article 509.06.

Concrete or metal surfaces on which the neoprene expansion joints are to be set shall be dry, clean, level, and sound with no broken or spalled concrete. Adjacent joint seats shall be on a common plane with each other. Joint seals shall not be placed until the Engineer has approved the blockout. Errors shall be corrected by

grinding or other approved procedures, including, if necessary, concrete removal and replacement to obtain proper alignment.

The neoprene molded sealing element shall be furnished and installed in one continuous, unbroken length for the entire joint length including parapets, curbs, and walls. The seal shall be installed in an adhesive/sealant bedding compound in the blockout as shown on the plans. Neoprene surfaces to be in contact with adhesive shall be cleaned with a solvent as recommended by the manufacturer, prior to installation. The adhesive/sealant shall be liberally applied over the entire blockout or metal seat area as the sealing element is set into it. The anchor blocks shall then be set in position over the seal with the nuts torqued to at least 65 ft lb (90 N m). A minimum of 24 hours after initial installation, the nuts shall be retorqued to the initial 65 ft lb (90 N m).

Prior to filling the space in the bolt wells, the Engineer's inspection of the anchor fasteners and tightening of the units will be required. All joints between units, around connecting bolts, and cavity plugs shall be sealed in a neat manner. Neoprene surfaces to be in contact with sealant shall be cleaned with a solvent as recommended by the manufacturer prior to sealing.

Where longitudinal joints intersect with transverse joint seals, a positive seal shall be provided by flattening and extending the longitudinal joint neoprene seal element under the transverse joint pad. When this procedure is not practical, a separate neoprene apron, bonded to the longitudinal seal element, may be used.

The finished joint shall present a smooth, neat appearance with no protruding bolts or rough joints. Excess sealant shall be wiped or scraped away before it becomes hard. Upon completion of an entire joint, the Contractor shall grind any uneven end butt connections flush. Any openings between butt ends not showing sealant to the top shall be cleaned and filled with sealant. Where the joint pads are inset into the concrete blockouts, the edges between the concrete and the pads shall be sealed with sealant. When the bridge deck is to be waterproofed and surfaced, the installation of the joint shall be completed prior to placement of the deck waterproofing and hot-mix asphalt (HMA) surfacing.

520.08 Preformed Elastomeric Strip Seals. Preformed elastomeric strip seals (strip seals) shall be installed according to the manufacturer’s specifications and as specified herein.

The steel locking edge support rails for strip seals shall be either a one-piece extrusion (rolled section) or a combination of extruded and stock plate, shop welded according to Section 505. The locking portion of the steel edge support rail shall be extruded, with a cavity, properly shaped to allow the insertion of the strip seal gland and the development of a mechanical interlock. The top of the steel edge support rails shall be smooth and free of burrs.

Preparation and placement of the gland will only be allowed after the anchoring material has fully cured.

Prior to placement of the strip seal, the cavity shall be cleaned of debris. Surface rusting shall be removed and any bare steel touched up according to Article 506.05. The steel extrusion cavities shall be kept clean and dry until the strip seal is placed.

The placement of the strip seal will only be permitted when the ambient air and steel substrate temperatures are above the minimum temperature recommended by the manufacturer. Prior to inserting the strip seal in the steel retainer cavities, the "locking ears" portion of the seal shall be coated with adhesive/lubricant. A maximum of 5 ft (1.5 m) of gland shall be coated at a time to prevent the lubricant/adhesive from drying prior to insertion into the cavities of the steel locking edge rails. After each section is coated, the coated portion of the seal shall be inserted in the steel locking edge rail cavities.

520.09 Finger Plate Expansion Joint. This work shall include all stools, shims, sliding and bent plates, fabric reinforced elastomeric trough, and other associated hardware necessary to construct the finger plate joint as detailed.

The fabric reinforced elastomeric trough and flaps shall not be installed until all structural steel has been field painted. For abutment finger plate joints the trough shall be connected to the abutment backwall with predrilled anchor bolts utilizing the 1/4 x 2 in. (6 x 50 mm) plate as a template for drilling the holes. Cast in place concrete inserts will not be allowed. Following installation of the trough flattening plate, a suitable sealant shall be applied to prevent leakage between the trough and the backwall.

520.10 End Treatment. The end treatment for curbs, parapets, and sidewalks shall be as detailed on the plans and as recommended by the manufacturer of the joint system.

520.11 Technical Support. The manufacturer shall supply technical support during surface preparation and the installation of the entire joint system.

520.12 Method of Measurement. This work will be measured for payment in place, in feet (meters), along the centerline of the joint.

When paid for as a separate item, fabric reinforced elastomeric trough will be measured for payment in place, in feet (meters), along the centerline of the trough flow line.

520.13 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for PREFORMED JOINT SEAL, of the design movement specified; PREFORMED JOINT STRIP SEAL, or FINGER PLATE EXPANSION JOINT, of the design movement specified; NEOPRENE EXPANSION JOINT, of the expansion range specified; or NEOPRENE EXPANSION JOINT (DAM).

When a pay item is provided in the contract, the trough for finger plate expansion joints and all associated hardware will be paid for at the contract unit price per foot (meter) for FABRIC REINFORCED ELASTOMERIC TROUGH.

SECTION 521. BEARINGS

521.01 Description. This work shall consist of furnishing and installing bearings.

521.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Elastomeric Bearings	1083
(b) Structural Steel	1006.04
(c) Anchor Bolts and Rods	1006.09

CONSTRUCTION REQUIREMENTS

521.03 Metal Bearings. Metal bearings and metal bearing components shall be fabricated according to Section 505. Exposed surfaces and other portions of the structural steel bearing plates shall be painted according to Article 506.05. During cleaning and painting, the stainless steel and TFE sheet sliding surfaces and elastomers shall be protected from abrasion and paint.

521.04 Shipping and Handling. The bearing assemblies shall be furnished as a complete unit from one manufacturing source. Bearing assemblies shall be furnished, packaged, and handled in such a manner that the bearing assembly will be protected from damage.

521.05 Setting of Bearings. Fixed and expansion bearings on concrete shall be set level and not be placed upon areas that are improperly finished, damaged, or irregular. The concrete under each bearing shall be finished smooth and level, within 1/8 in. (3 mm) of the specified elevation before the bearings are placed.

The location of expansion bearings shall correspond with the temperature at the time of erection.

Leveling plates, pads, and/or adjustment shims shall be placed as shown on the plans.

Bearing plates to be cast into concrete superstructures shall be secured in the proper position, and all wedges or blocking used to position expansion bearings shall be removed as soon as practicable after the concrete is placed.

521.06 Anchor Bolts, Rods, and Side Retainers. Anchor bolts and rods shall be hot-dip galvanized. Side retainers shall be painted according to Article 505.06 or hot-dip galvanized according to Article 506.04.

Anchor rods shall be drilled and set according to Article 509.06, except where anchor bolts are cast into the concrete. Before setting anchor rods with chemical adhesive, hole depths and diameters in the concrete will be verified. Holes shall be kept dry and shall be blown clean prior to installing the anchor rods.

After the anchors are installed, the upper end will be checked to verify proper embedment. Anchor lengths shall leave the exposed end projecting between 1/2 in. (13 mm) and 2 in. (50 mm) above the top of the nut. Nuts for anchors in non-moving elements shall be installed snug tight by a few impacts of an impact wrench or the full force of a worker using an ordinary spud wrench. The nuts on anchors through moving parts at expansion bearings shall be adjusted to provide clearance as shown on the plans.

All side retainers shall be secured in place prior to forming the bridge deck.

521.07 Work Under Separate Contracts. When the fabrication and erection of elastomeric bearings and other collateral work are accomplished under separate contracts, the requirements of Article 505.09 shall apply.

521.08 Method of Measurement. Elastomeric bearings will be measured for payment as each. When paid for as a separate item, steel bearings, will be measured for payment as each. Each will be defined as one complete bearing assembly.

When paid for as a separate item, anchor bolts will be measured for payment as each. Each will be defined as an anchor bolt assembly which shall include all washers, nuts, and chemical adhesive necessary to install one anchor bolt.

521.09 Basis of Payment. Elastomeric bearings fabricated and erected under a single contract will be paid for at the contract unit price per each for ELASTOMERIC BEARING ASSEMBLY, of the type specified.

Elastomeric bearings fabricated under a separate contract will be paid for at the contract unit price per each for FURNISHING ELASTOMERIC BEARING ASSEMBLY, of the type specified. Storage and care of fabricated elastomeric bearings by the fabrication Contractor beyond the specified storage period, will be paid for at the contract unit price per calendar day for STORAGE OF ELASTOMERIC BEARING ASSEMBLIES when a pay item is provided for in the contract, or will be paid for according to Article 109.04 when a pay item is not provided for in the contract.

Elastomeric bearings erected under a separate contract will be paid for at the contract unit price per each for ERECTING ELASTOMERIC BEARING ASSEMBLY, of the type specified.

When an elastomeric bearing is requested by the Department for testing, the furnishing and delivering of the additional bearing assembly will be paid for according to Article 109.04.

When steel bearings are paid for separately, this work will be paid for at the contract unit price per each for STEEL BEARING ASSEMBLY.

When paid for as a separate item, anchor bolts will be paid for at the contract unit price per each for ANCHOR BOLTS, of the diameter specified.

CULVERTS

SECTION 540. BOX CULVERTS

540.01 Description. This work shall consist of constructing cast-in-place concrete and precast concrete box culverts.

540.02 Materials. Materials shall be according to the following.

	Item	Article/Section
(a)	Cast-In-Place Culverts	503.02
(b)	Precast Culverts	504.02
(c)	Coarse Aggregate (Note 1)	1004.05
(d)	Mastic Joint Sealer for Pipe	1055
(e)	External Sealing Band	1057
(f)	Geotechnical Fabric (Note 2)	1080.01

Note 1. The porous granular material placed below a precast box shall be gradation CA 7, CA 11, or CA 18.

Note 2. The minimum weight of the fabric shall be 4 oz/sq yd (135 g/sq m).

540.03 Equipment. Equipment shall be according to Articles 503.03 and 504.03.

CONSTRUCTION REQUIREMENTS

540.04 General. Cast-in-place concrete box culverts shall be constructed according to the applicable portions of Section 503.

The Contractor shall have the option, when a cast-in-place concrete box culvert is specified, of constructing the box culvert using precast box culvert sections when the design cover is 6 in. (150 mm) minimum. The precast box culvert sections shall be designed for the same design cover and live load shown on the plans for cast-in-place box culvert and shall be of equal or larger size opening.

The Contractor shall be responsible for diverting the water flow from the construction area using a method meeting the approval of the Engineer.

The excavation and backfilling for concrete box culverts shall be according to Section 502.

540.05 Cast-In-Place Concrete Box Culverts. Concrete culvert footings shall be considered as consisting of all monolithic wingwall footings, all curtain walls below the flow line of the barrel, the base slab, and the sidewalls and wingwalls to a height of approximately 6 in. (150 mm) above the base slab.

The footings shall be placed as a monolith and allowed to set for a period of time sufficient to preclude the possibility of damage by subsequent work. In the construction of box culverts 6 ft (2 m) or less in vertical clearance, the side walls and

top slab may be constructed as a monolith in the same placing operations. When this method of construction is used, any necessary construction joints shall be vertical and at right angles to the axis of the culvert. In box culverts of sufficient size to prohibit that part above the footing being completed in one continuous operation, horizontal construction joints will be permitted below the top slab at locations shown on the plans. A horizontal construction joint will be required below the top slab of any culvert having a vertical clearance of more than 6 ft (2 m).

Cast-in-place concrete culvert slabs built to roadway grade shall be finished according to Article 503.16(a).

540.06 Precast Concrete Box Culverts. End sections may be precast or cast-in-place. Cast-in-place end sections shall include all cast-in-place collars, headwalls, cutoff walls, wingwalls, footings, and reinforcement necessary to complete the end sections.

Where cast-in-place headwalls and vertical cantilever wingwalls are used as shown in the contract plans, they shall be collared around the end of the precast section. Where cast-in-place horizontal cantilever wingwalls are used as shown in the contract plans, they shall be poured monolithically with at least 6 ft (2 m) of cast-in-place box section. The cast-in-place box section shall be collared around the end of the precast section. The cast-in-place collars shall be reinforced.

Shop drawings shall be submitted according to Article 1042.03(b) for all precast concrete box culvert sections, precast or cast-in-place end sections and headwalls, and cast-in-place collars. Shop drawings for precast concrete box culvert sections which satisfy the standard shapes, reinforcement, and detailing of AASHTO M 259 or M 273 are not required to be reviewed and approved by the Engineer.

The excavation and backfilling for precast concrete box culverts shall be according to the requirements of Section 502, except a layer of porous granular material, at least 6 in. (150 mm) in thickness, shall be placed below the elevation of the bottom of the box. The porous granular material shall extend at least 2 ft (600 mm) beyond each side of the box. The precast concrete box culvert shall be laid according to the applicable requirements of Article 542.04(d). After installation, the interior and exterior joint gap between precast concrete box culvert sections shall be a maximum of 1 1/2 in. (38 mm).

The joints between precast box sections shall be sealed and all voids filled with a mastic joint sealer. In addition, the joints shall be externally sealed on all four sides using either 13 in. (325 mm) wide external sealing bands or 24 in. (600 mm) wide nonwoven geotechnical fabric. The seal or fabric shall be centered over the joint and secured to remain in place during the backfilling operation.

When multi-cells are used, a 3 in. (75 mm) nominal space shall be left between adjacent sections. After the precast cells are in place and backfill has been placed to midheight of the precast concrete box sections on each side, the space between the cells shall be filled with Class SI concrete. The Class SI concrete shall be according to Section 1020, except the maximum size coarse aggregate shall be 3/8 in. (10 mm).

540.07 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. Concrete for cast-in-place box culverts will be measured for payment in cubic yards (cubic meters) as specified in Article 503.21.

Reinforcement bars for cast-in-place concrete box culverts will be measured for payment in pounds (kilograms) as specified in Article 508.07.

When precast concrete box culverts are specified on the plans, they will be measured for payment in feet (meters), except the length measured shall not exceed the length shown on the plans or authorized by the Engineer. The overall length shall be measured as shown on the plans along the centerline of each cell of the culvert. The end sections will be measured for payment in place as each.

540.08 Basis of Payment. Cast-in-place concrete box culverts will be paid for at the contract unit price per cubic yard (cubic meter) for CONCRETE BOX CULVERTS. Reinforcement will be paid for according to Article 508.08.

Expansion bolts will be paid for at the contract unit price per each for EXPANSION BOLTS of the size indicated.

When specified on the plans, precast concrete box culverts will be paid for at the contract unit price per foot (meter) for PRECAST CONCRETE BOX CULVERTS of the size specified.

End sections will be paid for at the contract unit price per each for BOX CULVERT END SECTIONS of the culvert number specified. If the Contractor, with the approval of the Engineer, elects to use a different end section from that shown on the plans, no adjustment in the cost of the precast box culverts or end sections will be allowed.

When the plans specify cast-in-place concrete box culvert and the Contractor, at his/her option, constructs the alternate precast concrete box culvert, no adjustment in the cost for the specified cast-in-place culvert will be allowed. Compensation under the contract bid items for concrete box culverts and reinforcement bars shall cover the cost of the precast concrete box culvert alternate complete.

SECTION 541. CORRUGATED STRUCTURAL PLATE DRAINAGE STRUCTURES

541.01 Description. This work shall consist of furnishing and installing corrugated structural plate pipe culverts, corrugated structural plate pipe arches and corrugated structural plate arches, fabricated and erected in sections.

541.02 Materials. Materials shall be according to the following.

	Item	Article/Section
(a)	Corrugated Structural Plate Pipe, Pipe Arches, and Arches (Note 1) (Note 2)	1006.02
(b)	Fine Aggregate	1003.04
(c)	Portland Cement Concrete	1020

Note 1. The Department reserves the right to specify either steel or aluminum alloy. When a particular material is specified, no other material will be permitted.

Note 2. All steel channels, angles, bolts, washers, or other hardware shall be galvanized by the hot-dip process after fabrication.

When metric sizes are specified on the plans, the next larger available manufactured English size may be used at no additional cost to the Department.

541.03 Plates. Plates shall consist of structural units of steel or aluminum alloy furnished in standard sizes to permit structure length increments of 2 ft (600 mm). The corrugations shall run at right angles to the longitudinal axis of the structure.

The plates at longitudinal and circumferential seams shall be staggered so that not more than three plates come together at one point.

The minimum cover over the top of corrugated structural plate drainage structures shall be as shown in Tables I and II for structural plate pipes and pipe arches. The minimum cover for arches shall be one sixth of the span length, but not less than 1 ft (300 mm).

Plates for corrugated structural plate pipe culverts and for corrugated structural plate pipe arches shall be furnished in the thickness shown in Tables I and II for the respective size and cover over the pipe.

Plates for corrugated structural plate arches shall be furnished in the thickness shown on the plans.

TABLE IA
Wall Thickness (inches) for Corrugated Steel Structural Plate Pipe Culverts for H-20 Loading

Dia. of Pipe (in.)	Height of Cover to Nearest Foot														
	1.0*	1.5*	2.0* thru 14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0
60.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
66.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
72.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
78.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
84.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
90.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
96.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
102.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140
108.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140
114.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140
120.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140
126.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140
132.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140
138.0		0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140
144.0		0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
150.0			0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
156.0			0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
162.0			0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
168.0			0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
174.0			0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170
180.0			0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170

* Required minimum cover.

TABLE IA continued
Wall Thickness (inches) for Corrugated Steel Structural Plate Pipe Culverts for H-20 Loading

Dia. of Pipe (in.)	Height of Cover to Nearest Foot													
	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0
60.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
66.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
72.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140
78.0	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140
84.0	0.111	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
90.0	0.111	0.111	0.111	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
96.0	0.111	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
102.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
108.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140
114.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170
120.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170
126.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170
132.0	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170
138.0	0.140	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
144.0	0.140	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
150.0	0.140	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
156.0	0.140	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188
162.0	0.140	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188
168.0	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188	0.188	0.188
174.0	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188	0.188	0.188	0.188
180.0	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.188	0.188	0.188	0.188	0.188	0.188

TABLE IA (Metric)
Wall Thickness (millimeters) for Corrugated Steel Structural Plate Pipe Culverts for M 18 Loading

Dia. of Pipe (mm)	Height of Cover to Nearest 0.1 Meter														
	0.3*	0.5*	0.6* thru 4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.6	7.9
1500	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1650	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1800	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1950	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2100	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2250	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2400	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
2550		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56
2700		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56
2850		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56
3000		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56
3150		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56
3300		2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56
3450		2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56
3600		2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
3750			2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
3900			2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
4050			2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
4200			2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
4350			2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32
4500			2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32

* Required minimum cover.

TABLE IA (Metric) continued
Wall Thickness (millimeters) for Corrugated Steel Structural Plate Pipe Culverts for M 18 Loading

Dia. of Pipe (mm)	Height of Cover to Nearest 0.1 Meter													
	8.2	8.5	8.8	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9	12.2
1500	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1650	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82
1800	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56
1950	2.82	2.82	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2100	2.82	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2250	2.82	2.82	2.82	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2400	2.82	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2550	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2700	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
2850	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32
3000	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32
3150	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32
3300	3.56	3.56	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3450	3.56	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3600	3.56	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3750	3.56	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
3900	3.56	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78
4050	3.56	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78
4200	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78	4.78	4.78
4350	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78	4.78	4.78	4.78
4500	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.78	4.78	4.78	4.78	4.78	4.78

TABLE IB
Wall Thickness (inches) for Corrugated Aluminum Alloy Structural Plate Pipe Culverts for H-20 Loading

Dia. of Pipe (in.)	Height of Cover to Nearest Foot																
	1.0*	1.5*	2.0* thru 10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
60.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
66.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
72.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125
78.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
84.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
90.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125
96.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
102.0		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
108.0		0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
114.0		0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150
120.0		0.125	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150
126.0		0.125	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150
132.0		0.125	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150
138.0		0.125	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150
144.0		0.125	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150
150.0			0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.175
156.0			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.175	0.175
162.0			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175
168.0			0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175
174.0			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175
180.0			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.200

* Required minimum cover.

TABLE IB continued
Wall Thickness (inches) for Corrugated Aluminum Alloy Structural Plate Pipe Culverts for H-20 Loading

Dia. of Pipe (in.)	Height of Cover to Nearest Foot															
	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0
60.0	0.100	0.100	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
66.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150
72.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150
78.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150
84.0	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
90.0	0.125	0.125	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175
96.0	0.125	0.125	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175
102.0	0.125	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.175
108.0	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.200
114.0	0.150	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200
120.0	0.150	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.200
126.0	0.150	0.150	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.200	0.225	0.225
132.0	0.150	0.150	0.175	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.225
138.0	0.150	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.225	0.250	0.250
144.0	0.175	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250	0.250
150.0	0.175	0.175	0.175	0.175	0.200	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250	0.250	
156.0	0.175	0.175	0.175	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250				
162.0	0.175	0.175	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250					
168.0	0.175	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250						
174.0	0.200	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250							
180.0	0.200	0.200	0.225	0.225	0.225	0.250	0.250	0.250								

TABLE IB (Metric)
Wall Thickness (millimeters) for Corrugated Aluminum Alloy Structural Plate Pipe Culverts for M 18 Loading

Dia. of Pipe (mm)	Height of Cover to Nearest 0.1 Meter																
	0.3*	0.5*	0.6* thru 3.0	3.3	3.6	3.9	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3
1500	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1650	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1800	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18
1950	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
2100	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
2250	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2400	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2550		2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2700		2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
2850		2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81
3000		3.18	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81
3150		3.18	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81
3300		3.18	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81
3450		3.18	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81
3600		3.18	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81
3750			2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	4.44
3900			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	4.44	4.44
4050			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44
4200			3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44
4350			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44
4500			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	5.08

* Required minimum cover.

TABLE IB (Metric) continued
Wall Thickness (millimeters) for Corrugated Aluminum Alloy Structural Plate Pipe Culverts for M 18 Loading

Dia. of Pipe (mm)	Height of Cover to Nearest 0.1 Meter															
	7.6	7.9	8.2	8.5	8.8	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9	12.2
1500	2.54	2.54	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
1650	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81
1800	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81
1950	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81
2100	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
2250	3.18	3.18	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44
2400	3.18	3.18	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44
2550	3.18	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	4.44
2700	3.81	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	5.08
2850	3.81	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08
3000	3.81	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.08
3150	3.81	3.81	3.81	3.81	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.08	5.72	5.72
3300	3.81	3.81	4.44	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	5.72
3450	3.81	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	5.72	6.35	6.35
3600	4.44	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35	6.35
3750	4.44	4.44	4.44	4.44	5.08	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35	6.35	
3900	4.44	4.44	4.44	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35				
4050	4.44	4.44	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35					
4200	4.44	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35						
4350	5.08	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35							
4500	5.08	5.08	5.72	5.72	5.72	6.35	6.35	6.35								

TABLE IIA
Sizes, Layout Details, and Wall Thicknesses (inches) for Corrugated Steel Structural Plate Pipe Arches for H-20 Loading

Span	Rise	Area	"B"	Height of Cover to Nearest Foot																
(in.)	(in.)	(sq ft)	(in.)	1.0*	1.5*	2.0*	2.5*	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
73	55	22	21.0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
76	57	24	20.5	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
81	59	26	22.0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
84	61	28	21.4	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
87	63	31	20.8	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
92	65	33	22.4	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
95	67	35	21.7	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
98	69	38	20.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
103	71	40	22.7		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
106	73	43	21.8		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
112	75	46	23.8		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
114	77	49	22.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
117	79	52	21.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
123	81	55	23.9		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
128	83	58	26.1		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
131	85	61	25.1		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
137	87	64	27.4		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109

* Required minimum cover

"B" The horizontal distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIA continued
Sizes, Layout Details, and Wall Thicknesses (inches) for Corrugated Steel Structural Plate Pipe Arches for H-20 Loading

Span	Rise	Area	"B"	Height of Cover to Nearest Foot																
(in.)	(in.)	(sq ft)	(in.)	1.0*	1.5*	2.0*	2.5*	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
139	89	67	26.3		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**
142	91	71	25.2		0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**
148	93	74	27.5			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**
150	95	78	26.4			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**
152	97	81	26.4			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**
154	100	85	24.0			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**
161	101	89	26.3			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**	**0.109**
167	103	93	28.9			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	**0.109**	**0.109**	**0.109**
159	112	97	38.5			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
162	114	102	37.7			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
168	116	105	39.6			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
170	118	109	38.8			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
173	120	114	37.9			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
179	122	118	39.8			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
184	124	123	41.8			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
187	126	127	40.9			0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
190	128	132	40.0			0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
195	130	137	42.1				0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
198	132	142	41.1				0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138

Bold type Indicates areas where soil bearing pressure approximately 3.0 tons/sq ft is required.
* Required minimum cover.
"B" The vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIA (Metric)
Sizes, Layout Details, and Wall Thicknesses (millimeters) for Corrugated Steel Structural Plate Pipe Arches for M 18 Loading

Span	Rise	Area	"B"	Height of Cover to Nearest 0.1 meter															
(mm)	(mm)	(sq m)	(mm)	0.3*	0.5*	0.6*	0.8*	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6
1854	1397	2.0	533	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
1930	1448	2.2	521	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2057	1499	2.4	559	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2134	1549	2.6	544	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2210	1600	2.9	528	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2337	1651	3.1	569	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2413	1702	3.3	551	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2489	1753	3.5	531		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2616	1803	3.7	577		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2692	1854	4.0	554		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2845	1905	4.3	605		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2896	1956	4.6	582		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
2972	2007	4.8	556		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3124	2057	5.1	607		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3251	2108	5.4	663		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3327	2159	5.7	638		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
3480	2210	5.9	696		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77

* Required minimum cover.

"B" The vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIA (Metric) continued
Sizes, Layout Details, and Wall Thicknesses (millimeters) for Corrugated Steel Structural Plate Pipe Arches for M 18 Loading

Span	Rise	Area	"B"	Height of Cover to Nearest 0.1 Meter															
(mm)	(mm)	(sq m)	(mm)	0.3*	0.5*	0.6*	0.8*	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6
3531	2261	6.2	668		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**
3607	2311	6.6	640		2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**
3759	2362	6.9	699			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**
3810	2413	7.2	671			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**
3861	2464	7.5	671			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**
3912	2540	7.9	610			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**
4089	2565	8.3	668			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**	**2.77**
4242	2616	8.6	734			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	**2.77**	**2.77**	**2.77**
4039	2845	9.0	978			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4115	2896	9.5	958			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4267	2946	9.8	1006			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4318	2997	10.1	986			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4394	3048	10.6	963			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77
4547	3099	11.0	1011			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
4674	3150	11.4	1062			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
4750	3200	11.8	1039			2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	3.51
4826	3251	12.3	1016			3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
4953	3302	12.7	1069				3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
5029	3353	13.2	1044				3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51

Bold type Indicates areas where soil bearing pressure approximately 290 kPa is required.

* Required minimum cover.

"B" The vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIB
Sizes, Layout Details, and Wall Thicknesses (inches) for Corrugated Aluminum Alloy Structural Plate Pipe Arches for H-20 Loading

Span	Rise	Area	"B"	Height of Cover to Nearest Foot															
(in.)	(in.)	(sq ft)	(in.)	1.0*	1.5*	2.0*	2.5*	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
71	65	25	31.8	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
74	68	27	32.1	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
78	69	30	32.0	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
82	71	32	32.5	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
87	72	35	33.1	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
91	74	37	33.9	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
95	76	40	33.7	0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
98	77	42	32.3		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
103	79	45	33.1		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
106	81	48	32.6		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
111	82	51	33.6		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125
116	84	54	34.6		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125
121	85	57	35.9		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125
125	87	60	35.3		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
128	89	63	34.7		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
132	91	66	34.0		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125
138	92	69	37.5		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
140	94	73	34.6		0.125	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
145	95	76	36.0			0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125
149	97	80	35.2			0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.125	0.125	0.125	0.125	0.125
154	99	83	36.8			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
157	100	87	35.9			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
163	102	91	37.5			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
168	103	94	39.4			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
167	113	102	39.4			0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
171	115	106	42.0			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
176	116	110	44.0			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
179	118	114	43.2			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
184	120	119	45.3			0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
187	122	123	44.4			0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
193	124	128	46.6				0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
196	126	132	45.7				0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175
201	128	137	47.9				0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
204	130	142	46.9				0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

* Required minimum cover.

"B" The vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

TABLE IIB (Metric)
Sizes, Layout Details, and Wall Thicknesses (millimeters) for Corrugated Aluminum Alloy Structural Plate Pipe Arches for M 18 Loading

Span	Rise	Area	"B"	Height of Cover to Nearest 0.1 Meter															
(mm)	(mm)	(sq m)	(mm)	0.3*	0.5*	0.6*	0.8*	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.3	4.6
1803	1651	2.3	808	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1880	1727	2.5	815	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
1981	1753	2.8	813	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2083	1803	3.0	826	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2210	1829	3.3	841	3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2311	1880	3.4	861	3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2413	1930	3.7	856	3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2489	1956	3.9	820		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2616	2007	4.2	841		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2692	2057	4.5	828		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
2819	2083	4.7	853		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18
2946	2134	5.0	879		2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18
3073	2159	5.3	912		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18
3175	2210	5.6	897		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
3251	2261	5.9	881		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
3353	2311	6.1	864		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18
3505	2337	6.4	953		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
3556	2388	6.8	879		3.18	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
3683	2413	7.1	914			2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18
3785	2464	7.4	894			2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	3.18	3.18	3.18	3.18	3.18
3912	2515	7.7	935			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
3988	2540	8.1	912			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4140	2591	8.5	953			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4267	2616	8.7	1001			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4242	2870	9.5	1001			3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
4343	2921	9.8	1067			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4470	2946	10.2	1118			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4547	2997	10.6	1097			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4674	3048	11.1	1151			3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81
4750	3099	11.4	1128			4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
4902	3150	11.9	1184				4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
4978	3200	12.3	1161				4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44	4.44
5105	3251	12.7	1217				5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08
5182	3302	13.2	1191				5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08

* Required minimum cover.

"B" The vertical distance from a horizontal line across the widest part of the arch to inside crests of the corrugations of the lowest portion of the arch.

541.04 Shipping and Storing. The loading, transporting, unloading, and storing of material shall be conducted so the steel and aluminum will be kept free from damage. Special care shall be taken to prevent disturbing the curvature in the plates. They shall be blocked to prevent damage during shipment and storage.

CONSTRUCTION REQUIREMENTS

541.05 Bearing Surfaces for Corrugated Structural Plate Arches. Each side of each arch shall be bolted to a steel bearing surface. Steel bearing surfaces shall be either structural steel channels or angles. The horizontal leg of the bearing surface shall be securely anchored to or embedded in the foundation and the vertical leg shall be punched to allow bolting to the bottom row of structural plates.

Channels shall be a minimum of 3/16 in. (5 mm) in thickness. Angles shall be a minimum of 3 x 3 x 1/4 in. (75 x 75 x 6 mm). Where the span of the arch is greater than 15 ft (4.5 m) or where the skew angle is more than 20 degrees, the steel bearing surface shall have a width at least equal to the depth of corrugation.

541.06 Erection and Backfill. The erection and backfill for corrugated structural plate drainage structures shall be according to the following.

(a) Corrugated Structural Plate Pipe Culverts and Corrugated Structural Plate Pipe Arches. When a plate pipe structure is to be erected in a trench, the width of the trench shall be sufficient to permit thorough tamping of the earth backfill against every plate. The pipe shall be bedded on an earth foundation of uniform density shaped to fit the lower plate at the proper grade. Any soil below the foundation grade which has been disturbed by the Contractor's operations shall be removed. If the foundation excavation has been made deeper than necessary, the foundation shall be brought to proper grade by the addition of well-compacted fine aggregate.

Where a firm foundation is not encountered at the grade established, due to soft, spongy, or other unsuitable soil, all such unsuitable soil under the plate pipe structure and for a width of at least one diameter on each side of the structure, shall be removed and replaced with well compacted fine aggregate.

Where rock, in either ledge or boulder formation is encountered, it shall be removed and replaced with a cushion of well-compacted fine aggregate to a depth below the structure of not less than 1/2 in./ft (40 mm/m) of height of fill over the top of the structure, with a minimum thickness of 8 in. (200 mm).

All excavated material not needed on the work shall be disposed of according to Article 202.03.

When a corrugated structural plate pipe culvert or corrugated structural plate pipe arch has been completely erected in place, moist fine aggregate shall be placed alongside the structure in lifts not to exceed 8 in. (200 mm) in depth, loose measurement, and compacted for the full width of the trench, or so that on each side of the structure there shall be a berm of compacted or undisturbed soil at least as wide as the greatest external dimension of the

structure. The fine aggregate shall be placed longitudinally along the structure, except at the outer 3 ft (1 m) at each end of the structure, impervious material shall be used. The elevation of the backfill material on each side of the structure shall be the same. Special care shall be taken to compact the fine aggregate and impervious material under the haunches of the pipe. The backfill material, fine aggregate and impervious material shall be compacted to the satisfaction of the Engineer by mechanical means. This method of placement shall be continued until the top of the structure is covered with at least 1 ft (300 mm) of backfill material.

(b) Corrugated Structural Plate Arches. Excavation for corrugated structural plate arches shall be according to the applicable provisions of Section 502.

When backfilling a structure before headwalls are placed, the first material shall be placed midway between the ends of the arch forming as narrow a ramp as possible until the top of the arch is reached. The ramp shall be built evenly from both sides, and the backfilling material shall be thoroughly compacted as it is placed. After the ramps have been built to the top of the arch, the remainder of the backfill shall be deposited from the top of the arch, both ways from the center to the ends, and as evenly as possible on both sides of the arch.

If the headwalls are built before the structure is backfilled, the filling material shall first be placed adjacent to one headwall until the top of the arch is reached, after which the fill shall be dumped from the top of the arch toward the other headwall, with care being taken to deposit the material evenly on both sides of the arch.

In multiple installations, the procedure specified above shall be followed, but extreme care shall be used to bring the backfill up evenly on each side of each arch so that unequal pressure will be avoided.

In all cases, the filling material shall be thoroughly but not excessively tamped. Puddling the backfill will not be permitted.

After the structure has been covered with 1 ft (300 mm) of backfill, additional embankment shall be constructed according to Article 542.04(h). The height of the additional embankment shall be that specified.

541.07 Workmanship. In addition to compliance with the required details of construction, the completed structural plate structure shall show careful, finished workmanship in all particulars. The following defects are specified as constituting poor workmanship and the presence of any or all of them in any individual plate or in any shipment shall be cause for rejection of the plate or shipment:

(1) Uneven laps.
(2) Elliptical shaping (unless specified).
(3) Variation from a straight centerline.
(4) Ragged edges.
(5) Loose or unevenly lined or spaced bolts.
(6) Bruised, scaled, or broken zinc coating.
(7) Dents or bends in the metal.

541.08 Method of Measurement. Corrugated structural plate drainage structures of the types and sizes specified, or of a particular material when specified, will be measured for payment in place in feet (meters). Measurement will be from end to end along the flow line of pipes and along the bearing leg of structural plate arches.

Concrete will measured for payment according to Article 503.21

Excavation for corrugated structural plate arches and rock excavation for all corrugated steel plate drainage structures will be measured for payment according to Article 502.12.

541.09 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for CORRUGATED STRUCTURAL PLATE PIPE CULVERTS, of the diameter specified; CORRUGATED STRUCTURAL PLATE PIPE ARCHES, of the area specified; and CORRUGATED STRUCTURAL PLATE ARCHES, of the area specified.

Concrete will be paid for according to Article 503.22

Excavation for corrugated structural plate arches and rock excavation for all corrugated steel plate drainage structures will be paid for according to Article 502.13.

The removal of unstable or unsuitable material or rock below foundation grade and the replacement thereof with the specified material, including additional excavation required to widen the trench, if required, will be paid for according to Article 109.04, unless the contract contains unit prices for the work included.

SECTION 542. PIPE CULVERTS

542.01 Description. This work shall consist of furnishing and installing pipe culverts.

542.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Corrugated Steel Pipe	1006.01
(b) Corrugated Steel Pipe Arch	1006.01
(c) Bituminous Coated Corrugated Steel Pipe	1006.01
(d) Bituminous Coated Corrugated Steel Pipe Arch	1006.01
(e) Zinc and Aramid Fiber Composite Coated Corrugated Steel Pipe	1006.01
(f) Aluminized Steel Type 2 Corrugated Pipe	1006.01
(g) Aluminized Steel Type 2 Corrugated Pipe Arch	1006.01
(h) Precoated Galvanized Corrugated Steel Pipe	1006.01
(i) Precoated Galvanized Corrugated Steel Pipe Arch	1006.01
(j) Corrugated Aluminum Alloy Pipe	1006.03
(k) Corrugated Aluminum Alloy Pipe Arch	1006.03
(l) Extra Strength Clay Pipe	1040.02
(m) Concrete Sewer, Storm Drain, and Culvert Pipe	1042
(n) Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe	1042
(o) Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe	1042
(p) Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe	1042
(q) Polyvinyl Chloride (PVC) Pipe	1040.03
(r) Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior	1040.03
(s) Polyvinyl Chloride (PVC) Profile Wall Pipe-794	1040.03
(t) Polyvinyl Chloride (PVC) Profile Wall Pipe-304	1040.03
(u) Corrugated Polyethylene (PE) Pipe with a Smooth Interior	1040.04
(v) Polyethylene (PE) Profile Wall Pipe	1040.04
(w) Polyethylene (PE) Pipe with a Smooth Interior	1040.04
(x) Rubber Gaskets and Preformed Flexible Joint Sealants for Concrete Pipe	1056
(y) Mastic Joint Sealer for Pipe	1055
(z) External Sealing Band	1057
(aa) Fine Aggregate (Note 1)	1003.04
(bb) Coarse Aggregate (Note 2)	1004.05
(cc) Packaged Rapid Hardening Mortar or Concrete	1018
(dd) Nonshrink Grout	1024.01

Note 1. The fine aggregate shall be moist.

Note 2. The coarse aggregate shall be wet.

542.03 Material Permitted. When a Class of pipe is specified, the material shall be selected from the following table. When a particular material is specified, no other kind of material will be permitted.

Class	Materials
A	Rigid Pipes: Extra Strength Clay Pipe Concrete Sewer Storm Drain and Culvert Pipe, Class 3 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe
C	Rigid Pipes: Extra Strength Clay Pipe Concrete Sewer Storm Drain and Culvert Pipe, Class 3 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe Flexible Pipes: Aluminized Steel Type 2 Corrugated Pipe Aluminized Steel Type 2 Corrugated Pipe Arch Precoated Galvanized Corrugated Steel Pipe Precoated Galvanized Corrugated Steel Pipe Arch Corrugated Aluminum Alloy Pipe Corrugated Aluminum Alloy Pipe Arch Polyvinyl Chloride (PVC) Pipe Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior Polyvinyl Chloride (PVC) Profile Wall Pipe-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-304 Polyethylene (PE) Profile Wall Pipe Polyethylene (PE) Pipe with a Smooth Interior
D	Rigid Pipes: Extra Strength Clay Pipe Concrete Sewer Storm Drain and Culvert Pipe, Class 3 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe Flexible Pipes: Corrugated Steel Pipe Corrugated Steel Pipe Arch Bituminous Coated Corrugated Steel Pipe Bituminous Coated Corrugated Steel Pipe Arch Zinc and Aramid Fiber Composite Coated Corrugated Steel Pipe Aluminized Steel Type 2 Corrugated Pipe Aluminized Steel Type 2 Corrugated Pipe Arch Precoated Galvanized Corrugated Steel Pipe Precoated Galvanized Corrugated Steel Pipe Arch Corrugated Aluminum Alloy Pipe Corrugated Aluminum Alloy Pipe Arch Polyvinyl Chloride (PVC) Pipe Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior Polyvinyl Chloride (PVC) Profile Wall Pipe-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-304 Corrugated Polyethylene (PE) Pipe with a Smooth Interior Polyethylene (PE) Profile Wall Pipe Polyethylene (PE) Pipe with a Smooth Interior

When metric sizes are specified on the plans, the next larger available manufactured English pipe may be substituted at no additional cost to the Department.

For PE pipe culverts, where no end treatment is specified, a standard corrugated PE coupling shall be provided for each exposed end of the pipe. The coupling shall be installed flush with the end(s) of the pipe.

The Contractor may, at no additional cost to the Department, substitute a stronger pipe of the same kind of material specified.

When a pipe diameter is specified, only a circular pipe will be permitted. When a round size equivalent is specified, only elliptical or arch pipe will be permitted.

The kind of material and thickness or thickness class required for the various types of pipe culverts shall be according to Tables IA - IC, IIA, IIB, and IIIA – IIIC and the following.

(a) Steel or aluminum alloy arch and concrete elliptical or arch pipes will be designated pipe culverts, special for fill heights exceeding 15 ft (4.5 m).

(b) Extra strength clay pipe will only be permitted for pipe culverts Types 2 and 3, up to and including 36 in. (900 mm), for all pipe classes.

(c) Concrete sewer, storm drain, and culvert pipe Class 3 will only be permitted for pipe culverts Type 2, up to and including 36 in. (900 mm); and pipe culverts Type 3, up to and including 24 in. (600 mm), for all pipe classes.

TABLE IA: CLASSES OF REINFORCED CONCRETE PIPE FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE							
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Nominal Diameter in.	Fill Height: 3' and less 1' min. cover	Fill Height: Greater than 3' not exceeding 10'	Fill Height: Greater than 10' not exceeding 15'	Fill Height: Greater than 15' not exceeding 20'	Fill Height: Greater than 20' not exceeding 25'	Fill Height: Greater than 25' not exceeding 30'	Fill Height: Greater than 30' not exceeding 35'
12	IV	II	III	IV	V	V	V
15	IV	II	III	IV	V	V	V
18	IV	II	III	IV	IV	V	V
21	IV	II	III	IV	IV	V	V
24	IV	II	III	IV	IV	V	V
30	IV	II	III	IV	IV	V	V
36	III	II	III	IV	IV	V	V
42	III	II	III	IV	IV	V	V
48	II	II	III	IV	IV	V	V
54	II	II	III	IV	IV	V	V
60	I	I	III	IV	V	V	V
66	I	I	III	IV	V	V	V
72	I	I	III	IV	V	V	V
78	I	I	III	IV	*V	*V	*V
84	I	I	III	IV	*V	*V	*V
90	I	I	III	*IV	*V	*V	*V
96	I	I	III	*IV	*V	*V	*V
102	I	I	III	*IV	*V	*V	*V
108	I	I	III	*IV	*V	*V	*V

* Special Design Required

TABLE IA: CLASSES OF REINFORCED CONCRETE PIPE
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE
(Metric)

Nominal Diameter mm	Type 1 Fill Height: 1 m and less 0.3 m min. cover	Type 2 Fill Height: Greater than 1 m not exceeding 3 m	Type 3 Fill Height: Greater than 3 m not exceeding 4.5 m	Type 4 Fill Height: Greater than 4.5 m not exceeding 6 m	Type 5 Fill Height: Greater than 6 m not exceeding 7.5 m	Type 6 Fill Height: Greater than 7.5 m not exceeding 9 m	Type 7 Fill Height: Greater than 9 m not exceeding 10.5 m
300	IV	II	III	IV	V	V	V
375	IV	II	III	IV	V	V	V
450	IV	II	III	IV	IV	V	V
525	IV	II	III	IV	IV	V	V
600	IV	II	III	IV	IV	V	V
750	IV	II	III	IV	IV	V	V
900	III	II	III	IV	IV	V	V
1050	III	II	III	IV	IV	V	V
1200	II	II	III	IV	IV	V	V
1350	II	II	III	IV	IV	V	V
1500	I	I	III	IV	V	V	V
1650	I	I	III	IV	V	V	V
1800	I	I	III	IV	V	V	V
1950	I	I	III	IV	*V	*V	*V
2100	I	I	III	IV	*V	*V	*V
2250	I	I	III	*IV	*V	*V	*V
2400	I	I	III	*IV	*V	*V	*V
2550	I	I	III	*IV	*V	*V	*V
2700	I	I	III	*IV	*V	*V	*V

* Special Design Required

TABLE IB: THICKNESS OF CORRUGATED STEEL PIPE
FOR THE RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 2 2/3" x 1/2" AND 3" x 1" CORRUGATIONS

Nominal Diameter in.	Type 1 Fill Height: 3' and less 1' min. cover		Type 2 Fill Height: Greater than 3' not exceeding 10'		Type 3 Fill Height: Greater than 10' not exceeding 15'		Type 4 Fill Height: Greater than 15' not exceeding 20'		Type 5 Fill Height: Greater than 20' not exceeding 25'		Type 6 Fill Height: Greater than 25' not exceeding 30'		Type 7 Fill Height: Greater than 30' not exceeding 35'	
	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"
**10	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
12	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
15	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
18	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
21	0.064		0.064		0.064		0.064		0.064		0.064		0.064	
24	0.079		0.079		0.079		0.079		0.079		0.079		0.109	
30	0.079		0.079		0.079		0.079		0.079		0.109		0.138	
36	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.109	0.079	0.138	0.109	0.168	0.109
42	0.109	0.079	0.079	0.079	0.079	0.079	0.109	0.079	0.109	0.079	0.168	0.109	0.109E	0.109
48	0.109	0.109	0.079	0.079	0.109	0.079	0.109	0.109	0.138	0.109	0.109E	0.109	0.138E	0.109
54	0.109	0.109	0.109	0.079	0.109	0.079	0.109	0.109	0.168	0.109	0.138E	0.109	0.138E	0.138E
60	0.138	0.109	0.109	0.079	0.109	0.109	0.138	0.109	0.138E	0.109	0.168E	0.138	0.168E	0.138E
66	0.138	0.109	0.138	0.079	0.138	0.109	0.138	0.109	0.168E	0.109	0.168E	0.138E	NB	0.138E
72	0.138Z	0.109	0.138	0.079	0.138	0.109	0.168	0.109	NB	0.109	NB	0.138E	NB	0.138E
78	0.168Z	0.109	0.168	0.079	0.168	0.109	NB	0.109	NB	0.138	NB	0.138E	NB	0.138E
84	0.168Z	0.109	0.168	0.109	0.168	0.109	NB	0.109	NB	0.138E	NB	0.138E	NB	0.138E
90	NB	0.109	NB	0.109	NB	0.109	NB	0.109	NB	0.138E	NB	0.138E	NB	0.138E
96	NB	0.109	NB	0.109	NB	0.109	NB	0.138	NB	0.138E	NB	0.138E	NB	0.168E
102	NB	0.109Z	NB	0.109	NB	0.109	NB	0.138	NB	0.138E	NB	0.168E	NB	0.168E
108	NB	0.109Z	NB	0.109	NB	0.138	NB	0.138	NB	0.168E	NB	0.168E	NB	NB
114		0.138Z		0.109		0.138		0.168		0.168E		NB		NB
120		0.138Z		0.109		0.138		0.168		NB		NB		NB
126		0.138Z		0.138		0.168		0.168		NB		NB		NB
132		0.168Z		0.138		0.168		NB		NB		NB		NB
138		0.168Z		0.138		0.168		NB		NB		NB		NB
144		0.168Z		0.138		NB		NB		NB		NB		NB

Note: 125 mm x 25 mm Metric corrugations may be used in lieu of 3"x1" corrugations
** 1 1/2" x 1/4" corrugations shall be used in lieu of 2 2/3" x 1/2" for 6", 8", and 10" diameters
E Elongate according to Article 542.04(e)
NB Use uncoated corrugated steel structural plate pipe according to Section 541
Z 1'-6" minimum fill

TABLE IB: THICKNESS OF CORRUGATED STEEL PIPE
FOR THE RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 68 mm x 13 mm AND 75 mm x 25 mm CORRUGATIONS
(Metric)

Nominal Diameter mm	Type 1 Fill Height: 1 m and less 0.3 m min. cover		Type 2 Fill Height: Greater than 1 m not exceeding 3 m		Type 3 Fill Height: Greater than 3 m not exceeding 4.5 m		Type 4 Fill Height: Greater than 4.5 m not exceeding 6 m		Type 5 Fill Height: Greater than 6 m not exceeding 7.5 m		Type 6 Fill Height: Greater than 7.5 m not exceeding 9 m		Type 7 Fill Height: Greater than 9 m not exceeding 10.5 m	
	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68mm x 13mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm
**250	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
300	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
400	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
450	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
500	1.63		1.63		1.63		1.63		1.63		1.63		1.63	
600	2.01		2.01		2.01		2.01		2.01		2.01		2.77	
700	2.01		2.01		2.01		2.01		2.01		2.77		3.51	
800	2.01		2.01		2.01		2.01		2.77	3.51	3.51	4.27	4.27	
900	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.77	2.01	3.51	2.77	4.27	2.77
1000	2.77	2.01	2.01	2.01	2.01	2.01	2.77	2.01	2.77	2.01	4.27	2.77	2.77E	2.77
1200	2.77	2.77	2.01	2.01	2.77	2.01	2.77	2.77	3.51	2.77	2.77E	2.77	3.51E	2.77
1400	2.77	2.77	2.77	2.01	2.77	2.01	2.77	2.77	4.27	2.77	3.51E	2.77	3.51E	3.51E
1600	3.51	2.77	3.51	2.01	3.51	2.77	3.51	2.77	4.27E	2.77	4.27E	3.51E	NB	3.51E
1800	3.51Z	2.77	3.51	2.01	3.51	2.77	4.27	2.77	NB	2.77	NB	3.51E	NB	3.51E
2000	4.27Z	2.77	4.27	2.01	4.27	2.77	NB	2.77	NB	3.51	NB	3.51E	NB	3.51E
2200	4.27Z	2.77	4.27	2.77	4.27	2.77	NB	2.77	NB	3.51E	NB	3.51E	NB	3.51E
2400	NB	2.77	NB	2.77	NB	2.77	NB	3.51	NB	3.51E	NB	3.51E	NB	4.27E
2700	NB	2.77Z	NB	2.77	NB	3.51	NB	3.51	NB	4.27E	NB	4.27E	NB	NB
3000		3.51Z		2.77		3.51		4.27		NB		NB		NB
3300		4.27Z		3.51		4.27		NB		NB		NB		NB
3600		4.27Z		3.51		NB		NB		NB		NB		NB

Note:

** 38 mm x 6.5 mm corrugations shall be used in lieu of 68 mm x 13 mm for 250 mm diameters

E Elongate according to Article 542.04(e)

NB Use uncoated corrugated steel structural plate pipe according to Section 541

Z 450 mm minimum fill

TABLE IC: THICKNESS OF CORRUGATED ALUMINUM ALLOY PIPE
FOR RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 2 2/3" x 1/2" AND 3" x 1" CORRUGATIONS

Nominal Diameter in.	Type 1 Fill Height: 3' and less 1' min. cover		Type 2 Fill Height: Greater than 3' not exceeding 10'		Type 3 Fill Height: Greater than 10' not exceeding 15'		Type 4 Fill Height: Greater than 15' not exceeding 20'		Type 5 Fill Height: Greater than 20' not exceeding 25'		Type 6 Fill Height: Greater than 25' not exceeding 30'		Type 7 Fill Height: Greater than 30' not exceeding 35'	
	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3 "x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"	2 2/3"x1/2"	3"x1"
10	0.060		0.060		0.060		0.060		0.060		0.060		0.060	
12	0.060		0.060		0.060		0.060		0.060		0.060		0.060	
15	0.060		0.060		0.060		0.060		0.060		0.060		0.060	
18	0.060		0.060		0.060		0.060		0.060		0.060		0.105	
21	0.060		0.060		0.060		0.060		0.060		0.105		0.135	
24	0.075		0.075		0.075		0.075		0.105		0.105		0.164	
30	0.105	0.105	0.075	0.075	0.105	0.075	0.105	0.105	0.105	0.105	0.135E	0.105	0.105E	X
36	0.105	0.105	0.105	0.075	0.105	0.075	0.105	0.105	0.164	0.105	0.135E	0.135	0.135E	X
42	0.135	0.105	0.105	0.075	0.105	0.075	0.135	0.105	0.135E	0.105	0.164E	0.135	0.164E	X
48	0.135	0.105	0.105	0.075	0.135	0.105	0.164	0.105	0.164E	0.105	X	X	X	X
54	0.164	0.105	0.135	0.075	0.164	0.105	X	0.105	X	0.135	X	X	X	X
60	0.164Z	0.105	0.135	0.105	X	0.105	X	0.105	X	X	X	X	X	X
66	X	0.105	0.164	0.105	X	0.105	X	0.105	X	X	X	X	X	X
72	X	0.135	X	0.105	X	0.105	X	0.135	X	X	X	X	X	X
78	X	0.135	X	0.105	X	0.135	X	0.135	X	X	X	X	X	X
84	X	0.164	X	0.105	X	0.135	X	0.164	X	X	X	X	X	X
90	X	0.164	X	0.135	X	0.164	X	X	X	X	X	X	X	X
96	X	X	X	0.135	X	0.164	X	X	X	X	X	X	X	X
102	X	X	X	0.164	X	X	X	X	X	X	X	X	X	X
108	X	X	X	0.164	X	X	X	X	X	X	X	X	X	X
114	X	X	X	0.164	X	X	X	X	X	X	X	X	X	X
120	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Note:
E Elongate according to Article 542.04(e)
X Use either steel or concrete pipe
Z 1'-6" minimum fill

TABLE IC: THICKNESS OF CORRUGATED ALUMINUM ALLOY PIPE
FOR RESPECTIVE DIAMETER OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE FOR 68 mm x 13 mm AND 75 mm x 25 mm CORRUGATIONS
(Metric)

Nominal Diameter mm	Type 1		Type 2		Type 3		Type 4		Type 5		Type 6		Type 7	
	Fill Height: 1 m and less 0.3 m min. cover		Fill Height: Greater than 1 m not exceeding 3 m		Fill Height: Greater than 3 m not exceeding 4.5 m		Fill Height: Greater than 4.5 m not exceeding 6 m		Fill Height: Greater than 6 m not exceeding 7.5 m		Fill Height: Greater than 7.5 m not exceeding 9 m		Fill Height: Greater than 9 m not exceeding 10.5 m	
	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm	68 mm x 13 mm	75 mm x 25 mm
250	1.52		1.52		1.52		1.52		1.52		1.52		1.52	
300	1.52		1.52		1.52		1.52		1.52		1.52		1.52	
400	1.52		1.52		1.52		1.52		1.52		1.52		1.52	
450	1.52		1.52		1.52		1.52		1.52		1.52		2.67	
500	1.52		1.52		1.52		1.52		1.52		2.67		3.43	
600	1.91		1.91		1.91		1.91		2.67		2.67		4.17	
700	2.67		1.91		2.67		2.67		2.67		3.43		2.67E	
800	2.67	2.67	2.67	1.91	2.67	1.91	2.67	2.67	4.17	2.67	3.43E	3.43	3.43E	X
900	2.67	2.67	2.67	1.91	2.67	1.91	2.67	2.67	4.17	2.67	3.43E	3.43	3.43E	X
1000	3.43	2.67	2.67	1.91	2.67	1.91	3.43	2.67	3.43E	2.67	4.17E	3.43	4.17E	X
1200	3.43	2.67	2.67	1.91	3.43	2.67	4.17	2.67	4.17E	2.67	X	X	X	X
1400	4.17	2.67	3.43	1.91	4.17	2.67	X	2.67	X	3.43	X	X	X	X
1600	X	2.67	4.17	2.67	X	2.67	X	2.67	X	X	X	X	X	X
1800	X	3.43	X	2.67	X	2.67	X	3.43	X	X	X	X	X	X
2000	X	3.43	X	2.67	X	3.43	X	3.43	X	X	X	X	X	X
2200	X	4.17	X	2.67	X	3.43	X	4.17	X	X	X	X	X	X
2400	X	X	X	3.43	X	4.17	X	X	X	X	X	X	X	X
2700	X	X	X	4.17	X	X	X	X	X	X	X	X	X	X
3000	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Note:
E Elongate according to Article 542.04(e)
X Use either steel or concrete pipe
Z 450 mm minimum fill

TABLE IIA: THICKNESS FOR CORRUGATED STEEL PIPE ARCHES AND CORRUGATED ALUMINUM ALLOY PIPE ARCHES FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Equivalent Round Size in.	Corrugated Steel Pipe Arch 2 2/3"x1/2"		Corrugated Steel Pipe Arch 3"x1"		Corrugated Aluminum Pipe Arch 2 2/3"x1/2"		Min. Cover	Type 1 Fill Height: 3' and less			Type 2 Fill Height: Greater than 3' not Exceeding 10'			Type 3 Fill Height: Greater than 10' not Exceeding 15'		
								Steel		Aluminum	Steel		Aluminum	Steel		Aluminum
	Span in.	Rise in.	Span in.	Rise in.	Span in.	Rise in.	Steel & Alum	2 2/3 x 1/2 in.	3 x 1 in.	2 2/3 x 1/2 in.	2 2/3 x 1/2 in.	3 x 1 in.	2 2/3 x 1/2 in.	2 2/3 x 1/2 in.	3 x 1 in.	2 2/3 x 1/2 in.
15	17	13			17	13	1'-0"	0.064		0.060	0.064		0.060	0.064		0.060
18	21	15			21	15	1'-0"	0.064		0.060	0.064		0.060	0.064		0.060
21	24	18			24	18	1'-0"	0.064		0.060	0.064		0.060	0.064		0.060
24	28	20			28	20	1'-6"	0.079		0.075	0.079		0.075	0.079		0.075
30	35	24			35	24	1'-6"	0.079		0.105	0.079		0.105	0.079		0.105
36	42	29	40	31	42	29	1'-6"	0.079	0.079	0.105	0.079	0.079	0.105	0.079	0.079	0.105
42	49	33	46	36	49	33	1'-6"	0.109	0.079	0.135	0.079	0.079	0.105	0.109	0.079	0.135
48	57	38	53	41	57	38	1'-6"	0.109	0.079	0.164	0.109	0.079	0.135	0.109	0.079	0.164
54	64	43	60	46	64	43	1'-6"	0.109	0.079	X	0.109	0.079	0.164	0.138	0.109	X
60	71	47	66	51	71	47	1'-6"	0.138	0.109	X	0.138	0.079	X	0.138	0.109	X
66	77	52	73	55	77	52	1'-6"	0.168	0.109	X	0.168	0.079	X	0.168	0.109	X
72	83	57	81	59	83	57	1'-6"	0.168	0.109	X	0.168	0.109	X	0.168	0.109	X
78			87	63			1'-6"		0.109			0.109			0.109	
84			95	67			1'-6"		0.109			0.109			0.109	
90			103	71			1'-6"		0.109			0.109			0.109	
96			112	75			1'-6"		0.138			0.109			0.138	
102			117	79			1'-6"		0.138			0.109			0.138	
108			128	83			1'-6"		0.138			0.138			0.168	
114			137	87			1'-6"		0.168			0.138			0.168	
120			142	91			1'-6"		0.168			0.138			0.168	

NOTES: The Type 1 and 3 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 3 tons per square foot. The Type 2 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 2 tons per square foot. This minimum bearing capacity will be determined by the Engineer in the field.

The 125 mm x 25 mm metric corrugations for Corrugated Steel Pipe Arch may be used in lieu of the 3" x 1" corrugations.

X Use either steel or concrete.

TABLE - IIA: THICKNESS FOR CORRUGATED STEEL PIPE ARCHES AND CORRUGATED ALUMINUM ALLOY PIPE ARCHES FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE
(Metric)

Equivalent Round Size mm	Corrugated Steel Pipe Arch 68 x 13 mm		Corrugated Steel Pipe Arch 75 x 25 mm		Corrugated Aluminum Pipe Arch 68 x 13 mm		Min. Cover	Type 1 Fill Height: 1 m and less			Type 2 Fill Height: Greater than 1 m not Exceeding 3 m			Type 3 Fill Height: Greater than 3 m not Exceeding 4.5 m		
								Steel		Aluminum	Steel		Aluminum	Steel		Aluminum
	Span mm	Rise mm	Span mm	Rise mm	Span mm	Rise mm	Steel & Alum.	68 x 13 mm	75 x 25 mm	68 x 13 mm	68 x 13 mm	75 x 25 mm	68 x 13 mm	68 x 13 mm	75 x 25 mm	68 x 13 mm
400	460	340			460	340	0.3 m	1.63		1.52	1.63		1.52	1.63		1.52
450	510	380			510	380	0.3 m	1.63		1.52	1.63		1.52	1.63		1.52
500	560	420			560	420	0.3 m	1.63		1.52	1.63		1.52	1.63		1.52
600	680	500			680	500	0.5 m	2.01		1.91	2.01		1.91	2.01		1.91
700	800	580			800	580	0.5 m	2.01		2.67	2.01		2.67	2.01		2.67
800	910	660			910	660	0.5 m	2.01		2.67	2.01		2.67	2.01		2.67
900	1030	740	1016	787	1030	740	0.5 m	2.01	2.01	2.67	2.01	2.01	2.67	2.01	2.01	2.67
1000	1150	820	1168	914	1150	820	0.5 m	2.77	2.01	3.43	2.01	2.01	2.67	2.77	2.01	3.43
1200	1390	970	1330	1030	1390	970	0.5 m	2.77	2.01	4.17	2.77	2.01	3.43	2.77	2.01	4.17
1400	1630	1120	1550	1200	1630	1120	0.5 m	2.77	2.01	4.17	2.77	2.01	3.43	2.77	2.01	4.17
1600	1880	1260	1780	1360	1880	1260	0.5 m	4.27	2.77	X	4.27	2.01	X	4.27	2.77	X
1800	2130	1400	2010	1500	2130	1400	0.5 m	4.27	2.77	X	4.27	2.77	X	4.27	2.77	X
2000			2230	1700			0.5 m		2.77			2.77			2.77	
2200			2500	1830			0.5 m		2.77			2.77			2.77	
2400			2800	1950			0.5 m		3.51			2.77			3.51	
2700			3300	2080			0.5 m		3.51			3.51			4.27	
3000			3650	2280			0.5 m		4.27			4.27			4.27	

NOTES: The Type 1 and 3 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 290 kN/sq m. The Type 2 corrugated steel or aluminum pipe arches shall be placed on soil having a minimum bearing capacity of 192 kN/sq m. This minimum bearing capacity will be determined by the Engineer in the field.

X Use either steel or concrete.

TABLE IIB: CLASSES OF REINFORCED CONCRETE ELLIPTICAL AND REINFORCED CONCRETE ARCH PIPE FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE

Equivalent Round Size in.	Reinforced Concrete Elliptical Pipe in.		Reinforced Concrete Arch Pipe in.		Min. Cover	Type 1 Fill Height: 3' and less		Type 2 Fill Height: Greater than 3' not Exceeding 10'		Type 3 Fill Height: Greater than 10' not Exceeding 15'	
	Span	Rise	Span	Rise	RCCP HE & A	HE	Arch	HE	Arch	HE	Arch
15	23	14	18	11	1'-3"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
18	23	14	22	13 1/2	1'-3"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
21	30	19	26	15 1/2	1'-0"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
24	30	19	28 1/2	18	1'-0"	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
27	34	22	36 1/4	22 1/2	1'-0"	HE-III	A-III	HE-I	A-II	HE-III	A-III
30	38	24	36 1/4	22 1/2	1'-0"	HE-III	A-III	HE-I	A-II	HE-III	A-III
36	45	29	43 3/4	26 5/8	1'-0"	HE-III	A-III	HE-I	A-II	HE-III	A-III
42	53	34	51 1/8	31 5/16	1'-0"	HE-II	A-II	HE-I	A-II	HE-III	A-III
48	60	38	58 1/2	36	1'-0"	HE-II	A-II	HE-I	A-II	HE-III	A-III
54	68	43	65	40	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III
60	76	48	73	45	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III
66	83	53	88	54	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III
72	91	58	88	54	1'-0"	HE-I	A-II	HE-I	A-II	HE-III	A-III

TABLE IIB: CLASSES OF REINFORCED CONCRETE ELLIPTICAL AND REINFORCED CONCRETE ARCH PIPE FOR THE RESPECTIVE EQUIVALENT ROUND SIZE OF PIPE AND FILL HEIGHTS OVER THE TOP OF PIPE
(Metric)

Equivalent Round Size mm	Reinforced Concrete Elliptical Pipe mm		Reinforced Concrete Arch Pipe mm		Min. Cover	Type 1 Fill Height: 1 m and less		Type 2 Fill Height: Greater than 1 m not Exceeding 3 m		Type 3 Fill Height: Greater than 3 m not Exceeding 4.5 m	
	Span	Rise	Span	Rise	RCCP HE & A	HE	Arch	HE	Arch	HE	Arch
375	584	356	457	279	0.4 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
450	584	356	559	343	0.4 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
525	762	483	660	394	0.3 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
600	762	483	724	457	0.3 m	HE-IV	A-IV	HE-I	A-II	HE-III	A-III
686	864	559	921	572	0.3 m	HE-III	A-III	HE-I	A-II	HE-III	A-III
750	965	610	921	572	0.3 m	HE-III	A-III	HE-I	A-II	HE-III	A-III
900	1143	737	1111	676	0.3 m	HE-III	A-III	HE-I	A-II	HE-III	A-III
1050	1346	864	1299	795	0.3 m	HE-II	A-II	HE-I	A-II	HE-III	A-III
1200	1524	965	1486	914	0.3 m	HE-II	A-II	HE-I	A-II	HE-III	A-III
1350	1727	1092	1651	1016	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III
1500	1930	1219	1854	1143	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III
1676	2108	1346	2235	1372	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III
1800	2311	1473	2235	1372	0.3 m	HE-I	A-II	HE-I	A-II	HE-III	A-III

TABLE IIIA: PLASTIC PIPE PERMITTED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter in.	Type 1 Fill Height: 3' and less, with 1' min. cover							Type 2 Fill Height: Greater than 3', not exceeding 10'						
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW
10	X	NA	NA	NA	X	NA	NA	X	*	NA	NA	X	NA	NA
12	X	X	X	X	X	X	NA	X	X	X	X	X	X	NA
15	X	X	X	X	NA	X	NA	X	X	X	X	NA	X	NA
18	X	X	X	X	X	X	X	X	X	X	X	X	X	X
21	X	X	X	X	NA	NA	X	X	X	X	X	NA	NA	X
24	X	X	X	X	X	X	X	X	X	X	X	X	X	X
30	X	X	X	X	X	X	X	X	X	X	X	X	X	X
36	X	X	X	X	X	X	X	X	X	X	X	X	X	X

TABLE IIIB: PLASTIC PIPE PERMITTED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE

Nominal Diameter in.	Type 3 Fill Height: Greater than 10', not exceeding 15'						Type 4 Fill Height: Greater than 15', not exceeding 20'				
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	
10	X	*	NA	NA	X	NA	X	*	NA	NA	
12	X	X	X	X	X	NA	X	X	X	X	
15	X	X	X	X	NA	NA	X	X	X	X	
18	X	X	X	X	X	X	X	X	X	X	
21	X	X	X	X	NA	X	X	X	X	X	
24	X	X	X	X	X	X	X	X	X	X	
30	X	X	X	X	X	X	X	X	X	X	
36	X	X	X	X	X	X	X	X	X	X	

X	Indicates this diameter pipe may be used.
NA	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe With a Smooth Interior
PEPW	Polythylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturer's Certification.

TABLE IIIC: PLASTIC PIPE PERMITTED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE										
Nominal Diameter in.	Type 5 Fill Height: Greater Than 20', not exceeding 25'				Type 6 Fill Height: Greater than 25', not exceeding 30'				Type 7 Fill Height: Greater than 30', not exceeding 35'	
	PVC	CPVC	PVCPW -794	PVCPW -304	PVC	CPVC	PVCPW -794	PVCPW -304	PVC	
10	X	*	NA	NA	X	*	NA	NA	X	
12	X	X	X	X	X	X	X	X	X	
15	X	X	X	X	X				X	
18	X	X	X	X	X				X	
21	X	X	X	X	X				X	
24	X	X	X	X	X				X	
30	X				X				X	
36	X				X				X	

X	Indicates this diameter pipe may be used.
NA	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe With a Smooth Interior
PEPW	Polyethylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturers' Certification.

TABLE IIIA: PLASTIC PIPE PERMITTED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE
(Metric)

Nominal Diameter mm	Type 1 Fill Height: 1 m and less with 0.3 m min. cover							Type 2 Fill Height: Greater than 1 m, not exceeding 3 m						
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	PE	CPE	PEPW
250	X	NA	NA	NA	X	NA	NA	X	*	NA	NA	X	NA	NA
300	X	X	X	X	X	X	NA	X	X	X	X	X	X	NA
375	X	X	X	X	NA	X	NA	X	X	X	X	NA	X	NA
450	X	X	X	X	X	X	X	X	X	X	X	X	X	X
525	X	X	X	X	NA	NA	X	X	X	X	X	NA	NA	X
600	X	X	X	X	X	X	X	X	X	X	X	X	X	X
750	X	X	X	X	X	X	X	X	X	X	X	X	X	X
900	X	X	X	X	X	X	X	X	X	X	X	X	X	X

TABLE IIIB: PLASTIC PIPE PERMITTED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE
(Metric)

Nominal Diameter mm	Type 3 Fill Height: Greater than 3 m, not exceeding 4.5 m						Type 4 Fill Height: Greater than 4.5 m, not exceeding 6 m				
	PVC	CPVC	PVCPW -794	PVCPW -304	PE	PEPW	PVC	CPVC	PVCPW -794	PVCPW -304	
250	X	*	NA	NA	X	NA	X	*	NA	NA	
300	X	X	X	X	X	NA	X	X	X	X	
375	X	X	X	X	NA	NA	X	X	X	X	
450	X	X	X	X	X	X	X	X	X	X	
525	X	X	X	X	NA	X	X	X	X	X	
600	X	X	X	X	X	X	X	X	X	X	
750	X	X	X	X	X	X	X	X	X	X	
900	X	X	X	X	X	X	X	X	X	X	

X	Indicates this diameter pipe may be used.
NA	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe with a Smooth Interior
PEPW	Polythylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturers' Certification.

TABLE IIIC: PLASTIC PIPE PERMITTED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE
(Metric)

Nominal Diameter mm	Type 5 Fill Height: Greater Than 6 m, not exceeding 7.5 m				Type 6 Fill Height: Greater Than 7.5 m, not exceeding 9 m				Type 7 Fill Height: Greater Than 9 m, not exceeding 10.5 m	
	PVC	CPVC	PVCPW -794	PVCPW -304	PVC	CPVC	PVCPW -794	PVCPW -304	PVC	
250	X	*	NA	NA	X	*	NA	NA	X	
300	X	X	X	X	X	X	X	X	X	
375	X	X	X	X	X				X	
450	X	X	X	X	X				X	
525	X	X	X	X	X				X	
600	X	X	X	X	X				X	
750	X				X				X	
900	X				X				X	

X	Indicates this diameter pipe may be used.
NA	Not acceptable
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
PVCPW-304	Polyvinyl Chloride (PVC) Profile Wall Pipe-304
PE	Polyethylene (PE) Pipe With a Smooth Interior
CPE	Corrugated Polyethylene (PE) Pipe With a Smoother Interior
PEPW	Polythylene (PE) Profile Wall Pipe
*	May be used with approval of Bureau of Materials and Physical Research and with Manufacturer's Certification.

542.04 Method I Construction. Unless otherwise permitted in writing by the Engineer because of conditions encountered in construction, all pipe culverts, except entrance culverts, shall be constructed according to the following.

(a) Removal and Replacement of Unstable or Unsuitable Material or Rock. Where unstable material such as soft or spongy soil, unsuitable material, or rock in either ledge or boulder formation is encountered at locations along the line of the pipe culvert and at the grade established for the culvert, the material or rock shall be removed and replaced before proceeding with the construction.

The unstable and unsuitable material shall be removed to a depth determined by the Engineer and for a width of one diameter (or equivalent diameter) of the pipe on each side of the pipe culvert, and replaced with aggregate. Rock shall be removed to an elevation 1 ft (300 mm) lower than the bottom of the pipe or to a depth equal to 1/2 in./ft (40 mm/m) of ultimate fill height over the top of the pipe culvert, whichever is the greater depth, and for a width as specified in (b) below, and replaced with aggregate. Replacement material shall be placed in 8 in. (200 mm) lifts, loose measurement, and compacted by mechanical means to the satisfaction of the Engineer.

(b) Trenching. Pipe culverts shall be constructed in trenches free of water, excavated either in embankments or natural ground. Water shall be removed by use of a diversion channel or by other methods approved by the Engineer.

When all or a portion of a pipe will be in fill, the embankment, or a portion thereof, shall be constructed prior to excavating the trench. The embankment shall be constructed to a height which will provide approximately 1 ft (300 mm) of cover over the pipe, except that in no case shall the height of the embankment constructed result in a finished trench depth exceeding 5 ft (1.5 m). The width of the top of the embankment shall be a minimum of 13 ft (4 m) on each side of the pipe culvert, measured at right angles to its centerline, and the longitudinal slopes shall be 1:6 (V:H) or flatter. The embankment shall be constructed according to the requirements of Section 205, except the material shall be select material from excavation or borrow, meeting the approval of the Engineer.

Trenches shall be excavated to an elevation 4 in. (100 mm) below the bottom of the pipe and to the following widths.

Inside Diameter or Equivalent Diameter of Pipe	Required Trench Width On Each Side of the Pipe
24 in. (600 mm) and less	9 in. (225 mm)
Greater than 24 in. (600 mm) up to 48 in. (1.2 m)	12 in. (300 mm)
Greater than 48 in. (1.2 m)	18 in. (450 mm)

The faces of the excavated trench shall be vertical. If the width of the trench at the top exceeds the maximum horizontal dimension of the pipe by more than the above specified widths as a result of careless or faulty construction methods, that portion of the trench shall be corrected by backfilling in 8 in. (200 mm) lifts and again excavating the trench to the required width. The backfill material and its placement shall be according to Article 542.04(f).

(c) Preparation of Foundation. Well compacted aggregate, at least 4 in. (100 mm) in depth below the pipe culvert, shall be placed the entire width of the trench and for the length of the pipe culvert, except well compacted impervious material shall be used for the outer 3 ft (1 m) at each end of the pipe culvert. When the trench has been widened by the removal and replacement of unstable or unsuitable material, the foundation material shall be placed for a width not less than the above specified widths on each side of the pipe culvert. The aggregate and impervious material shall be compacted by mechanical means to the satisfaction of the Engineer.

When pipe having bells or hubs is used, cross trenches not more than 2 in. (50 mm) wider than the bell or hub shall be excavated to provide uniform bearing along the length of the pipe.

(d) Laying Pipe. No pipe culvert shall be placed until the trench and the prepared foundation have been approved by the Engineer.

The pipe shall be laid so that the flow line of the finished culvert will be at the grade shown on the plans or established by the Engineer. Laying of pipes shall commence at the outlet end, with the spigot ends of the pipe pointing in the direction of the flow, and proceed toward the inlet end with pipes abutting.

The ends of the pipe shall be carefully cleaned before the pipes are placed and the pipes shall be placed to avoid unnecessary handling on the foundation. As each length of the pipe is laid, the ends of the pipe shall be protected to prevent the entrance of any material. The pipes shall be fitted and matched so that when laid in the work, they will form a culvert with a smooth, uniform invert.

All joints in concrete culverts shall be sealed with rubber gaskets, preformed flexible joint sealants, mastic joint sealer, or external sealing bands. When mastic joint sealer is used, the material shall completely fill the joint after the pipes have been brought together. After each joint is sealed, it shall be wiped clean on the inside. Each section of pipe shall be pushed or pulled to the section in place to ensure tight joints. Pipe having a diameter or equivalent diameter greater than 42 in. (1 m) shall be set or "brought home" with a winch, come-a-long, or other positive means.

Handling holes in concrete pipe shall be filled with a precast concrete plug, sealed, and covered with mastic or mortar.

When corrugated steel or aluminum alloy culvert pipe (including bituminous coated steel or aluminum and precoated steel) is used, the pipe shall be placed such that the longitudinal lap is placed at the sides and separate

sections of pipe shall be joined with a hugger-type band. When the pipes are fabricated with a smooth sleeve-type coupler, the gasket material shall be according to Article 1006.01.

(e) Elongation. Circular corrugated steel or aluminum alloy culvert pipe (including bituminous coated steel or aluminum and precoated steel) that are specified as elongated in Table IB or IC shall be elongated vertically 5 percent ± 0.75 percent out of a round before any fill is placed. The pipe, except for bituminous coated corrugated steel or aluminum culvert pipe, shall be elongated by one of the following methods.

(1) Deformation during fabrication.

(2) Elongation by the use of wires, rods, or straps during fabrication.

(3) Elongation at the time of installation by the use of vertical struts, wedged or jacked inside the pipe in a manner approved by the Engineer.

Bituminous coated corrugated steel or aluminum culvert pipe shall be elongated by either method (1) or (2) prior to coating.

Pipe elongated by the manufacturer shall be marked to show the top. The pipe shall be stored, transported, and handled in such a manner so that at the time of installation the pipe shall have retained its elongation.

When the pipe is elongated by method (2) or (3), it shall be installed in a manner that will permit the gradual reduction of elongation as the fill over the pipe is placed. This reduction in elongation shall be as directed by the Engineer and may be accomplished by the use of softwood compression caps when struts or jacks are used, or by the use of turnbuckles or other devices when wires, rods, or straps are used.

After the fill has been placed and compacted, all struts, wires, rods, or straps shall be removed and any holes in the pipe resulting from their use shall be plugged in a manner satisfactory to the Engineer. Heavy asphaltic or tar material, or other material, or a device meeting the approval of the Engineer may be used to plug the holes.

No strutting or elongation will be permitted on corrugated steel or aluminum (including bituminous coated steel or aluminum and precoated steel) pipe arches.

(f) Backfilling. As soon as the condition of the pipe culvert will permit, the entire width of the trench shall be backfilled with aggregate to a height of at least the center of the pipe. The aggregate shall be placed longitudinally along the pipe culvert, except at the outer 3 ft (1 m) at each end of the culvert which shall be backfilled with impervious material. The elevation of the backfill material on each side of the pipe shall be the same. The space under the pipe shall be completely filled. The aggregate and impervious material shall be placed in lifts not exceeding 8 in. (200 mm) in depth, loose

measurement, and compacted by mechanical means to the satisfaction of the Engineer.

When using flexible pipe, as listed in the first table of Article 542.03, the aggregate shall be continued to a height of at least 1 ft (300 mm) above the top of the pipe and compacted to a minimum of 85 percent of standard lab density by mechanical means.

The installed pipe and its embedment shall not be disturbed when using movable trench boxes and shields, sheet pile, or other trench protection.

The remainder of the trench shall be backfilled as follows.

(1) Trench Backfill. For trenches made in the subgrade of the proposed improvement, and trenches where the inner edge of the trench is within 2 ft (600 mm) of the proposed edge of pavement, curb, gutter, curb and gutter, stabilized shoulder, or sidewalk, the remainder of the trench shall be backfilled with trench backfill material meeting the requirements of Section 208. The material shall be placed in lifts not exceeding 8 in. (200 mm) in depth, loose measurement, and compacted to a minimum of 85 percent of standard lab density by mechanical means.

(2) Select Material. For all other trenches, the remainder of the trench shall be backfilled with select material. The select material shall be from excavation or borrow, free from large or frozen lumps, clods, or rock, meeting the approval of the Engineer. The material shall be placed in lifts not exceeding 8 in. (200 mm) in depth, loose measurement, and compacted to 95 percent of standard lab density by mechanical means.

Before compaction, each lift shall be wetted or dried to bring the moisture content within 80 to 110 percent of optimum as determined according to AASHTO T 99 (Method C).

The Contractor may, at no additional cost to the Department, backfill the remainder of the trench with aggregate in lieu of select material. The aggregate shall be placed in lifts not exceeding 8 in. (200 mm) in depth, loose measurement and compacted by mechanical means to the satisfaction of the Engineer.

The outer 3 ft (1 m) at each end of all trenches shall be backfilled with impervious material. The material shall be placed in lifts not exceeding 8 in. (200 mm) in depth, loose measurement and compacted to 95 percent of standard lab density by mechanical means.

In lieu of trench backfill or select material, the Contractor may, at no additional cost to the Department, backfill the entire trench, excepting the outer 3 ft (1 m), with controlled low-strength material according to Section 593.

All backfill material shall be placed in such a manner as not to damage the culvert. The filling of the trench shall be carried on simultaneously on both sides of the pipe.

When the trench has been widened for the removal and replacement of unstable or unsuitable material, the backfilling with aggregate and impervious material, will be required for a width of at least the specified widths on each side of the pipe. The remaining width of each lift may be backfilled with select material. Each 8 in. (200 mm) lift for the entire trench width shall be completed before beginning the placement of the next lift.

(g) Embankment. When the top of the completed backfill is less than 1 ft (300 mm) above the top of the pipe, embankment shall be constructed to an elevation of 1 ft (300 mm) over the top of the pipe. The width and longitudinal slopes of the embankment shall be as specified in Article 542.04(b).

The embankment shall be constructed according to Section 205, except the material shall be select material, from excavation or borrow, meeting the approval of the Engineer. While constructing the embankment, no loads, other than the equipment permitted by the Engineer for the construction of the embankment, shall be introduced upon the pipe culvert and no heavy earth-moving equipment will be permitted within 4 ft (1.2 m) of either side of the pipe culvert.

(h) Additional Embankment. After the trench has been backfilled and embankment constructed to an elevation of 1 ft (300 mm) over the top of the pipe culvert, additional embankment shall be constructed before the Contractor will be permitted to introduce any loads upon the pipe culvert. The required cover, including any embankment cover over the pipe and additional embankment, shall be sufficient for the maximum load, including the weight of equipment, which the Contractor proposes to operate or move across the pipe culvert. The total cover required for various loadings shall be as shown in Table IV, Wheel Loads and Total Cover.

Additional embankment shall be constructed according to Section 205. Its width on each side of the pipe culvert shall be 13 ft (4 m) and the longitudinal slopes shall not be steeper than 1:6 (V:H). The width of the additional embankment, measured along the pipe culvert, shall be the actual fill width indicated on the cross sections at the elevation required in the table below or sufficient to accommodate two-way traffic of the Contractor's grading operations and so no equipment is operated within 10 ft (3 m) of either shoulder line, whichever is the least.

Where the elevation of the additional embankment is above the elevation of the finished embankment, the Contractor shall remove it at the time of final grading operations.

Where the elevation of the finished embankment is higher than the additional embankment, the Contractor shall scarify the surface of the slopes and the top of the embankment.

Table IV: Wheel Loads and Total Cover												
		Wheel Load in tons										
		1	5	10	15	20	25	30	35	40	45	50
Pipe Type	Nominal or Equivalent Diameter in.	Total Cover in feet										
Type 1 & 4	8 to 108, incl.	1.0	2.0	3.0	4.0	5.0	5.5	6.5	7.5	8.5	9.5	10.5
Type 2 & 3	8 to 108, incl.	2.0	3.0	4.0	5.5	7.0	8.5	10.0	11.5	13.0	14.0	15.0
Type 5 & 6	8 to 72, incl.	1.0	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.0	5.5	6.0
	78 to 108, incl.	1.0	1.5	2.0	3.0	3.5	4.0	4.5	5.0	5.0	5.5	6.0
Type 7	8 to 72, incl.	1.0	1.5	2.0	2.5	3.0	3.0	3.5	3.5	4.0	4.0	4.5
	78 to 108, incl.	1.0	1.0	2.0	2.0	3.0	3.0	3.5	3.5	4.0	4.0	4.5

Table IV: Wheel Loads and Total Cover (Metric)												
		Wheel Load in kiloNewtons										
		9	44	89	133	178	223	267	311	356	400	445
Pipe Type	Nominal or Equivalent Diameter mm	Total Cover in meters										
Type 1 & 4	200 to 2700, incl.	0.3	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	2.9	3.2
Type 2 & 3	200 to 2700, incl.	0.6	0.9	1.2	1.7	2.1	2.6	3.0	3.5	4.0	4.3	4.6
Type 5 & 6	200 to 1800, incl.	0.3	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.5	1.7	1.8
	1950 to 2700, incl.	0.3	0.5	0.6	0.9	1.1	1.2	1.4	1.5	1.5	1.7	1.8
Type 7	200 to 1800, incl.	0.3	0.5	0.6	0.8	0.9	0.9	1.1	1.1	1.2	1.2	1.4
	1950 to 2700, incl.	0.3	0.3	0.6	0.6	0.9	0.9	1.1	1.1	1.2	1.2	1.4

(i) Deflection Testing for Pipe Culverts. All PE and PVC pipe culverts shall be tested for deflection not less than 30 days after the pipe is installed and the backfill compacted.

For PVC and PE pipe culverts with diameters 24 in. (600 mm) or smaller, a mandrel drag shall be used for deflection testing. For PVC and PE pipe culverts with diameters over 24 in. (600 mm), deflection measurements other than by a mandrel shall be used.

Where the mandrel is used, the mandrel shall be furnished by the Contractor and pulled by hand though the pipeline with a suitable rope or cable connected to each end. Winching or other means of forcing the deflection gauge through the pipeline will not be allowed.

The mandrel shall be of a shape similar to that of a true circle enabling the gauge to pass through a satisfactory pipeline with little or no resistance. The mandrel shall be of a design to prevent it from tipping from side to side and to prevent debris build-up form occurring between the channels of the adjacent fins or legs during operation. Each end of the core of the mandrel shall have fasteners to which the pulling cables can be attached. The mandrel shall have nine various sized fins or legs of appropriate dimension for various diameter of pipes. Each fin or leg shall have a permanent marking that states its designated pipe size and percent of deflection allowable.

The outside diameter of the mandrel shall be 95 percent of the base inside diameter, where the base inside diameter is:

(1) For all PVC pipe and Profile Wall PE pipe: as defined using ASTM D 3034 methodology.

(2) For all other PE pipe: the average inside diameter based on the minimum and maximum tolerances specified in the corresponding ASTM or AASHTO material specifications.

If the pipe is found to have a deflection greater than that specified, that pipe section shall be removed, replaced, and retested.

542.05 Method II Construction. Method II Construction may be used to construct pipe culverts, except entrance culverts, only when specified or when physical conditions are encountered in construction which make the use of Method I Construction impractical and written permission is obtained from the Engineer. In Method II Construction, all or a portion of a pipe culvert may be constructed in a trench excavated in the existing ground prior to placement of the required embankment.

The construction procedures for Method II Construction shall be the same as previously specified in Article 542.04 for Method I Construction, except as follows.

(a) Trenching. Trenching shall be according to Article 542.04(b), except the trench depth shall be such that the bottom of the pipe is at least one-tenth of

its diameter (or equivalent diameter) below the top of the trench. When the bottom of the pipe is less than the specified distance below the natural ground line, sufficient embankment shall be constructed to an elevation that will provide the required pipe embedment.

(b) Backfill and/or Embankment. Backfill and/or embankment extending to an elevation of 1 ft (300 mm) over the top of the pipe shall be constructed according to Articles 542.04 (f) and 542.04(g), except that the material up to the elevation of the center of the pipe and extending to a width of at least 18 in. (450 mm) on each side of the pipe, exclusive of the outer 3 ft (1 m) at each end of the pipe, shall consist of aggregate. At the outer 3 ft (1 m) at each end of the culvert, impervious material shall be used.

542.06 Method III Construction. Entrance culverts shall be constructed according to the following.

(a) Trenching. Normally, trenching other than that necessary to place the pipe culvert to a depth equal to one-tenth of its external diameter will not be required. Additional trenching may be necessary in some cases due to the location of a pipe culvert. The trenching shall be performed as specified for Method II, except as follows.

The trench shall be excavated only to the bottom of the pipe culvert and for a width sufficient to place the pipe. The bottom of the trench shall be shaped to approximately the size and shape of the pipe culvert.

(b) Preparation of Foundation. After the trench has been excavated for the entire length of the pipe culvert and any necessary removal and replacement of unstable or unsuitable material or rock has been completed, the bottom of the trench shall be shaped to substantially fit the exterior of the pipe. If necessary, material meeting the approval of the Engineer shall be used to fill depressions. The material comprising the foundation shall then be compacted to the satisfaction of the Engineer.

(c) Laying Pipe. The pipe shall be laid as specified in Article 542.04(d).

(d) Backfill and/or Embankment. As soon as the condition of the pipe culvert will permit, the trench shall be backfilled and/or embankment constructed.

The material used shall be select material, meeting the approval of the Engineer, from excavation or borrow. The material shall be placed in lifts not exceeding 8 in. (200 mm), loose measurement, and compacted by mechanical means to the satisfaction of the Engineer. Special care shall be taken to completely fill the space under the pipe. The material shall be placed to an elevation 1 ft (300 mm) above the top of the pipe culvert or to the finished grade, whichever is the lesser height.

When embankment is being constructed, the material used for its construction shall be placed to a width, on each side of the pipe culvert, not less than one diameter of the pipe.

(e) Deflection Testing. Deflection testing for entrance culverts may be required at the option of the Engineer. When required, it shall be according to Article 542.04(i).

542.07 End Treatment. When an end treatment is required, it will be shown on the plans. When a particular type of end treatment is specified, only that type shall be used.

When the pipe is at a 15 degree skew or less with the roadway, the diameter is 84 in. (2100 mm) or less, and an end treatment is required but the type of treatment is not specified on the plans, the Contractor shall have the option of using either a cast-in-place reinforced concrete end section or a prefabricated end section of precast reinforced concrete or metal. When a prefabricated end section is used, it shall be of the same material as the pipe culvert, except for polyethylene (PE) and polyvinylchloride (PVC) pipes which shall have metal end sections.

(a) Cast-In-Place Reinforced Concrete End Section. Cast-in-place reinforced concrete end sections shall be constructed of Class SI concrete according to the requirements of Section 503 and the details shown on the plans.

(b) Precast Reinforced Concrete Flared End Sections. Precast reinforced concrete flared end sections shall be constructed according to the details shown on the plans.

End blocks and grating for precast reinforced concrete flared end sections shall be according to the following.

(1) End Blocks. End blocks shall be either precast or cast in place, and shall be in proper position and backfilled according to the applicable paragraphs of Article 502.10 prior to the installation of the precast reinforced concrete flared end sections.

(2) Gratings. Gratings shall be fabricated and installed as shown on the plans.

Structural steel shapes and plates shall be according to the requirements of Article 1006.04. Galvanized steel pipe shall be according to the requirements of Article 1006.27(b). Bolts, nuts, and washers shall be according to the requirements of Article 1006.27(f).

Fabrication of the grating shall be completed and ready for assembly before galvanizing.

(c) Metal End Sections. Metal end sections shall be fabricated of aluminum or steel, and all component parts shall be of the same material. When steel end sections are used, the base metal, rivets and spelter coating shall be according to AASHTO M 36 (M 36M). When aluminum end sections are used, the material shall be according to AASHTO M 196 (M 196M). Toe plates shall be furnished and the metal thickness shall be the same as that used in the end section.

Fabrication shall be according to the dimensions and details shown on the plans. All 3-piece bodies shall have 0.109 in. (2.77 mm) sides and 0.138 in. (3.51 mm) center panels. Width of center panels shall be greater than 20 percent of the pipe periphery. Multiple panel bodies shall have lap seams which shall be tightly jointed with 3/8 in. (M10) rivets or bolts.

(d) Inlet Boxes, General. Inlet boxes shall be constructed as shown on the plans and shall be either cast-in-place or precast units.

When inlet boxes are cast-in-place, they shall be constructed of Class SI concrete according to the applicable requirements of Section 503.

When precast units are used, they shall be fabricated according to Article 1042.08. A 3 in. (75 mm) deep bedding of aggregate shall be provided under the full width and length of the unit.

For both cast-in-place and precast units, the lap length of reinforcement bars shall be 13 in. (325 mm) and exposed edges of concrete shall be beveled 3/4 in. (20 mm).

Excavation and backfill shall be performed according to the applicable portions of Section 502. All voids around the pipe entrance, both inside and out, shall be sealed with mortar.

(1) Inlet Box, Standards 542501, 542506, 542511, 542516, 542521, 542536, and 542541. Galvanized steel pipe shall meet the requirements of ASTM A 53, Grade B, Schedule 40. Galvanized U-bolts, nuts, and washers shall meet the requirements of Article 1006.27(f). Steel plates shall meet the requirements of Article 1006.04, and shall be galvanized according to the requirements of AASHTO M 111 after fabrication.

(2) Inlet Box, Standards 542526, 542531, and 542546. Grating and frames shall be steel or cast grating fabricated according to the details shown on the plans and shall be approved by the Engineer. Steel grating and frames shall be according to Article 1006.04 and shall be galvanized according to requirements of AASHTO M 111 after fabrication. Cast grating shall be according to Article 1006.15, Grade 60-40-18, or to Article 1006.14. Cast frames shall be according to Article 1006.14. Cast grating and frames shall not be galvanized.

Either steel frames and grating or cast frames and grating may be used at the Contractor's option, but steel frames with cast grating or cast frames with steel grating will not be permitted.

Pressure lock type steel grating and riveted steel grating with reticuline bars will be accepted for galvanizing according to the requirements of AASHTO M 111.

Steel grating shall seat firmly in the frame but shall not be secured to the frame. The grating shall be cut in such manner that all riveted or welded connections are left intact. The edges of the main bearing bars

shall be laterally supported by transverse bars. Grating shall be approved by the Engineer. All welding shall be done according to the applicable requirements of Section 505, and shall be done before galvanizing.

a. Standards 542526 and 542531. The steel grating shall have the main bearing bars running perpendicular to the centerline of the inlet box. The main bearing bars shall have a minimum section modulus of 3.29 cu in./ft (176,900 cu mm/m) width of grating. The cross sectional shape shall be rectangular or a modified "I" but shall not have any flanges which would retain trash. The length and width of the grating shall be such as to leave no more than 5/8 in. (16 mm) clearance on either side when placed in the frame.

b. Standard 542546. The steel grating shall have the main bearing bars running parallel to the centerline of the median. The main bearing bars shall be as specified or shall be 3 1/2 in. (89 mm) in depth and have a minimum section modulus of 3.78 cu in./ft (203,200 cu mm/m) width of grating with a maximum spacing of 2 in. (50 mm) center-to-center.

542.08 Pipe Elbows, Tees, and Collars. Pipe elbows and tees shall be installed at the locations shown on the plans. The degree of elbow and the pipe size required for elbows and tees will be detailed on the plans and shall be verified in the field.

Elbows, tees, and collars shall be of the same material as the pipe culvert.

(a) Reinforced Concrete. Reinforced concrete elbows and tees shall be fabricated according Article 1042.06.

Reinforced concrete collars shall be constructed according to Section 503 and as detailed on the plans. Reinforcement for concrete collars shall be according to Section 508.

(b) Metal. The bonding or connecting device for the elbows, tees, and/or collars will be approved by the Engineer prior to use.

542.09 Pipe Culverts (Temporary). Pipe culverts used as drainage structures for proposed temporary connections and detour roads shall be designated Pipe Culverts (Temporary) and shall be furnished, installed, and maintained as specified, except that the material for the pipe culvert need not be new material.

Used pipe with a thickness equal to or greater than that required in Table IB or IC of Article 542.03 may be used provided it meets the approval of the Engineer. The Engineer will visually inspect the pipe for acceptance. Small dents or inadequate galvanizing on the pipe will not be cause for rejection.

After the temporary connection or detour road has been removed, the pipe culvert shall become the property of the Contractor.

542.10 Method of Measurement. Pipe culverts will be measured for payment in place in feet (meters), except the length measured will not exceed the length shown on the plans or authorized in writing by the Engineer. When elbows or tees are included in pipe culverts, the measured length of the culvert shall exclude the length of the elbow or tee section.

Excavation in rock will be measured for payment according to Article 502.12.

Trench backfill will be measured for payment according to Article 208.03.

Embankment will be measured for payment according to Article 202.07 and/or Article 204.07.

Additional embankment and its subsequent removal will not be measured for payment.

542.11 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for PIPE CULVERTS, or PIPE CULVERTS (TEMPORARY), of the class and type specified; or PIPE CULVERTS, SPECIAL, of the diameters or equivalent round size specified, and of the particular kind of material when specified.

The removal of unstable or unsuitable material, or rock below plan bedding grade, and the replacement with the specified material, including additional excavation required to widen the trench will be paid for according to Article 109.04 unless the contract contains unit prices for the work included.

Excavation in rock will be paid for according to Article 502.13.

Embankment will be paid for according to Article 202.08 and/or Article 204.08.

Trench backfill will be paid for according to Article 208.04

When the Contractor has the option of using either cast-in-place reinforced concrete end sections or prefabricated end sections as specified in Article 542.07, the work will be paid for at the contract unit price per each for END SECTIONS, for the size of pipe specified.

When specified on the plans, precast reinforced concrete flared end sections will be paid for at the contract unit price per each for PRECAST REINFORCED CONCRETE FLARED END SECTIONS, of the diameter or equivalent round size specified.

When specified on the plans, steel end sections and aluminum end sections will be paid for at the contract unit price per each for STEEL END SECTIONS and ALUMINUM END SECTIONS, respectively, of the diameter or equivalent round size specified.

End sections for polyethylene (PE) culvert pipe will be paid for at the contract unit price per each for METAL END SECTIONS, of the diameter specified.

When cast-in-place reinforced concrete end sections are specified on the plans, the work will be paid for at the contract unit price per each for CAST-IN-PLACE REINFORCED CONCRETE END SECTIONS, of the diameter specified.

When cast-in-place concrete collars are specified on the plans, the concrete will be paid for at the contract unit price per cubic yard (cubic meter) for CONCRETE COLLAR. Reinforcement will be paid for according to Section 508. Expansion bolts, when required, will be paid for according to Section 540.

When specified on the plans, elbows and tees for polyethylene or metal pipe will be paid for at the contract unit price per each of PIPE ELBOW and PIPE TEE, of the diameter specified.

Grating for precast reinforced concrete flared end sections will be paid for at the contract unit price per each for GRATING FOR CONCRETE FLARED END SECTION, of the size specified.

Inlet boxes for median slopes and for side slopes will be paid for at the contract unit price per each for INLET BOX, STANDARD 542501; INLET BOX, STANDARD 542521; INLET BOX, STANDARD 542511; INLET BOX, STANDARD 542506; INLET BOX, STANDARD 542536; INLET BOX, STANDARD 542516; and INLET BOX, STANDARD 542541.

Inlet boxes for median ditch checks will be paid for at the contract unit price per each for INLET BOX, STANDARD 542526 or INLET BOX, STANDARD 542531.

Inlet boxes to be placed flush in medians will be paid for at the contract unit price per each for FLUSH INLET BOX FOR MEDIAN, STANDARD 542546.

Reinforced concrete pipe elbows will be paid for at the contract unit price per each for REINFORCED CONCRETE PIPE ELBOW, of the diameter specified.

Reinforced concrete pipe tees will be paid for at the contract unit price per each for REINFORCED CONCRETE PIPE TEE, of the pipe diameter and riser diameter specified.

SECTION 543. INSERTION LINING OF PIPE CULVERTS

543.01 Description. This work shall consist of insertion lining of existing pipe culverts and the grouting of the annular space between the existing culvert and the liner pipe.

543.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Polyethylene (PE) Pipe with a Smooth Interior (Note 1)	1040.04
(b) Polyethylene (PE) Profile Wall Pipe (Note 1)	1040.04
(c) Reinforced Plastic Mortar (RPM) Pipe (Note 1)	1040.05
(d) Nonshrink Grout	1024.01
(e) Corrugated PVC with a Smooth Interior (Note 1)	1040.03
(f) Grout Mixture (Note 2)	

Note 1. Insertion linings are specified to minimum allowable inside diameters. Any of the listed pipe materials are permitted if the inside diameter requirement is met.

Note 2. The grout mixture shall be 6.50 hundredweight/cu yd (385 kg/cu m) of portland cement plus fine aggregate and water. Fly ash may replace a maximum of 5.25 hundredweight/cu yd (310 kg/cu m) of the portland cement. The water/cement ratio, according to Article 1020.06, shall not exceed 0.60. An air-entraining admixture shall be used to produce an air content, according to Article 1020.08, of not less than 6.0 percent nor more than 9.0 percent of the volume of the grout. The Contractor shall have the option to use a water-reducing or high range water-reducing admixture.

Nominal Size (in.)	PE-F714		RPM-D3262		Profile Wall-F894		PVC-F949	
	I.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)
10					10.00	11.20	9.8	10.8
12	11.92	12.75			12.00	13.47	11.7	12.8
13	12.50	13.38						
14	13.09	14.00						
15					15.00	16.85	14.3	15.7
16	14.96	16.00						
18	16.80	18.00	18.0	19.5	18.00	20.24	17.6	19.2
20	18.67	20.00	20.0	21.6				
21					21.00	23.65	20.1	22.6
22	20.54	22.00						
24	22.40	24.00	24.0	25.8	24.00	27.06	23.5	25.6
27					27.00	30.43	26.4	28.9
28	26.14	28.00						
30			30.0	32.0	30.00	33.82	29.5	32.1
32	29.50	31.59						
36	33.61	36.00	36.0	38.3	36.00	40.65	35.5	38.7
40	36.85	39.47			40.00	45.20		
42	39.21	42.00	42.0	44.5	42.00	47.47		

Nominal Size (in.)	PE-F714		RPM-D3262		Profile Wall-F894		PVC-F949	
	I.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)	I.D. (in.)	O.D. (in.)
48	44.24	47.38	48.0	50.8	48.00	53.76		
54			54.0	57.1	54.00	60.48		
55	51.63	55.30						
60			60.0	62.9	60.00	67.20		
63	59.02	63.21						
66			66.0	69.2	66.00	73.92		
72			72.0	75.4	72.00	80.64		
78			78.0	81.6	78.00	87.36		
84			84.0	88.0	84.00	94.08		
90			90.0	94.3	90.00	100.80		
96			96.0	100.6	96.00	107.52		

Nominal Size (mm)	PE-F-714		RPM-D3262		ProfileWall-F894		PVC-F949	
	I.D. (mm)	O.D. (mm)	I.D. (mm)	O.D. (mm)	I.D. (mm)	O.D. (mm)	I.D. (mm)	O.D. (mm)
250					250.0	284.5	250.1	273.9
300	302.8	323.9			300.0	342.1	297.6	325.0
325	317.5	339.9						
350	332.5	355.6						
375					375.0	428.0	364.2	397.7
400	380.0	406.4						
450	426.7	457.2	457.2	495.3	450.0	514.1	445.8	486.5
500	474.2	508.0	508.0	548.6				
525					525.0	600.7	525.9	573.7
550	521.7	558.8						
600	569.0	609.6	609.6	655.3	600.0	687.3	596.1	649.7
675					675.0	772.9	671.6	733.0
700	664.0	711.2						
750			762.0	812.8	750.0	859.0	748.5	816.6
800	749.3	802.4						
900	853.7	914.4	914.4	922.8	900.0	1032.5	901.1	984.0
1000	936.0	1002.5			1000.0	1148.1		
1050	995.9	1066.8	1066.8	1130.3	1050.0	1205.7		
1200	1123.7	1203.5	1219.2	1290.3	1219.2	1365.5		
1350			1371.6	1450.3	1371.6	1536.2		
1375	1311.4	1404.6						
1500			1524.0	1597.7	1524.0	1706.9		
1600	1499.1	1605.5						
1650			1676.4	1757.7	1676.4	1877.6		
1800			1828.8	1915.2	1828.8	2048.2		
1950			1981.2	2072.6	1981.2	2218.9		
2100			2133.6	2235.2	2133.6	2389.6		
2250			2286.0	2395.2	2286.0	2560.3		
2400			2438.4	2555.2	2438.4	2731.0		

CONSTRUCTION REQUIREMENTS

543.03 General. Prior to installing the insertion lining, the existing culvert shall be completely cleaned.

PE pipe with a smooth interior shall be joined into a continuous length by the butt fusion method according to ASTM D 2657 or by an approved screw-on or push-on joint. PE profile wall pipe shall be joined by heat fusion, extrusion, welding, screw-on, or other approved connections. RPM pipe or corrugated PVC with a smooth interior pipe shall be joined according to the manufacturer's recommendations using joint lubricant. The joining may be accomplished in a jacking pit or other convenient location where the assembled liner can be brought into alignment with the existing culvert bore without damage. The Engineer will approve each joint before each section of liner pipe is inserted.

The insertion may be made by pushing or pulling the assembled liner pipe from either end of the culvert. The Engineer may require the liner to have a temporary nose cone or plug to guide the liner pipe past minor obstructions. The insertion operation shall not cause joints to separate nor damage the liner pipe.

After the liner has been completely inserted and has been inspected in place by the Engineer, it shall be cut off flush with the ends of the existing culvert or as otherwise directed by the Engineer. Liner pipe shall be allowed to cool to the temperature of the existing culvert before it is cut off. The entire length of the annular space between the existing culvert and the liner pipe shall be filled with a grout mixture.

Prior to filling the annular space, the upstream and downstream ends of the annular space shall have a cement mortar mixture grout stop. The mixture shall be one part cement and two parts sand. The grout stop shall be no closer than 6 in. (150 mm) from the end. Holes shall be required at the grout stop to allow air to escape when pumping grout and to allow verification that the annular space has been filled with grout.

When the grout is pumped into the annular space, the Contractor shall prevent the floating of the liner pipe. This shall be accomplished by any of the following methods.

(a) Intermittent Pumping Method. Small amounts of grout shall be pumped into the annular space and allowed to harden. This shall continue until the bond between the liner pipe and grout is sufficient to resist floating. The remainder of the annular space shall then be filled.

(b) Bracing Method. Braces shall be installed in the annular space to prevent floating of the liner pipe. Only braces which do not damage the liner pipe shall be used.

(c) Water Fill Method. The liner pipe shall be temporarily filled with water before filling the annular space with grout.

The pumping operation shall effectively fill the annular space along the entire length, but shall be performed in a manner that does not distort the liner pipe. The

pressure developed in the annular space shall not exceed the liner pipe manufacturer's recommended value.

Upon completion of the pumping operation, the remaining 6 in. (150 mm) at the upstream and downstream ends shall be filled with a nonshrink grout. Only enough water to make a stiff but workable nonshrink grout shall be used.

543.04 Method of Measurement. This work will be measured for payment in place in feet (meters).

Excavation in rock will be measured for payment according to Article 502.12.

543.05 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for INSERTION CULVERT LINER of the inside diameter specified.

Excavation in rock will be paid for according to Article 502.13.

SEWERS

SECTION 550. STORM SEWERS

550.01 Description. This work shall consist of constructing storm sewers.

550.02 Materials. Materials shall be according to the following.

Item	Article Section
(a) Clay Sewer Pipe	1040.02
(b) Extra Strength Clay Pipe	1040.02
(c) Concrete Sewer, Storm Drain, and Culvert Pipe	1042
(d) Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe	1042
(e) Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe (Note 1)	1042
(f) Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe (Note 1)	1042
(g) Polyvinyl Chloride (PVC) Pipe	1040.03
(h) Corrugated Polyvinyl Chloride (PVC) Pipe with a Smooth Interior	1040.03
(i) Polyvinyl Chloride (PVC) Profile Wall Pipe-794	1040.03
(j) Rubber Gaskets and Preformed Flexible Joint Sealants for Concrete Pipe	1056
(k) Mastic Joint Sealer for Pipe	1055
(l) External Sealing Band	1057
(m) Fine Aggregate (Note 2)	1003.04
(n) Coarse Aggregate (Note 3)	1004.05

Note 1. The class of elliptical and arch pipe used for various storm sewer sizes and heights of fill shall conform to the requirements for circular pipe.

Note 2. The fine aggregate shall be moist.

Note 3. The coarse aggregate shall be wet.

550.03 Kinds of Material Permitted. When a Class of storm sewer is specified, the material shall be selected from the following table. When a particular material is specified, no other kind of material will be permitted.

Class	Materials
A	Rigid Pipes: Clay Sewer Pipe Extra Strength Clay Pipe Concrete Sewer, Storm Drain, and Culvert Pipe Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe
B	Rigid Pipes: Clay Sewer Pipe Extra Strength Clay Pipe Concrete Sewer, Storm Drain, and Culvert Pipe Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe Flexible Pipes: Polyvinyl Chloride (PVC) Pipe Corrugated Polyvinyl Chloride Pipe with a Smooth Interior Polyvinyl Chloride (PVC) Profile Wall Pipe-794

When a storm sewer diameter is specified, only a circular pipe will be permitted. When a round size equivalent is specified, only a reinforced concrete arch pipe or reinforced concrete elliptical pipe will be permitted.

When metric sizes are specified on the plans, the next larger available manufactured English pipe may be substituted at no additional cost to the Department.

The Contractor may, at no additional cost to the Department, substitute a stronger pipe of the same kind of material specified.

The kind of material and thickness or thickness class required for the various types of storm sewers shall be according to the following tables.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

Nom. Dia. in.	Type 1 Fill Height: 3' and less with 1' min. cover						Type 2 Fill Height: Greater than 3', not exceeding 10'						Type 3 Fill Height: Greater than 10', not exceeding 15'					
	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794
10	NA	3	X	X	NA	N A	NA	1	*X	X	**	NA	NA	3	X	X	**	NA
12	IV			X	X	X	III	1	*X	X	X	X	IV		X	X	X	X
15	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
18	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
21	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
24	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
27	IV			X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
30	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
33	III		X	X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
36	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
42	II	NA		NA	NA	NA	III	NA		NA	NA	NA	IV	NA		NA	NA	NA
48	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
54	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
60	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
66	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
72	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
78	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
84	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
90	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
96	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
102	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
108	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturer's Certification.
Note	RCCP Class V - 3160D, etc. shall be furnished according to AASHTO M 170 Section 6. These loads are D loads to produce a 0.01 in. crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS (Metric)

Nom. Dia. mm	Type 1 Fill Height: 1 m and less, with 0.3 m min. cover						Type 2 Fill Height: Greater than 1 m, not exceeding 3 m						Type 3 Fill Height: Greater than 3 m, not exceeding 4.5 m					
	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794	RCCP Class	CSP Class	ESCP	PVC	CPVC	PVCPW -794
250	NA	3	X	X	NA	N A	NA	1	*X	X	**	NA	NA	3	X	X	**	NA
300	IV			X	X	X	III	1	*X	X	X	X	IV		X	X	X	X
375	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
450	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
525	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
600	IV			X	X	X	III	2	X	X	X	X	IV			X	X	X
675	IV			X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
750	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
825	III		X	X	NA	NA	III		X	X	NA	NA	IV			X	NA	NA
900	III		X	X	X	X	III		X	X	X	X	IV			X	X	X
1050	II	NA		NA	NA	NA	III	NA		NA	NA	NA	IV	NA		NA	NA	NA
1200	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
1350	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
1500	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	IV	NA	NA	NA	NA	NA
1650	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
1800	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
1950	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2100	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2250	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2400	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2550	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA
2700	I	NA	NA	NA	NA	NA	II	NA	NA	NA	NA	NA	III	NA	NA	NA	NA	NA

RCCP Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP Extra Strength Clay Pipe
PVC Polyvinyl Chloride (PVC) Pipe
CPVC Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X Indicates this diameter pipe may be used.
NA Not Acceptable
* May also use standard strength Clay Sewer Pipe
** May be used if Bureau of Materials and Physical Research approves and with Manufacturer's Certification.
Note RCCP Class V - 150D, etc. shall be furnished in accordance with AASHTO M 170M Section 6. These loads are D loads to produce a 0.3 mm crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

Nom. Dia. in.	Type 4 Fill Height: Greater than 15', not exceeding 20'				Type 5 Fill Height: Greater than 20', not exceeding 25'				Type 6 Fill Height: Greater than 25', not exceeding 30'			
	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794
10	NA	X	**	N A	NA	X	**	NA	NA	X	**	NA
12	V	X	X	X	V-3160D	X	X	X	V-3790D	X	X	X
15	V	X	X	X	V-3080D	X	X	X	V-3390D	X		
18	V	X	X	X	V	X	X	X	V-3115D	X		
21	V	X	X	X	V	X	X	X	V	X		
24	V	X	X	X	V	X	X	X	V	X		
27	V	X	NA	NA	V	X	NA	NA	V	X	NA	NA
30	V	X	X	X	V	X			V	X		
33	IV	X	NA	NA	V	X	NA	NA	V	X	NA	NA
36	IV	X	X	X	V	X			V	X		
42	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
48	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
54	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
60	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
66	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
72	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
78	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
84	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
90	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
96	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
102	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
108	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA

RCCP Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP Extra Strength Clay Pipe
PVC Polyvinyl Chloride (PVC) Pipe
CPVC Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794 Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X Indicates this diameter pipe may be used.
NA Not Acceptable
* May also use standard strength Clay Sewer Pipe
** May be used if Bureau of Materials and Physical Research approves and with Manufacturer's Certification.
Note RCCP Class V - 3160D, etc. shall be furnished according to AASHTO M 170 Section 6. These loads are D loads to produce a 0.01 in. crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS
(Metric)

Nom. Dia. mm	Type 4 Fill Height: Greater than 4.5 m, not exceeding 6 m				Type 5 Fill Height: Greater than 6 m, not exceeding 7.5 m				Type 6 Fill Height: Greater than 7.5 m, not exceeding 9 m			
	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794	RCCP Class	PVC	CPVC	PVCPW -794
250	NA	X	**	N A	NA	X	**	NA	NA	X	**	NA
300	V	X	X	X	V-150D	X	X	X	V-180D	X	X	X
375	V	X	X	X	V-145D	X	X	X	V-160D	X		
450	V	X	X	X	V	X	X	X	V-150D	X		
525	V	X	X	X	V	X	X	X	V	X		
600	V	X	X	X	V	X	X	X	V	X		
675	V	X	NA	NA	V	X	NA	NA	V	X	NA	NA
750	V	X	X	X	V	X			V	X		
825	IV	X	NA	NA	V	X	NA	NA	V	X	NA	NA
900	IV	X	X	X	V	X			V	X		
1050	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1200	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1350	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1500	IV	NA	NA	NA	V	NA	NA	NA	V	NA	NA	NA
1650	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
1800	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
1950	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2100	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2250	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2400	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2550	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA
2700	IV	NA	NA	NA	IV	NA	NA	NA	V	NA	NA	NA

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 150D, etc. shall be furnished according to AASHTO M 170M Section 6. These loads are D loads to produce a 0.3 mm crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS

Nom. Dia. in.	Type 7 Fill Height: Greater than 30', not exceeding 35'		
	RCCP Class	PVC	
10	NA	X	
12	V-4000D	X	
15	V-3575D	X	
18	V-3300D	X	
21	V-3110D	X	
24	V	X	
27	V	X	
30	V	X	
33	V	X	
36	V	X	
42	V	NA	
48	V	NA	
54	V	NA	
60	V	NA	
66	V	NA	
72	V	NA	
78	V	NA	
84	V	NA	
90	V	NA	
96	V	NA	
102	V	NA	
108	V	NA	

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 3160D, etc. shall be furnished according to AASHTO M 170 Section 6. These loads are D loads to produce a 0.01 in. crack.

KIND OF MATERIAL PERMITTED AND STRENGTH REQUIRED
FOR THE RESPECTIVE DIAMETERS OF PIPE AND FILL HEIGHTS OVER THE TOP OF THE PIPE FOR STORM SEWERS
(Metric)

Nom. Dia. mm	Type 7 Fill Height: Greater than 9 m, not exceeding 10.5 m		
	RCCP Class	PVC	
250	NA	X	
300	V-190D	X	
375	V-170D	X	
450	V-160D	X	
525	V-150D	X	
600	V	X	
675	V	X	
750	V	X	
825	V	X	
900	V	X	
1050	V	NA	
1200	V	NA	
1350	V	NA	
1500	V	NA	
1650	V	NA	
1800	V	NA	
1950	V	NA	
2100	V	NA	
2250	V	NA	
2400	V	NA	
2550	V	NA	
2700	V	NA	

RCCP	Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
CSP	Concrete Sewer, Storm Drain, and Culvert Pipe
ESCP	Extra Strength Clay Pipe
PVC	Polyvinyl Chloride (PVC) Pipe
CPVC	Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior
PVCPW-794	Polyvinyl Chloride (PVC) Profile Wall Pipe-794
X	Indicates this diameter pipe may be used.
NA	Not Acceptable
*	May also use standard strength Clay Sewer Pipe
**	May be used if Bureau of Materials and Physical Research approves and with Manufacturers' Certification.
Note	RCCP Class V - 150D, etc. shall be furnished according to AASHTO M 170M Section 6. These loads are D loads to produce a 0.3 mm crack.

CONSTRUCTION REQUIREMENTS

550.04 Excavation and Foundation. Trenches shall be excavated to an elevation 4 in. (100 mm) below the bottom of the pipe and to the following widths.

Trench Depth/Protection	Required Trench Width On Each Side of the Pipe
5 ft (1.5 m) and less, without protection	9 in. (225 mm)
5 ft (1.5 m) and less, with protection	18 in. (450 mm)
Greater than 5 ft (1.5 m)	18 in. (450 mm)

The trench shall be excavated so that vertical faces are maintained at least to the elevation of the top of pipe. For trench depths greater than 5 ft (1.5 m), trench protection shall be utilized according to the applicable standards for work place safety. The Contractor shall provide to the Engineer, in writing, his/her procedures for fulfilling the safety requirements for trench protection.

If a water main is encountered during storm sewer construction, the requirements of the IEPA shall govern the horizontal and vertical separation of the water main from the storm sewer.

Well compacted aggregate, at least 4 in. (100 mm) in depth below the pipe, shall be placed for the entire width of the trench and length of the pipe; except when the storm sewer outlets from an embankment or natural ground, the last 3 ft (1 m) of the pipe shall be bedded in impervious material. The aggregate and impervious material shall be compacted by mechanical means to the satisfaction of the Engineer.

When pipe having bells or hubs is used, cross trenches not more than 2 in. (50 mm) wider than the bell or hub shall be excavated to provide uniform bearing along the length of the pipe.

If the excavation has been made deeper than necessary, the foundation shall be brought to the proper grade by the addition of well compacted bedding material.

Where a firm foundation is not encountered at the grade established due to soft, spongy, or otherwise unsuitable soil, unless other special construction methods are called for in the contract, all such unsuitable soil under the pipe and for the width of the trench shall be removed and replaced with well-compacted bedding material.

Where rock, in either ledge or boulder formation, is encountered, it shall be removed to an elevation at least 8 in. (200 mm) below the bottom of the pipe and replaced with a cushion of well compacted bedding material.

All excavated material not needed on the work shall be disposed of according to Article 202.03.

550.05 Plugging Existing Sewers and Drains. Abandoned sewers and drains, as designated by the Engineer, shall be plugged with Class SI concrete, or brick and suitable mortar, to the satisfaction of the Engineer.

This work will not be paid for separately, but shall be considered as included in the contract unit price bid for the storm sewer items or in the absence of such items for earth excavation.

550.06 Laying Sewer Pipe. The trench shall be kept free from water while the sewer is being placed and until the joint has been sealed. The laying of pipes shall be started at the outlet end with the spigot ends pointing in the direction of flow, and shall proceed toward the inlet end with pipes abutting and true to line and grade. The flow line at the outlet end of the pipe shall be at least 6 in. (150 mm) above the flow line of the open ditch.

When an end treatment, pipe tee, or elbow is required, it will be specified on the plans. End treatments shall be according to Article 542.07. Pipe tees and elbows shall be according to Article 542.08.

The ends of pipes shall be carefully cleaned before the pipes are lowered into the trenches, and the pipes shall be lowered so as to avoid unnecessary handling in the trench.

As each length of pipe is laid, the mouth of the pipe shall be properly protected to prevent the entrance of earth or the bedding material. The pipes shall be fitted and matched so that when laid in the work they will form a sewer with a smooth, uniform invert. If reinforced concrete pipe is used, the word "Top" or "Bottom" may be stenciled on the inside of the pipe sections. All concrete pipe so marked shall be placed as indicated by these marks. Each section of pipe shall be pushed or pulled to the section in place to ensure tight joints. Pipe having a diameter greater than 42 in. (1050 mm) shall be set or "brought home" with a winch, come-a-long, or other positive means.

All joints in concrete sewer pipe shall be sealed with rubber gaskets, preformed flexible joint sealants, mastic joint sealer, or external sealing bands. When mastic joint sealer is used, it shall be applied according to the manufacturer's recommendations and the material shall completely fill the joint after the pipes have been brought together. After each joint is sealed, it shall be wiped clean on the inside. Lifting holes shall be filled with a precast concrete plug sealed and covered with mastic or mortar.

PVC pipes shall be joined according to ASTM D 3034.

550.07 Backfilling. As soon as the condition of the pipe will permit, the entire width of the trench shall be backfilled with aggregate to a height of at least the center of the pipe; except when the storm sewer outlets from an embankment or natural ground, the last 3 ft (1 m) of the pipe shall be backfilled with impervious material. The backfill material shall be placed longitudinally along the pipe. The elevation of the backfill material on each side of the pipe shall be the same. The space under the pipe shall be completely filled. The backfill material shall be placed in 8 in. (200 mm) lifts, loose measurement, and compacted by mechanical means to the satisfaction of the Engineer.

When using flexible pipe, as listed in the first table of Article 550.03, the aggregate shall be continued to a height of at least 1 ft (300 mm) above the top of the

pipe and compacted to a minimum of 85 percent of standard lab density by mechanical means.

The installed pipe and its embedment shall not be disturbed when using movable trench boxes and shields, sheet pile, or other trench protection.

The remainder of the trench shall be backfilled to the natural line or finished surface as rapidly as the condition of the sewer will permit. The backfill material shall consist of suitable excavated material from the trench or trench backfill as herein specified. All backfill material shall be deposited in such a manner as not to damage the sewer. The filling of the trench shall be carried on simultaneously on both sides of the pipe.

The backfill material for trenches made in the subgrade of the proposed improvement, and trenches where the inner edge of the trench is within 2 ft (600 mm) of the proposed edge of pavement, curb, gutter, curb and gutter, stabilized shoulder or sidewalk, shall be trench backfill

All backfill material shall be deposited and compacted as specified in Method 1, 2, or 3 below. The method used shall be the choice of the Contractor. If the method used does not produce results satisfactory to the Engineer, the Contractor will be required to alter or change the method being used.

When trench backfill is used with Method 1, the lifts shall not exceed 8 in. (200 mm) in depth, loose measurement, and each lift shall be compacted to 85 percent of standard lab density by mechanical means. When trench backfill is used with Method 2 or 3, gradations CA 6 and CA 10 will not be allowed.

(a) Method 1. The material shall be deposited in uniform lifts not exceeding 12 in. (300 mm) in depth, loose measurement, and each lift shall be compacted by mechanical means to the satisfaction of the Engineer.

(b) Method 2. The material shall be deposited in uniform lifts not exceeding 12 in. (300 mm) thick, loose measurement, and each lift shall be either inundated or deposited in water.

(c) Method 3. The trench shall be backfilled with loose material, and settlement secured by introducing water through holes jetted into the backfill to a point approximately 2 ft (600 mm) above the top of the pipe. The holes shall be spaced as directed by the Engineer but shall be no farther than 6 ft (2 m) apart.

The water shall be injected at a pressure just sufficient to sink the holes at a moderate rate of speed. The pressure shall be such that the water will not cut cavities in the backfill material nor overflow the surface. If water does overflow the surface, it shall be drained into the jetted holes by means of shallow trenches.

Water shall be injected as long as it will be absorbed by the backfill material and until samples taken from test holes in the trench show a satisfactory moisture content. The Contractor shall bore the test holes not more than 50 ft (15 m) apart and at such other locations in the trench designated by the

Engineer. As soon as the water soaking has been completed, all holes shall be filled with soil and compacted by ramming with a tool approved by the Engineer.

Backfill material which has been water soaked shall be allowed to settle and dry for at least ten days before any surface course or pavement is constructed on it. At the end of the settling and drying period, the crusted top of the backfill material shall be scarified and, if necessary, sufficient backfill material added, as specified in Method 1, to complete the backfilling operations.

In lieu of suitable excavated material or trench backfill, the Contractor may, at no additional cost to the Department, backfill the entire trench with controlled low-strength material according to Section 593.

When sheeting and bracing have been used, sufficient bracing shall be left across the trench as the backfilling progresses to hold the sides firmly in place without caving or settlement. This bracing shall be removed as soon as practicable. Any depressions which may develop within the area involved in the construction operation due to settlement of the backfilling material shall be filled in a manner meeting the approval of the Engineer.

When the Contractor constructs the trench with sloped or benched sides according to Article 550.04, backfilling for the full width of the excavation shall be as herein before specified, except no additional compensation will be allowed for trench backfill material required outside the vertical limits of the specified trench width.

Whenever excavation is made for installing sewer pipe across earth shoulders or private property, the topsoil disturbed by excavation operations shall be replaced as nearly as possible in its original position, and the whole area involved in the construction operations shall be left in a neat and presentable condition.

550.08 Deflection Testing for Storm Sewers. All PVC storm sewers shall be tested for deflection not less than 30 days after the pipe is installed and the backfill compacted.

For PVC storm sewers with diameters 24 in. (600 mm) or smaller, a mandrel drag shall be used for deflection testing. For PVC storm sewers with diameters over 24 in. (600 mm), deflection measurements other than by a mandrel drag shall be used.

Where the mandrel is used, the mandrel shall be furnished by the Contractor and pulled by hand through the pipeline with a suitable rope or cable connected to each end. Winching or other means of forcing the deflection gauge through the pipeline will not be allowed.

The mandrel shall be of a shape similar to that of a true circle enabling the gauge to pass through a satisfactory pipeline with little or no resistance. The mandrel shall be of a design to prevent it from tipping from side to side and to prevent debris build-up from occurring between the channels of the adjacent fins or legs during operation. Each end of the core of the mandrel shall have fasteners to which the pulling cables can be attached. The mandrel shall have nine, various sized fins or legs of appropriate dimension for various diameter pipes. Each fin or leg shall have a

permanent marking that states its designated pipe size and percent of deflection allowable.

The outside diameter of the mandrel shall be 95 percent of the base inside diameter, where the base inside diameter is:

For all PVC pipe: as defined using ASTM D 3034 methodology.

If the pipe is found to have a deflection greater than that specified, that pipe section shall be removed, replaced, and retested.

550.09 Method of Measurement. Storm sewers will be measured for payment in place in feet (meters). When the storm sewer enters a manhole, inlet, or catch basin, the measurement will end at the inside wall of the manhole, inlet or catch basin. Allowance will be made for the length of pipe necessary to permit the pipe to meet the sides of the manhole. No payment for storm sewer will be made through an inlet or manhole where the inlet or manhole is paid for as a separate item. However, when the storm sewer is continuous and the inlet is constructed on top of the storm sewer, the measurement will be from end to end of storm sewer with a deduction made for the tee section which is paid for separately.

Trench backfill will be measured for payment according to Article 208.03.

Excavation in rock will be measured for payment according to Article 502.12.

550.10 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for STORM SEWERS, of the class, type, and diameter specified, and of the kind of material when specified.

Trench backfill will be paid for according to Article 208.04.

Excavation in rock will be paid for according to Article 502.13.

Removal and replacement of unsuitable material below plan bedding grade will be paid for according to Article 109.04.

End treatments, pipe tees, and elbows will be paid for according to Article 542.11.

SECTION 551. STORM SEWER REMOVAL AND INSTALLATION

551.01 Description. This work shall consist of the removal and/or installation of storm sewers, including laterals.

551.02 Materials. New materials shall be according to Articles 550.02 and 550.03.

CONSTRUCTION REQUIREMENTS

551.03 Removal. Existing storm sewers shall be removed so that all pipe considered suitable by the Engineer for future use shall be salvaged. The location and manner of storage of salvaged material shall be as directed by the Engineer.

Any of the material having salvage value which has been damaged by the Contractor shall be replaced with new pipe of the same kind and size. Material not suitable for salvage shall be disposed according to Article 202.03.

Excavation of trenches shall be performed according to the applicable requirements of Article 550.04. Backfill of trenches shall be performed according to the applicable requirements of Article 550.07.

551.04 Installation. Suitable pipe salvaged from storm sewer removal shall be used when available. When salvaged pipe is available for use, any new material required shall be of the same kind as the salvaged pipe.

Storm sewer installation shall be performed according to the applicable requirements of Section 550.

551.05 Method of Measurement. This work will be measured for payment according to Article 550.09.

Excavation in rock will be measured for payment according to Article 502.12.

Trench backfill for storm sewer removal will be measured for payment according to Article 208.03, except an addition will be made for one-half of the volume of the pipe removed.

Trench backfill for storm sewer installation will be measured for payment according to Article 208.03.

551.06 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for STORM SEWER REMOVAL or STORM SEWER INSTALLATION, of the diameter specified.

The furnishing of new pipe, except for replacement of pipe damaged by the Contractor, will be paid for according to Article 109.04.

Excavation in rock will be paid for according to Article 502.13.

Trench backfill will be paid for according to Article 208.04.

Removal and replacement of unsuitable material below plan bedding grade will be paid for according to Article 109.04.

SECTION 552. STORM SEWERS JACKED IN PLACE

552.01 Description. This work shall consist of furnishing and installing, by jacking, storm sewers of the required inside diameter at locations shown on the plans.

552.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Reinforced Concrete Culvert, Storm Drain and Sewer Pipe (Note 1)	1042
(b) Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe (Note 1)	1042

Note 1. Tongue and Groove Type Joint. Not less than a Class IV Pipe.

552.03 Traffic Control. The road shall be kept open to traffic according to Article 701.17(d)(3).

CONSTRUCTION REQUIREMENTS

552.04 General. Storm sewers, of the type and size specified, shall be jacked in a continuous operation. The construction may be accomplished by jacking the storm sewer, or if the Contractor elects, a metal liner of sufficient strength and size first, then the storm sewer installed inside the liner. If the liner is used, it shall remain in place to support the embankment, and the voids between the liner and the sewer pipe shall be completely filled with sand or grout mixture as approved by the Engineer. The diameter of the metal liner, if used, shall not exceed the outside diameter of the storm sewer by more than 6 in. (150 mm).

The Contractor may shorten the length of storm sewer to be jacked by open cutting and sheeting, shoring or bracing the excavation outside the roadway limits. No open cutting shall be permitted inside the shoulder lines. If continuous jacking operation cannot be maintained, the Contractor shall take the necessary precautions for not allowing the jacked pipe to freeze in place.

All sheeting, bracing, shoring, jacking frame, guide rails, backstop, shields, sleeves, and other materials necessary for the complete installation of the storm

sewer shall be of sufficient strength to support the loads that are to be imposed on them.

The types, sizes, and number of jacks, jacking pit, and other equipment used shall be such as to exert sufficient force to overcome the greatest resistance to be encountered, considering both weight of the pipe or liner and the friction on its exterior surface. Lubricants, if required, may be used to decrease the frictional resistance on the exterior surface of the pipe being jacked. Suitable lubricants may be applied directly to the surface or through 1/2 in. (13 mm) nipples through holes drilled in the cutting shield at the lead pipe.

Care shall be taken in arranging the jacking equipment and struts to ensure that thrust is applied parallel with the centerline of the pipe or liner or as approved by the Engineer. A jacking head or collar shall be used to apply pressure from the jack to the pipe or liner. Pressure applied with the metal of the jack in direct contact with concrete pipe will not be permitted.

A cutting edge at least 1/2 in. (13 mm) greater in diameter than the pipe or liner being jacked shall be provided for the leading pipe or liner. The upper half of the cutting edge shall project beyond the pipe or liner end to support the embankment. Excavation within the jacked pipe or liner shall be performed in such a manner as to not increase the excavated diameter larger than the pipe or liner being jacked. Excavation shall not be carried beyond the end of the cutting edge of the pipe or liner. Any holes provided in the lead pipe to attach the cutting edge shall be properly filled with plug and mastic as approved by the Engineer after completion of the jacking operation and removal of cutting edge.

552.05 Joints. As each succeeding pipe section is placed against the previously jacked pipe, a 1/2 in. (13 mm) manila rope or other suitable material shall be inserted throughout the entire groove of the joint and set in place with asphalt mastic. The opening on the inside of the pipe shall be mortared with a mixture composed of one part cement to three parts sand, by volume, based on dry materials, after the complete sewer has been jacked in place. Any other method of jointing must be approved by the Engineer prior to the start of construction.

552.06 Accuracy of Placement. The alignment and elevation of the forward end of the pipe shall be checked at regular intervals as work proceeds and appropriate measures immediately taken to correct any observed deviation. When the Contractor elects to jack a metal liner prior to installing the storm sewer, all earth and other foreign material shall be removed from inside the liner. The storm sewer sections shall be installed by jacking the sections through the liner.

552.07 Method of Measurement. This work will be measured for payment in place in feet (meters).

Excavation in rock will be measured for payment according to Article 502.12.

552.08 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for STORM SEWERS JACKED IN PLACE, of the diameter specified.

Excavation in rock will be paid for according to Article 502.13.

UTILITIES

SECTION 560. CAST IRON SOIL PIPE

560.01 Description. This work shall consist of constructing a cast iron soil pipe.

560.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Cast Iron Soil Pipe	1006.20

CONSTRUCTION REQUIREMENTS

560.03 General. Construction requirements shall be according to Section 550 with the following exceptions.

The pipe shall be laid with its spigot end lacking 1/4 in. (6 mm) of being driven full into the bell. Gaskets of clean, sound hemp yarn braided or twisted and tightly driven shall be used to pack the joints, followed by caulking with pure soft lead of the best quality for the purpose, so as to make a tight and permanent joint. All pipes shall be carefully cleaned before laying, and shall be left clean and in working order. The pipe shall have a solid bearing throughout its entire length. If it becomes necessary to cut the pipe, it shall be cut in such a manner that the ends will be square with the axis of the pipe.

560.04 Method of Measurement. This work will be measured for payment in place in feet (meters).

Excavation in rock will be measured for payment according to Article 502.12.

Trench backfill will be measured for payment according to Article 208.03.

560.05 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for CAST IRON SOIL PIPE, of the diameter specified.

Excavation in rock will be paid for according to Article 502.13.

Trench backfill will be paid for according to Article 208.04.

SECTION 561. WATER MAIN

561.01 Description. This work shall consist of constructing a water main.

561.02 Materials. Materials shall be as shown in the contract.

CONSTRUCTION REQUIREMENTS

561.03 General. The construction of water mains, including protection from sewers, pressure testing, and disinfection, shall be according to the "Standard Specifications for Water & Sewer Main Construction in Illinois", except as follows.

(a) Excavation and Foundation. This work shall be according to the applicable requirements of Article 550.04.

(b) Backfilling. This work shall be according to Article 550.07, except backfilling shall not be done in freezing weather nor made with frozen material.

Backfilling around joints shall not be performed until the pressure testing has been completed.

561.04 Method of Measurement. This work will be measured for payment in place in feet (meters). The length measured will include stops, fittings, and valves.

Excavation in rock will be measured for payment according to Article 502.12.

Trench backfill will be measured for payment according to Article 208.03.

561.05 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for WATER MAIN, of the diameter specified.

Excavation in rock will be paid for according to Article 502.13.

Trench backfill will be paid for according to in Article 208.04.

SECTION 562. WATER SERVICE LINE

562.01 Description. This work shall consist of constructing a water service line.

562.02 Materials. Materials shall be as shown in the contract.

CONSTRUCTION REQUIREMENTS

562.03 General. Work shall be performed according to the Illinois Plumbing Code or local codes where applicable, except as follows.

Any excavation required shall be only sufficient to install the water service line. Surplus material shall be disposed of according to Article 202.03.

The applicable requirements of Article 550.07 shall govern the backfilling, except that backfilling shall not be done in freezing weather nor made with frozen material.

562.04 Method of Measurement. This work will be measured for payment in place in feet (meters). The length measured will include stops, fittings, and valves.

Excavation in rock will be measured for payment according to Article 502.12.

Trench backfill will be measured for payment according to Article 208.03.

562.05 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for WATER SERVICE LINE, of the internal diameter specified.

Excavation in rock will be paid for according to Article 502.13.

Trench backfill will be paid for according to Article 208.04.

SECTION 563. ADJUSTING SANITARY SEWERS AND WATER SERVICE LINES

563.01 Description. This work shall consist of adjusting sanitary sewers and water service lines.

563.02 Materials. Materials shall be as shown in the contract. Materials for replacement shall be new and of the same kind as, or equal to, the material being replaced.

CONSTRUCTION REQUIREMENTS

563.03 General. When a Sanitary District, Municipality, or Water District has jurisdiction of a sanitary sewer or water service line, the work shall be performed as prescribed by the Sanitary District, Municipality, or Water District and shall meet the approval of its Engineer.

Materials suitable for reuse in the opinion of the Engineer shall be carefully removed to prevent damage. Such materials damaged by the Contractor shall be replaced. All material removed and not reused shall become the property of the Contractor.

Surplus material shall be disposed of according to Article 202.03.

563.04 Adjusting Sanitary Sewers. Adjustment of sanitary sewers shall be according to the "Standard Specifications for Water and Sewer Main Construction in Illinois". The applicable requirements of Article 550.07 shall govern the backfilling, except that backfilling shall not be done in freezing weather nor made with frozen material.

563.05 Adjusting Water Service Lines. The work necessary to adjust water service lines shall be performed according to Article 562.03.

Any water service line, other than copper, which is or will be under a base or surface course and which requires adjustment, shall be replaced with copper pipe according to the requirements of Article 1006.33.

563.06 Method of Measurement. This work will be measured for payment in place in feet (meters). The length measured will include stops, fittings, and valves.

Excavation in rock will be measured for payment according to Article 502.12.

Trench backfill will be measured for payment according to Article 208.03.

563.07 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for ADJUSTING SANITARY SEWERS, (8 IN. (200 MM) DIAMETER OR LESS); ADJUSTING SANITARY SEWERS, (OVER 8 IN. (200 MM) DIAMETER); and ADJUSTING WATER SERVICE LINES.

Excavation in rock will be paid for according to Article 502.13.

Trench Backfill will be paid for according to Article 208.04.

The furnishing of materials, except for replacement of materials damaged by the Contractor, will be paid for according to Article 109.04.

SECTION 564. MOVING FIRE HYDRANTS

564.01 Description. This work shall consist of moving and adjusting existing fire hydrants, with auxiliary valves when applicable, which interfere with the construction of the proposed improvement.

564.02 Materials. Materials shall be as shown in the contract. Materials for replacement shall be new and of the same kind as, or equal to, the material being replaced.

CONSTRUCTION REQUIREMENTS

564.03 General. The work shall be performed in a manner approved by the Engineer of the Municipality or the Water District.

Fire Hydrants shall be set on a firm foundation and shall be thrust blocked. Thrust blocking shall consist of Class SI concrete cast against the fittings and the undisturbed earth on the side where the thrust is expected to occur. A minimum of 1/4 cu yd (0.2 cu m) of concrete shall be used for the thrust block. The dimensions of the thrust block shall be determined by the Engineer. Blocking shall be placed such that the pipe, fittings and joints shall be accessible for future repair.

Upon completion of relocating or adjusting the fire hydrant, it shall be tested and disinfected according to Article 561.03.

The hole formed by the removal of a fire hydrant and the remaining excavated area around the relocated fire hydrant shall be backfilled with fine aggregate.

Surplus material shall be disposed of according to Article 202.03.

Any fire hydrant damaged by the Contractor shall be repaired.

564.04 Basis of Payment. This work will be paid for at the contract unit price per each for FIRE HYDRANTS TO BE MOVED.

SECTION 565. MOVING DOMESTIC METER VAULTS AND WATER SERVICE BOXES

565.01 Description. This work shall consist of moving domestic meter vaults and water service boxes.

565.02 Materials. Materials shall be as shown in the contract. Materials for replacement shall be new and of the same kind as, or equal to, the material being replaced.

CONSTRUCTION REQUIREMENTS

565.03 General. The work shall be performed in a manner approved by the Engineer of the Municipality or the Water District.

The hole formed by the removal of the domestic meter vault or water service box shall be backfilled with fine aggregate.

Surplus material shall be disposed of according to Article 202.03.

Any domestic meter vault or water service box, including the stop cocks, which are damaged by the Contractor, shall be repaired.

565.04 Basis of Payment. This work will be paid for at the contract unit price per each for DOMESTIC METER VAULTS TO BE MOVED or DOMESTIC WATER SERVICE BOXES TO BE MOVED.

MISCELLANEOUS

SECTION 580. MEMBRANE WATERPROOFING FOR RAILWAY STRUCTURES

580.01 Description. This work shall consist of furnishing, transporting and placing all materials required to construct a membrane waterproofing system on railway structures.

The membrane waterproofing shall be of the bituminous or butyl rubber type as specified on the plans.

580.02 Materials. Materials shall be according to the following.

	Item	Article/Section
(a)	Waterproofing Materials (Note 1)	1060
(b)	Fine Aggregate	1003.05

Note 1. The bitumen used shall be asphalt. The bitumen for mopping and for the protective cover shall be the same type as that with which the fabric is treated.

CONSTRUCTION REQUIREMENTS

580.03 General. Surfaces to be waterproofed shall be smooth and free from projections which might damage the waterproofing membrane and there shall be no depressions in horizontal surfaces of the finished waterproofing. Projections or depressions on the surface on which the membrane is to be applied that may cause damage to the membrane shall be removed or filled as directed by the Engineer. The surface shall be cleaned of dust, dirt, grease, and loose particles, and shall be dry before the waterproofing is applied. Concrete surfaces shall not be waterproofed until

a period of at least seven days has elapsed after the placing of the concrete, unless otherwise approved by the Engineer.

There shall be no depressions or pockets in horizontal surfaces of the finished waterproofing. The membrane shall be carefully turned into drainage fittings. Special care shall be taken to make the waterproofing effective along the sides and ends of girders and at stiffeners, gussets, and all other plates where the membrane terminates.

Bituminous membrane waterproofing shall not be applied when the atmospheric temperature is below 50 ºF (10 ºC) and butyl rubber membrane shall not be applied when the atmospheric temperature is below 10 ºF (-12 ºC), without written permission of the Engineer.

Surfaces of concrete or steel that are to be waterproofed shall be given one coat of Asphalt Primer (RC-70) before the first mopping of Asphalt (AWP), except that at construction and expansion joints where insulation is to be used, the surfaces shall not be coated with primer. The primer shall be applied to the surface in a uniform coating and may be applied without heating. A minimum of 1 gal (4 L) of primer per 100 sq ft (10 sq m) of surface shall be used. The priming coat shall be applied at least 24 hours before applying the waterproofing membrane and it shall be dry before the first mopping of bitumen is applied.

The primer shall be omitted for a width of 9 in. (225 mm) on each side of construction and expansion joints and a strip of insulating paper 18 in. (450 mm) wide shall be laid thereon before the waterproofing is applied. Insulating paper shall be a waterproof paper weighing not less than 10 lb/100 sq ft (0.5 kg/sq m).

Expansion joints and grooves shall be dry and clean; and shall be filled with plastic cement. Expansion joints and grooves filled with plastic cement shall be overfilled to allow for shrinkage.

580.04 Membrane Application. Bituminous and butyl rubber membranes shall be applied as specified.

(a) Bituminous Membrane. On surfaces that are vertical, or nearly so, the strips of fabric shall be laid vertically or with the slope; on other surfaces the strips shall be laid horizontally, beginning at the lowest part of the surface to be waterproofed. Sufficient fabric shall be allowed for anchorage at the upper edge of the surface to be waterproofed.

Surfaces to be waterproofed shall be mopped in sections. While the first mopping of bitumen is still hot, a strip of fabric shall be laid on the mopping and pressed into place. Each mopping thereafter shall be applied so that it will completely cover and seal the fabric. The amount of bitumen used for each mopping shall be not less than 4 1/2 gal/100 sq ft (1.8 L/sq m) of surface. The bitumen for mopping shall be heated to a temperature which will permit uniform application. Asphalt shall not be heated above a temperature of 350 ºF (175 ºC).

Asphalt (AWP) shall be used for mopping asphalt saturated cotton fabric.

Application of bituminous membrane shall be started by mopping a section of the surface 2 in. (50 mm) wider than 1/3 of the width of fabric. On this hot mopping, a 1/3 width of fabric shall be laid. The top surface of this fabric and an adjacent section of the surface 2 in. (50 mm) wider than 1/3 width of fabric shall then be mopped. On this hot mopping, a 2/3 width of fabric shall be laid completely covering the first strip. The top surface of this fabric and an adjacent section of the surface 2 in. (50 mm) wider than 1/3 width of fabric shall then be mopped. On this hot mopping shall be laid a full width of fabric completely covering the first and second strips. The top surface of this fabric and adjacent section, the width of 1/3 width of the fabric, shall then be mopped. On this hot mopping, the second full strip of fabric shall be laid lapping the first 1/3 width of the fabric at least 2 in. (50 mm). Thereafter, full widths of fabric shall be laid in hot moppings of bitumen and in such manner that each strip will lap the third preceding strip at least 2 in. (50 mm). Side laps shall be not less than 2 in. (50 mm) and end laps not less than 12 in. (300 mm).

The bituminous membrane shall be free from punctures, pockets or folds, and patching shall not be done without the permission of the Engineer. Where patching is permitted for defective waterproofing, the first ply shall extend at least 12 in. (300 mm) beyond the defective portion. The second and each succeeding ply of the patch shall extend at least 3 in. (75 mm) beyond the preceding ply.

The work shall be regulated so that at the end of the day all fabric that has been laid shall have received the final coat of bitumen, except that the fabric for making the lap shall not be mopped with bitumen until the joint is to be completed. With the approval of the Engineer, spraying will be permitted in lieu of mopping.

(b) Butyl Rubber Membrane. Butyl rubber membrane sheets shall be laid and secured in a hot mopping of bitumen applied over the primed surfaces. When the surface has been primed using RC-70, the mopping shall be with asphalt (AWP). An adhesive, compatible to the membrane and other materials, may be used in lieu of the hot mopping of bitumen, at the option of the Contractor. If adhesive is used, it shall be applied to the areas to be waterproofed in a thin layer with a squeegee at a rate of 1 gal/100 sq ft (0.4 L/sq m).

Membrane sheets shall first be positioned and drawn tight without stretching. Half of the membrane sheet shall then be uniformly rolled up in a direction away from the starting edge or subsequent splice. The bitumen or adhesive shall now be applied to the exposed area. If adhesive is used, it shall be allowed to dry so as not to stick to a dry finger touch. The membrane shall then be unrolled and pressed firmly and uniformly in place, using care to avoid trapping air. The same procedure shall be used for the remaining half of the membrane sheet. Wrinkles and buckles shall be avoided. Each succeeding sheet shall be positioned to fit the previously installed sheet and spliced.

Splices shall be of tongue-and-groove or lap type. All seam, lap, and splice areas shall be cleaned with heptane, hexane, toluene, trichlorethlene, or

white gasoline, using a clean cloth, mop, or similar synthetic cleaning device. Rubber cement shall be spread continuously on seam, lap, and splice areas at a uniform rate of not less than 2 gal/100 sq ft (0.8 L/sq m). After the rubber cement is allowed to dry until it will not stick to a dry finger touch, butyl gum tape shall be applied to the cemented area of membrane. The tape shall be extended at least 1/8 in. (3 mm) beyond edges of splice and lap areas. The tape shall be rolled or pressed firmly into place so full contact is obtained. Bridging and wrinkles shall be avoided. Corner splices shall be reinforced with two continuous layers of rubber membrane over one layer of butyl tape.

All projecting pipe, conduits, and sleeves passing through butyl rubber membrane waterproofing shall be flashed with prefabricated or field-fabricated boots or fitted coverings, as necessary to provide watertight construction. Butyl gum tape shall be used between layers of rubber membrane.

Any holes in the membrane sheeting shall be patched with a minimum overlap of 4 in. (100 mm) and according to the manufacturer's instructions. During construction, care shall be exercised to prevent damage to the membrane by workers or equipment.

580.05 Protective Cover. The protective cover shall be placed over the membrane as soon as practicable after the membrane has been laid. Dirt and other foreign material shall be removed from the surface of the membrane before the protective cover is placed.

At expansion joints of decks protected with butyl rubber membrane, a strip of anti-bonding paper 18 in. (450 mm) wide shall be laid above and below the membrane before the protective cover is applied.

One of the following methods of protection shall be used.

(a) A layer of asphalt plank not less than 1 1/4 in. (30 mm) thick laid in a mopping of asphalt with all joints filled with asphalt.

(b) A layer or layers of asphaltic panels not less than 3/4 in. (20 mm) in total thickness.

For bituminous membrane, the asphalt plank protection shall be laid in hot asphalt (AWP). The asphalt shall be applied at the rate of not less than 5 gal/100 sq ft (2 L/sq m) of surface. As successive planks are laid, the edges and ends of adjacent planks already laid shall be coated heavily with hot asphalt. The planks shall be laid tight against those previously laid so that the asphalt will completely fill the joints and be squeezed out at the top. After all planks are laid, any joints not completely filled shall be filled with hot asphalt. The ends of adjacent planks shall be staggered.

For butyl rubber membrane, the asphalt plank shall be laid in a coating of bonding adhesive. The bonding adhesive shall be the same as that used for securing the membrane to the deck. The adhesive shall be applied at a rate of not less than

1 gal/100 sq ft (0.4 L/sq m). Voids between the joints shall be filled with a compatible material.

Asphaltic panels are available in various thicknesses. To obtain the thickness of 3/4 in. (20 mm) required, the recommended application is in two layers with the joints staggered. The panels shall be laid tight jointed with an approved adhesive. For bituminous membrane, the asphaltic panels shall be laid in hot asphalt (AWP) and for butyl rubber membrane, the panels shall be laid in a coating of bonding adhesive. The application rate shall be the same as previously specified for asphalt planks. Any voids between the panels shall be filled with a material compatible to both the membrane and the panel.

When asphaltic panels are used as a protective cover, a 2 in. (50 mm) layer of fine aggregate shall be placed over the panels as a cushion prior to placement of ballast. The cost of this cushion shall be included in the bid price for membrane waterproofing.

580.06 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of Contract Quantities shall conform to Article 202.07(a).

(b) Measured Quantities. The membrane waterproofing will be measured for payment in place, and the area computed in square feet (square meters). The area for measurement will include only the surface of the membrane waterproofing covered with a protective cover.

580.07 Basis of Payment. This work will be paid for at the contract unit price per square foot (square meter) for MEMBRANE WATERPROOFING.

SECTION 581. WATERPROOFING MEMBRANE SYSTEM

581.01 Description. This work shall consist of furnishing and placing a waterproofing membrane system over a properly prepared concrete bridge deck prior to placing of the hot-mix asphalt (HMA) surface course.

581.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Water	1002
(b) Waterproofing Membrane System (Note 1)	1061

Note 1. The waterproofing membrane system shall consist of a penetrating primer, a built-up coal tar pitch emulsion membrane with two plies of coated glass fabric, and a 1/2 in. (13 mm) thick asphalt sand seal protection layer.

CONSTRUCTION REQUIREMENTS

581.03 General. All methods employed in performing the work and all equipment, tools, and machinery used for handling materials and executing any part of the work shall be subject to approval of the Engineer before the work is started, and whenever found unsatisfactory, shall be changed or improved as required. All equipment, tools, machinery, and containers used shall be kept clean and maintained in a satisfactory condition.

581.04 Preparation of Concrete Deck. All surfaces which are to be covered shall be thoroughly cleaned by the use of air jets, water jets, mechanical sweeper, hand brooms, or other approved methods, or as required by the Engineer until the surface is free of all sand, clay, dust, salt deposits, and all loose or foreign matter. Any accumulations of oil or grease shall be scraped off the surface of the roadway after which those areas shall be cleaned with a strong caustic solution, the residue of which shall be thoroughly flushed away with clean water before application of the primer.

All cleaned areas shall be primed without delay as soon as they are dry. All dust and dirt shall be blown off with air jets immediately preceding application of primer. Any unusually sharp concrete edges on the deck surface which could puncture the membrane shall be corrected in a manner satisfactory to the Engineer prior to application of the primer. Exposed aggregate or rough spots shall be smoothed.

A 1/2 to 3/4 in. (13 to 20 mm) fillet of concrete or epoxy grout shall be placed in the cove area between curb, parapet, median and expansion dam faces, and the deck surface to prevent a void area where the membrane turns up the vertical face.

Concrete surfaces, structural steel, railing, passing vehicles, etc. shall be protected to prevent their being defaced by primer or other materials being used. Should defacement occur, the Contractor shall clean surfaces on the structure to the satisfaction of the Engineer and be solely responsible and liable for damage to passing vehicles. From the time the bridge deck is cleaned and prepared for the prime coat until the HMA is spread and compacted, the only traffic permitted on the area being treated shall be the necessary men and equipment to perform the work required.

581.05 Weather and Moisture Limitations. Work shall not be done during wet weather conditions, or when the deck and ambient air temperatures are below 45 ºF (7 ºC). The deck shall be surface-dry at the time of the application of the primer. The membrane shall not be placed until at least 28 days after deck-concrete placement on new structures unless otherwise directed. On existing structures where the normal traffic flow is interrupted by the project work, as much drying time after the curing period shall be allowed as is feasible before membrane placement.

581.06 Application of Membrane System. Pressure distributors used for the application of the tar emulsion shall be self-propelled, equipped with pneumatic tires, and capable of applying 0.08 to 0.10 gal/sq yd (0.4 to 0.5 L/sq m) of tar emulsion over the required width of application. Distributors shall be equipped with removable manhole covers, tachometers, pressure gauges, and volume measuring devices.

Mixing and agitating equipment furnished shall be either a portable power mixer or a tank-type power mixer. A portable mixer for use in drums shall have sufficient power and propeller blades shaped to thoroughly mix and pull the material upward from the bottom of the drum. Mixing in tanks may be done in round bottom tanks equipped with a power driven mixer of sufficient capacity to maintain the emulsion in suspension.

The primer and full membrane shall extend up the curb faces and other vertical barriers to at least the elevation of the top of the surfacing. The lips of drain openings and edges of open joints, deck slab, and other openings at deck level shall be completely sealed by extending the full waterproofing course over the lip or edge.

The penetrating primer shall be applied by spraying, preferably with high pressure hydraulic equipment using hand-held spray bars that permit close control of the quantity applied. Applied at the rate of approximately 0.01 gal/sq yd (0.05 L/sq m), the quantity shall be controlled to produce a "brown coat" filling all pores and depressions but devoid of lakes or pools showing a solid film when dried out. The purpose of the primer is to neutralize the concrete surface and not to produce a membrane film by itself.

Primer shall not be diluted unless ordered by the Engineer. A distributor truck shall not be used to apply the primer unless its performance has been demonstrated and its use approved by the Engineer. Surfaces shall be dry when primer is applied, and the weather and atmospheric conditions favorable for a drying period of at least four hours. Care shall be taken that the primer does not flow onto nor is applied over bituminous or mastic materials.

Coal tar pitch emulsion shall not be applied until the primer has cured for 24 hours or until all solvents that may cause bleeding of the emulsion have evaporated. The coal tar pitch emulsion coatings shall not be applied when the weather is foggy or when rain threatens, or when the atmospheric or pavement temperature is below 45 ºF (7 ºC).

Due to the settling that may take place in transit, the emulsion shall be thoroughly agitated by power mixers so that a homogeneous consistency is assured for proper and uniform application.

A total of four applications of emulsion shall be applied to the deck, the fourth coat being in the form of a slurry. The slurry shall be applied at the rate of 0.30 gal/sq yd (1.4 L/sq m) in order to obtain 0.13 to 0.15 gal (0.5 to 0.6 L) of undiluted coal tar emulsion per square yard (square meter). The first three coats of undiluted coal tar emulsion shall be applied at the rate of 0.08 to 0.10 gal/sq yd (0.4 to 0.5 L/sq m). Two layers of fiberglass fabric shall be placed parallel to the length of the bridge. The necessary time shall be allowed between coats for proper setting. After the roadway surface has been properly primed and approved by the Engineer, the coal tar pitch emulsion shall be applied according to one of the two following methods.

(a) Hand Method. The emulsion shall be applied in four coats in the amounts per square yard (square meter) as required. The undiluted material shall be poured in strips on the pavement and spread with a squeegee or brush, smoothing out with a brush. This procedure shall be continued until the

entire area is covered. Application can also be made by means of a heavy spray gun when approved by the Engineer. The first coat shall be allowed to dry or cure sufficiently to prevent pickup before the second coat is applied. When spreading the second coat, it shall be spread crosswise to the placing of the first coat when practicable.

(b) Distributor or Applicator. When applied by distributor or approved type of applicator, the emulsion shall be applied uniformly to the surface of the pavement at the prescribed pressures and in the amount per square yard (square meter) as stated. The emulsion shall be thoroughly mixed before use. When necessary to dilute the emulsion in order to aid proper application, the emulsion may be diluted with a maximum of ten percent by volume of clean fresh water as directed by the Engineer.

In all cases, the waterproofing shall begin at the low point of the surface to be waterproofed so that water will run over and not against the laps.

One width of the fiberglass fabric shall be laid loosely into the second coat of emulsion while the film is still wet. The fabric shall be brushed into the emulsion thereby eliminating all wrinkles and blisters, but without stretching the fabric tight. The adjoining widths of fabric shall be installed in the same fashion, side lapping the former by 3 in. (75 mm). All end laps shall be at least 12 in. (300 mm). The upper layer of fabric shall be applied in the same manner, but the laps shall extend over the lower laps by at least 6 in. (150 mm).

The fourth coat shall be a slurry top coat. The emulsion and aggregate shall be blended and premixed to produce a slurry top coat. The coal tar emulsion may be diluted up to a ratio by volume of 0.1 parts water to one part coal tar pitch, emulsion to facilitate the mixing and spreading of the slurry. The slurry shall contain a nominal 4 lb (0.5 kg) of fine aggregate per gallon (liter) of coal tar pitch emulsion.

Before application, the materials shall be proportioned accurately and mixed by suitable mixing equipment. Mixing machines for preparing the slurry may be mortar mixers, concrete mixers, or any type approved by the Engineer capable of producing a uniform mixture of emulsion and aggregate. The emulsion and the water shall be first charged into the mixer and blended into the desired consistency. Then the aggregate shall be added at a slow and uniform rate while the mixing is continued until the batch aggregate is incorporated. After all the components are in the mixer, the mixing shall continue for minimum of five minutes or as long as may be necessary to produce a smooth, free flowing, homogeneous mixture of a uniform consistency. Mixing shall be continuous from the time the bitumen is placed into the mixer until the slurry is poured into the spreading equipment.

During the entire mixing process, there shall be no breaking, segregating or hardening of the emulsion, nor balling, lumping, or swelling of the aggregate. After the required mixing period, the slurry shall be spread over the designated area while the slurry is of the proper consistency. The slurry shall be applied at the rate of 0.28 to 0.30 gal/sq yd (1.3 to 1.4 L/sq m) in order to obtain 0.13 to 0.15 gal (0.5 to 0.6 L) of undiluted coal tar emulsion per square yard (square meter).

The application of the slurry shall be either by hand methods using rubber squeegees for spreading or by any other suitable mechanical method approved by the Engineer. The slurry shall be applied at a uniform rate as specified.

A suitable spray type applicator or distributor approved by the Engineer may be used for applying the slurry. Such equipment shall be equipped with an agitator to keep the slurry uniformly mixed before and during application and so designed to uniformly spread the slurry on the roadway at the specified rate of application.

At all times, particular care shall be taken to protect the membrane from damage. Any damage which may occur shall be repaired by patching in a manner satisfactory to the Engineer. The complete membrane shall be allowed to cure for at least 24 hours before placement of the protection layer.

581.07 Protection Layer. The fine aggregate and asphalt binder shall be combined in such proportions that the composition by weight of the finished mixture shall be as directed by the Engineer but within the following range limits.

Fine Aggregate	90.0 to 93.0 %
Asphalt Binder	7.0 to 10.0 %

The hot-mix asphalt (HMA) plant used for the manufacture of the protection course material shall be capable of producing completely coated uniform mixtures within the tolerances set forth and at a uniform workable temperature as specified by the Engineer, but not to exceed 350 ºF (175 ºC) for the mixture when leaving the plant.

The exact proportions, within the limits specified, shall be regulated so as to produce a satisfactory mixture with all particles coated with asphalt binder. The fine aggregate shall be mixed dry for not less than 15 seconds. The asphalt binder shall then be added in an evenly spread sheet over the full length of the mixer box. The mixing shall be continued for a period of not less than 30 seconds and at least until the aggregate is completely coated with asphalt binder.

The asphalt sand seal protection layer shall be placed and compacted according to the requirements of Section 406, except that the material shall not be mixed or placed when the atmospheric temperature is below 50 ºF (10 ºC). The temperature of the mix shall not be less than 290 ºF (144 ºC) at time of placement. The mix shall be placed and compacted so as to provide a protection layer of approximately 1/2 in. (13 mm) in thickness.

581.08 Sequence of Construction Operations. The sequence of construction operations for the waterproofing membrane systems shall be as follows.

(a) Penetrating Primer 0.01 gal/sq yd (0.05 L/sq m) [Cure 24 Hrs.]

(b) Coal Tar Emulsion 0.08 to 0.10 gal/sq yd (0.4 to 0.5 L/sq m) [Cure 4 Hrs.]

(c) Coal Tar Emulsion 0.08 to 0.10 gal/sq yd (0.4 to 0.5 L/sq m) & Fiberglass Fabric 1.65 oz/sq yd (55 g/sq m) [Cure 4 Hrs.]

(d) Coal Tar Emulsion 0.08 to 0.10 gal/sq yd (0.4 to 0.5 L/sq m) & Fiberglass Fabric 1.65 oz/sq yd (55 g/sq m) [Cure 4 Hrs.]

(e) Coal Tar Emulsion Slurry 0.3 gal/sq yd (1.4 L/sq m) [Cure 24 Hrs.]

(f) Asphalt Sand Seal Protection Layer 1/2 in. (13 mm) thick

581.09 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of contract quantities shall conform to Article 202.07(a).

(b) Measured Quantities. This work will be measured for payment and the area computed in square yards (square meters) of bridge deck surface covered. No measurement or allowance will be made for laps, material used for extending up curb faces or other vertical barriers, material used for extensions over lips or edges, or for repairs.

581.10 Basis of Payment. This work will be paid for at the contract unit price per square yard (square meter) for WATERPROOFING MEMBRANE SYSTEM.

SECTION 582. HOT-MIX ASPHALT SURFACING ON BRIDGE DECKS

582.01 Description. This work shall consist of constructing a hot-mix asphalt (HMA) surface course on a prepared bridge deck.

582.02 Materials. Materials shall be according to Article 406.02.

582.03 Equipment. Equipment shall be according to Article 406.03, except vibratory rollers will not be permitted on bridge decks.

CONSTRUCTION REQUIREMENTS

582.04 General. Work shall be according to Section 406, except as specified herein.

Only a tandem roller, meeting the requirements of Table 1 of Article 406.07(a), will be permitted for breakdown rolling.

582.05 Target Density. A target density will be established from tests conducted on a calibration strip consisting of 100 ft (30 m) of HMA surface course placed on the bridge deck.

A target count rate which represents the maximum compactive effort will be determined with nuclear testing equipment within the calibration strip.

Compaction of the calibration strip with the breakdown roller shall commence immediately after the surface course is placed and shall be continuous and uniform over the entire area. All rolling operations must be completed before the temperature

of the mixture drops below 190 ºF (90 ºC). At a minimum of two random locations within the calibration strip, a growth curve consisting of a plot of counts per minute vs. number of passes with a breakdown roller will be developed.

The growth curve at each random location will be established by using a nuclear gauge using a fast count or with a nuclear gauge using a 30-second timing cycle in the backscatter position. Tests will be made after each pass until the lowest count either raises or remains the same. At this time, mineral filler will be spread and a 4 minute (calibration) count will be taken in the backscatter position to establish the relative target density.

The established average target density shall apply throughout the project unless there are changes in mix materials or an appreciable change in the job mix formula. The Engineer may require a new average target density to be established if there is reason to believe that the mixture being placed is not the same as the mixture used to determine the target density.

582.06 Acceptance Tests. Acceptance tests will be performed once the average target density has been established. At least one acceptance test will be taken for each 200 ft (60 m) or portion thereof of bridge deck per paver pass. Acceptance tests on material placed in a single day shall average 98 percent of the established average target density with no one test being below 95 nor more than 103 percent of the established target density. If the above requirements for average or individual density tests cannot be obtained, placement of additional material will be discontinued until the cause of the failure is investigated and corrected.

Acceptance tests will be performed with the same nuclear equipment used to establish the average target density. Acceptance tests will be for one-minute duration and the area to be tested shall be prepared with mineral filler prior to testing.

582.07 Method of Measurement. This work will be measured for payment according to Article 406.13.

582.08 Basis of Payment. This work will be paid for according to Article 406.14.

SECTION 583. PORTLAND CEMENT MORTAR FAIRING COURSE

583.01 Description. This work shall consist of placing portland cement mortar along precast, prestressed concrete bridge deck beams as required for fairing out any unevenness between adjacent deck beams prior to placing of waterproofing membrane and surfacing.

583.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Portland Cement	1001
(b) Fine Aggregate	1003.02
(c) Water	1002

CONSTRUCTION REQUIREMENTS

583.03 General. This work shall only be performed when the air temperature is 45 ºF (7 ºC) and rising. The mixture for portland cement mortar shall consist of three parts sand to one part portland cement by volume. The amount of water shall be no more than that necessary to produce a workable, plastic mortar.

Prior to placement of the mortar fairing course, all areas where unevenness occurs between the deck beams shall be prepared according to Article 503.09(b).

The mortar shall be placed to the thickness necessary to eliminate unevenness between the beams. It shall be placed to form a smooth even surface from the higher beam edges to the lower surface. The mortar finished surface shall slope not less than 1:3 (V:H) and shall be feathered smoothly into the deck beam surfaces. The finish shall be free of depressions or sharp edges.

The mortar shall be cured for a period of not less than three days by the wetted burlap method according to Article 1020.13(a)(3). Curing shall commence as soon as practicable after mortar placement.

583.04 Method of Measurement. This work will be measured for payment in feet (meters) along the beam edges.

583.05 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for PORTLAND CEMENT MORTAR FAIRING COURSE.

SECTION 584. EPOXY GROUTING OF ANCHOR RODS AND BARS

584.01 Description. This work shall consist of drilling and epoxy grouting anchor rods and bars into hardened concrete.

584.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Chemical Adhesive Resin System	1027

CONSTRUCTION REQUIREMENTS

584.03 General. Holes shall be drilled in the concrete to 1/4 in. (6 mm) larger in diameter than the diameter of the anchor rods or bars and to the depth shown on the plans. A template or other approved method shall be used to assure accurate location of the drilled holes. All holes shall be blown free of concrete dust and chips and shall be absolutely dry prior to placing the epoxy grout.

Prior to inserting the anchor rod or bar into the hole, the hole shall be filled approximately 1/3 full of the mixed epoxy grout. The anchor rod or bar shall be inserted into the partially filled hole and moved up and down several times to insure total contact of the grout with concrete as well as the rod or bar. Additional grout shall be extruded to proper concrete level and finished as necessary. The anchor rod

or bar shall be aligned to maintain a perpendicular plane. No load shall be applied to the anchors until the grout has cured for at least 24 hours.

584.04 Basis of Payment. This work will not be measured or paid for separately, but shall be considered as included in the unit price bid for the item of construction involved.

SECTION 585. RESERVED

SECTION 586. SAND BACKFILL FOR VAULTED ABUTMENTS

586.01 Description. This work shall consist of furnishing, transporting and placing sand backfill behind vaulted abutments to serve as a form for the placement of the concrete approach slab.

586.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Fine Aggregate (Note 1)	1003.01

Note 1. The material for backfilling shall be bank-run or stockpiled sand.

CONSTRUCTION REQUIREMENTS

586.03 General. The wedge behind the abutments shall be backfilled with the sand material to the required elevation of the bottom of the approach span slabs. The backfill shall be placed in convenient lifts for the full width between the abutment sidewall. Mechanical compaction will not be required. Backfilling shall not be started until test specimens show that the concrete in the abutment has attained a flexural strength of 650 psi (4,500 kPa) but in no case until at least seven days have elapsed after the placing of the concrete. In the absence of tests to determine the flexural strength, the sand backfill shall not be placed until at least 14 days have elapsed after the placing of the concrete, exclusive of days on which the temperature of the air surrounding the concrete falls below 45 ºF (7 ºC).

The sand backfill shall be brought to the finished grade of the bottom of the abutment approach slab to serve as a base for placement of the slab. The Contractor, subject to approval of the Engineer, may prepare the top surface of the fill to receive the concrete as he/she deems necessary for satisfactory placement at no additional cost to the Department.

586.04 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of contract quantities shall conform to Article 202.07(a).

(b) Measured Quantities. This work will be measured for payment in place and the volume computed in cubic yards (cubic meters). The volume will be

determined by measuring the wedge areas above the embankment slope, behind the abutment mainwalls, and for the full width between sidewalls.

586.05 Basis of Payment. This work will be paid for at the contract unit price per cubic yard (cubic meter) for SAND BACKFILL.

SECTION 587. CONCRETE SEALER

587.01 Description. This work shall consist of furnishing and applying a sealer to concrete structures as shown on the plans.

587.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Concrete Sealer	1026

CONSTRUCTION REQUIREMENTS

587.03 General. Before the sealer is applied, the concrete surface shall have a minimum 48 hour drying period, and shall be cleaned with oil-free compressed air or wire brushes to remove all oil, grime, and loose particles. Surfaces that will not respond to cleaning by compressed air or wire brushes shall be cleaned by sandblasting.

Care shall be taken to prevent the sealer from flowing over the edges and onto any concrete that is not to be sealed.

The sealer shall be applied according to the manufacturer's instructions, and information provided in the approved list of Concrete Sealers.

587.04 Method of Measurement. This work will be measured for payment in place and the area computed in square feet (square meters).

587.05 Basis of Payment. This work will be paid for at the contract unit price per square foot (square meter) for CONCRETE SEALER.

SECTION 588. CONCRETE JOINT SEALER

588.01 Description. This work shall consist of sealing the horizontal joint in the bridge roadway slab.

588.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Concrete Joint Sealer	1058

CONSTRUCTION REQUIREMENTS

588.03 General. The faces of all joints to be sealed shall be free of all foreign matter, curing compound, oils, grease, dirt, free water, and laitance. Concrete joints to be sealed shall be free of cracked or spalled areas. Any cracked areas shall be chipped back to sound concrete before placing joint sealer.

The concrete joint sealant shall be applied only when the ambient temperature is 68 ºF (20 ºC) and rising.

A continuous length of backer rod of the size designated on the plans, shall be placed in the joint opening at the depth below the finished surface of the joint shown on the plans. The surface of the rod shall be wiped clean with solvent (toluene or xylol) before installation.

All sealing compound shall be placed with an applicator recommended by the manufacturer, and the mixing and placing instructions of the manufacturer shall be adhered to. A copy of these directions and the specifications for the applicator to be used shall be filed with the Bureau of Materials and Physical Research.

No sealing compound shall be placed in a joint on any material (joint filler or expansion board) containing any bituminous material until a separating barrier of foil or other suitable material has been placed on top of bituminous material in such a manner so that the sealing compound cannot contact the bituminous material. No material that will allow bitumen to soak through may be used. When it is deemed necessary to prevent bonding of the sealing compound to a joint surface, the Engineer may require the Contractor to place, at no extra cost, paper, plastic, or foil barriers over the joint surface before applying the sealing compound.

The joint must be covered with a masking tape before the application of the protective coat on the bridge deck to prevent the spray from filming the vertical faces.

All bridge joints shall be filled to 1/4 in. (6 mm) below the finished surface of the joint. This is to be interpreted to mean that the surface of the sealant shall be level and the point of its contact with the sidewalls of the joint shall be 1/4 in. (6 mm) below the finished surface of the joint.

Any sealing compound that is not bonded to the joint wall or face 24 hours after placing shall be removed and the joint shall be cleaned and resealed.

588.04 Basis of Payment. This work will not be paid for as a separate item, but shall be considered as included in the unit price bid for the major item of construction involved.

SECTION 589. ELASTIC JOINT SEALER

589.01 Description. This work shall consist of furnishing and placing an elastic sealer in joints of hot-mix asphalt (HMA) surface course on bridge decks.

589.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Hot-Poured Joint Sealer	1050.02

CONSTRUCTION REQUIREMENTS

589.03 General. Prior to sealing, the joint shall be sawed to form a reservoir for the sealing material. The sawed joint shall be 1/4 in. (6 mm) wide and 3/4 in. (20 mm) deep. Immediately prior to pouring the elastic sealer, the joint shall be cleaned with compressed air and shall be free of foreign and loose material and in a dry condition. The joint shall not be poured when the temperature is below 40 ºF (4 ºC) or when the weather is foggy or rainy.

The equipment required for this work shall be approved by the Engineer before the work will be permitted to start. The heating apparatus and equipment for applying the sealing material shall meet the recommendations of the manufacturer supplying the sealing material, and shall be such that the joint will be completely filled from bottom to top to the satisfaction of the Engineer.

Sufficient compound shall be placed in the joints so that the top of the seal is flush with the top surface of the wearing course.

589.04 Basis of Payment. This work will not be paid for as a separate item, but shall be considered as included in the unit price bid for the item of HMA surface course involved.

SECTION 590. EPOXY CRACK INJECTION

590.01 Description. This work shall consist of injecting cracks in structural concrete with an epoxy bonding compound, or as designated in the contract.

590.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Epoxy Bonding Compound	1025.01

CONSTRUCTION REQUIREMENTS

590.03 General. Only cracks or portions thereof that are 0.007 in. (0.2 mm) or wider shall be injected.

The areas for epoxy crack injection shall be prepared by removing all dust, debris, or disintegrated material from the crack by the use of oil-free compressed air and/or vacuuming. Any cracks holding oil or grease shall be chipped out to clean concrete.

Horizontal and vertical cracks shall have suitable one-way injection ports installed every 6 to 18 in. (150 to 450 mm) or as required, depending on the width of crack, the horizontal or vertical location, and the dimensions of the member. The surface of cracks between the injection ports shall be sealed with a suitable sealing compound recommended by the supplier of the epoxy bonding compound. When the sealing compound is cured, mechanical pressure equipment shall be used to inject the epoxy bonding compound into the cracks.

Injection shall begin at the bottom and progress upward when applicable. The injection pressure and epoxy bonding compound flow characteristic shall result in 90 percent penetration of the epoxy bonding compound. Injection shall continue until refusal, and without damage to the structural concrete. Pressure injection shall not exceed 500 psi (3450 kPa). When the epoxy bonding compound is cured, the injection ports and sealing compound shall be removed and the surface smoothed by stoning or grinding.

590.04 Method of Measurement. This work will be measured for payment in place in feet (meters).

590.05 Basis of Payment. This work will be paid for at the contract unit price per foot (meter) for EPOXY CRACK INJECTION.

SECTION 591. GEOCOMPOSITE WALL DRAIN

591.01 Description. This work shall consist of furnishing and installing geocomposite wall drain on the soil side of abutment walls, wing walls, retaining walls, and culvert sidewalls.

591.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Geocomposite Wall Drain	1040.07

CONSTRUCTION REQUIREMENTS

591.03 General. Geocomposite wall drain shall be constructed in horizontal courses with the first course resting on the top of the footing. The geocomposite shall be in direct contact with the wall and secured with concrete nails not less than 2 in. (50 mm) long with approved washers not less than 9 sq in. (5800 sq mm) in area. The spacing of the concrete nails shall be as directed by the Engineer but shall not be more than 3 ft (1 m) apart, both horizontally and vertically. There shall be at least one horizontal row of nails in each course.

Horizontal seams shall be formed by a 4 in. (100 mm) flap of geotextile extending from the upper course and lapping over the top of the lower course or by a 12 in.

(300 mm) wide continuous strip of geotextile centered over the seam and securely fastened to the upper course with continuous 3 in. (75 mm) wide plastic tape. The overlapping flap or strip shall be fastened to the lower course intermittently as directed by the Engineer, but the spacing shall not exceed 2 ft (600 mm). Vertical splices shall be formed by a 4 in. (100 mm) flap of geotextile extending from one or the other abutting pieces or by a 12 in. (300 mm) wide continuous strip of geotextile centered over the splice. Vertical splice flaps or strips shall be continuously fastened to the geocomposite with continuous applications of contact adhesive or 3 in. (75 mm) wide plastic tape.

The bottom, side, and top edges of the geocomposite shall be covered with a suitable cap formed by folding a 6 in. (150 mm) flap or a 12 in. (300 mm) wide strip of geotextile over the edge and securing it in place with a continuous application of contact adhesive or 3 in. (75 mm) wide plastic tape. All seams, splices, bottom caps, top caps, and end caps shall be constructed so that backfill material cannot enter the geocomposite during or after construction.

Connection to pipe outlet systems shall be as shown on the plans. Outlet fittings shall be fastened to the wall drains as directed by the manufacturer and so that backfill materials cannot enter the system during or after construction. If necessary, to facilitate the rapid and complete flow of water from the wall drain into the pipe outlet, a portion of the wall drain core equal to the cross section at the outlet shall be removed. Weep holes shall be accommodated by cutting a matching hole through the wall drain. An approved weep hole cover extending at least 4 in. (100 mm) from the edge(s) of the hole shall be securely fastened to the soil side of the wall drain by 3 in. (75 mm) wide plastic tape or contact adhesive applied continuously around its periphery.

591.04 Method of Measurement. This work will be measured for payment in place and the area computed in square yards (square meters).

591.05 Basis of Payment. This work will be paid for at the contract unit price per square yard (square meter) for GEOCOMPOSITE WALL DRAIN.

SECTION 592. BRIDGE WASHING

592.01 Description. This work shall consist of washing the entire bridge, including bridge deck, sidewalk, curbs, pier and abutment caps, all superstructure members, trusses, interior of truss members, flanges and webs of beams or girders, expansion joints, and drains to prevent deterioration of the structure.

592.02 Materials. Water shall be according to Section 1002.

592.03 Equipment. Washing equipment shall consist of power brooms, air compressors, water tanks, water pumps with associated delivery hardware, and hand tools, to properly flush, clean, and remove all foreign material from the bridge structure. Other types of washing equipment may be used, subject to approval of the Engineer. Water pressure shall be sufficient to remove the accumulated material without damaging paint coverage of the structural steel.

Other equipment may be necessary to gain access to areas designated for washing. It will be the Contractor's responsibility to determine and utilize whatever method and equipment best suits his/her operation to successfully wash the structure. This equipment shall be available to the inspector until final acceptance of the work.

CONSTRUCTION REQUIREMENTS

592.04 General. All accumulated foreign material shall be removed from the bridge. Special care shall be taken on connected parts, members below open joints and difficult to reach areas to remove all foreign material.

All deck drains shall be flushed with water under pressure. Blockages in the deck drains shall be removed so that they will drain properly. The drain system may have to be taken apart to remove large blockages. Should they be taken apart, they shall be returned to their original configuration immediately after washing. Foreign material in the scuppers at the drains shall be either removed externally or flushed down the drain system. The area beneath all expansion devices shall be thoroughly flushed and washed with water under pressure. These areas include drain troughs beneath the expansion device and pier tops immediately adjacent to the expansion device. All abutment and bridge seats shall have foreign material removed by compressed air, water under pressure, or hand sweeping. All structural steel and bearings shall be washed with water under pressure. All foreign debris shall be removed from truss members. All foreign material accumulated in the interior of members shall be removed. Areas which have been washed shall be free of all accumulate sand, gravel, dirt, bird nests and excrete, and other foreign materials. Free standing water shall be removed upon completion of washing.

The Contractor shall provide adequate protection against worker inhalation of dust from his/her washing operations.

The Contractor shall exercise due caution while washing those portions of the structures that are adjacent to or above parking lots, buildings, sidewalks, roadways, and railroad tracks. Dirt and debris deposited on adjacent property or redeposited on the bridge shall be removed to the satisfaction of the Engineer.

The Contractor shall obtain his/her own source of water.

592.05 Traffic Control. The road shall be kept open to traffic according to Article 701.17(d)(4).

592.06 Method of Measurement. This work will be measured for payment in units of each, at the locations specified.

592.07 Basis of Payment. This work will be paid for at the contract unit price per each for BRIDGE WASHING at the location specified.

SECTION 593. CONTROLLED LOW-STRENGTH MATERIAL, BACKFILL

593.01 Description. This work shall consist of furnishing and placing controlled low-strength material (CLSM) as backfill for pipe culverts, storm sewers, structure excavation, or other excavations as specified.

593.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Controlled Low-Strength Material (CLSM)	1019

CONSTRUCTION REQUIREMENTS

593.03 General. The mix shall not be placed on frozen ground, in standing water, or during wet weather conditions. Mixing and placing shall begin only when the air temperature is at least 35 ºF (2 ºC) and rising. At the time of placement, the material temperature shall be at least 40 ºF (5 ºC). Mixing and placing shall stop when the air temperature is 40 ºF (5 ºC) and falling.

The mix shall not be exposed to freezing temperatures or wet weather conditions during the first 24 hours after placement.

The mix may be subjected to loading upon approval by the Engineer or when a penetration of 1.5 in./blow (38 mm/blow) or less has been obtained with the Dynamic Cone Penetration (DCP) test.

593.04 Placement. The mix shall be placed directly from the chute into the space to be filled. Other placement methods may be approved by the Engineer if the mix design is appropriate.

(a) Structures. When backfilling against structures, the mix shall be placed in lifts to prevent damage by lateral pressures. Side slopes shall be stepped or serrated to prevent wedging action of the backfill against the structure. Each lift shall be allowed to harden prior to placing the next lift.

(b) Pipes. When backfilling pipe culverts or storm sewers, the mix shall be distributed evenly on each side of the pipe and placed in lifts. The first lift shall be placed up to one-fourth the height of the pipe and allowed to settle. After settlement of the first lift, as determined by the Engineer, the second lift shall be placed up to one-half the height of the pipe and allowed to settle. After settlement of the second lift, as determined by the Engineer, the remainder of the trench shall be filled.

When backfilling concrete pipes, the mix may be placed in a single lift.

593.05 Method of Measurement. This work will be measured for payment as follows.

(a) Contract Quantities. The requirements for the use of contract quantities shall be according to Article 202.07(a).

(b) Measured Quantities. This work, when specified, will be measured for payment in place and the volume computed in cubic yards (cubic meters).

(1) Structures. When CLSM is specified for backfilling structures, the computed volume will not exceed the volume computed for the excavation according to Article 502.12(b) with a deduction for the volume of the structure.

(2) Pipe Culverts and Storm Sewers. When CLSM is specified for backfilling pipe culverts or storm sewers, the computed volume will not exceed the volume of the trench as computed by using the trench width specified in Sections 542 and 550 and the actual depth of the completed backfill above the top of the bedding materials, with a deduction for the volume of the pipe.

593.06 Basis of Payment. This work will be paid for at the contract unit price per cubic yard (cubic meter) for CONTROLLED LOW-STRENGTH MATERIAL.