DIVISION 500
STRUCTURES

SECTION 501
STEEL SHEET PILING

DESCRIPTION

501.01 This work consists of furnishing and driving corrugated steel sheeting or steel sheet piling in accordance with these specifications and in conformity to the lines and grades shown on the plans or established.

MATERIALS

501.02 Type I Steel Sheet Piling shall be used where shown on the plans and shall be a corrugated steel sheeting non-galvanized interlocking type, at least 8 gauge in thickness with a minimum section modulus of 1.300 cubic inches per unit of 12 inches in width. Steel sheeting shall conform to ASTM A 857, Grade 36 for 7 gauge or 8 gauge steel, Grade 30 for heavier gauges. The sides for each piece of sheeting shall be furnished with an interlock that is continuous for the full length of the sheeting. The interlock shall have an opening of sufficient width to allow free slippage of the adjoining sheet.

501.03 Type II Steel Sheet Piling shall be of the type and weight shown on the plans and shall conform to the requirements of AASHTO M 202 or AASHTO M 270, Grade 50.

CONSTRUCTION REQUIREMENTS

501.04 Steel sheet piling shall be driven to form a tight bulkhead. A driving head shall be used and any piling which does not provide a tight bulkhead shall be pulled and replaced at the Contractor's expense.

Steel sheet piling that is full length as shown on the plans and is required to be driven below the specified cut-off elevation shall be spliced with additional steel sheet piling with a full penetration butt weld. Splicing will be limited to three per pile sheet. A splice shall not be less than 3 feet from another splice on the same pile.

Welding shall conform to the applicable requirements of ANSI/AWS D 1.1.

Where specified on the plans, sheet piling shall be painted as described in subsection 509.24.

METHOD OF MEASUREMENT

501.05 Steel sheet piling will be measured by the square foot, complete in place and accepted, to cut-off elevation. Each approved splice will be measured as an additional 3 square feet of sheet pile.

The area of sheet piling cut-off to be measured will be those random areas of sheet piling which result from cutting off the tops of driven sheet piling and not used in the work.

BASIS OF PAYMENT

501.06 The accepted quantities of steel sheet piling will be paid for at the contract unit price per square foot of each type used.

Payment will be made under:

Pay Item	Pay Unit
Steel Sheet Piling (Type__)	Square Foot

Sheet piling cut-offs 10 square feet or less in area will be paid for at the contract unit price less 20 percent. These cut-offs shall become the property of the Contractor.

Sheet pile cut-offs greater than 10 square feet will not be paid for.

SECTION 502
PILING

DESCRIPTION

502.01 This work consists of furnishing and driving all types of piling shown in the Contract, other than sheet piling, in accordance with these specifications and at the locations shown on the plans or established.

MATERIALS

502.02 Steel Piling. Structural steel shapes used as piling shall conform to the requirements of AASHTO M 270 Grade 50.

Steel pipe shall conform to the requirements of ASTM A 252, Grade 2. Closure ends shall conform, to the requirements of AASHTO M 270 Grade 36.

Steel shell piles shall conform to the requirements of AISI C 1010 or C 1015 steel.

Closure plates, driving points, and their connecting welds shall not project beyond the perimeter of the pile tip for steel pipe and steel shell piles.

Commercial driving points may be used for end bearing piles. All steel pipe piles and steel shell piles shall be filled with Class B concrete conforming to subsection 601.02.

Steel piling may be ordered in plan lengths or in 30 to 60 foot lengths.

CONSTRUCTION REQUIREMENTS

502.03 Pile Driving Equipment.

(a) *Pile Hammers.* Steam, air, diesel, or hydraulic impact hammers may be used to drive all types of piles. Vibratory or gravity hammers shall not be used to drive bearing piles.

1. For steam, air, and diesel hammers, a minimum manufacturer's rated energy as shown in Table 502-1 shall be used.

Table 502-1

Pile Size	Area (Square Inches)	Minimum Energy (Foot-Pounds)
HP 10x42	12.4	26,000
HP 10x57	16.8	26,000
HP 12x53	15.5	26,000
HP 12x74	21.8	42,000
HP 14x89	26.1	52,000
HP 14x117	34.4	68,000

The rated energy of the hammer shall not be greater than 2500 foot-pounds per square inch of unit area. Exceptions to these limits are permissible if it is demonstrated by wave equation analysis that the piles can be safely and efficiently installed with hammers having ratings outside of these energy limits.

If more than one size of piling is designated in the Contract, the Contractor shall provide the necessary hammer or hammers to meet these requirements for all sizes of piles used.

2. Hydraulic hammers may be substituted for steam, air, and diesel hammers. The minimum energy requirement for hydraulic hammers shall meet the value specified in Table 502-1.

3. When designated in the Contract, a hammer with a rated energy determined by the Wave Equation Analysis from an approved program such as WEAP shall be used. When wave equation analysis is used in the design phase of a project, a range of acceptable hammer energies will be included in the Contract.

(b) *Hammer Cushion.* All impact pile driving equipment except hydraulic hammers shall be equipped with a suitable hammer cushion to prevent damage to the hammer or piles and to ensure uniform driving behavior. Wood, wire rope, and asbestos cushion material shall not be used. A striker plate as recommended by the hammer manufacturer shall be used. The hammer cushion may be inspected by the Engineer at any time during progress of the work. Any hammer cushion whose thickness is reduced by 10 percent or more of the original thickness shall be replaced at the Contractor's expense before driving is permitted to continue.

(c) *Pile Driving Head.* Appropriate driving heads, mandrels, or other devices shall be provided in accordance with the driving head manufacturer's recommendations. The driving head or insert shall be capable of capturing the pile in alignment such that the center of the pile is held within 10 percent or 2 inches, whichever is less, of the center of the force of the hammer.

(d) *Leads.* Pile driving leads shall be constructed in a manner that affords the pile hammer freedom of movement while maintaining alignment of the pile hammer and the pile to insure concentric impact for each blow. Leads may be either fixed or swinging. Swinging leads shall be fitted with a pile gate at the bottom of the leads and shall be long enough to be securely fixed at the ground at all times.

(e) *Followers.* Followers shall be used only when specified on the plans or approved in writing by the Engineer.

502.04 Approval of Pile Driving Equipment. All pile driving equipment proposed in conformance with subsection 502.03 shall be submitted to the Engineer for approval prior to delivery to the site. Approval will be based upon

pile driving equipment data, such as rated energy, impact energy, or striking ram weight, which the Contractor shall submit.

If the Contract requires hammers determined by subsection 502.03(a)3, the Contractor will be notified of the acceptance or rejection of the driving system within ten calendar days of the Engineer's receipt of the pile and driving equipment data. The approval criteria for wave equation analysis will consist of (1) the pile stress at the required ultimate pile capacity and (2) pile drivability.

The driving stresses in the pile indicated by the Wave Equation Analysis shall not exceed 90 percent of the yield stress of the steel.

Once approved, changes in the pile driving equipment shall not be made without additional approval, and will be considered only after the Contractor has submitted the necessary information for a revised Wave Equation Analysis. The approval process outlined above shall be applied to the revised driving equipment.

All pile hammers delivered to the job site which the Engineer determines, either by observation or by Pile Driving Analyzer (PDA), are not in good working condition will be rejected.

502.05 Driving Piles. Foundation piles shall not be driven until the excavation is complete unless authorized by the Engineer. After driving is complete, all loose and displaced material shall be removed from around the piling before pouring any concrete.

Piles shall be driven within a variation of not more than ¼ inch or less per foot from the vertical or from the batter shown in the Contract. Foundation piles shall not be more than within 6 inches out of the position shown in the Contract after driving.

A minimum pile penetration of 10 feet in natural ground is required for all piles. This requirement may be waived by the Engineer if the subsurface material at the pile tip location is bedrock or other acceptable bearing material provided that the bearing elevation is below scour depth.

If a minimum pile tip elevation is specified in the Contract, all piles shall be driven to or below this elevation unless otherwise approved in writing. If the pile cannot be driven to the minimum tip elevation, the Engineer will determine if pre-drilling is required. Any pre-drilling not required by the Contract and ordered by the Engineer will be paid for in accordance with subsection 109.04. The depth of the pre-drilling will be determined by the Engineer.

Unless otherwise specified in the Contract, a minimum of two piles per structure will be monitored, each at a separate foundation element (abutment or pier foundation). Monitoring will be conducted using a PDA to determine the condition of the pile, the efficiency of the hammer and the static bearing capacity of the pile, and to establish the pile driving criteria. Monitoring will be conducted by the Engineer or the Contractor’s Engineer. The plans will designate the party responsible for monitoring. The PDA measurement equipment takes approximately one hour per pile to install. All necessary work

performed by the Contractor associated with the dynamic monitoring will not be paid for separately but shall be included in the work. If the Engineer requests additional piles to be monitored, or requests the Contractor to monitor the pile or piles, all necessary time required and work performed by the Contractor will be paid for in accordance with subsection 109.04.

If piles are monitored by the Contractor, the Contractor shall provide to the Engineer a written pile driving summary from the Contractor's Engineer. The summary shall detail the driving criteria including driving resistance and driving stresses based on the wave equation analysis using program such as WEAP. and The summary shall also detail the pile capacity criteria based upon signal matching analysis using an approved program such as CAPWAP. The criteria shall be approved by the Engineer prior to the driving of additional piles.

Piles shall be driven to refusal in natural ground as determined by the PDA, at or below the estimated minimum tip elevations specified on the plans. Refusal criteria will be established by the Engineer after PDA monitoring has been performed. If refusal criteria has been reached in natural ground and piles have not been driven to the estimated tip elevation but have been driven below minimum tip elevation, the Engineer may order the driving to be continued for 40 additional blows. If changes are made to the pile driving system (hammer, fuel setting, piling, cushioning, etc.) after the PDA monitoring has been completed and refusal criteria established, new refusal criteria shall be determined using the PDA. New criteria shall be determined at the Contractor's expense.

Water jets may be used in conjunction with the hammer to obtain the specified penetration only with approval. The last 3 feet of penetration shall be obtained by driving without the use of water jets. Test blows to determine average penetration shall be applied after the jets have been removed. The use of water jets will not modify any of the requirements of this section.

502.06 Drilling Holes to Facilitate Pile Driving. Holes to facilitate pile driving shall be drilled at all locations shown on the plans and to elevations shown.

When test piles are shown on the plans they shall be used to determine if drilling holes to facilitate pile driving is required.

If the test pile or piles do not reach the estimated tip elevation as specified in subsection 502.05, holes shall be drilled to facilitate pile driving.

If the test pile or piles reach the estimated tip elevation shown on the plans and develop the required bearing capacity as determined in subsection 502.05, drilling holes will not be required and the remainder of the piles shall be driven in the normal manner.

The drilling of holes shall be done in such manner that the piling will stand accurately positioned as shown on the plans.

The diameter of the drilled holes and the material used to fill oversize holes shall be as stipulated herein unless otherwise designated on the plans.

The diameter of the drilled holes shall be 1 to 3 inches larger than the outside diameter of steel pipe piles. The diameter of the drilled holes shall be 1 to 3 inches larger than the diagonal web depth for H piles.

If the maximum diameter of the drilled hole is exceeded due to sloughing, drifting, over-drilling, or other causes, the void area between the driven pile and the edge of the hole shall be filled with sand or pea gravel at the Contractor's expense.

The Engineer will determine if shooting holes with explosives or redesign is necessary when piles cannot be driven or holes drilled.

502.07 Capping Piles. Steel pipe or shell piles will be inspected after all adjacent piles within a 5 foot radius have been driven. The Contractor shall supply suitable lights for the inspection of the insides of these piles. Water or other foreign material shall be removed and the pipe or shell shall be filled with concrete.

The tops of all steel piles shall be cut off square and embedded in the concrete as shown on the plans.

502.08 Extensions and Splices. There will not be a limit placed on the number of splices allowed for steel piles; however, payment will be limited to two splices per pile. Commercial splices may be used if approved by the Engineer.

Steel piling shall be spliced with a square-groove butt-joint weld using a ⅛ inch root opening. Weld deposition on pipe piles shall be made in two separate passes around the outside perimeter of the pile. Weld deposition on steel "H" piles shall be made in two passes. The first pass shall be made from one side of the part being welded and shall penetrate one-half the thickness of the member. The second pass shall be made on the side opposite from the first. For both types of piles, the slag left by the first pass shall be completely removed before making the second pass. All cuts at splices are to be made normal to the longitudinal axis of the pile. The cut-off portion may be driven to start the next pile or it may be welded to previously driven piles to provide the necessary extension length. Splices must be authorized.

Welding shall conform to the applicable requirements of ANSI/AWS D1.1.

Welders shall be prequalified in accordance with the standard qualification procedure of the American Welding Society and follow the required welding procedures specified in the plans. The Engineer may consider a welder qualified when the Welders' Certificate states that the welder has been doing satisfactory welding of the required type within a one year period previous to the subject work. A certification shall be submitted for each welder and for each project, stating the name of the welder, the name and title of the person who conducted the examination, the kind of specimens, the position of welds, the results of the tests and the date of the examination. Such certification of pre-qualification may also be accepted as proof that a welder on field welding is qualified, if the Contractor who submits it is properly staffed and equipped to conduct such an examination or if the examining and testing is done by a recognized agency which is staffed and equipped for such purpose.

Approved commercial splices may be used as an alternate for welded splices.

502.09 Defective Piling. Piles damaged in driving by reasons of internal defects or improper driving; driven out of their proper location; or driven below the elevation specified on the plans without approval shall be corrected at the Contractor's expense by one of the following approved methods:

(1) The pile shall be withdrawn and replaced by a new, and if necessary, longer pile.

(2) A second pile shall be driven adjacent to the defective pile.

(3) The pile shall be spliced or built up.

(4) A sufficient portion of the footing shall be extended to properly embed the pile.

All piles pushed up by the driving of adjacent piles shall be driven down again.

502.10 Pile Tips. Pile tips shall be placed on piles when shown on the plans. Pile tips and details for fastening tips to piles shall be in accordance with the plans or approved. If difficult driving conditions are encountered, the Engineer may order the Contractor to furnish and attach pile tips even though tips are not required by the plans. In that event, the tips will be paid for in accordance with subsection 109.04.

502.11 Painting Steel Piles. The exposed portion of steel piles not embedded in concrete, including 2 feet below the stream bed or ground line, shall be painted as described in Section 509.

METHOD OF MEASUREMENT

502.12 Piling will be measured by the linear foot in place. Measurement shall be from the tip to the cut-off elevation.

The length of pile cut-off to be measured will be those random lengths of piling which result from cutting off the tops of driven piles and which are not used in the work.

Where piling is driven to within 1 foot of the elevation of cut-off, butt ends will be included in the length measured for piling actually driven.

Measurement of splices will be limited to two per steel pile, except when extra splices are ordered.

Splices for piles will be measured as additional length of pile. The additional length for each splice will be as follows: steel “H” piles, 3 linear feet; steel pipe piles, 3 linear feet.

Pile tips and end closure plates for steel pipe piles will be measured by the actual number used.

Drilled holes to facilitate pile driving will be measured by the linear foot, to the nearest foot.

BASIS OF PAYMENT

502.13 The accepted quantities will be paid for at the contract unit price per unit of measurement for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
Steel Piling (size)	Linear Foot
Steel Pipe Piling (size)	Linear Foot
Steel Shell Piling (size)	Linear Foot
Drilling Hole to Facilitate Pile Driving	Linear Foot
End Plate	Each
Pile Tip	Each

Steel cut-offs 10 feet or less in length will be paid for at the contract unit price less 20 percent. These cut-offs shall become the property of the Contractor.

Pile cut-offs greater than the above specified lengths will not be paid for.

Authorized jetting, blasting, or other work necessary to obtain the specified penetration of piles will be paid for in accordance with subsection 104.03.

Concrete used to fill steel pipe will not be measured and paid for separately, but shall be included in the work.

SECTION 503
DRILLED CAISSONS

DESCRIPTION

503.01 This work consists of drilling holes and placing reinforcing steel and concrete in the drilled holes in accordance with these specifications and in conformity with the lines and grades on the plans or established.

MATERIALS

503.02 Concrete shall be Class BZ or as specified in the Contract, and shall conform to the requirements of Section 601.

Reinforcing steel shall conform to the requirements of Section 602.

CONSTRUCTION REQUIREMENTS

503.03 Drilled Holes. Caisson excavation shall be performed by heavy duty drilling rigs suitable for penetrating the cobbles, boulders, and bedrock to the required depths. Blasting will not be allowed.

The top of the caissons shall be the elevation shown on the plans. The elevations of the bottom of the caissons shown on the plans are approximate only and may be revised by the Engineer depending on the conditions encountered. The minimum embedment length into bedrock shall be as shown on the plans. Materials resulting from drilling shall be disposed of by the Contractor.

The maximum permissible variation of the center axis of any shaft at the top from its plan location shall be the greater of 3 inches or $\frac{1}{24}$ of the shaft diameter. Caissons shall not be out of plumb more than three percent of their length. If a drilled hole does not meet these requirements, it shall be reamed or re-drilled as required to bring it to the proper alignment, or drilled an additional distance, as approved by the Engineer. Additional concrete required as a result of these measures shall be provided at the Contractor's expense.

The excavation shall be protected with a suitable cover which will prevent persons or materials from failing into the hole.

When caving conditions are encountered, drilling shall be discontinued until the construction method used will prevent excessive caving.

503.04 Cleaning and Inspection. Holes shall be pumped free of water, cleaned of the loose material, and inspected by the Engineer. A drilled hole may be entered for inspection when deemed necessary by the Engineer, but only when a protective casing is in place. The Contractor shall provide fresh air ventilation, electric lights, suitable means of access, the protective casing, and shall assist the Engineer, as directed, in making the required inspection of the drilled excavation and foundation material.

503.05 Reinforcing Steel. After a hole has been inspected and approved, the reinforcing steel shall be installed and the concrete placed as soon as possible.

The required reinforcing steel cage for the drilled caisson shall be completely assembled and placed as a unit for the full length of the caisson immediately prior to the placing of any concrete. If concrete placement does not immediately follow the cage placement, the Engineer may order the steel to be removed from the excavation so that the integrity of the excavation, including the presence of loose material in the bottom of the hole, and the surface condition of the reinforcing steel may be determined by inspection.

The reinforcing steel cage shall be supported from the top during the placement of the concrete to achieve the clearances shown on the plans. Setting the cage on the bottom of the hole will not be permitted. The support system shall be concentric to prevent racking and displacement of the cage. Approved spacers shall be provided at intervals not to exceed 10 feet along the cage to insure concentric positioning for the entire length of the cage; a minimum of three spacers shall be provided at each spacing interval. Additional reinforcement may be added to stiffen the cage at the Contractor's option and expense.

503.06 Steel Casing. If casings are used, they shall be steel of ample thickness and strength to withstand distortion due to handling, the internal pressure of fresh concrete, and the external pressure of the surrounding soil and ground water, and shall be watertight. The inside diameter of the casing shall be equal to or larger than the caisson dimensions shown on the plans. The use of casings larger than the diameter of the caissons shown on the plans must have prior approval from the Engineer. Additional concrete required due to the use of oversize casings shall be provided at the Contractor's expense.

Casings shall be removed unless otherwise designated on the plans. Casings shall be removed in a manner such that voids between the excavation and the casing will be completely filled with fresh concrete. The removal method shall prevent the intrusion of water, sloughing of the excavation, displacement of the reinforcing steel, and lifting of the concrete. The casing removal shall be performed in a manner that minimizes the displacement of the concrete from its initial placement point. If the casing is stuck and can't be removed without damaging the hole, it may be cut off and left in place with the Engineer's approval, or other remedial measures taken as approved. The top elevation of the reinforcing steel cage shall be checked before and after the casing removal. Upward movement in excess of 2 inches or downward movement in excess of 6 inches of the reinforcing steel cage will be cause for rejection of the caisson. Concrete settlement in the caisson will be determined by measuring the top surface of the concrete: (1) immediately after the casing is removed and additional concrete poured to the desired elevation; and, (2) at least four hours later. Concrete settlements in excess of ½ of the caisson diameter will also be cause for rejection of the caisson.

503.07 Concrete. For any portion of the caisson socketed in shale, if the concrete is not placed within four hours of drilling, the Contractor shall drill into the bedrock an additional ⅓ of the specified penetration prior to placing the concrete. The reinforcing cage shall extend to the new tip elevation.

Foundation piling shall not be driven nor excavation performed within a radius of 20 feet, nor additional caissons drilled within a clear distance of 3 feet, of concrete that has not attained a compressive strength of at least 1500 psi as determined by the Engineer.

Other construction methods, such as slurry displacement, may be used, if approved. The procedure for step-by-step construction shall be approved prior to beginning the work.

Concrete for each drilled caisson shall be placed in one continuous pour. Concrete may be placed in a dry hole by free-drop from the surface provided that a hopper or other approved device is used to force the concrete to drop straight down without hitting the sides of the hole or any reinforcing steel before striking the bottom. A drilled hole may be considered dry at the time of concrete placement if, without dewatering, the water depth at the bottom of the hole is not in excess of 2 inches.

Where an excavation cannot be practically dewatered for the placement of concrete, the Engineer may authorize a portion of the concrete to be placed under water in accordance with subsection 601.12(f). Concrete placed below water shall be limited to a height sufficient to seal the excavation and to withstand hydrostatic pressure. Immediately following the placement of this sealing concrete, the remaining portion of the hole shall be dewatered and the remainder of the concrete shall be placed. Concrete within the top 5 feet of the caisson shall be vibrated during placement. The layer of water-diluted concrete which has been floated to the top during placement shall be removed to the depth directed by the Engineer and wasted. The removed layer shall not be less than 4 inches thick. Only that concrete which meets specification requirements shall remain as part of the caisson.

Immediately following the concrete placement and the casing removal, the projecting reinforcing steel shall be thoroughly cleaned to remove accumulations of splashed mortar. This work shall be completed before the concrete takes its initial set. Care shall be taken when cleaning the reinforcing steel to prevent damage to or breakage of the concrete-steel bond.

METHOD OF MEASUREMENT

503.08 Drilled caisson will be measured by the linear foot from the elevation shown on the plans to the bottom of the hole as drilled.

Each approved splice of the reinforcing cage for additional length of caisson will be measured as ½ linear foot of additional length of drilled caisson.

BASIS OF PAYMENT

503.09 The unit price of drilled caissons shall be full compensation for making all excavations; hauling and disposal of excavated material; performing all necessary pumping; furnishing and placing required concrete and reinforcement steel, including the reinforcement projecting above the tops of the caissons necessary for splicing; all backfilling; removing casings; and for furnishing all tools, labor, equipment, and incidentals necessary to complete the work. No extra payment will be made for casing left in place.

(a) *Payment.* The accepted quantities for drilled caissons will be paid for at the Contract unit price per linear foot except for price adjustments allowed in (b) below.

Payment will be made under:

Pay Item	Pay Unit
Drilled Caisson (__Inch)	Linear Foot

(b) *Price Adjustments.* When the Engineer orders holes to be drilled to a lower elevation than shown on the plans, compensation for additional depth will be as follows:

Additional Length	Compensation
0 to 5 feet	Contract Unit Price
Over 5 feet to 15 feet	Contract Unit Price plus 15%
Over 15 feet	As provided in subsection 109.04

Additional compensation will not be paid for the portions of a caisson that are extended due to the Contractor's method of operation, as determined by the Engineer.

SECTION 504
WALLS

DESCRIPTION

504.01 This work consists of constructing a Concrete Panel Facing Mechanically Stabilized Earth (MSE) Retaining Wall System at the locations and to the lines and grades shown on the plans. Either metallic or geosynthetic reinforcement (woven fabrics or geogrids) as specified in this specification may be used as MSE reinforcement in the reinforced structure backfill zone. The retained structure backfill zone is the structure backfill retained by the reinforced structure backfill zone as shown on the plans.

MATERIALS

504.02 Shop Drawings. The Contractor shall submit six sets of shop drawings and certified material test reports for review prior to construction of the wall. See subsection 504.12, for a complete list of submittal requirements. Shop drawings shall be submitted in accordance with subsection 105.02.

The shop drawings shall provide the details necessary to demonstrate compliance with the Contract, including:

(a) *Wall Layouts.* Wall layouts shall conform to lines and grades on the plans including start, corner, and end stations, leveling pad step breaks, total number of panels, and top and bottom of wall elevations. For walls with rail anchoring slabs, the top of panel elevations shall be within 8 inches of the elevation shown on the plans measured from the bottom of the anchoring slab. The construction batter required to achieve the batter shown on the plans shall be shown on the shop drawings. If temporary walls are required for the construction of the permanent wall, the permanent wall vendor shall provide the shop drawings and certified material test reports for temporary walls.

(b) *Panel and Reinforcement Locations.* Unless otherwise shown on the plans, each layer of soil reinforcement shall be connected to the back of each facial panel and the panel numbering and placement sequence shall be shown. The back of each panel shall be logically numbered with its location.

Panel to panel, panel to reinforcement connection detail, and limits of special panels at curved wall corner shall be shown.

(c) *Wall Elevations*. Except for the top of the leveling pad, wall elevations given on the plans are based on the desirable wall height. The actual panel and reinforcement elevations shall be marked on the shop drawings by taking into account the supplied panel as well as special panel heights for matching the front and top finished grade.

(d) *Soil Reinforcement Material*. The soil reinforcement type, Minimum Average Roll Value of the Ultimate tensile strength T_{ULT} (MARV) for geosynthetic soil reinforcement or yield strength for metallic soil reinforcement, spacing,

lengths, elevations, and the corresponding wall design height shall be shown on the shop drawings. The starting and ending stations for change in grade of reinforcement material shall be shown for walls with different grade of reinforcement material at the same elevation. Material grade shall be clearly identified on each roll of reinforcement to avoid errors in placement. Elevations of the reinforcement layers shall be as specified on the shop drawings.

(e) *Soil Reinforcement Length (RL).* The soil reinforcement length shall be measured from the back face of the concrete panel to the end of the soil reinforcement as measured to the last cross member. Except for secondary reinforcements, soil reinforcement lengths shall not be less than the lengths specified on the plans.

For wall segments with a Design Height (DH) greater than or equal to 8 feet, the soil reinforcement shall be the same length from top to bottom of the wall.

For wall segments with a Design Height (DH) less than 8 feet, the length of the top layer of soil reinforcement shall be 8 feet and all other layers of soil reinforcement shall be the same length from top to bottom of the wall.

Unless shown otherwise on the plans, the soil reinforcement lengths shall be as follows:

Design Height (DH)	**Reinforcement Length (RL)**	**Reinforcement Length Top Layer**
DH ≤ 6'-0"	6'-0"	8'-0"
6'-0" < DH < 8'-0"	DH	8'-0"
DH ≥ 8'-0"	0.7 x DH but at least 8'-0"	0.7 x DH but at least 8'-0"

The Reinforcement Lengths shown on the shop drawings shall be the reinforcement length required for internal stability and pull-out only, but they shall not be less than those shown in the table above. External stability (bearing pressure, sliding, and overturning) and global stability have already been considered and checked in the design.

(f) *Panel Size and Soil Reinforcement Spacing*.

1. Except for full height panels, the maximum panel size is 50 square feet and the minimum panel height shall be 30 inches.

2. For full height panels, the maximum panel width shall be 10 feet and the maximum panel height shall be 30 feet. Differential deflection between adjacent panels shall be limited to 1/500. The vendor shall supply design calculations regarding panel concrete crack size control during shipment and construction and estimated joint width and differential deflection

limits. The use of full height panels with widths greater than 10 feet or heights greater than 30 feet Is subject to the Engineer's approval.

3. The maximum vertical spacing between layers of adjacent soil reinforcement shall not exceed 30 inches. Except the half height panel used at the top and bottom of the wall, including all partial and extended height panels at the top of the wall, there shall be at least two layers of reinforcement per panel.

4. The first and bottom layers of reinforcement shall be within 15 inches measured from the top of panel and from the top of leveling pad accordingly.

5. Shiplap joints are required at horizontal and vertical joints for segmental panel walls and all vertical joints for full height panel walls. The gap between two adjacent panels shall be ½ to 1 inch. Shiplap joints are not required at the vertical joints of segmental and full height panel when a minimum of 12 inches depth of continuous crushed rock wrapped with Class 2 geotextile is installed behind the joints as shown in the shop drawings. geotextile (Class 2) and crushed rock will not be measured and paid for separately, but shall be included in the work. Neoprene cushions shall be provided at all horizontal joints as shown on the plans.

(g) *Long Term Design Strength (LTDS) of Reinforcement.*

1. The design charts on the plans define the strengths required for the zone of mechanical reinforcement of soil. Based on the total summed LTDS, the reinforcement proposed by the shop drawings for a specific wall height shall meet or exceed the total LTDS shown on the plans. This proposed reinforcement shall allow for a maximum of plus or minus 15 percent variation in each individual layer.

2. Metallic (Inextensible) Soil Reinforcement. The net section at the soil reinforcement to panel connection shall be used for the sacrificial thickness calculation. The following minimum sacrificial thickness for reinforcement shall be used for the 75 year LTDS calculations:

Galvanization Loss	15 µm/year for first 2 years 4 µm/year for subsequent years
Carbon Steel Loss	12 µm/year after zinc depletion

3. Geosynthetic (Extensible) Soil Reinforcement. Geosynthetic soil reinforcement shall be a geogrid or woven geotextile. For polyester (PET), polypropylene (PP) and high-density polyethylene (HDPE) reinforcement, the LTDS of material shall be determined using the following factors of safety to ensure the required design life. Unless otherwise specified, LTDS shall not exceed the following K percent of its ultimate tensile strength, T_{ULT} (MARV), i.e.

$$LTDS = K * T_{ULT} (MARV),$$

(1) Geogrid reinforcement (HDPE, PET):

Products	K
Tensar	20%
Fortrac, Miragrid, Strata, Synteen and Raugrid	24%

(2) All products not listed above:

Products	K
All geogrid or woven geotextile products meeting AASHTO Standard Specifications for Highway Bridges, 16th Edition	10%
Products not meeting AASHTO Standard Specifications for Highway Bridges, 16th Edition including Non-woven geotextile products	5%

(h) *Design Heights and Supplied Reinforcing Material*. Unless otherwise defined on the plans, the wall design height shall be measured vertically from the top of the leveling pad to the top of the concrete rail anchoring slab for walls with railing, or to the top of the cast-in-place concrete coping for walls without railing. For walls that are in front of a bridge abutment that is founded on a deep foundation, the design height used to determine the soil reinforcement length shall be measured vertically from the top of the leveling pad to the top of the roadway carried by the bridge and the wall. Bridge approach slabs shall not be considered in the design of the MSE wall.

For both geosynthetic and metallic reinforcement, the required reinforcement LTDS and the supplied LTDS (determined in accordance with the K factors or depletion of material as defined above) with corresponding brand and grade of material shall be marked clearly on the elevation view or in a tabulation summary. The LTDS of the supplied reinforcement grade must meet or exceed the required LTDS corresponding to the reinforcement spacing provided.

(i) *Tiered Walls*. For the reinforcement layouts of tiered walls, the overall geometry, the reinforcement length, and the sum of the LTDS provided from all layers in all tiers shall be in close conformity with the retaining wall system shown on the plans in order to ensure that local, global, and internal stability requirements have been met.

(j) *Obstructions*. Details for the placement of soil reinforcement around obstructions (i.e. steel piles, concrete piers, concrete boxes, pipes, etc.) shall be shown on the shop drawings. Design calculations shall be provided

showing that the internal stability of the wall meets the required safety factors in the area of the obstruction.

(k) *Table of Quantities*. A table comparing the Structure Backfill (Class 1), Mechanical Reinforcement of Soil, Geomembrane, and Panel Facing quantities shown on the plans to the quantities shown in the shop drawings and the percent difference (positive percent indicates an increase in shop drawing quantities from the plans) shall be shown on the shop drawings. Structure Backfill (Class 1), Mechanical Reinforcement of Soil, Geomembrane, and Panel Facing quantities shall be calculated in accordance with the Contract. The Contractor shall notify the Engineer of the difference in plan and shop drawing quantities before wall construction begins.

(l) *Placement Schedule*. Geomembrane placement schedule and clearances to soil reinforcements shall be shown.

(m) *Vertical Slip Joints*. Locations of vertical slip joints for differential settlement relief shall be as specified in subsection 504.16.

504.03 Backfill. Unless otherwise specified on the plans, wall backfill material in the reinforced structure backfill zone and the associated trapezoidal retained structure backfill zone shall conform to the requirements for Structure Backfill (Class 1) of Section 206. For reinforcement tensile stress and associated pullout, a friction angle of 34 degrees shall be assumed for Structure Backfill (Class 1). Structure Backfill (Class 1) shall be considered to be non-aggressive soil for corrosion and durability computations. All reinforcing elements shall be designed to ensure a minimum design life of 75 years for permanent structures.

504.04 Leveling Pad. Concrete for the leveling pad shall be Concrete (Class D) conforming to the requirements of Section 601. Unless specified on the plans, the maximum vertical step shall be no greater than 36 inches. The leveling pad shall be reinforced only at the steps. When the toe of wall is founded on slope steeper than 1.5 (H) to 1 (V), the leveling pad shall be constructed with reinforced concrete with same reinforcing schedule as at its steps. Leveling pad concrete shall be cured for at least 12 hours before placement of the concrete panels. To avoid panel cracking from high contact points, a ¼ inch thick expansion joint material with the same thickness as the panels may be installed between the first layer of panels and the leveling pad.

504.05 Geomembrane and Joint. A geomembrane shall be installed on all walls at the top of the reinforced structure backfill zone and retained structure backfill zone to intercept surface runoff and prevent salt penetration into the backfill of the wall as shown on the plans. The geomembrane shall meet the requirements of subsection 712.08 for geomembrane, and shall have a minimum thickness of 30 mils. It shall be spliced with a dual track field seamed joint in accordance with ASTM D4437 or ASTM D7717. For small local coverage areas, less than 30 square feet, the membrane may be spliced using a 6 inch minimum overlap and an adhesive or a single seam portable thermal welding tool, as suggested by the membrane manufacturer and approved by the Engineer. Unless otherwise shown

on the plans, the membrane shall have a minimum coverage length measured perpendicular to the wall face of at least the wall Design Height (DH) plus Soil Reinforcement Length (RL) plus 1.5 feet. The membrane shall be installed with a slope between 20:1 (minimum) and 10:1 (maximum) , as shown on the plans, from the panel facing to a drainage system located at the cut or pre-filled slope as shown on the plans.

The drainage system shall consist of a 12 inch wide geocomposite strip drain inserted into a slot in the geomembrane, at 10 foot maximum spacing, that collects the water from the membrane and conveys it to a water collector system at the toe of the 1:1 slope as shown on the plans. The water collector system shall consist of a 4 inch diameter perforated collector pipe surrounded by Filter Material Class B and wrapped with class 3 geotextile. A 4 inch diameter non-perforated drain pipe, at 100 foot maximum spacing, shall be used to discharge the water in the water collector system out the face of the wall.

Alternatives for the drainage system shown on the plans may be used by the Contractor. A detailed layout of this equivalent water collection system shall be provided by the Contractor and approved by the Engineer.

For tiered walls, a geomembrane shall be installed between the top of the bottom wall and the toe of the top wall as shown on the plans.

504.06 Pre-Cast Concrete Panel Facing Unit and Panel Joint Material. The pre-cast concrete panels shall conform to the requirements shown on the plans and these specifications including the color, texture, dimensions and pattern. These facing units shall be factory made with Class B Concrete with the following additional requirements:

(1) Minimum Cementitious Content: 610 lb./cu. yd.

(2) No more than 50 percent fine aggregate (AASHTO M6) by volume of total aggregate.

(3) Ambient temperature: shall be a minimum of 40° F and rising when casting panels.

(4) Pre-cast panels shall be cured in accordance with AASHTO M170.

Reinforcing steel shall conform to the requirements of Section 602. The concrete in the pre-cast units shall be compacted using a vibrating table, grid vibrator, or screed vibrator. All panels shall be cast face down on a flat level surface.

Panel dimensions and facing treatment shall conform to the architectural requirements shown on the plans. Width of panel from center to center of joint shall be an even whole increment of the pattern dimensions selected to match the architectural treatment. Thickness shall be a minimum of 6 inches plus the depth of rustication. Panel shall be cast to the dimension that accommodates the architectural treatment.

Panels may be longer than 5 feet provided their section strength can be shown to accommodate handling and erection without cracking. Soil reinforcement attachment devices shall be within 1 inch of shop drawing locations. All unit dimensions shall be within ¼ inch of plan. Concrete surface for the front face of the wall shall match the architectural treatment requirements and structural concrete color shown on the plans. Squareness determined by the difference between two diagonals, shall not exceed ½ inch. Surface defects on the front face textured surface, shall not exceed $^{3}/_{16}$ inch when measured with a 5 foot straight edge, except when intentionally roughened.

The Engineer shall be allowed access to the manufacturer's facilities to inspect and sample units from lots prior to delivery with a minimum of 2 working days advance notice. The Engineer will reject any concrete panels, which do not meet the requirements of this specification. Panels shall not be shipped until the concrete strength, at the time of shipping, is greater than 0.9 times f'_C. The Contractor shall notify the Engineer in writing at least 3 working days before shipment of panels begins.

Cover on the back face of the wall for horizontal and vertical joints is required between panels and shall be a drainage geotextile conforming to Subsection 712.08, a minimum of 12 inches wide, nailed or glued in place prior to placing backfill.

At horizontal joints, a cellular type or molded expansion joint material shall be placed and shall be a size suggested by the supplier and approved by the Engineer.

504.07 Certifications, Calculations and Testing Reports. The Contractor shall provide the following reports, certifications, calculations, and checklists as needed to accompany the shop drawing submittal. All engineering calculations, as stated in subsections 504.07(f), 504.07(g), 504.07(j), 504.07(k), 504.12(e), 504.12(f), 504.12(g), and 504.12(i) shall be certified and stamped by a Professional Engineer licensed in the State of Colorado.

(a) *Certification of T_{ULT} (MARV).* For geosynthetic reinforced system only, the Contractor shall submit a certification letter from the manufacturer which provides the T_{ULT} (MARV) and certifies the T_{ULT} (MARV) of the supplied materials have been determined in accordance with ASTM D4595 or ASTM D6637 as appropriate.

(b) *Mill Report for Metallic Reinforcements and Connectors*. This includes, but is not limited to, mill certifications on weldability, ultimate tensile strength, and yield strength.

(c) *Report of The Panel-Reinforcement Connection Test*. The test report shall be prepared and certified by an independent laboratory. The panel to reinforcement connection test method shall conform to the industrial standards. The report shall provide data on the ultimate as well as service limit state.

(d) *Report for Soil to Reinforcement Interface Pullout Test*. The test report shall be prepared and certified by an independent laboratory. The soil to reinforcement interface pullout test method shall conform to the requirements of ASTM D6706. Tests shall include the full range of overburden pressures defined by wall design heights.

(e) *Certification of Facial Panel to Reinforcement Long-Term Connection Strength*. Certification shall include calculations to demonstrate that the facial panel to reinforcement connection meets or exceeds current AASHTO 75 years design life requirements.

(f) *Certification of Reinforcement Pullout*. Certification shall be provided with detail calculations to demonstrate that reinforcement pullouts meet or exceed current AASHTO requirements. For metal reinforcement breakage and pullout, calculations shall include a combination of 75 years material depletion of carbon steel and galvanization loss.

(g) *Report and Certification for the Initial Concrete Compression Strength, Shipping and Handling Stress*. Cylinder compressive test is acceptable to verify the initial concrete strength of panel at time of shipping. Concrete tensile stress shall not exceed the modulus of rupture. The report shall include calculations of panel cracking stress according to the proposed method of lifting and shipping. Panels shall not be shipped from the precast yard to the wall site, until the Engineer has approved the time of shipping, the method of lifting, and the supporting condition during shipping as well as storage condition at the site before panel installation.

(h) *Calculations*. Calculation of the LTDS of reinforcement shall conform to the 17th edition of the AASHTO Standard Specifications for Highway Bridges *Efflorescence and Air Content Test*. Panel shall be visually efflorescence free. Efflorescence control agent shall be used in concrete mix design. When fly ash is used as the efflorescence control agent, the fly ash shall be ASTM C618 Class F fly ash and shall be a minimum of 20 percent by weight of the total cementitious material content. Air Content shall be determined in accordance with AASHTO T152. Concrete shall be tested a minimum of the first three batches each day and then once per five batches for the rest of the day to assure specified air entrainment.

(i) *Submittal Checklist*. The Contractor shall submit the Panel Faced MSE Wall Submittal Checklist, Form 1402 with the Certifications, Calculations and Testing Report submittal package included with the shop drawing submittal.

504.08 Hybrid MSE Wall Systems.

A hybrid system is one which combines elements of both externally and internally stabilized systems.

An externally stabilized system uses a physical structure to hold the retained soil. The stabilizing forces of this system are mobilized either through the weight of a

shape stable structure or through the restraints provided by the embedment of wall into the soil, if needed, plus the tieback forces of anchorages.

An internally stabilized system involves reinforced soils to retain fills and sustain loads. Reinforcement may be added to either the selected fills as earth walls or to the retained earth directly to form a more coherent stable slope. These reinforcements can either be layered reinforcements installed during the bottom-to-top construction of selected fills, or be driven piles or drilled caissons built into the retained soil. All this reinforcement must be oriented properly and extend beyond the potential failure mass.

Hybrid MSE wall systems may be used unless otherwise noted on the plans. Hybrid MSE wall systems are subject to the same design requirements for MSE walls and this specification. The shop drawings for the Hybrid MSE wall system shall include a combination of design calculations and appropriate test results to demonstrate that it meets or exceeds the regular system. Hybrid MSE wall systems shall have a facing area of 3.5 square feet and be stabilized by a counterfort. The Certifications, Calculations and Testing Reports in subsection 504.07(e) are not required for Hybrid MSE wall systems. The facing to soil reinforcement connection test, subsection 504.07(c), may be waived only if the soil reinforcing spacing is less than or equal to 8 inches or the facing is secured and stabilized by hybrid components with primary reinforcement spacing less than 24 inches.

The Contractor shall provide the following additional reports, certifications and calculations to accompany the shop drawing submittal for Hybrid MSE wall systems:

(1) The facing to counterfort long-term connection test.

The Contractor shall submit the Panel Faced MSE Wall Submittal Checklist, Form 1402, with the Certifications, Calculations, and Testing Report submittal package included with the shop drawing submittal.

CONSTRUCTION REQUIREMENTS

504.09 Approval and Qualifications of MSE Wall Installer. The job site wall foreman shall have experience in construction of at least five transportation related MSE walls within the last three years. Transportation related MSE walls are walls that carry or are adjacent to vehicular traffic and are constructed with MSE reinforcement in the reinforced structure backfill zone. The foreman must have prior experience or adequate training on the products that the Contractor elects to use on the project. The resume and credentials of the foreman shall be submitted to the Engineer for approval prior to the Pre-construction Conference. The foreman shall be on the site for 100 percent of the time during which the work is being done.

504.10 Wall Test Segment. The wall test segment shall be the first segment of the wall constructed. The wall test segment shall be constructed in the presence of the Technical Representative and the Engineer and shall include construction of

each of the 5 elements listed in subsection 504.11 below. The minimum length of the wall test segment shall be 40 feet or the full length of the wall if less than 40 feet. A wall test segment shall be constructed for the first wall constructed from each wall product used on the project.

504.11 Technical Representative of Wall Product Supplier. The Contractor shall arrange for a technical representative (Tech Rep) of the manufacturer of the selected wall products to be present during the construction of each wall test segment. If the selected wall products are supplied from different manufacturers, a Tech Rep from each wall product shall be present. The Tech Rep shall be present for construction of the wall test segment and each of the following elements:

(1) Placement of a minimum of the first four layers of primary soil reinforcement and backfill.

(2) If obstructions (i.e. steel piles, concrete piers/abutments, concrete boxes, pipes, etc.) exist, placement of primary soil reinforcement and backfill at obstructions.

(3) Placement of a minimum of the first two rows of panels or a minimum of a four foot wall height.

(4) If a vertical slip joint is required, construction of the vertical slip joint in a minimum of a two row portion of panels or a minimum of a four foot wall height.

(5) If corners are required, construction of a corner representative of the corners in the wall in the project in a minimum of a two row portion of panels or a minimum of a four foot wall height.

Before construction of the wall test segment the Tech Rep shall provide the Contractor and the Engineer the following:

(1) Technical instructions as required for the construction of the earth retaining wall system.

(2) Product specific specifications for the placement of the soil reinforcement and backfill in accordance with the wall system.

(3) Guidelines for placing the facing units and attaching them to the soil reinforcement in accordance with the system requirements.

(4) Technical assistance to the facing unit fabricator.

At the completion of the wall test segment the Tech Rep shall provide the following:

(1) Documentation that the wall test segment was constructed in accordance with the product specific specifications. This documentation shall include a location description (starting and ending stations and elevations) of the wall test segment.

(2) Documentation that the job site wall foreman is familiar with the wall products used to construct the walls on the project.

After completion of the wall test segment the Tech Rep shall be available when there is any special field condition such as change of geological condition, when there are equipment or personnel changes, or when requested by the Engineer.

504.12 Facial Panel Process Control, Placing Plan, and Daily Placement Logs. Before the start of wall construction, the Contractor shall provide a panel-placing plan and shall supply daily placement logs to the Engineer weekly and at the completion of the wall. The daily placement log shall consist of an elevation view of the wall showing the dates, number of panels placed, and the serial numbers of the panels placed. The panel process control log shall contain multiple submittals if required by subsections 504.07(g) and (h). Panels shall be labeled with a serial number for each panel and corresponding certification with one set of random samples tested for each 220 panels or 5500 square feet of wall face. At least one certification with supporting test results is required for each wall. Test results will be reviewed and pre-approved by the Engineer before shipment. The Contractor shall coordinate and mark the panel and backfill placing sequence on the daily placement logs. The log serves as means for the Engineer to identify where each panel was placed.

504.13 Wall With Curved Alignments, Tight Curved Corners, and Sections Adjacent To Bridge Abutment. The Contractor shall provide a placement plan that shows curved layouts, special corner panel, sequence of panel placement, and construction off-sets as recommended by the manufacture. To avoid panels with random cracks, the Contractor shall install vertical slip joints as shown on the shop drawings for tight curved corners (8 foot radius or less) and dissimilar foundations such as bridge abutments.

504.14 Excavation and Backfill. The base of leveling pad shall receive the same compaction as cut area required by subsection 203.07. The Contractor shall report to the Engineer in writing density test results for any unsatisfactory bearing material that does not meet the minimum 90 percent compaction for walls less than 16 feet high and 95 percent compaction for walls higher than 16 feet when tested in accordance with AASHTO T 180. If the excavation for the placement of the leveling pad exposes an unsatisfactory bearing material, the Engineer may require removal and replacement of that material. The removed material shall be replaced with Structure Backfill (Class 1) compacted in conformance with subsection 206.03. The Engineer with the assistance of the geotechnical engineer of record will provide the limits including the depth of removal. As directed by the Engineer, and if required, Structure Backfill (Class 1) shall be reinforced with soil reinforcements in conjunction with wick drains and outlet pipes

The Contractor shall grade the foundation for the bottom of the wall for a width equal to or exceeding the limits of the Reinforcement Length (RL) plus 18 inches as shown on the plans. This graded area shall be compacted with an appropriate vibratory roller weighing a minimum of 8 tons for at least five passes or as directed by the Engineer. For cut wall with continuous seepage, phasing of

foundation construction or a different drainage and foundation improvement plan may be necessary.

The reinforced structure backfill zone and the retained structure backfill zone portion immediately behind the wall as defined on the plans shall be Structure Backfill (Class 1). Recycled asphalt, recycled concrete, and flow-fill material shall not be substituted for Structure Backfill (Class 1). Each compacted layer of backfill within a distance equal to the reinforcement spacing away from the back of the panels shall not exceed 4 inches. The triangular or trapezoidal portion behind the concrete panels and above the spill of backfill, as shown on the plans, shall be filled with ⅜ inch or larger crushed rock, filter aggregates with filter fabric, or wall system specific fill as approved by the Engineer. Density tests behind and parallel to the wall in the triangular or trapezoidal portion above the backfill spill zone are not required. Each compacted layer of backfill shall be in even increments up to 8 inches thick. The fill and compaction operation shall start 3 feet from the wall back face and progress toward the end of the reinforcement. All Structure Backfill (Class 1) including fill material under the wall and on-site material as allowed by subsection 504.03 shall be compacted to a density of at least 95 percent of the maximum density according to AASHTO T 180. For on-site foundation material containing more than 30 percent retained on the ¾ inch sieve, a method of compaction consisting of a conventional heavy vibratory roller starting with minimum 5 passes shall be used to establish the number of passes required to exceed the 95 percent compactionin accordance with AASHTO T 180.

At least 6 inches of material shall be in place prior to operation of tracked vehicles over soil with reinforcement. Only power operated roller or plate compaction equipment weighing less than 1,000 pounds is allowed within 3 feet of the front of the wall face. The reinforcement shall not be connected to the wall until the compacted fill is at or slightly higher than the location of the connector.

Backfill containing frost or frozen lumps shall not be used. Backfill that has been placed and becomes frozen shall be removed and replaced at the Contractor's expense. If cold weather conditions prevent the placement of Structure Backfill (Class 1), the Contractor may use Filter Material Class B as backfill without compaction at the Contractor’s expense if approved by the Engineer. The Contractor shall provide a test report, prepared and certified by an independent laboratory, that the internal friction angle of soil for the Filter Material Class B meets or exceeds that shown on the plans.

The Contractor shall place additional panels including partial height panels and properly compacted fill material to return the finished grade to the plan elevations if settlement, as determined by the Engineer, has occurred. A final inspection before the installation of rail anchoring slab will be made after construction settlement, if any, has occurred or 30 days after the completion of the wall. The Contractor shall provide immediate temporary storm water protection and wind erosion control at the end of each day during construction. If settlement occurs as the result of loss of backfill due to wind or water erosion, non-conforming backfill such as frozen fill or over-saturated fill, or if the backfill does not meet compaction requirements, the Contractor shall remove the backfill, wash the soil

reinforcement, and bring the elevation to the finished grade at the Contractor's expense. Before final project acceptance, the Contractor shall repair all backfill losses due to wind and water erosion.

To avoid the foundation of the leveling pad being washed out by rain, the area in front of the wall and around the leveling pad shall be backfilled as soon as practicable.

504.15 Reinforcement. Steel reinforcement shall be slack free and geosynthetic reinforcement shall be slightly pre-tensioned. The minimum coverage ratio for geogrid reinforcement shall be 67 percent and the spaces between rolls shall be staggered between layers of soil reinforcement. The minimum coverage ratio for woven fabric reinforcement shall be 100 percent and an overlap between rolls is not required. Soil reinforcement shall not be cut to avoid obstruction unless shown on the shop drawings.

504.16 Leveling Pad. The foundation of the leveling pads shall meet the requirement of subsection 504.11. The leveling pad shall be level within the tolerance of ⅛ inch for any two points along the length of a panel, and within ¼ inch for any two points 10 feet apart.

Cushion or shimming material (expansion joint material, concrete mortar grout, roofing felt, or geosynthetic reinforcement) shall be used to support panels directly founded on the leveling pad. Before starting a new course of panels, the Contractor shall take steps to ensure that the wall elevations are matched at the neighboring panels. Cushion or shimming material shall be used to obtain necessary panel elevations at next leveling pad step. No more than 2 shims (each $\frac{3}{16}$ inch thick) should be required to level the panels on the leveling pad.

504.17 Wooden Wedges. Wooden wedges may be used to help to hold the panels at the correct batter during the backfill operation. The wooden wedges shall be made from hard wood (such as oak, maple or ash). Wooden wedges shall be removed as soon as the precast panels above the wedged panels are completely erected and backfilled. There shall not be more than three rows of wooden wedges in place at one time. Panels that crack or spall due to failure to remove the wooden wedges shall be repaired or replaced.

504.18 Panel Facing. For walls that support a roadway, the wall layout line at the leveling pad shall be set back and pre-measured with appropriate batter (5 to 8 percent) from the top of the panels according to the offset with respect to the centerline of the road. For walls adjacent to a roadway, the wall layout line at the leveling pad shall be directly offset from the centerline of the road. An overall negative batter (wall face leaning outward) between the bottom and the top of the wall is not allowed. Unless otherwise noted on the plans for battered walls, the final wall face shall be vertical, or have a positive batter of not greater than 5 percent for construction control purpose. The surface of the wall face shall be tested with a 10 foot straightedge laid along the surface in horizontal and vertical directions. Except as necessary for horizontal alignment of the wall, convex

deviation of the wall face from the straightedge (belly wall) shall not be allowed, and concave deviation from the straightedge shall be less than ½ inch.

Walls without a rail-anchoring slab, cast-in-place reinforced concrete coping with uniform exposed height is required to match the required finished elevations as well as to retain the panels' lateral deformation.

For walls with rail anchoring slabs, the top of panel elevations shall be within 8 inches of the bottom of the anchoring slab. Cast-in-place concrete or saw-cut partial height panels may be used to accomplish this.

Where the geomembrane for drainage interferes with the continuation of reinforcement, the panels beyond the termination shall be reinforced with the same grade of additional soil reinforcing material to maintain the total amount of reinforcement per panel. To avoid leaking or soil erosion through the joint, a filter fabric at least 12 inches wide shall be glued to the panels behind all vertical joints.

As shown on the plans, facing panels directly exposed to spray from deiced pavements and indirect windborne spray shall have three coats of water resistant or repellant concrete sealer applied to the front face of the wall before the wall is opened to traffic.

All damages to a completed wall or parts of a completed wall, including blemishes and discoloring of panels, shall be replaced or repaired before final payment is made. Sand blasting may be used if approved by the Engineer.

504.19 Fill under Leveling Pad. For walls requiring fill under the planned elevation of the leveling pad, the Contractor may lower the elevation of the leveling pad as approved by the Engineer, except that the finished elevation at the top of the wall shall not be altered. As requested by the Contractor, and with the Engineer's approval, the higher wall shall be redesigned with longer reinforcement length and revised reinforcement schedule.

METHOD OF MEASUREMENT

504.20 MSE retaining walls will not be measured for payment in the field, but will be paid for by the calculated quantities shown on the plans for the five major components of the wall: structure excavation, structure backfill, concrete panel facing, mechanical reinforcement of soil, and geomembrane. The Contractor's construction of a system that requires increased or decreased quantities of any of the components to complete the wall to the dimensions shown will not result in a change in pay quantities. Exceptions will be made when field changes are ordered or when it is determined that there are discrepancies on the plans in an amount of at least plus or minus five percent of the plan quantity.

(1) The panel facing quantity was calculated for the square foot of wall front face area from the top of the leveling pad (or average pad elevations) as shown on the plans to the top of the anchoring slab for walls with railing, or to the top of the cast in place coping for walls without railing.

(2) The structure excavation quantity was calculated for the total volume of earth to be removed before the installation of the reinforced zone as shown on the plans.

(3) The structure backfill quantity was calculated for the total volume behind the wall (the retained structure backfill zone) including the material in the reinforced zone as shown on the plans.

(4) The mechanical reinforcement of soil quantity was calculated for the total volume of the reinforced zone as shown on the plans.

(5) Geomembrane was calculated as the design height (DH) plus soil reinforcement length (RL) plus 1.5 feet, disregarding the slope of the membrane.

The square foot and cubic yard quantities computed for payment are the wall plan quantities based on the height measured at 20 foot maximum intervals along the wall layout line.

BASIS OF PAYMENT

504.21 The accepted quantity will be paid for at the contract unit price per unit of measurement for the pay items listed below:

Payment will be made under:

Pay Item	Pay Unit
Panel Facing	Square Foot

Structure excavation will be paid for under the Section 206 Pay Item Structure Excavation. Structure backfill will be paid for under the Section 206 Pay Item Structure Backfill (Class 1). Soil reinforcement will be paid for under the Section 206 Pay Item Mechanical Reinforcement of Soil. Geomembrane will be paid for under the Section 420 Pay Item Geomembrane.

Rail anchoring systems (slabs) at the tops of walls and leveling pads at the bottom of wall will be measured and paid for separately under the Section 601Pay Item Concrete and the Section 602 Pay Item Reinforcing Steel.

Payment will be full compensation for all work and materials required to construct the concrete panel facing MSE wall. Miscellaneous items such as dual track welding of geomembrane, drainage ditches, rundowns, filter material, filter fabric, grout, pins, shimming material, ¼ inch thick expansion joint material, concrete coating and providing a technical representative will not be measured and paid for separately but shall be included in the work.

504.22 Panel Facing Payment Reductions. In this subsection, a “panel” refers to either a concrete panel or a hybrid unit. Each of the following shall be considered a defect:

(1) Dislocated Panel. A dislocated panel is an individual panel or its corner located outward more than ¼ inch from the adjacent panels.

(2) Cracked Panel. A cracked panel is an individual panel with any visible crack when viewed from a distance equal to the wall height in natural light.

(3) Corner Knock Off. A corner knock-off is a panel with any missing facial corners or architectural edges.

(4) Substandard panel. Substandard panels are concrete panels installed in any wall segments that do not meet the certified values for compressive strength. Each substandard panel counts as one defect.

(5) Oversize Joints. Panels with oversize joints are two adjacent panels that do not meet the required values in subsection 504.02(f).

(6) Panels Failing the 10 Foot Straightedge Test. Straightedge test failures are joints that that deviate from even by more than ¼ inch when measured by placing a 10 foot straightedge across the joint.

Defects shared by two adjacent panels such as oversized joint, dislocated panel and panels not passing 10 foot straight edge test will be count as one defect.

In the completed wall, or completed portion of the wall the number of defects, as described above, in each 40 foot section (horizontal or arc length) will be counted. If there are defects, the number of defects in the 40 foot section will be considered for price reduction according to the table below. For panels subjected to price reduction, if the defects are repairable or the overall quality of wall can be improved, with the consent from the Engineer, the Contractor may elect to repair and reduce the percent of price reduction. A walkthrough inspection will be made as requested by the Contractor before final payment.

No. of Defects in 40 Foot Section	**Percent of Price Reduction for that section**
2	3
3	9
4	15
5	21
> 5	Rejection

When the number of defects exceeds 5, the Engineer will reject the entire wall or portions thereof. The Contractor shall replace the rejected wall at his own expense.

SECTION 506
RIPRAP

DESCRIPTION

506.01 This work consists of the construction of riprap in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

506.02 Riprap shall consist of hard, dense, durable stone, angular in shape and resistant to weathering. Rounded stone or boulders shall not be used as riprap material. The stone shall have a specific gravity of at least 2.5. Each piece shall have its greatest dimension not greater than three times its least dimension.

Material used for riprap may be approved by the Engineer if, by visual inspection, the rock is determined to be sound and durable. The Engineer may require the Contractor to furnish laboratory results if, in the Engineer's opinion, the material is marginal or unacceptable. At the request of the Engineer, the Contractor shall furnish laboratory test results indicating that the material meets the requirements for abrasion resistance or compressive strength as indicated in Table 506-1.

Table 506-1

Test Description	Test Method	Specification Requirement
Abrasion Resistance by Los Angeles Machine	ASTM C 535	50% Loss, max.
Unconfined Compressive Strength of Drilled Core Specimen	AASHTO T 24	2500 psi, min.

Riprap shall conform to the gradation requirements given in Table 506-2.

Table 506-2

Pay Item		Percent of Material Smaller Than Typical Stone[2]	Typical Stone Dimensions[3] (Inches)	Typical Stone Weight[4] (Pounds)
	Stone Size d50[1] (Inches)			
Riprap	6	70-100 50-70 35-50 2-10	12 9 6 2	85 35 10 0.4
Riprap	9	70-100 50-70 35-50 2-10	15 12 9 3	160 85 35 1.3
Riprap	12	70-100 50-70 35-50 2-10	21 18 12 4	440 275 85 3
Riprap	18	100 50-70 35-50 2-10	30 24 18 6	1280 650 275 10
Riprap	24	100 50-70 35-50 2-10	42 33 24 9	3500 1700 650 35

[1]d50 = nominal stone size
[2]based on typical rock mass
[3]equivalent spherical diameter
[4]based on a specific gravity = 2.5

Nominal stone size and total thickness of the riprap shall be as shown on the plans.

Control of gradation will be by visual inspection. The Contractor shall provide two samples of rock at least 5 tons each, meeting the gradation specified. One sample shall be provided at the construction site and may be a part of the finished riprap covering. The other sample shall be provided at the quarry.

These samples will be used as a reference for judging the gradation of the riprap supplied. When it is determined necessary, conformance of the gradation will be verified by dumping and checking the gradation of two random truck loads of stone. Mechanical equipment, a sorting site, and labor needed to assist in checking gradation shall be provided at the Contractor's expense.

CONSTRUCTION REQUIREMENTS

506.03 Stones with typical stone dimensions that are equal to d50 and larger shall be placed at the top surface with faces and shapes matched to minimize voids and form as smooth a surface as practical. Dumping and backhoe placement alone is not sufficient to ensure a properly interlocked system. The material may be machine-placed and then arranged as necessary by use of an excavator with a multi-prong grappling device or by hand to interlock and form a substantial bond.

Excavation for toe or cut-off walls shall be made to the neat lines of the wall. Allowance will not be made for work outside the neat lines.

METHOD OF MEASUREMENT

506.04 Riprap of the sizes specified in the Contract will be measured by the ton or by the cubic yard. Cubic yards will be by the method of average end areas based on dimensions shown on the plans or ordered.

BASIS OF PAYMENT

506.05 The accepted quantities of riprap will be paid for at the contract unit price per cubic yard or per ton.

Payment will be made under:

Pay Item	Pay Unit
Riprap (___inch)	Cubic Yard or Ton

Structure excavation will be measured and paid for in accordance with Section 206.

RIPRAP (GABIONS) AND SLOPE MATTRESS

DESCRIPTION

506.06 This work consists of the construction of riprap in wire mesh gabions and in wire mesh slope mattresses in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

506.07 The wire, wire mesh, cages, anchor stakes and riprap shall conform to subsection 712.09.

CONSTRUCTION REQUIREMENTS

506.08 Gabions and Slope Mattresses. Gabions and slope mattresses shall be placed to conform to the plan details. Riprap material shall be placed in close contact in the unit so that maximum fill is obtained. The units may be filled by machine with sufficient hand work to accomplish requirements of this specification.

Where the length of the unit exceeds its horizontal width the gabion is to be equally divided by diaphragms, of the same mesh and gauge as the body, into cells whose length does not exceed the horizontal width. The unit shall be furnished with the necessary diaphragms secured in proper position on the base section in such a manner that no additional tying at this juncture will be necessary.

(a) *Gabions.* All perimeter edges of gabions are to be securely selvedged or bound so that the joints formed by tying the selvedges have approximately the same strength as the body of the mesh.

The gabion bed shall be excavated to the width, line, and grade as staked by the Engineer. The gabions shall be founded on this bed and laid to the lines and dimensions required.

Excavation for toe or cut-off walls shall be made to the neat lines of the wall.

All gabion units shall be tied together each to its neighbor along all contacting edges in order to form a continuous connecting structure.

(b) *Slope Mattresses.* Slope mattresses shall be filled with angular or fractured stone. Rounded boulders will not be permitted. Before the mattress units are filled, the longitudinal and lateral edge surfaces of adjoining units shall be tightly connected by means of wire ties placed every 4 inches or by a spiral tie having a complete loop every 4 inches. The lid edges of each unit shall be connected in a similar manner to adjacent units. The slope mattress shall be anchored as shown on the plans.

The Contractor shall determine whether the holes for the soil anchor stakes are to be drilled or whether the stakes may be driven. Care shall be taken to avoid drilling holes to a greater depth than is necessary to place the top of the finished stake slightly above the top of the finished mattress.

The Contractor will be allowed to assemble, partially fill, and tie together mattress-units on the subgrade provided they can be placed on the slope without abrading the zinc coating on the wire mattress or permanently distorting the shape of the mattress in transporting and installing the units on the slope. All prefabrication procedures shall be subject to approval.

METHOD OF MEASUREMENT

506.09 The quantity to be measured under this item will be the number of cubic yards of riprap required to fill the gabions and slope mattresses in accordance with the dimensions shown on the plans, or ordered.

BASIS OF PAYMENT

506.10 The accepted quantity measured as provided above will be paid for at the contract unit price per cubic yard for “Riprap (Gabions)” or “Slope Mattress” as the case may be.

Payment will be made under:

Pay Item	Pay Unit
Riprap (Gabions)	Cubic Yard
Slope Mattress	Cubic Yard

Structure excavation and structure backfill will be measured and paid for in accordance with Section 206.

SECTION 507
SLOPE AND DITCH PAVING

DESCRIPTION

507.01 This work consists of the construction of slope and ditch paving in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

507.02 Concrete Slope and Ditch Paving. Concrete shall conform to the requirements of Section 601. Concrete shall be Macro Fiber-Reinforced Class B Concrete.

507.03 Dry Rubble Slope and Ditch Paving. Stone shall conform to the material requirements of subsection 506.02. Size of stone and total thickness of paving shall be as shown on the plans.

507.04 Grouted Rubble Slope and Ditch Paving. Stone shall conform to the material requirements of subsection 506.02. Size of stone and total thickness of paving shall be as shown on the plans.

Mortar shall consist of one part portland cement and three parts of fine aggregate by volume thoroughly mixed with as much water as is necessary to obtain the required consistency. Materials shall meet the requirements specified in the following subsections:

Hydraulic Cement	701.01
Fine Aggregate	703.01
Water	712.01

Mortar shall be used within 45 minutes after mixing and shall not be re-tempered. Class B concrete, conforming to the requirements of Section 601, may be substituted for mortar.

507.05 Grouted Riprap Slope and Ditch Paving. Concrete mortar for grouted riprap slope and ditch paving shall meet the requirements of Section 601 and the following:

Field Compressive Strength (28 days) (Not a specification requirement)	2000 psi
Minimum Cement Content	560 lbs./cu. yd.
Air Content	6-9%
Slump, AASHTO Designation T-119	5-9 inches
Fine Aggregate, AASHTO M-6	65-75%
Coarse Aggregate, AASHTO M-43	⅜" nominal maximum size
Polypropylene Fibers (1" fiber length or equivalent)	1.5 lbs./cu. yd.

Riprap stone shall conform to the quality requirements of subsection 506.02 and the classification and gradation requirements specified in the following table:

Table 507-1
CLASSIFICATION AND GRADATION
OF ROCK FOR GROUTED RIPRAP

Riprap Designation	Percent Smaller Than Given Size By Weight	Intermediate Rock Dimension, Inch
	100	30
d50 = 24" (Type HG)	50 - 70	24
	0 - 5	18
	70 - 100	21
d50 = 18" (Type MG)	50 - 70	18
	0 - 5	12

507.06 Asphalt Slope and Ditch Paving. The mixture used shall conform to the requirements for the asphalt pavement used on the project.

CONSTRUCTION REQUIREMENTS

507.07 Paving thickness shall be as specified on the plans. In ditch construction, the excavated areas adjacent to the paving which are not occupied by the paving shall be refilled to the level of original ground with acceptable material and thoroughly tamped.

Excavation for toe or cut-off walls shall be made to the neat lines of the wall. Allowance will not be made for work outside the neat lines.

507.08 Concrete Slope and Ditch Paving. Concrete shall be mixed, placed and cured in accordance with Section 601.

Unsuitable soil shall be removed and replaced with a suitable soil as designated by the Engineer.

Where the thickness of concrete lined ditch as shown on the plans is less than 4 inches, this concrete slope and ditch paving shall be installed with slip-form machine, except for the following:

(1) Where it is deemed impossible to construct the ditch lining by the slip-form method, the lining shall be hand formed and the thickness shall be at least 1 inch greater than the thickness shown on the plans.

(2) The Contractor may use hand method of placement in lieu of the slip-form method, provided the thickness of this hand-placed lining is at least 1 inch greater than the thickness shown on the plans.

Where the thickness of concrete lined ditch as shown on the plans is 4 inches or greater, the Contractor will be permitted to place the material with a slip-form machine or by hand method.

507.09 Dry Rubble Slope and Ditch Paving. Stones shall be placed with close joints which shall be broken to minimize straight construction joints. The stones shall be placed to give the appearance of plating the fill slope.

Larger stones shall be placed on the lower courses. Open joints shall be filled with spalls.

Oversize stones and protrusions that present a safety hazard will not be permitted.

507.10 Grouted Rubble Slope and Ditch Paving. Stones shall be laid as specified in subsection 507.09, with care to prevent earth and sand filling the joints. Joints shall be filled with grout from bottom to top and the surfaces swept with a stiff broom.

Grouting shall not be done in freezing weather. In hot, dry weather the work shall be protected and kept moist for at least three days after grouting, or clear membrane curing compound may be used.

507.11 Grouted Riprap Slope and Ditch Paving. All placement of concrete mortar shall be in conformance with subsection 601.12 with the following exceptions:

(1) All concrete mortar shall be delivered by means of a low pressure (less than 10 psi) grout pump using a 2 inch diameter nozzle.

(2) Full depth penetration of the concrete mortar into the riprap shall be required. To achieve this, a pencil vibrator shall be used.

(3) The top 6 inches of the rock layer shall be left exposed.

(4) After placement, all exposed rocks shall be cleaned with a wet broom.

(5) All concrete mortar between rocks shall be finished with a broom finish.

(6) Weep holes constructed of 1½ inch or 2 inch PVC pipe shall be installed when required by the Engineer. The PVC pipe shall be cut flush with the surrounding grout. To alleviate plugging, the PVC pipe shall be pushed into the bedding, or if bedding is not required, under the rock layer. The PVC pipe shall be wrapped in a coarse geotextile fabric filled with 1½ inch rock.

(7) All concrete mortar shall be sprayed with a clear liquid membrane curing compound as specified in subsection 601.13(b).

(8) Cold weather curing shall be in accordance with subsection 601.13(d).

507.12 Asphalt Slope and Ditch Paving. The asphalt mixture shall be properly shaped to the required cross section and thoroughly compacted.

A fog seal shall be placed on the exposed surfaces of the paving at the rate of approximately 0.1 gallon per square yard. Material for fog seal shall be Emulsified Asphalt (CSS-1) or as designated.

METHOD OF MEASUREMENT

507.13 Asphalt slope and ditch paving will be measured by the ton and shall include asphalt. Slope and ditch paving of the other various types will be measured by the cubic yard by the method of average end areas based on dimensions shown on the plans or ordered.

When the plans call for concrete lined ditch less than 4 inches thick but the actual thickness placed is greater than the plan thickness, measurement and payment will be made only for the thickness shown on the plans.

BASIS OF PAYMENT

507.14 The accepted quantities will be paid for at the contract unit price for the various items below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
Concrete Slope and Ditch Paving	Cubic Yard
Concrete Slope and Ditch Paving (Reinforced)	Cubic Yard
Dry Rubble Slope and Ditch Paving	Cubic Yard
Grouted Rubble Slope and Ditch Paving	Cubic Yard
Grouted Riprap Slope and Ditch Paving	Cubic Yard
Asphalt Slope and Ditch Paving (Asphalt)	Ton

Structure excavation will be measured and paid for in accordance with Section 206.

Polyolefin fiber reinforcement will not be measured and paid for separately, but shall be included in the work.

Fog seal and asphalt required for asphalt slope and ditch paving will not be measured and paid for separately but shall be included in the work.

Mortar or concrete used for grout in grouted rubble slope and ditch paving will not be measured and paid for separately but shall be included in the work.

Payment for Grouted Riprap Slope and Ditch Paving will be full compensation for all work and materials required to complete the item.

SECTION 508
TIMBER STRUCTURES

DESCRIPTION

508.01 This work consists of the construction of timber structures and timber portions of other structures in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

508.02 Sawn lumber and timber shall conform to AASHTO M 168. Timber shall be Douglas Fir of the coast region or Southern Yellow Pine. "Native" timber may be used when noted on the plans. "Native" timber shall be Red Cedar, Douglas Fir of the inland region, Lodgepole Pine, Ponderosa Pine, Spruce, as listed and described in AASHTO M 168, or any other native wood specifically approved for the intended purpose. All timber shall be of the grade or shall meet the working stresses shown on the plans. Timber used in non-structural applications, whose working stresses are not shown on the plans, shall be graded to produce a working stress of 1000 pounds per square inch on the extreme fibers when subjected to bending and 800 pounds per square inch when subjected to compression parallel to the grain. Material of equal or greater stress values may be used.

All lumber shall be manufactured in accordance with Product Standard 20-70 as published by the Department of Commerce, and shall be grade-marked by a grading agency or have an accompanying certificate from a grading agency. The grading agency shall be certified by the Board of Review of the American Lumber Standards Committee.

508.03 Treated Timber. The preservative to be used shall be as specified on the plans. The preservatives and entire treatment process shall be as described in AASHTO M 133.

508.04 Inspection. All timber furnished shall be covered by a certificate of inspection issued by an approved inspection agency. Inspection approval shall be marked on each piece. The destination of the material and the project to which it is being shipped shall be shown on the certificate. The Department reserves the right to re-examine the timber at its destination and to reject any material not conforming to specification requirements.

Shop drawings shall be submitted in accordance with subsection 105.02 for all major structures and for other structures when specified.

The Department may provide an inspector at the treating plant for material quality review and inspection of the treatment process for treated timber. The plant shall notify the Engineer sufficiently in advance of time of treating so that inspection may be arranged.

508.05 Hardware. Hardware shall include all bolts with necessary nuts and washers, timber connectors, drift pins, dowels, nails, screws, spikes, metal pile protectors, steel anchor plates and all other metal fastenings as shown on the plans. Bolts shall conform to the requirements of Section 509. Bolts over 12 inches long shall be threaded at least 4 inches. Drift bolts, spikes, boat spikes and other spikes shall be wrought iron or steel. Washers shall be standard cast iron ogee or malleable cast washers. Timber connectors and common nails shall be of the type and size specified on the plans. All hardware, except timber connectors and common nails, shall be galvanized in accordance with AASHTO M 232.

CONSTRUCTION REQUIREMENTS

508.06 Timber for the various portions of the structure shall be treated or untreated as stipulated on the plans.

Treated timbers shall not be sized or trimmed in the field, except when ordered. The Contractor shall not make temporary use of treated timber. All pieces that have been field cut shall be treated in accordance with AWPA Standard M4.

Untreated stringer ends shall be separated at least ½ inch and shall be secured to the timber on which they rest.

Sway bracing shall be securely bolted to piling or post and caps as shown on the plans. Treated filling pieces shall be used in lieu of framing or dapping to bring bracing into a plane. Bulkheads, where required, shall be full size timber. Posts for framed bents shall be of the proper length for their position and provide an even bearing on cap and sill. All untreated caps shall be sized over the piles or posts to a uniform thickness and even bearing on piles or posts. Caps shall be within ¼ inch of nominal depth before treatment and may be surfaced on the vertical grain face.

Before the timber capping is placed, a No. 20 gauge galvanized sheet metal cap shall be placed on each pile in accordance with the plans. In lieu of the sheet metal cap, three layers of heavy burlap may be used. Each layer of burlap shall be cut square to a dimension of 12 inches greater than the diameter of the pile head and shall be thoroughly swabbed with hot asphalt. The overhanging ends shall be turned down and secured to the pile with galvanized wire. The entire wrapping shall then be swabbed with a heavy application of hot asphalt.

Longitudinal X-braces shall be properly framed and secured to piles or posts. Truss and bent timbers shall be cut and framed in such manner that they will have even bearing over the entire contact surface of the joint. Blocking or shimming will not be allowed in making joints. Open joints will not be accepted. Stringers shall not be more than ¼ inch off nominal size, before treatment.

Floors shall be constructed as shown on the plans. The plank shall be secured to each stringer with two 7 inch spikes. Half inch cracks between planks shall be left in plain plank floors without surfacing. Laminated floors shall be secured as shown on the plans.

508.07 Holes and Bolts. All holes bored shall be treated in accordance with AWPA M4. Holes drilled for drift bolts shall be $\frac{1}{32}$ inch smaller than the diameter of the bolt. All other holes shall be bored to such size as to ensure a snug fit. Unless otherwise designated, all bolts shall be provided with two ogee washers.

508.08 Painting. All paint shall conform to the requirements of Section 708. Timber to be painted shall be surfaced on four sides and shall be cleaned immediately preceding painting.

New timber to be painted shall receive one coat of primer. "White Wood Primer" shall be used when the surface is to be finished with "Outside White Paint." For "Exterior Black Paint," the specification paint shall be thinned by adding one part linseed oil and one part turpentine to eight parts paint for use as a primer.

The surfaces of all untreated timber to be painted shall be primed with one coat of primer immediately after the material is delivered to the project. Unless otherwise designated, pieces shall be primed as specified for the finish coat of paint, or "White Wood Primer" shall be used when additional painting is not required. Untreated timber will not require additional priming.

All handrails and handrail posts shall be of untreated timber and shall be painted as described hereafter. Contact surfaces shall receive the primer and one coat of paint before placing handrails.

Parts specified herein, parts shown on the plans, and all exposed non-galvanized iron and steel shall, after the prime coat, be given two coats of the specified paint, which shall be thoroughly brushed in. Paint shall be applied only to thoroughly dry surfaces. All previous coats shall have thoroughly dried before subsequent coats are to be applied. Portions to be painted above the wheel guards or top wales shall be painted white and those portions below the wheel-guards or top wales to be painted shall be painted black.

508.09 Structure Number. The location, letters, figures, and paint used for stenciling shall be in accordance with the plan details.

METHOD OF MEASUREMENT

508.10 Timber will be measured by the thousand feet board measure [MFBM] actually incorporated in the structure, and shall include hardware unless otherwise designated on the plans.

BASIS OF PAYMENT

508.11 The accepted quantities will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
Untreated Timber	MFBM
Treated Timber	MFBM

Structure excavation and structure backfill will be measured and paid for in accordance with Section 206.

Timber piling will be measured and paid for in accordance with Section 502.

SECTION 509
STEEL STRUCTURES

DESCRIPTION

509.01. This work consists of furnishing, fabricating, erecting, and painting structural steel in accordance with these specifications and to the dimensions, shapes, and design shown on the plans, and to the lines and grades established. Structural steel shall include galvanizing, bolting, welding, special and alloy steels, electrodes, and steel forgings.

When the term “main stress carrying members” or “main members” is used, it shall include: girder web and flange plates and splice plates; pier and abutment diaphragm web and flange plates and splice plates.

509.02 The latest edition of the AASHTO LRFD Bridge Design Specifications, with current interim specifications, will govern the design of steel bridges, unless otherwise noted on the plans. Welding and fabrication of steel structures shall conform to the Bridge Welding Code ANSI/AASHTO/ AWS D1.5, as amended by the contract documents. When AWS D1.5 is cited in the Standard Specifications, the reference shall be to the latest edition of the Bridge Welding Code.

MATERIALS

509.03 Structural Carbon Steel. Structural carbon steel for bolted or welded construction shall conform to AASHTO M 270 (ASTM A 709) Grade 36. Material supplied for main members in tension as designated in the Contract shall meet a longitudinal Charpy V-notch (CVN) value of 15 foot-pounds at 40 °F. Testing shall be in accordance with AASHTO T 243 (ASTM A 673). The H frequency of heat testing shall be used.

509.04 High-Strength Low-Alloy Structural Steel. High-strength low-alloy structural steel for welding shall conform to the following specifications:

High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, Grade 50	AASHTO M 270 (ASTM A 709)
High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 inches thick	AASHTO M 270 (ASTM A 709)

Steel conforming to AASHTO M 270 (ASTM A 709) Grade 50W shall not be painted unless otherwise shown on the plans.

Material supplied for main members in tension, as designated in the Contract, shall meet the longitudinal Charpy V-notch tests as specified for Zone 2 in AASHTO M 270.

509.05 Self Weathering Tubing. Self weathering structural steel tubing shall conform to ASTM A 847, Cold-Formed Welded and Seamless High Strength, Low Alloy Structural Tubing With Improved Atmospheric Corrosion Resistance.

509.06 Structural Tubing. Steel base metal to be used for tubular structures, including bridge rail, shall conform to the plans or AWS D1.1 section 5.2.1. The grade and specification to be used shall be specified in the Contract.

509.07 Bolts. Bolts not otherwise specified in the Contract shall be zinc plated and meet the requirements of ASTM A 307 for Grade A Bolts. Bolts shall have single self-locking nuts or double nuts unless otherwise specified in the Contract. Beveled washers shall be used when bearing surfaces have a slope exceeding 1:20 with respect to a plane normal to the bolt axis.

509.08 High Strength Bolts. Unless otherwise shown in the Contract, all bolts for fastening of structural steel shall be high strength bolts. High strength bolts, including suitable nuts and plain hardened washers, shall conform to AASHTO M 164. Type 1 bolts shall be used. Bolts for self weathering steels shall be Type 3, unless otherwise shown in the Contract.

Bolt and nut dimensions shall conform to AISC, section 4. Threads for all bolts shall conform to the United Standard Series UNC-ANSI B1.1, Class 2A for external threads and Class 2B for internal threads. The length of the bolts shall be such that the point of the bolt will be flush with or outside of the face of the nut when completely installed. Sufficient thread must be provided to prevent the nut from encountering thread runout.

Washers and beveled washers shall conform to ASTM F436. Washers and beveled washers for AISC American Standard beams and channels or when bearing surfaces have a slope exceeding 1:20 with respect to a plane normal to the bolt axis shall be square or rectangular, shall taper in thickness, and shall conform to the dimensions given in AISC, section 4.

509.09 Pins and Rollers. Steel for pins and rollers shall conform to ASTM A 668, Class C, D, F, or G as specified in the Contract. They shall be accurately manufactured to the dimensions shown in the Contract. Pins larger than 9 inches in diameter shall have a hole at least 2 inches in diameter bored longitudinally through their centers. The hole shall be bored before the pin is subjected to heat treatment. Threads for all pins shall conform to the United Standard Series UNC-ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 1½ inches or more shall have six threads per 1 inch.

509.10 Anchor Bolts. Unless otherwise shown in the Contract, all anchor bolts shall conform to ASTM A 449 and shall be zinc plated.

509.11 Galvanized and Metallized Steel. When shown in the Contract, structural steel shall be galvanized in accordance with AASHTO M 111. Steel surfaces to be metallized shall be coated in accordance with AWS C2.2, Recommended Practice for Metallizing with Aluminum and Zinc for Protection of Iron and Steel. When the Contract specifies galvanizing, metallizing may be substituted.

509.12 Welded Stud Shear Connectors. Studs shall meet the requirements of ASTM A 108, grades 1010 through 1020, killed or semi-killed. In addition, studs shall conform to AWS D1.5, paragraphs 7.2 and 7.3, Type B studs, unless otherwise noted. Furnishing, testing, and qualifying of stud welding procedures shall be at the Contractor's expense. Manufacturer shall furnish the Engineer a certification as required by AWS D1.5 paragraph 7.3.3.

509.13 Mill Test Reports. The fabricator shall furnish the quality assurance inspector with copies of the certified mill test reports on all material that will be used. Mill test reports shall be furnished prior to cutting of the steel or any other fabrication. The fabricator may furnish, with approval of the Engineer, material from stock, provided it can be identified by rolling direction (where orientation is specified), heat number, and mill test reports.

Material which has been used elsewhere shall not be used in any part of this work without written approval or unless specifically provided for in the Contract.

SHOP FABRICATION AND INSPECTION REQUIREMENTS

509.14 Notice of Fabrication.

(a) *Process Control and Quality Assurance.* Process Control (PC) of structural steel fabrication is the responsibility of the Contractor. The PC inspector is the duly designated person who acts for and in behalf of the fabricator on inspection, testing, and quality matters within the scope of the contract documents. PC inspection and testing shall be performed at least to the extent specified in chapter 6 of AWS D1.5, and additionally as necessary to assure conformance with the requirements of the contract documents.

Quality Assurance (QA) is the prerogative of the Engineer. The QA inspector is the duly designated person who acts for and in behalf of the Engineer on all matters within the scope of the contract documents as delegated by the Engineer. QA inspection and testing shall be performed to the extent necessary to verify that an acceptable product is being finished in accordance with the provisions of the contract documents. The QA inspector shall have the authority to verify the qualifications of PC inspectors and nondestructive testing (NDT) personnel to specified levels by written or performance tests or other means as determined necessary.

(b) *Start of Shop Work.* Shop work shall not be started until the Contractor notifies the Engineer in writing where the shop orders were placed. The fabricator shall give prior notice to beginning of shop work, so that inspection may be provided. The proposed production schedule, including the start of production and shipment dates, shall be submitted to the Engineer.

(c) *Notice of Shipment.* The Department's QA inspector shall be notified seven days in advance of shipment of structural steel to the jobsite.

509.15 Plans and Shop Drawings. The Contractor shall furnish shop drawings in conformity with subsection 105.02 for all structural steel bid under this section. Shop drawings shall specifically identify each piece, the direction of rolling for plates where specific orientation is required, the location of all welded splices, and the location, the extent, and the criteria of nondestructive testing. Pieces of steel that require Charpy V-Notch tests shall be identified and listed as to the frequency of test used.

509.16 Shop Facilities for Fabrication. Structural steel fabricators for all bridge structures other than rolled beams shall be certified under the AISC Quality Certification Program, Major Steel Bridges. Portions of work exposed to view shall be neatly finished. Lifting chains shall be provided with adequate softeners to prevent damage to the material while lifting and turning. If hooks are used for lifting, they shall have sufficient width of jaw and throat to prevent overstress and distortion from handling. Spreader beams, or multiple cranes, shall be provided for lifting plates and long members to prevent overstress and distortion. Welds and tack welds shall not be cracked from moving of members. Such occurrence shall require a written distortion control plan and complete inspection until the problem is corrected. The distortion control program and process control reports shall be forwarded to the QA inspector.

All cutting, fitting, welding, and painting shall be done in areas that are kept dry.

509.17 Inspection.

(a) *Process Control Plan.* The fabricator shall submit a written process control plan to the QA inspector prior to the beginning of fabrication. The process control plan shall outline the process control tasks to be performed by the fabricator to ensure that all work conforms to the Contract. The fabricator's personnel intended to be used for inspection and nondestructive testing shall be listed. The process control plan shall be subject to approval by the QA inspector.

(b) *Frequency.* Inspection of all intervals of fabrication welding, including each shift on a daily basis, shall be performed by an AWS certified welding inspector, or an AWS certified assistant welding inspector under the direct supervision of the certified welding inspector. Direct supervision shall be defined as on site monitoring of all inspection activities on each shift on a daily basis.

(c) *Supervision.* Adequate supervision and process control inspection of all welding shall be provided to ensure satisfactory, consistent, and uniform workmanship. Recurring weld defects shall be considered as evidence that proper control and supervision are not being provided. Welding and associated fabrication operations shall be suspended when, in the opinion of the QA inspector, there is a lack of proper process control. Operations shall not resume until the fabricator has made a significant change in procedure. Proposed changes shall be defined and submitted in writing and approved by the QA inspector prior to resuming fabrication.

(d) *Edge Discontinuities.* All plates and shapes shall be inspected at the edges and ends of plates for the presence of laminar discontinuities and inclusions prior to welding or fitting to other pieces. The extent of all areas to be repaired shall be reported to the QA inspector.

(e) *Welding Meters.* Verification of welding meters shall be performed no less than once every ten working days. A calibrated tong ammeter and volt meter, external to the welding machine, shall be used. Records of these calibrations shall be available for review by the QA inspector.

(f) *Reports.* The PC inspector shall submit the following reports to the QA inspector prior to acceptance: all nondestructive test reports, including tests of all repaired areas, the visual test report for all welds, dimensions, camber, and sweep measurements, welder qualification records, welding procedure specifications, procedure qualification records, welding machine settings, material traceability to each main member plate, and paint inspection reports. After each girder has been inspected by process control and has been accepted as conforming to the contract requirements, but prior to painting, the QA inspector shall be notified. The QA inspector shall determine the acceptability of the girder.

All contract deficiencies discovered shall be corrected by the fabricator prior to acceptance. The QA inspector will mark approval of the member with the Department's stamp, when accepted. Material subsequently found defective due to damage incurred in shipping and handling may be rejected even if previously accepted.

Materials rejected by the QA inspector will be subject to re-inspection prior to shipment. Re-inspection will normally be made at the next regular inspection; however, if no regular inspection is scheduled, and re-inspection is deemed necessary by the Engineer to assure compliance with the contract documents, the Contractor will be responsible for the transportation and per diem cost for the re-inspection. A deduction shall be made from the bid item cost for the item requiring re-inspection.

Materials will not be accepted at the project site if they do not bear the inspector's stamp of acceptance. Request for quality assurance inspection shall be given seven calendar days in advance. If it is determined that materials are not acceptance-stamped because they were not offered for shop inspection, or shipped after rejection at the shop, the materials shall be returned to the shop for inspection and correction as necessary. The cost of inspection and corrections made to rejected material at the project site shall be borne by the Contractor.

509.18 Nondestructive Testing.

(a) *Written Practice and Records*. The fabricator's Process Control Plan shall detail the nondestructive testing procedures, including the weld identification and location system. It shall also include the fabricator's Written Practice for the Administration of Personnel Qualification and Certification Program in accordance with The American Society for Nondestructive Testing SNT-TC-

1A. The written practice shall indicate the specific requirements of the fabricator. Qualification records of all nondestructive testing personnel shall be included in the written practice. Each fabricator's written practice shall be subject to the approval of the QA inspector. All nondestructive test results shall be available for review during fabrication and forwarded to the QA inspector prior to acceptance of the assembly.

(b) *Ultrasonic Inspection of Complete Penetration Groove Welds.*

1. *Weld Stress Categories.* The following weldments shall be categorized as follows:

   A. *Attachments.* Longitudinal and transverse stiffeners, gussets, pintles, and all other attachments shall be considered as part of the flange, web, end, or pier diaphragm to which they are welded.

   B. *Pier and End Diaphragms.* Pier and end diaphragms shall be considered as part of the web or flange to which they are welded.

   C. *Splices.* Splices of main members, secondary members, or backing, when approved to be left in place, which attach to a main member, shall be ultrasonically tested and accepted prior to attaching to another member. Ultrasonic acceptance-rejection criteria shall be in accordance with either table 6.3 or table 6.26.3.2, of AWS D1.5 as determined by the category of stress of the main member to which the secondary member is attached. All flanges which connect at a splice, indicating a change from tension to compression, shall be tested in accordance with the tension criteria of table 6.3 of AWS D1.5.

   D. *Sequence.* All flange and web splices shall be welded and tested prior to fitting of the web to the flange.

2. *Extent and Acceptance Criteria of Ultrasonic Testing.* Ultrasonic testing of complete penetration groove welds shall be performed by PC to the extent listed in Table 509-1. The percent inspection indicated for each category is the minimum percent of the total length of each weld that must be tested.

Table 509-1

Element	Tension-Compression[1]	Weld Orientation[2]	Percent Inspection[3]
Flange	Tension	Transverse	100
Flange	Tension	Longitudinal	25
Flange	Compression	Transverse	25
Flange	Compression	Longitudinal	10
Web	Tension[4]	Transverse	100
Web	Tension[4]	Longitudinal	25
Web	Compression	Transverse	25
Web	Compression	Longitudinal	10
Pier & End Diaphragms	Tension[4]	Transverse	100
	Tension[4]	Longitudinal	25
	Compression	Transverse	25
	Compression	Longitudinal	10

Notes:

[1] Tension areas shall be tested in accordance with AWS DI.5 Table 6.3. Compression areas shall be tested in accordance with Table 6.4 of AWS D1.5.

[2] The orientation is referenced with respect to the longitudinal center line of the girder for flanges and webs. The orientation is referenced parallel to the center line of bearing for end and pier diaphragms.

[3] If any rejectable discontinuities are found in any weld tested less than 100%, the remaining length of that weld and all similar welds in that member shall be tested.

[4] The tension area of webs and end or pier diaphragms is defined as ⅙ the depth of the web from the tension flange.

3. *Preparation of Test Material and Testing Procedures.* All groove welds shall be ground flush to a maximum surface roughness (ANSI B46.1) of 125 microinches and a medium range waviness such that no gap greater than 0.020 inch is present beneath a 2 inch long straightedge placed anywhere on the test surface. The test surface shall be ground to bright metal and allow intimate coupling with the search unit. Failure to provide this condition shall result in repair or removal and re-welding of the joint, or alternative nondestructive testing methods, as determined by the QA inspector. The testing procedures established in AWS D1.5, section 6.19 shall be amended as follows:

   A. *Splices.* All materials spliced shall be tested prior to attaching into the assembly.

   B. *Alternate Procedures.* Scanning of welds may be made using other methods, as approved by the Engineer, provided evaluation is made in accordance with chapter 6, part C of AWS D1.5.

   C. *Butt Joints.* All butt joints shall be ground flush and shall include mandatory scanning using pattern "D" (Figure 6.7 of AWS D1.5) longitudinal to their axis.

D. *Scanning Procedure.* Table 6.2 of AWS D1.5 shall be amended as follows:

(1) Testing from both sides of the weld axis shall be made in both Leg I and Leg II.

(2) Face A on both connecting members of flanges at a butt weld must lie in a single plane. Scanning of butt welds in which Face A and Face B individually lie within the same plane shall be performed in Leg I and Leg II from each side of the weld axis (Form VII-9, AWS D1.5). Should neither Face A nor Face B lie in a single plane, the testing procedure shall be as follows: Face A from the thinner material shall be tested both in Leg I and Leg II. The thicker material shall be tested from Leg I from both Face A and Face B. Leg II from Face A shall be evaluated when it originates from the thinner material. Transducers with frequencies greater than 2.25 MHZ may be used to facilitate locating the discontinuities, but evaluation for acceptance shall be made in accordance with chapter 6, part C of AWS D1.5.

(3) T joints shall be evaluated from both Face A and Face B in Legs I, II, and III. In addition, scanning pattern E shall be performed. All indications which are up to and including 6 dB less critical than reject shall be recorded on the test report and reported to the Engineer for acceptance evaluation.

(4) Tables 6.3 and 6.4 of AWS D1.5 shall include the following: Flaws evaluated with 60 or 45 degree search units and rejected, but which have indication levels at or above the minimum level listed for a 70 degree search unit, shall be evaluated with 70, 60, and 45 degree search units. If this testing reveals that the sound beam of the 60 or 45 degree search unit is striking the flaw at 90 plus or minus 15 degrees, the acceptance level listed for a 70 degree search unit shall be used as the basis for acceptance, regardless of the angle of search unit used to evaluate the flaw.

(5) Evaluation using reject may be used to evaluate flaws, only if calibration in accordance with AWS D1.5, 6.17.1 and the vertical linearity is within plus or minus 1 dB for a 60 dB range. Both AWS D1.5 forms VII-8 and VII-9 shall be recorded and submitted to the QA inspector prior to approval, whether or not reject is used.

E. *Index Marking.* Two low stress die stamp marks shall be located on Face A, 12 inches from the centerline of the joint on one side of the joint, and 3 inches from each edge of the plate.

4. *Through Thickness Tension Plate.* Ultrasonic testing of plates as identified in the plans as exhibiting tension in the through thickness direction shall be performed in accordance with ASTM A 578. Plates

greater than ¾ inch thick shall be tested using 2.25 MHZ 1 inch diameter transducers. Plates less than and including ¾ inch thick shall be tested with a 5 MHZ ½ inch diameter transducer. Supplementary requirement S2 shall be used as the acceptance standard.

(c) *Dye Penetrant Testing.* Dye penetrant testing in accordance with ASTM E 165 may be substituted for magnetic particle testing with approval of the Engineer.

(d) *Magnetic Particle Testing.* Magnetic particle testing shall be performed on areas defined in AWS D1.5 and this subsection. Magnetic particle testing shall be conducted in accordance with ASTM E 709 and AWS D1.5, except as amended herein. Alternating current shall be used. The yoke spacing shall be between 2 and 4 inches. The minimum lifting power shall be 10 pounds. Red dry particles shall be used. The light intensity shall meet ASTM E 709, Section 7.

The yokes shall be set in two positions when testing the weld or base metal. They shall be positioned both normal and parallel with respect to the weld axis and rolling direction of the base metal.

Magnetic particle tests shall be performed at the following locations:

1. *Base metal.* All areas contacted by the carbon arc gouge electrode, the electrode cup, and the welding electrode. All three conditions are arc strikes.

2. *Fillet Welds.* Each design weld size on main member to main member and secondary member to main member weldments. All stop-starts and weld termini. All linear indications shall further be evaluated with 10x or 30x magnification. Verification shall be resolved by excavation.

3. *Groove welds.* All through thickness edges on transverse butt joint weldments in tension areas.

4. *Repairs.* All repair welds to correct: defects in groove and fillet welds, plate cut edges, correction of fabrication errors in cutting, punching, drilling, or fitting, and members which are tacked or welded and subsequently cut apart and re-welded.

(e) *Radiographic Testing.* When radiographic testing is specified, it shall be performed in accordance with chapter 6, part B of AWS D1.5, except that *edge blocks shall be used. Radiographs shall be identified as follows:*

1. *Contract Number.*

2. *Weld Identification Number.* The fabrication number of the girder in which the radiographed weld occurs, followed by a dash (-).

3. *Letter Designation.* Letter combination designating the section as follows: TF (top flange); BF (bottom flange); W (web); and when applicable, N (near side) and F (far side).

4. *Joint Designation.* A letter preceded by a space followed by a number. The number shall designate the joint in which the radiograph occurs and shall correspond to the number of welded joints between the reference end of the section and the radiographed weld.

5. *Defect Description.* All defects shall be outlined on the radiograph clearly showing the rejected areas. The report shall indicate the type of discontinuity and its location from a reference point on the film.

(f) *Hardness Testing*. Hardness testing shall be conducted as required by AWS D1.5. Oxygas cutting procedures used on tension flanges shall be qualified prior to fabrication. The procedure shall be qualified on all of the following parameters: the grade and type of steel, thickest material cut, highest carbon equivalency, and lowest base metal temperature at the time of cutting. Tests shall be witnessed by the Inspector.

The test equipment and procedures shall be in accordance with ASTM E 18. Each test area shall be contained within 6 square inches.

The mean value of five readings, within a test area, shall not exceed 30 HRC. Excessive values shall require establishing higher material temperatures at the time of cutting. The base metal temperature shall be measured on the surface opposite the cutting source: 3 inches from the point on the surface nearest to the heat source.

Production Process Control tests shall be performed by the Contractor. The number of tests shall be the next highest whole number calculated as follows:

Total number of tension flanges on the bridge divided by 10

Production Process Control tests shall include the first production cut of the thickest fabricated flange. A minimum of 50 percent of production Process Control tests shall be performed on the thickest flanges fabricated**.**

All test results shall document the base metal thickness and temperature measured at the time of cutting. Test reports shall be forwarded to the QA Inspector. Test values greater than Rockwell C 30 shall be reported to the QA Inspector immediately.

509.19 General Fabrication Requirements.

(a) *Identification of Steels During Fabrication*. Materials received from the mill shall be stored so that heat numbers are visible. Plates shall be step stacked with the heat number of each plate marked at the end, along with the contract number and size of the plate as received from the mill. Shapes, bars, and other materials that are furnished in tagged lifts or bundles, shall be received and stored with identification as required by AASHTO M 160. Pieces of steel which, prior to assembling into members, will be subject to painting, galvanizing, or any other operations that will obliterate the heat numbers shall be marked with the heat number and plate number (CVN plate frequency, if applicable) with low stress die stamp (spherical indent).

Any excess material placed into stock for future use shall be marked with the heat number, rolling direction, and plate number if applicable, and grade of steel. Secondary members shall be identified at a frequency of once for every 20 pieces (or less) per heat.

The fabricator shall furnish to the QA inspector cutting lists indicating the rolling direction, heat numbers (plate number for P frequency when applicable), and fabrication piece number marked in a timely manner during fabrication.

The Contractor shall furnish, if requested by the Engineer, an affidavit certifying that throughout the fabrication the identification of steel has been maintained in accordance with this specification.

(b) *Location of Splices.* Groove welded splices shall be located a minimum of 5 feet from the centerline of field splices and 1 foot minimum from centerline of the nearest bolt hole.

(c) *Location of Stiffeners and Connections.* Intermediate stiffeners or connection plates shall be placed at least 6 inches from a groove welded splice in the web or flange. Welder identification marks shall be made using low stress die stamps (spherical indent) near the weld, but not closer than 1 inch from the heat affected zone.

(d) *Rolling Direction and Cutting.* Unless otherwise shown on the plans, steel plates for girder flanges, webs, and splice plates shall be cut and fabricated so that the primary direction of rolling is parallel to the longitudinal centerline of the girder. Abutment and pier diaphragm plates (includes flanges, webs, and splice plates) shall be cut and fabricated so that the primary direction of rolling is parallel to the centerline of bearing. Sheared edges of plates more than ⅝ inch thick and carrying calculated stress shall be milled or sawn to a depth of ¼ inch. Reentrant corners shall be pre-cut to a minimum radius of 1 inch before cutting. The procedure for cutting plate edges of tension flanges shall be qualified in accordance with subsection 509.18(f).

(e) *End Treatment of Webs and Flanges.* The ends of webs and flanges shall be flush and within the same plane so as to leave no reentrant corners.

(f) *Minimum Base Metal Temperature.* The minimum base metal temperature qualified to cut flanges and webs in tension, shall be established by hardness testing in accordance with subsection 509.18(f).

(g) *Straightening Material.* Rolled material, before being worked, must be straight. If straightening is necessary, it shall be done by methods that will not injure the metal and is subject to the Engineer's approval.

(h) *Bent Plates.* Un-welded cold-bent steel plates shall conform to the following:

1. *Rolling Direction.* The bend line shall be at right angles to the direction of rolling.

2. *Minimum Radii.* Bending shall be such that no cracking of the plate occurs. Minimum bend radii, measured to the concave face of the metal, shall be as shown in Table 509-2.

3. *Bending Temperature.* If a shorter radius is essential the plates shall be bent hot at a temperature not greater than 1200 °F. Hot-bent plates shall conform to subsection 509.19(i).

4. *Corner Radii.* The corners of the plate shall be rounded to a radius of $\frac{1}{16}$ inch before bending throughout the portion of the plate at which the bending is to occur.

Table 509-2

Thickness (t) in inches	Up to ½	Over ½ to 1	Over 1 to 1½	Over 1½ to 2½
Minimum Bend Radius	2t	2 ½t	3t	3 ½t

(i) *Curving and Cambering of Rolled Beams and Welded Girders.* Heat curving of beams and girders will be allowed when the horizontal radius of curvature measured to the centerline of the member web is greater than both values calculated by the following two equations, and greater than 150 feet at any and all cross sections throughout the length of the member.

$$R = \frac{14bD}{\sqrt{F_y}\,\Psi\, t}, \quad R = \frac{7500b}{F_y\,\Psi} \quad \text{where}$$

F_y	=	specified minimum yield point in ksi of the member web.
Ψ	=	ratio of the total cross section area to the cross sectional area of both flanges.
b	=	width of the widest flange in inches.
D	=	clear distance between flanges in inches.
t	=	web thickness in inches.
R	=	radius in inches.

In addition to the above, when the required radius of curvature is less than 1000 feet, and the flange thickness exceeds three inches, or the flange width exceeds 30 inches, heat curving will not be allowed. Heat curving requirements shall be as follows:

1. *Materials.* Steels that are manufactured to a yield point greater than 50,000 psi shall not be heat curved.

2. *Type of Heating.* Beams and girders may be curved by either continuous or V-type heating as approved by the Engineer. For the continuous method, a strip along the edge of the top and bottom flange shall be heated simultaneously; the strip 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 wedge-shaped areas having their base along the flange edge and spaced at regular intervals along each flange; the spacing and temperature shall be as required to obtain the required curvature, and heating shall progress along the top and bottom flange at approximately the same rate.

For the V-type heating, the apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached. To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so the heat is not applied directly to the web. Asbestos sheet material ¼ inch thick shall be placed against the web before applying heat to the inside flange surface. When the radius of curvature is 1000 feet or more, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend to the juncture of the flange and web. When the radius of curvature is less than 1000 feet, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to ⅛ of the flange or 3 inches, whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees, but the base of the triangle shall not exceed 10 inches. Variations in the patterns prescribed above may be made upon approval by the QA inspector.

For both types of heating, the flange edges 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 only mandatory when the flange thickness is 1¼ inches or greater, in which case, the two surfaces shall be heated concurrently. The minimum temperature shall be as prescribed below.

Preload compressive stresses will be permitted up to a maximum of 60 percent of the specified yield strength of the steel to reduce the number of heat patterns required to produce the desired curvature. Loading that causes the member to distort permanently (yield without the application of heat) will result in rejection of the member. All nondestructive testing to evaluate damage and corrective work ordered by the Engineer to compensate for overstressing shall be performed at the Contractor's expense.

3. *Temperature.* The heat curving operation shall be conducted in such manner that the temperature of the steel does not exceed 1150 °F as measured by temperature indicating crayons or other suitable means. The inspector shall take heat measurements after the heating flame has been removed from the steel. The girder shall not be artificially cooled until after naturally cooling to 600 °F; the method of artificial cooling is subject to approval. Heat curving shall be directly supervised by the PC inspector.

4. *Position for Heating.* The girder may be heat curved with the web in either a vertical or a horizontal position. When curved in the vertical position, the girder must be braced or supported in such a manner that the

tendency of the girder to deflect laterally during the heat curving process will not cause the girder to overturn.

When curved in the horizontal position, the girder must be supported near its ends and at intermediate points, if required, to obtain a uniform curvature; the bending stress in the flanges due to the dead weight of the girder must not exceed the usual allowable design stress. When the girder is positioned horizontally for heating, intermediate safety catch blocks must be maintained at the midlength of the girder within 2 inches of the flanges at all times during the heating process to guard against a sudden sag due to plastic flange buckling.

Horizontal curvature shall be checked with the girder in the vertical position by measuring off-sets from a string line or wire attached to both flanges or by using other suitable means.

5. *Sequence of Operation.* Members shall be heat curved prior to the completion of the following:

   A. Attachment of end bearing stiffeners.

   B. Attachment of lateral gusset plates.

   C. Attachment of longitudinal stiffeners.

   D. Welding of intermediate stiffeners and connection plates to the flanges. When longitudinal stiffeners are required, they shall be heat curved, or oxygen-cut to the required radius prior to being welded to the curved girder. The girder shall be heat curved in the fabrication shop before it is painted. When cover plates are to be attached to rolled beams, they may be attached before heat curving if the total thickness of one flange and cover plate is less than 2½ inches and the radius of curvature is greater than 1000 feet. For other rolled beams with cover plates, the beams must be heat curved before the cover plates are attached; cover plates must be either heat curved or oxygen-cut separately and then welded to the curved beam.

6. *Camber.* Cambering of welded plate girders, except for minor adjustments required after welding, shall be achieved by curved cutting of web plates prior to welding to flanges. Girders shall be cambered prior to heat curving. Heat cambering procedures shall be in accordance with subsection 509.19(i) and shall be approved by the Engineer prior to beginning of work. Vertical camber shall not be measured for final acceptance before all welding and heating operations are completed and the flanges have cooled to a uniform temperature. Triangular heating patterns shall be spaced throughout the length of the member.

   The apex of the triangle shall be located in the web at a point not less than 75 percent of the depth of the member from the flange that will be concave after cambering. Heat shall begin at the apex and progress slowly toward the base. The included angle shall not exceed 20 degrees. The maximum width at the base shall not exceed 10 inches.

(j) *Facing of Bearing Surfaces.* The surface finish of bearing and base plates and other bearing surfaces that are to come in contact with each other or with concrete shall meet the following ANSI B46.1 surface roughness requirements in microinches:

Steel Slabs	ANSI 2000
Heavy plates in contact in shoes to be welded	ANSI 1000
Milled ends of compression members, milled or ground ends of stiffeners and fillers	ANSI 500
Bridge rollers and rockers	ANSI 250
Pins and pin holes	ANSI 125
Sliding bearings	ANSI 125

The maximum deviation from flatness of the contact area of every steel bearing surface shall not exceed $\frac{1}{32}$ inch. Deviation shall be measured by placing measured offset blocks of equal dimension outside the bearing contact area and placing a straightedge across the blocks. Measurements from the flange surface to the bottom of the straight edge shall not deviate by more than $\frac{1}{32}$ inch from the offset block dimension. Flatness shall be checked in both the longitudinal and transverse directions at 4 inch intervals within the area of bearing contact.

(k) *Holes for Fasteners.* All holes for bolts in main members, or secondary members that weld to main members, shall be either sub-punched and reamed, subdrilled and reamed, or drilled from the solid. Holes shall be sub-punched or subdrilled $\frac{1}{16}$ inch smaller than the nominal diameter of the fastener and reamed to $\frac{1}{16}$ inch larger than the nominal diameter of the fastener, or drilled to $\frac{1}{16}$ inch larger than the nominal diameter of the fastener. Subsized holes prior to reaming shall not be offset more than $\frac{1}{16}$ inch. Reaming or drilling full sized holes shall be done using a template with hardened bushings or with a numeric control (N/C) machine such that no offset equal to $\frac{1}{32}$ inch occurs in more than 15 percent of the connection. Enlarged or slotted holes for high strength bolts may be used only when shown on the plans or authorized. Holes shall be clean cut, without torn or ragged edges. All burrs shall be removed, as well as oil and other foreign matter. Holes shall be cylindrical within $\frac{1}{32}$ inch and perpendicular to the member. Connection parts requiring reaming or drilling shall be assembled and securely held and shall be match marked before disassembling. Poor matching of holes will be cause for rejection.

(l) *Boring Pin Holes.* Pin holes shall be bored true to the specified diameter, smooth and straight, at right angles with the axis of the member and parallel with each other unless otherwise required. The final surface shall be produced by a finishing cut. The distance outside to outside of holes in tension members, and inside to inside of holes in compression members shall not vary more than $\frac{1}{32}$ inch from that specified. Boring of holes in built-up members shall be done after fabrication of the member is completed. The diameter of the pin hole shall not exceed that of the pin by

more than $\frac{1}{50}$ inch for pins 5 inches or less in diameter, or $\frac{1}{32}$ inch for larger pins. Two pilot nuts and two driving nuts for each size pin shall be furnished unless otherwise specified.

509.20 Welding.

(a) *Process.* Welding of steel structures shall conform to AWS D1.5 as amended herein. All web and flange butt joints and web to flange welds shall be made using the submerged arc welding process (SAW). Alloy "active" fluxes shall not be used in groove welds or fillet welds with more than three passes. Repairs may be made using submerged arc welding or shielded metal arc welding (SMAW). Flux core arc welding (FCAW) will be permitted on secondary to main member attachments when performed in the flat or horizontal positions. Vertical or overhead FCAW welding shall be limited to only that work approved by the QA inspector.

The ratio of the width of the face to the depth of penetration of each Submerged Arc Welding fillet pass shall be a minimum of 1.1:1. This shall be verified by macroetch testing and included in the *Procedure Qualification Record (PQR)*. The test heat input and voltage qualified shall establish the maximum values used in fabrication welding. These values shall be indicated in the Welding Procedure Specification.

The macroetch shall be performed in accordance with Figure 5.8 of AWS D1.5, with the following exception: The T-joint shall contain an acute angle less than or equal to the smallest acute angle to be used in fabrication. The acute angle tested qualifies all angles equal to or greater than this angle. Both sides of the T-joint shall be welded.

(b) *Base Metal Preparation.* The preparation of base metal shall be in accordance with AWS D1.5, with the following exception: All mill scale and rust shall be removed from the surfaces of main members on which all welds are made by any process. Surfaces and edges to be welded shall not exceed an ANSI B46.1 roughness value of 500 microinches.

(c) *Run On-off Plates.* Run-on and run-off plates shall be used on all butt joints. They shall be of the same base metal as the material being welded. Removal of these plates shall be accomplished by cutting the plates off and grinding to a surface finish in accordance with AWS D 1.5.

(d) *Undercut.* Undercut in the stiffener, web or flange shall not exceed 0.01 inch in areas of tension as indicated on the plans when the axis of the undercut is normal to the longitudinal centerline of the girder, or normal to the centerline of bearings in the case of plate diaphragms. Undercut in compression areas shall not exceed $\frac{1}{32}$ inch.

(e) *Temporary Tack Welds.* Temporary tack welds will not be permitted on splice plates to facilitate stack drilling. All temporary tack welds not incorporated into the final weld, shall be submitted to the Engineer for approval. Temporary tack welds that are approved shall be removed by grinding such that the plate

thickness is not reduced by more than five percent, and tested in accordance with subsection 509.18(c).

(f) *Gusset Plates.* Lateral gusset plates welded to girder flanges in tension shall be pre-heated to 250 °F.

(g) *Repairs.* All welding required to repair cracks, oxygen cut gouges, porosity, and undercut, shall conform to the following:

1. *General.* Repairs made to correct undercut, craters, undersized welds, porosity, excessive roughness on oxygen cut gouges, and cracks shall not be performed without the knowledge of the PC inspector. Undercut may be prepared by contour grinding when approved by the Engineer. Areas repaired shall be recorded in accordance with AWS D 1.5, paragraph 6.5.8. Surfaces that are air carbon arc gouged shall be ground to bright metal prior to welding. Repair areas shall be preheated to a temperature of 200 to 300 °F prior to welding. Cracks removed prior to welding shall be penetrant tested or magnetic particle tested to assure their complete removal before welding. All repairs shall be penetrant or magnetic particle tested for soundness. This requirement applies equally to tack welds.

2. *Groove Welds.* The number of repairs shall be limited to three or fewer heat cycles in any groove weld.

3. *Cut Edges.* Cavities resulting from the removal of cut edge discontinuities in plates shall be prepared prior to welding using a minimum ¼ inch radius and a minimum 40 degree angle. The base metal shall be ground to bright metal prior to welding.

4. *Mislocated Holes.* Misfit holes shall not be repaired, unless approved by the Engineer. When holes are repaired in accordance with an approved welding procedure, the soundness shall be established by ultrasonic testing. In addition, the hardness of the heat affected zone of the repair area shall be less than or equal to Rockwell C 30, when tested in accordance with ASTM E 110. Post weld heat shall be 400 °F per inch of thickness.

(h) *Stud Welding.* Stud welding shall conform to AWS D1.5 section 7, as amended herein.

Studs shall not be welded to top flanges until after the formwork for the deck is in place in accordance with Occupational Safety and Health Administration (OSHA) regulations 29 CFR 1926 Subpart R.

1. *Camber.* Adequate provisions shall be made in fabrication of structural members to compensate for loss of camber due to welding of the shear connectors.

2. *Production 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 weld procedure shall be corrected and two successive studs successfully

welded and tested before any more studs are welded to the beam or girder. The QA inspector shall be promptly informed of all changes in the welding procedure at any time during fabrication.

(i) *Weld Termini Treatment.* All gussets, stiffeners, diaphragms, or other attachments at a corner of intersecting plates joined by a fillet or groove weld, shall be clipped 1½ inch minimum. Intersecting fillet welds will not be allowed. Treatment of all end weld termini on transverse secondary attachments to main members shall be such that the welds terminate ¼ inch short of the end of the attachment.

(j) *Gas Certification.* The Contractor shall furnish certification that the gas or gas mixture is suitable for the intended application in accordance with AWS D1.5 and the manufacturer's recommendations.

(k) *Miscellaneous Attachments.* Attachments shall not be welded to main members, unless approved.

509.21 Shop Assembly.

(a) The field connections of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be assembled in the shop with milled ends of compression members in full bearing and the subsize holes reamed to the specified size while the connections are assembled. Assembly may be full truss or girder assembly, progressive truss or girder assembly, full chord assembly, progressive chord assembly, or special complete structure assembly at the fabricator's option unless assembly methods are specified on the plans.

(b) *Full Truss or Girder Assembly.* Full truss or girder assembly shall consist of assembling all members of each truss, arch rib, bent, tower face, continuous beam line, plate girder, or rigid frame at one time.

(c) *Progressive Truss or Girder Assembly.* Progressive truss or girder assembly shall consist of assembling initially for each truss, arch rib, bent, tower face, continuous beam line, plate girder, or rigid frame at least three contiguous shop sections or all members in at least three contiguous panels, but not less than the number of panels associated with three contiguous chord lengths (i.e. length between field splices) and not less than 150 feet in the case of structures longer than 150 feet. At least one shop section or panel or as many panels as are associated with a chord length shall be added at the advancing end of the assembly before any member is removed from the rearward end, so that the assembled portion of the structure is never less than specified above.

(d) *Full Chord Assembly.* Full chord assembly shall consist of assembling, with geometric angles at the joints, the full length of each chord of each truss or open spandrel arch, or each leg of each bent or tower, then reaming the field connection holes while the members are assembled, and reaming the web member connections to steel templates set at geometric (not cambered) angular relation to chord lines. Field connection holes in web members shall

be reamed to steel templates. At least one end of each web member shall be milled or scribed normal to the longitudinal axis of the member and the templates at both ends of the member shall be accurately located from one of the milled ends or scribed lines.

(e) *Progressive Chord Assembly.* Progressive chord assembly shall consist of assembling contiguous chord members in the manner specified for full chord assembly and in the number and length specified for progressive truss or girder assembly.

(f) *Special Complete Structure Assembly.* Special complete structure assembly shall consist of assembling the entire structure, including the floor system. Each assembly, including camber, alignment, accuracy of holes, and fit of milled joints shall be in accordance with dimensional requirements prior to reaming or full size drilling of holes.

(g) *Fit.* Surfaces of metal in contact shall be cleaned before assembling. The parts of members to be assembled shall be well pinned and firmly drawn together with bolts before reaming operations.

(h) *Match Marking.* Connecting parts assembled in the shop for field connections shall be match-marked, and a diagram showing such marks shall be furnished to the Engineer.

(i) *Drifting of Holes.* The drifting done during assembling shall be only that necessary to bring the parts into position, and not sufficient to enlarge the holes or distort the metal. If holes must be enlarged to admit bolts, they shall be reamed.

(j) *Abutting Joints.* Abutting joints in compression members and girder flanges, and in tension members when so specified on the plans, shall be faced and brought to uniform bearing. Where joints are not faced, the opening shall not exceed ¼ inch.

(k) *Camber Tolerance.* Deviation from the design camber between any two supports (points of fixed elevations) shall be limited to:

+L/1200 -L/2880

Where: L = length in feet between supports

This requirement is in addition to the camber requirements of AWS D1.5 subsection 3.5.

509.22 Shop Connections Using High-Strength Bolts. Unless otherwise specified all shop connections shall be made with high-strength bolts. All shop connections shall be made in accordance with subsection 509.28.

509.23 Galvanizing. Bolts, washers, and nuts used in the assembly and erection of galvanized railing and posts or where specified, shall be galvanized in accordance with AASHTO M 232 Class C or shall be zinc coated in accordance with AASHTO M 298.

Structural steel shall be galvanized in accordance with AASHTO M 111. Uncleaned slag lines, bare spots, blisters, flux spots or inclusions, dross, acid, or black spots that exceed 1 square inch or occur on more than 5 percent of the pieces in the lot shall be cause for rejection of the lot. The materials may be stripped, regalvanized, and again submitted for test and inspection; otherwise the entire lot shall be rejected. Pieces less than 5 percent of the lot may, with the approval of the Engineer, be zinc coated by an approved zinc rod, in accordance with ASTM A 780, if applied to correct areas less than 1 square inch.

509.24 Shop Cleaning And Painting of Steel. Graffiti shall be removed prior to painting, or in the case of ASTM A 709 Grade 50W steel, prior to shipping.

(a) *Cleaning of Unpainted ASTM A 709 Grade 50W Steel.* The exterior surfaces of unpainted ASTM A 709 Grade 50W steel shall be blasted to remove mill scale and foreign material which would prohibit rusting to a uniform color.

(b) *Cleaning of Surfaces to be Painted.* Structural steel cleaning shall meet the requirements of the Steel Structures Painting Council Surface Preparation Specification No. 6 (SSPC-SP 6, Commercial Blast Cleaning). Painting shall be accomplished before new rust forms.

(c) *Paint Systems.* All structural steel shall be painted using a two coat system with inorganic zinc-rich primer (shop coat) and high-build urethane top coat as described in subsection 708.03. The shop coat shall have a dry film thickness of 3.0 mils. The top coat shall have a thickness of 3.0 mils.

(d) *Sequence.* Unless otherwise specified, steel work shall be given the shop coat of approved paint after it has been accepted by the QA inspector and before it is shipped from the plant. Shipping pieces shall not be loaded for shipment until they are thoroughly dry. Painting shall not be done after loading material on cars except for retouching areas damaged by loading or handling operations.

(e) *Procedure.* Application of paint shall be in accordance with the manufacturer's recommendations.

(f) *Surfaces in Contact with Concrete.* The areas that will come in contact with concrete shall not be painted.

(g) *Field Weld Areas.* Areas of structural steel to be field welded shall not be .painted before welding is completed.

(h) *Erection Marks.* Erection marks for field identification of members shall be readily visible on shop painted surfaces.

(i) *Faying Surfaces of Connections.* When splices are specified on the plans to be Class B slip critical, the contact surfaces of unpainted ASTM A 709 Grade 50W steel shall be blast cleaned to a SSPC-SP6 commercial blast. When the inorganic zinc-rich primer is provided, the manufacturer shall qualify the paint by test in accordance with “Test Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints” as adopted by the Research Council on Structural Connections. The manufacturer shall certify in writing that the slip coefficient is no less than 0.48.

509.25 Marking. Each member shall be painted or marked with an erection mark for identification, and an erection diagram shall be furnished to the Contractor and Engineer with erection marks shown.

FIELD CONSTRUCTION REQUIREMENTS

509.26 Field Welding and Inspection. Field welding will not be permitted unless shown on the plans or approved by the Engineer, except to attach studs. All field welding and inspection shall be performed in accordance with this specification and AWS D1.5. Studs shall be free from rust, rust pits, scale, oil, moisture, paint, and other deleterious matter that would adversely affect the welding operation. Surfaces to which studs are to be welded shall be free of scale, rust, moisture, paint, and other injurious material that would prevent proper welding or produce objectionable fumes. Additional studs shall be tested in accordance with AWS D1.5 paragraph 7.5.4.1 when the base metal temperature is below 32 °F at the time of welding. Stud welding shall not be done when the base metal temperature is below -4 °F at the time of welding.

(a) *Stud welding in the field.* Automatic stud welding guns shall be used to weld studs to girders. The operator shall be qualified per AWS D1.5 Subsection 7.7.4. The base metal where the stud is to be welded shall be ground to bright metal immediately prior to the weld being made. Manual welding will not be allowed except to make repairs. Stud welding shall be in accordance with subsection 509.20 (h).

(b) *Repairing Stud Welds.* Electrodes used to repair stud welds shall be kept in rod ovens in accordance with AWS D1.5 Subsection 12.6. The fillet weld size shall be a minimum of $^{5}/_{16}$ inch. The welder shall be prequalified for the welding process used and stud welding.

509.27 Erection of Steel Structures.

Structural steel members shall be erected to prevent damage to all elements of the structure and in a safe manner. Structural steel members to which the erection specification applies are those members that bear on the substructure of a bridge. The primary members such as beams and girders shall be temporarily anchored and braced as they are erected to preclude detrimental movement in any direction, and to prevent overturning and buckling. Struts, bracing, tie cables, and other devices used for temporary restraint shall be considered falsework and shall be designed to resist all loads imposed during each stage of construction until the deck concrete has attained the Field Compressive Strength shown in Table 601-1.

At least two steel girders shall be erected when girders are initially placed in any span, unless the Engineer provides a written waiver to this requirement. Diaphragms and cross frames between girders shall be connected to the girders and all diaphragm or cross frame connection bolt holes filled with bolts that are at least snug tight during erection. The Contractor's Engineer shall specify bolt torque requirements, if any, prior to releasing girders from the crane. Steel box girders need not be erected in pairs.

At least one week prior to the Pre-Erection Conference, the Contractor shall approve, sign and submit an Erection Plan to the Engineer for record purposes only. The Erection Plan shall be stamped "Approved for Construction" and signed by the Contractor. The Erection Plan will not be approved by the Engineer. If falsework drawings are required, they shall conform to and be submitted in accordance with subsection 601.11.

The Erection Plan and procedure shall provide complete details of the erection process with dimension tolerances including:

(1) Temporary falsework support, struts, bracing, tie cables and other devices, material properties and specifications for temporary works, bolt torque requirements prior to releasing girders from the cranes (if required), connection details and attachments to other structure components or objects.

(2) Procedure and sequence of operations, including a detailed schedule with completion times for work items that complies with the working hour limitations.

(3) Minimum load chart lift capacity, outrigger size, and reactions for each crane.

(4) Assumed loads and girder weights, lift points, lifting devices, spreaders, and angle of lifting cables.

(5) Girder stresses at critical points along the girder length during progressive stages of erection shall be investigated to assure that the structural integrity and stability of the girders is maintained. Stresses at lift points induced as a result of lifting shall be investigated and adequate bracing provided as indicated by the analysis.

(6) Locations of cranes, trucks delivering girders, and the location of cranes and outriggers relative to other structures, including retaining walls, wing walls and utilities.

(7) Drawings, notes, catalog data showing the manufacturer's recommendations or performance tests, and calculations clearly showing the above listed details, assumptions, and dimensions.

(8) Contingency plans detailing what measures the Contractor will take in case of inclement weather (forecast or actual), equipment failure, delivery interruption, and slower than planned production.

A Pre-Erection Conference will be held at least one week prior to the beginning of erection. The Engineer, Contractor, erection subcontractor, and the Contractor's Engineer shall attend the meeting. The erection subcontractor shall demonstrate his knowledge and familiarity of where the piece marks are located on the components to be erected, their orientation in the erected structure, and the shop drawing piece mark convention used by the girder fabricator at the Pre-Erection Conference. The girder fabricator shall participate in the conference, by way of speaker telephone, during only that portion in which the piece marks are discussed. The girder fabricator shall state whether the erection subcontractor has demonstrated a correct understanding of the piece marks, and if not, correct any misunderstanding.

Additional Pre-erection Conferences may be required for subsequent phases of construction, or for phases that differ from the original construction plan, as directed by the Engineer. Additional conferences may also be requested by the Contractor, and approved by the Engineer.

The Contractor shall submit a final Erection Plan to the Engineer prior to girder erection for record purposes only. The Contractor's Engineer shall sign and seal (1), (5), and (7) listed above in the final Erection Plan. The final Erection Plan shall be stamped "Approved for Construction" and signed by the Contractor.

When a bridge spans traffic of any kind, except for construction traffic and the Contractor's employees, the Contractor's Engineer shall inspect and provide written approval of the erected girders prior to opening the area beneath the girders to traffic. For this specification, traffic is defined as the vehicles, railroad, pedestrians, and watercraft moving along a route. The Contractor shall perform daily inspections of the erected girders and other permanent and temporary bridge elements until the deck concrete has attained the Field Compressive Strength. The Contractor's Engineer shall provide an inspection form to the Engineer and the Contractor that lists the items the Contractor will document during the daily inspection of the erected girders. The inspection form shall include inspection items specific to each bridge being constructed. The Contractor shall provide the Engineer and the Contractor's Engineer with written documentation of these inspections within 24 hours of each inspection.

All temporary struts, bracing, tie cables, other devices and extra material required shall be removed upon completion of the structure.

(a) *Equipment.* The Contractor shall provide the falsework and all tools, machinery, and supplies, including drift pins and fitting up bolts, necessary to complete the work.

(b) *Field Inspection.* Material and work not previously inspected will be inspected after delivery to the job site. The quality of all field welds, including inspection and testing, shall meet the requirements of this section.

(c) *Storage.* Girders and beams shall be placed upright and shored. Long members such as columns and chords shall be supported on skids placed in such positions as to prevent damage by deflection.

(d) *Falsework.* Falsework shall conform to subsection 601.11.

(e) *Bearings.* Bearings and bearing seats shall conform to Section 512.

(f) *Anchorage.* Anchor bolts in piers, abutments, or pedestals shall be accurately set either in the concrete as it is being placed, or in holes formed while the concrete is being placed, or in holes drilled after the concrete has set. Bolts placed in formed or drilled holes shall be grouted in place with a nonshrink or epoxy grout which shall completely fill the holes. Location of anchors and setting of rockers shall take into account any variation from mean temperature at time of setting and anticipated lengthening of bottom flange due to dead

load after setting. At mean temperature and under dead load the rockers shall be set vertical and anchor bolts at expansion bearings shall be centered in their slots. Care shall be taken that full and free movement at the movable bearings is not restricted by improper setting or adjustment of bearings or anchor bolts and nuts.

(g) *Straightening.* The straightening of bent material, when permitted, shall be done by methods that will not produce fracture or other damage. Distorted members shall be straightened by mechanical means or, if approved, by application of a limited amount of localized heat. Heat shall not be applied directly on the weld metal. The temperature of heated areas shall not exceed 1200 °F as controlled by temperature indication crayons. The surfaces of metal for all steels will be inspected visually, and by magnetic particle or dye penetrant tests for evidences of fracture following the straightening procedures.

(h) *Galvanizing.* Galvanized units on which the spelter coating has been burned by welding or damaged during erection shall be repaired by a hot dip or metallizing process as described in AASHTO M36 or shall be painted with one full brush coat of a zinc-rich paint meeting Military Specification DOD-P-21035A. Spray can applications of zinc will not be allowed.

(i) *Handling and Installation.* During erection the parts shall be accurately assembled, as shown on the plans, and match-marks shall be followed. The material shall be so handled that parts will not be bent, broken, or otherwise damaged. Hammering which will damage or distort the members will not be permitted. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Splices and field connections of main stress carrying members shall have a minimum of one half of the holes filled with high strength bolts and cylindrical erection pins, with the bolts fully tightened before external support systems are removed and the connections completed by belting, unless otherwise specified.

Erection pins which are no less than $\frac{1}{64}$ inch in diameter smaller than the drilled holes shall be used at the extreme corners of the pattern in main member connections. This requirement does not apply to diaphragms and lateral bracing in straight girder spans, provided the member is adequately supported prior to removal of the external support. Members that are assembled prior to being erected shall have all bolts installed and fully tightened. The structure shall not carry traffic or construction loads without approval of the Engineer.

(j) *Pin Connections.* Pilot and driving nuts shall be used in driving pins. Pins shall be so driven that the members will take full bearing on them. Pin nuts shall be screwed tight and the threads burred at the face of the nut with a pointed tool.

(k) *Misfits.* The correction of minor misfits involving minor reaming, cutting, and chipping will be considered a legitimate part of the erection. However, any error in shop fabrication or deformation resulting from handling and transportation which prevents proper assembling and fitting up of parts by

moderate use of drift pins or by a moderate amount of reaming and slight chipping or cutting shall be reported immediately to the Engineer. The Engineer's approval shall be obtained for methods of correction and the correction shall be made in the Engineer's presence.

(l) *Cleaning of Connections.* When splices are designated Class B slip critical on the plans, the contact surfaces of splices shall be field inspected immediately prior to assembly. All foreign material shall be removed prior to fitting and bolting of the splices.

509.28 Connections Using High-Strength Bolts.

(a) *Certification.* The Contractor shall submit the supplier's certified test reports which provide a corresponding lot number appearing on the shipping package and the certification. The supplier's certification shall state when and where all testing was done, and indicate the zinc thickness when galvanized bolts and nuts are used.

(b) *Materials.* Washer type direct tension indicators shall conform to ASTM F 959.

Bolts shall be AASHTO M164 Type 1 for connections which are painted. Bolts for unpainted ASTM A 709 Grade 50W steel shall be AASHTO M 164 Type 3. The maximum tensile strength shall be 150 ksi for bolts 1 inch or less in diameter and 120 ksi for larger bolts.

Nuts shall be AASHTO M 292 grade 2H or AASHTO M291 grade DH for plain or galvanized fasteners, except connections for unpainted ASTM A 709 Grade 50W steel, in which case nuts shall be AASHTO M 291 grade DH3 or C3. For galvanized fasteners, the nuts shall be over-tapped to the minimum amount required for the fastener assembly.

All nuts, bolts, and washers shall have the manufacturer's markings on them.

All galvanized nuts shall be lubricated with a lubricant containing a visible dye so a visual check can be made for the lubricant at the time of field installation. Plain bolts shall be "oily" to the touch when installed. Weathered or rusty items shall be cleaned and relubricated prior to installation.

(c) *Test Requirements.* All high strength fasteners, including black bolts and nuts, shall be subjected to a rotational-capacity test in accordance with AASHTO M 164, section 8.5 and shall meet the following requirements:

1. *Tension Procedure.* Fasteners shall be turned two times the required number of turns (from snug tight conditions) indicated in the AASHTO Standard Specifications for Highway Bridges,Table 10.17B, in a Skidmore-Wilhelm calibrator, or equivalent tension measuring device, without stripping or failure.

2. *Minimum Tension.* During this test the maximum record tension shall be equal to or greater than 1.15 times the required fastener tension, AASHTO Standard Specifications for Highway Bridges, Table 10.17A.

3. *Maximum Torque.* The measured torque to produce the required fastener tension shall not exceed the following equation:

   Torque = 0.25 PD
   Where:
   Torque = Measured torque in foot-pounds
   P = Measured bolt tension in pounds
   D = Nominal diameter in feet

4. *Proof Load Tests.* Proof load tests (ASTM F 606 Method 1) are required for the bolts. Wedge tests of full size bolts are required in accordance with section 8.3 of AASHTO M 164. Galvanized bolts shall be wedge tested after galvanizing. Proof load tests in accordance with ASTM F 606 are required for the nuts. The proof load tests for the nuts to be used with galvanized bolts shall be performed after galvanizing, overtapping, and lubricating.

5. *Snug Tight.* Installation of all high strength bolts shall be in accordance with AASHTO Standard Specifications for Highway Bridges, paragraph 10.17.4. The "snug tight" condition as defined in paragraph 10.17.4.3 or 10.17.4.6 shall be accomplished for any method of tightening.

(d) *Field Connections.* Unless otherwise specified, all field connections shall be made with high-strength bolts which include direct tension indicators. Direct tension indicators shall be either washer type direct tension indicators or tension control bolts. Washer type indicators shall not be used with unpainted ASTM A 709 Grade 50W steel.

(e) *Bolted Parts.* Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material. All joint surfaces, when assembled, shall be free of scale, except tight mill scale; dirt; burrs; other foreign material; and other defects that may prevent solid seating of the parts. Contact surfaces within friction-type joints shall be free of oil, paint, lacquer, or rust inhibiter. Contact surfaces may be galvanized only when specified on the plans.

(f) *Installation.* Fasteners and contact surfaces of splices shall be protected from dirt and moisture at the jobsite. All fasteners shall then be tightened, progressing systematically from the center or most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tightened fasteners. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic partial tightening prior to final tightening to obtain proper tension. A minimum of 10 percent of the bolts (must be at least six bolts) in each splice shall be tightened sufficiently to assure all plates are in firm contact before final tensioning is started. When all fasteners in the joint are tight, each fastener shall have a tension no less than the minimum bolt tension shown in Table 509-3 for the size of fastener used, and a minimum of two threads shall project beyond the surface of the nut.

1. *Impact Wrenches.* Impact wrenches, if used, shall be of adequate capacity to perform the required tightening of each bolt in approximately 10 seconds.

2. W*asher Location.* In addition to load indicating washers, each fastener shall have a hardened washer under the turning element.

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

4. *Reusing Fasteners.* Bolts may be reused once, if approved. Direct tension indicators shall be tensioned only once and shall not be reused. Retightening of previously tightened bolts shall not be considered as reuse.

(g) *Locknuts and Lock Washers.* Subsections 509.28 (c), (e), and (f) shall not apply to bolts for which the plans specify lock washers or locknuts. Fasteners with lock washers or locknuts shall be snug tight only.

(h) *Inspection.* The Contractor shall provide an acceptable platform from which the Engineer can inspect bolt tension and determine whether the work meets specification requirements. The following inspection procedure shall be used unless a more extensive or different inspection is specified.

1. *Quality Assurance.* The Engineer will inspect a sufficient number of fasteners to assure compliance with Table 509-3 using a method commensurate with the type of fastener used. All loose fasteners shall be brought into compliance.

2. *Procedure Qualification.* The Contractor shall demonstrate that the bolt tightening method is providing tension in accordance with Table 509-3.

3. *Frequency.* The demonstration shall be done daily on a minimum of three fasteners of each size and lot number using an accurate direct tension measuring device. (For short grip bolts, direct tension indicators with solid plates may be used to perform this test. The direct tension indicators shall be checked with a longer grip bolt in the tension measuring device first). There shall be a hardened washer under the nut or bolt head turned to tighten each bolt. The direct tension measurement device shall be furnished by the Contractor, and shall be certified by a testing laboratory at least once a year.

Table 509-3

Nominal Bolt Size	Required Minimum Bolt Tension (lbs.)
½	12,000
⅝	19,000
¾	28,000
⅞	39,000
1	51,000
1 ⅛	56,000
1 ¼	71,000
1 ⅜	85,000
1 ½	103,000

509.29 Field Cleaning and Painting of Steel.

(a) *Self Weathering Steel.* Unpainted ASTM A 709 Grade 50W steel shall be cleaned of foreign material after erection to assure uniform weathering of the steel.

(b) *Minimum Surface Preparation.* For painted steel, when the erection is completed, including all bolting and straightening of bent metal, all adhering dirt, grease, and foreign material shall be removed. Rust and scale shall be removed to bare metal.

(c) *Damaged Areas.* After the inspector has examined and approved the field connections and prior to application of top coats, all uncoated areas and areas with damaged shop primer shall receive one coat of shop primer. The shop primer shall be thoroughly cured prior to application of the top coat.

(d) *Top Coat.* After retouching the shop coat and field cleaning has been satisfactorily completed, all steel work shall be painted with the required top coat as specified in subsection 509.24. When the manufacturer of the top coat is different than the manufacturer of the shop primer, the Contractor shall submit written documentation that the paints are compatible.

(e) *Materials Handling.* All paints, solvents, coatings, and other chemical products or solutions shall be mixed, handled, applied, stored, and disposed of in such a manner that any spill, splash, or drip will be contained without contamination of the soil, vegetation, streams, or other water bodies.

509.30 Fracture Control Plan. The Fracture Control Plan (FCP) applies to all main stress carrying members identified on the plans as fracture critical. Welded butt joints spliced within fracture critical members (FCMs), including weld and fillet weld attachments to FCMs, shall be welded and tested in accordance with this plan. The FCP shall be in accordance with AWS D1.5, Section 12. Chemical and mechanical tests, as required by this plan, shall be the responsibility of the fabricator.

509.31 Structure Number. The location, letters, figures, and paint used for stenciling shall be in accordance with the plan details. Payment for structure number shall be included in the work.

METHOD OF MEASUREMENT

509.32

(a) *Computed Weight.* Computed weight for unit measurement will be used for estimating the quantities shown on the design plans and for determining overruns or underruns.

1. The weight of metal in pounds per cubic foot, unless otherwise provided, will be assumed as follows:

Steel, cast or rolled, including alloy	490.5
Cast Iron	445.0

2. The weight of rolled shapes, pipe, and structural tubing will be computed on the basis of their nominal weight and dimensions as shown in the latest edition of the Manual of Steel Construction published by AISC.

3. The weight of plates will be computed on the basis of their nominal dimensions as shown on the approved shop drawings with no additions for overrun.

4. Allowance will not be made for the weight of shop paint in computing the pay weight of metal.

5. Allowance will not be made for the weight of the spelter coating in computing the pay weight of galvanized steel.

6. The pay weight will be computed on the basis of net finished dimensions of the part, deducting for copes, cuts, clips, and all open holes except bolt holes.

7. The computed weight of high-strength bolts will be based on the portions outside the grip, including one washer and one nut, as tabulated in Table 509-4.

Table 509-4

Nominal Bolt Size (In Inches)	Weight of 100 Bolts in Pounds
⅝ - 11 UNC	32
¾ - 10 UNC	53
⅞ - 9 UNC	81
1 - 8 UNC	117
1 ⅛ - 7 UNC	165
1 ¼ - 7 UNC	212
1 ⅜ - 6 UNC	280

8. The weight of castings will be computed from the dimensions shown on the shop drawings with an additional five percent allowance for fillets and overruns.

9. Allowance will not be made for weight of welds in computing the pay weight of structural steel.

10. All castings, anchor bolts, expansion devices, shoes, rollers, rockers, weld metal, railing, and rail posts will be paid for as structural steel unless otherwise specified.

11. The weight of erection bolts or shapes, field paint, boxes, crates, or other containers used for packing, together with sills, struts, or rods used for supporting members during transportation will not be included in the pay weight.

(b) The weight of structural steel will not be remeasured but shall be the quantities shown on the plans. Exception will be made for changes in design or for an error of plus or minus 2 percent of the total design weight shown on the plans for the project. Payment for increased quantity, deduction due to decreased quantity, or stipulated error will be made on the basis of the unit price bid, in accordance with subsection 104.02.

(c) Prospective bidders shall verify the weight of structural steel before submitting a bid. Adjustment, other than for approved changes or for an error as stipulated in subsection 509.32(b), will not be made in the design weight shown on the plans even though the actual weight may deviate from the design weight.

BASIS OF PAYMENT

509.33 The accepted quantities of structural steel will be paid for at the contract unit price per pound.

Payment will be made under:

Pay Item	Pay Unit
Structural Steel	Pound
Structural Steel (Galvanized)	Pound

All costs associated with implementing the Fracture Control Plan shall be included in the price paid for structural steel of which the fracture critical members are a part.

All costs associated with the preparation and implementation of the Erection Plan will not be measured and paid for separately, but shall be included in the work.

SECTION 510
STRUCTURAL PLATE STRUCTURES

DESCRIPTION

510.01 This work consists of the construction of structural plate structures of the shape and dimensions called for on the plans in accordance with these specifications and in conformity with the lines and grades shown on the plans or established.

MATERIALS

510.02 Steel structural plate materials shall conform to the requirements of AASHTO M 167.

A copy of the base metal manufacturer's certificate showing the results of tests, plus the fabricator's certificate showing the results of spelter tests shall be provided to the Engineer prior to installation.

Aluminum alloy structural plate materials shall conform to AASHTO M 219. There is no limit on overthickness.

Bolt and washer shapes shall be as shown on the plans. All bolts shall be sufficiently long to provide full penetration of the nut by the threaded end.

A field applied two coat coating system using materials specified in AASHTO M 243 shall be applied when called for in the Contract. The coating shall be uniformly applied by spray, brush, or trowel to the entire surface of the culvert, both inside and outside. Each coating shall be applied at the approximate rate of 60 square feet per gallon. The first coat shall be dry to touch before the second coat is applied and the second coat shall be dry to touch before any backfill operations.

Thicker invert plates for round pipes shall be construed as the bottom plate. This plate shall be installed with the center of the plate as nearly on the centerline of the pipe as practicable; however, it shall extend at least 23 inches on either side of centerline, measured on the arc. Thicker invert plates for arch pipes shall be constructed as the bottom plate (or plates) between the corner plates.

The Contractor shall state at the Pre-construction Conference, the type of structural plate material (steel or aluminum) intended to be furnished, unless a specific material is specified in the Contract.

CONSTRUCTION REQUIREMENTS

510.03 Fabrication. When the completed structure is to be a full circle pipe, the plates shall be so curved that when bolted together, true circles shall be formed of the required diameter. When the completed structure is to be an arch pipe, the plates shall be so curved as to produce a structure with the span and rise dimensions shown on the plans. Each manufacturer of corrugated structural plates shall furnish data sheets showing the physical and chemical properties of all plates to be supplied under this specification.

Each plate shall be curved to the proper radius, and the bolt holes shall be so punched that all except end plates shall be interchangeable in the erection process.

All structural plates made from steel shall be made from plates formed and punched in accordance with Section 6 of AASHTO M 167.

All structural plates made from aluminum shall be made from plates formed and punched in accordance with Section 6 of AASHTO M 219.

Plates for forming skewed or sloped ends shall be so cut as to give the angle of skew or slope specified. Units on which the spelter coating has been burned by welding or otherwise damaged in fabrication shall be repaired as provided in subsection 707.09. Cut plates shall present a workmanlike finish with legible identification numerals placed on each plate to designate its proper position in the finished structure.

510.04 Excavation. Trenches shall be excavated to the widths required by the plans.

When the installation is to be placed in embankment fill, the excavation shall be made after the embankment has been completed to a height 0.3 times the diameter or 0.3 times the rise above the flow line of the structure.

The Contractor shall excavate three test pits to a depth of approximately 6 feet below proposed flow line. Pits shall be located at each end and near the center of the trench as directed. If the foundation is deemed unsuitable, a minimum of 1 foot underlying the structure shall be excavated and backfilled with suitable material in accordance with Section 206.

510.05 Erection. Plates at longitudinal and circumferential seams shall be connected by bolts. Joints shall be so staggered that no more than three plates come together at any one point.

Nuts shall be so tightened that when tested with a calibrated torque wrench furnished by the Contractor, a torque of between 150 and 250 foot pounds is attained. Tightening of bolts to a torque in excess of 250 foot pounds will not be permitted. The use of wrench sockets which will damage the metal or metal coating will not be permitted.

Prior to backfilling operations, the full length of each round culvert shall be distorted from a true circle by pre-forming to an elliptical shape. This elongation shall approximate 5 percent of the nominal diameter of the culvert. The preformed pipe shall be placed with its greatest dimension in the vertical axis.

510.06 Backfilling. Backfilling shall conform to the details shown on the plans.

Pipe damaged due to Contractor's operations shall be repaired or replaced at the Contractor's expense.

METHOD OF MEASUREMENT

510.07 Structural plate structures will be measured by the linear foot in place. Length of round or elliptical structures shall be the average of measurements along the top and bottom. Length of structural plate arch pipe will be measured along the bottom centerline only.

BASIS OF PAYMENT

510.08 The accepted quantities of structural plate structures will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

Payment will be made under:

Pay Item	Pay Unit
Structural Plate Pipe (_____)	Linear Foot
Structural Plate Arch Pipe (____x____)	Linear Foot

Structure excavation and structure backfill, including test pits, will be measured and paid for in accordance with Section 206.

Coating, when specified, will not be paid for separately but shall be included in the work.

SECTION 512
BEARING DEVICE

DESCRIPTION

512.01 This work consists of furnishing and placing bearing devices in accordance with these specifications and in conformity with the plan details.

MATERIALS

512.02 Elastomeric bearing pads shall include plain bearings and laminated bearings. Plain bearings are unreinforced pads, consisting of elastomer only, and laminated bearings are reinforced with steel laminates. The elastomer compound shall be classified as being of low temperature grade 3, 4 or 5. The grades are defined by the testing requirements of subsection 705.06, Tables 705-1 and 705-2. A higher grade of elastomer may be substituted for a lower grade. Elastomer grade, AASHTO Design method (A or B), elastomer shear modulus and elastomer hardness shall be shown in the contract documents. The sheer modulus shall be within 15 percent of the specified value.

Materials requirements for elastomeric bearing pads, sheet lead, polytetrafluoroethylene (PTFE) sheets, stainless steel sheets and adhesive material shall conform to the requirements of subsection 705.06.

Leveling pads are unlaminated bearings as called for on the plans. They shall be cut or molded from AASHTO elastomer grade 3, 4, or 5 as described in Tables 705-1 and 705-2 with a durometer (Shore “A”) hardness of 60.

The sealing mechanism used in pot bearing devices to prevent extrusion of the elastomer shall be of brass or bronze metal.

All steel, except stainless steel, used in fabricating bearing devices shall conform to AASHTO M 270 (ASTM A 709) Grade 36 unless otherwise required in the Contract. ASTM A 709 Grade 50W or ASTM A 709 Grade 50 may be substituted for ASTM A 709 Grade 36. Anchor bolts shall be ASTM A 449 zinc plated.

Structural steel elements of Type II Bearing Devices shall be painted in accordance with Section 509.

All metal surfaces of Type III Bearing Devices shall be completely zinc metallized in accordance with AWS C2.2 to a thickness of 8 mils, except the surfaces covered with PTFE and surfaces with stainless steel. The internal pot cavity and bottom surface of the piston for Type III bearings shall be zinc metallized to a thickness of 3 mils and polished to 125 microinches after zinc metallizing.

FABRICATION

512.03 Type I Bearing Device. A Type I Bearing Device consists of either a plain or laminated elastomeric bearing pad with an optional machined sole plate as shown on the plans.

Welding shall conform to applicable requirements of ANSI/AWS D1.5 ancillary items.

Pads ¾ inch or less in thickness may be either laminated or plain. Pads over ¾ inch in thickness shall be laminated.

Laminated pads shall be individually molded and shall consist of alternate laminations of elastomer and metal laminates. The bearings shall be vulcanized under heat and pressure. The mold finish shall conform to standard shop practice. The internal steel laminates shall be sandblasted and cleaned of all surface coatings, rust, mill scale, and dirt before bonding, and shall be free of sharp edges and burrs. Laminations of elastomer shall be ½ inch, plus or minus ⅛ inch in thickness. Unless otherwise noted on the plans, the top and bottom layers of metal shall be uniformly covered with a maximum of ⅛ inch of elastomer. The edges of the metal shall be uniformly covered with a minimum of ⅛ inch of elastomer, except at laminate restraining devices and around holes that will be entirely closed on the finished structure. Variations in the location of the metal reinforcement from its theoretical location shall not exceed ⅛ inch.

Plain bearings may be molded individually, cut from previously molded strips or slabs, or extruded and cut to length. Cut edges shall conform to the requirements of ANSI B46.1.

512.04 Type II Bearing Device. The upper sliding element shall consist of a polished stainless steel sheet finished to a No. 7 high luster polish (glossy, bright, buffed finish) and attached to a sole plate. The stainless steel sheet shall be seal welded to the sole plate. The operating coefficient of either static friction or sliding friction between the stainless steel and the PTFE sheet, when loaded to 1000 psi, shall not exceed 0.06.

Pads less than ¾ inch in thickness may be either laminated or plain. Pads ¾ inch and greater in thickness shall be laminated.

The lower sliding element shall consist of a filled or unfilled PTFE sheet with a minimum thickness of $\frac{3}{32}$ inch vulcanized to a stainless steel substrate. The stainless steel substrate shall be capable of resisting bending stresses to which the sliding surface may be subjected. The other side of the substrate material shall be vulcanized to an elastomeric pad as described in subsection 512.03 and as shown on the plans. The stainless steel substrate material shall have a thickness as shown on the plans or shall have sufficient tensile strength to restrain the elastomeric pads.

512.05 Type III Bearing Device. The manufacturer of Type III bearings shall be preapproved and listed in the Contract. Type III Bearing Devices are designed as Pot type or Disc type. Bearing devices shall be fabricated as fixed, guided expansion, or non-guided expansion bearings as designated in the Contract. Bearings shall satisfactorily provide for thermal expansion and contraction, rotation, camber changes, and creep and shrinkage of the structural members they support. Bearings shall be designed and fabricated so that they can be readily inspected and easily removed and replaced during the service life of the bridge. This shall include

provisions to allow removal and replacement of all components of the bearing device, excluding sole plates, by lifting the superstructure no more than ¼ inch. The static coefficient of friction shall be determined based on the force required to cause first movement under the vertical load applied during the test. The operating coefficient of static friction or sliding friction between the stainless steel and the PTFE sheet, when subjected to a 3500 psi load, shall not exceed 0.03.

(a) *Fixed Bearing.* A fixed bearing shall allow rotation but no longitudinal or transverse movement in the bearing plane.

(b) *Guided Expansion Bearing.* A guided expansion bearing shall allow rotation and longitudinal movement and shall restrict transverse movement in the bearing plane.

(c) *Nonguided Expansion Bearing.* A non-guided expansion bearing shall allow rotation and longitudinal and transverse movement in the bearing plane.

(d) *Pot Bearings.* The bearing device shall consist of a masonry plate, a sole plate, a top plate, an optional guide plate, a loading piston, and a cylindrical steel retainer (pot) to confine an elastomeric pad. The piston and pot shall each be machined from a solid steel plate. The piston may be welded to a guide or top plate as approved by the Engineer. The shape characteristics, clearances, and sealing mechanism of the piston and cylinder shall be designed to prevent extrusion of the elastomer material under rotational movement, vertical load, and where applicable, horizontal load. When a bearing must accommodate movement in the plane of the bearing (guided or non-guided type), the top surface of the piston plate shall be faced with PTFE sheet and the mating surface of the steel shall be faced with polished stainless steel finished to No. 8 mirror finish or better. When a bearing device restricts transverse movement (guided type), the device shall contain either a guide bar or a keyway system. These systems shall be designed so that the vertical interfaces are parallel throughout the range of rotation of the bearing device. The mating steel surfaces of the guide bar or keyway systems shall be faced with strips of PTFE and stainless steel.

(e) *Disc Bearings.* The bearing shall consist of an elastomeric rotational element (disc) confined by upper and lower steel bearing plates. The bearing shall be equipped with a shear restricting mechanism to prevent horizontal movement of the disc. When a bearing device must accommodate movement in the plane of the bearing (guided or non-guided type), the top surface of the upper steel bearing plate shall be faced with PTFE sheet and the mating surface of the steel plate shall be faced with polished stainless steel finished to a No. 8 mirror finish or better. Bearing devices designed to restrict transverse movement (guided type) shall contain either a guide bar or a keyway system. These systems shall be designed so that the vertical interfaces are parallel throughout the range of the rotation of the bearing device. The mating steel surfaces of the guide bar or keyway systems shall be faced with strips of PTFE and stainless steel.

(f) *Sliding Surfaces of Plates For Pot and Disc Bearings.* The PTFE sheet affixed to the top surface of a piston plate or upper steel bearing plate shall have a minimum finished thickness of $^{3}/_{16}$ inch and shall be recessed for ½ its thickness into its steel substrate. The PTFE sheet shall be bonded to the steel substrate using an epoxy resin applied to the full area of the contact surfaces. The surface of the PTFE sheet to be bonded shall be treated with sodium naphthalene or sodium ammonia process prior to bonding. Bonding shall be performed at the manufacturer's factory under controlled conditions and in accordance with the instructions of the manufacturer of the epoxy material. At the completion of the bonding operation, the surface of PTFE shall be smooth and free of bubbles.

Lubricants of any kind shall not be used in the sliding surfaces of bearing devices. The PTFE strips on the mating surfaces of guide systems shall be $^{3}/_{16}$ inch minimum and shall be recessed and bonded, or may be bonded and mechanically fastened to the mating steel surfaces of the guide bar or keyway systems. The fasteners shall provide full bearing on the PTFE strip and the steel surfaces to which the PTFE is attached.

The mating surfaces of structural steel elements shall be ground to a flatness of 0.01 inch per linear foot. Maximum surface roughness shall be ANSI 500 in accordance with American National Standards Institute B 46.1.

Bearing devices shall be designed so that stainless steel will cover the PTFE throughout the range of movement for the bearing device. The surface of stainless steel which slides on the PTFE shall have a flatness of 0.01 inch per linear foot.

512.06 Reserved.

512.07 Reserved.

512.08 The bearings shall be completely factory-produced assemblies and shall include all directly connected or welded anchorage hardware. The bearings shall adequately provide for the amount of movement due to temperature changes, post tensioning offsets, or girder rotation as shown on the plans.

512.09 Testing and Acceptance. The materials for elastomeric bearings and finished bearings shall be subjected to the tests described in this subsection. Material tests shall be in accordance with Table 705-1 or 705-2 and as described herein. The manufacturer shall furnish facilities for the testing and inspection of the completed bearings in the plant or at an independent test facility. At the Engineer’s discretion, testing may be performed in the presence of the Engineer or a designated representative. The Engineer or the Engineer’s representative shall be allowed free access to the necessary parts of the manufacturer’s plant and test facility, as arranged by the Contractor. The Contractor shall inform the Engineer a minimum of two weeks in advance of a date and time when a visit to the plant and test facility would be permitted.

(a) *Test Specimens.* One bearing per lot shall be tested. The Engineer will randomly select samples from the production bearings for testing. A lot shall be defined as the smallest number of bearings as determined by the following criteria:

1. One lot shall not exceed a single contract or project quantity.

2. One lot shall not exceed 25 bearings.

3. A lot shall consist of those bearings of the same type within a load category. The types of bearing devices are defined as fixed, guided expansion, and nonguided expansion which includes Type I, Type II, and Type III, bearings.

4. Load categories are 0 to 999 kips, 1000 to 2999 kips, and 3000 kips or more.

(b) *Test Method.* The test for the sliding coefficient of friction for Types II and III bearing devices consists of determining the sliding coefficient of friction between the PTFE and stainless steel elements of an expansion type bearing device by using equipment and a test procedure approved by the Engineer. Specially made bearings shall not be used; only actual bearings to be used in the project shall be tested.

1. Clean all bearing and sliding surfaces, assemble the bearing device and place it into the test apparatus.

2. Type III bearings, shall be subjected to a rotation of 0.02 radian or the rotation specified in the Contract, if larger.

3. The test shall be conducted at maximum working stress for the PTFE surface with the test load applied continuously for 12 to 24 hours prior to measuring friction.

4. At first movement, the static and dynamic coefficients of friction shall be determined by applying an approximate horizontal force to the bearing device in a cyclic manner to cause slipping along the PTFE stainless steel surface at a speed of less than 1 inch per minute and shall not exceed the coefficient of friction specified.

   The bearing shall then be subjected to a minimum of 100 movements of at least 1 inch in each direction from the centerline of the device at a speed of less than 12 inches per minute. After cycling, the static and dynamic coefficients of friction shall be determined again at a speed of less than 1 inch per minute and shall not exceed the coefficient of friction specified. After the load is removed the bearings shall be disassembled and the components carefully examined. Any visible damage to a component shall be cause for rejection.

5. *Rotational Test (Type III).* This test consists of applying a vertical load to the bearing device equal to 150 percent of its rated capacity and subjecting the bearing to the greater value of either rotation of 0.02 radians or the designed rotation for a period of one hour. During the

testing of pot bearings, if the confined elastomer extrudes beyond the sealing mechanism, the bearing shall be rejected. During the testing of disc bearings, any observed lift off between the rotational element and other components of the bearing shall be cause for rejection. After the load is removed the bearing device shall be disassembled and the components carefully examined. Any visible damage to the disk bearing components shall be cause for rejection.

6. Type I and II bearings incorporating laminated elastomeric pads shall be loaded and tested as follows:

   A. *Short-Duration Compression Test.* The bearing shall be loaded in compression to 1.5 times the maximum design load. The load shall be held constant for 5 minutes, removed and reapplied for another 5 minutes. The bearing shall be examined visually while under the second loading. Bulges indicating laminate nonparallelism or a layer thickness that is outside the specified tolerances, or poor laminate bond, shall result in the bearing being rejected. If there are three or more separate surface cracks that are greater than 0.08 inch wide and 0.08 inch deep, the bearing shall be rejected.

      The short duration test shall be performed for bearings designed under AASHTO method A or B.

   B. *Long-Duration Compression Test.* The bearing shall be loaded in compression to 1.5 times its maximum design load for a minimum period of 15 hours. If during the test, the load falls below 1.3 times the maximum design load, the test duration shall be increased by the period of time for which the load is below this limit. The bearing shall be examined visually at the end of the test while it is still under load. If the bulging pattern suggests laminate non-parallelism or a layer thickness that is outside the specified tolerances, or poor laminate bond, the bearing shall be rejected. If there are three or more separate surface cracks that are greater than 0.08 inch wide and 0.08 inch deep, the bearing shall be rejected.

      The long duration test shall be performed for bearings designed under AASHTO Method B.

   Bearings represented by test specimens passing the above requirements will be approved for use in the structure subject to on-site inspection for visible defects.

(c) *Certification.*

1. Certification for Type I, II, and III Bearings:

   The manufacturer shall certify that each bearing satisfies the requirements of the plans and these specifications.

   The manufacturer shall submit:

(1) Manufacturer's certification of the steel, elastomer, PTFE, and other materials used in the construction of the bearings.

(2) Details and calibration of the test equipment prior to testing.

(3) Certified test results on the samples of the completed bearing devices which show they conform to the requirements of this specification.

(4) Notification when fabrication is completed and when testing is to be performed.

2. Certification for leveling pads:

The supplier shall submit a Certificate of Compliance to the Engineer for acceptance.

512.10 Packaging. The bearings shall be packaged and protected in such a manner that they will not be damaged and the contact surfaces of the sliding elements will not be contaminated while being handled, transported, or stored. Each completed bearing shall have its components clearly identified and marked with an upstation arrow and the location on the structure. Except for Type I bearings, the markings shall be on a face that is visible after erection of the bridge. The bearing assemblies shall be furnished as a complete unit from one manufacturing source, unless otherwise approved.

CONSTRUCTION REQUIREMENTS

512.11 The concrete on which the bearings are to be placed shall be free of honeycomb. The concrete bearing contact surface shall be finished to a level plane with a flatness tolerance of $\frac{1}{16}$ inch for bearing seats up to 30 inches, $\frac{3}{32}$ inch for bearing seats over 30 inches and under 45 inches, and $\frac{1}{8}$ inch for bearing seats over 45 inches as measured using a straight edge placed in any direction across the area. The finished plane shall not vary more than $\frac{1}{8}$ inch from the elevation shown on the plans.

The initial installations of Type III bearings shall be performed by the Contractor in the presence of a representative of the manufacturer. This representative shall be experienced in such installations and provide information to the Contractor on handling and installation procedures. The representative shall provide information to the Engineer on inspection of the bearing installation and shall provide assistance until the Contractor and the Engineer agree that they understand the installation and inspection procedures.

Upon completion of the superstructure placement, the Contractor, Engineer and bearing manufacturer's representative, together, shall inspect each bearing's placement and alignment for Type III bearings. Subsequent to the inspection, and after correction of all deficiencies, the Contractor shall certify in writing that the bearing installation is correct.

512.12 Masonry plates of Type III bearing assemblies shall be set on a single thickness of sheet lead or preformed fabric pad when a monolithic cap seat is used.

512.13 Placement of elastomeric bearing pads or bearing devices on grout pads will not be permitted unless called for on the plans.

512.14 Non-metallic bearing pads shall be protected from damage due to welding heat. The Contractor shall submit a welding procedure for approval prior to beginning welding. Field welding to steel plates which have a bonded PTFE surface will be permitted provided that the welding procedure used does not increase the temperature of the area of the steel to which PTFE is bonded above 300 °F. Temperature indicating wax pencils or other approved means shall be used to determine whether this temperature limit is being exceeded.

512.15 Type II and Type III Bearing Devices shall not be disassembled during installation unless otherwise permitted. The Contractor shall protect all bearings from contamination and damage due to paint overspray or when placing concrete or other materials.

512.16 The Contractor shall furnish a manufacturer's certification that all components meet the Contract requirements.

512.17 The Contractor shall submit shop drawings, design calculations and load data for review of Type III Bearing Bevices as specified in subsection 105.02. The shop drawings shall include installation procedures and address storage, handling, disassembly, placement, alignment, offsets, protection during welding to steel girders, protection during painting of structure, and removal of banding or retaining clamps.

METHOD OF MEASUREMENT

512.18 Bearing devices will be measured by the unit.

BASIS OF PAYMENT

512.19 The accepted quantities of bearing devices will be paid for at the contract unit price each.

Payment will be made under:

Pay Item	Pay Unit
Bearing Device (Type_____)	Each

Elastomeric bearing pads, preformed fabric pads, and sheet lead when not included in Bearing Device (Type) will not be measured and paid for separately but shall be included in the work. Leveling pads will not be paid for separately, but shall be included in the work.

The presence of a manufacturer’s representative will not be measured and paid for separately, but shall be included in the work.

SECTION 514
PEDESTRIAN AND BIKEWAY RAILING

DESCRIPTION

514.01 This work consists of the construction of the designated type of railing in accordance with these specifications and in conformity with the details, lines and grades shown on the plans or established.

MATERIALS

514.02 Pipe Railing. Pipe for railing shall be standard steel, black or galvanized as specified. The pipe, and galvanizing when specified, shall conform to the requirements of ASTM A 53, Types E or S, Grade A, schedule 40 or better, for steel pipe. Threaded fittings shall be made from malleable iron, plain or galvanized, as specified, and slip-on fittings shall be of the type shown on the plans. Steel shapes shall conform to the requirements of Section 509.

514.03 Steel Tube Railing. Steel for this type of railing shall conform to the requirements of Section 509 and the following:

(1) Steel tubes shall conform to the requirements of ASTM A500 Grade B.

(2) Steel plates and bars shall conform to the requirement of ASTM A 709 Grade 36.

(3) Bolts shall conform to the requirements of ASTM A 307.

(4) Zinc coating shall conform to the requirements of ASTM A 123, A 153, A 385 and A 386.

(5) Welding shall conform to the American Welding Society Structural Welding Code - Steel, D1.1.

Steel for uncoated railing shall conform to the requirements of ASTM A 847 for structural steel tubing and ASTM A 709 Grade 50W for plates and shapes.

514.04 Timber Railing. Timber for posts and rails shall be pressure treated and shall be in accordance with Section 508. Timber for posts shall be Douglas Fir - Larch, #2 or equivalent. Timber for rails shall be Douglas Fir -Larch #1. Pressure treated timber shall conform to the requirements of the American Wood Preservers Association (AWPA) Standards, Section C1 and C2 (Soil Contact) Either Ammoniacal Copper Arsenate (ACA) or Chromated Copper Arsenate (CCA) preservative conforming to the requirements of Section P5 (Standards for Waterborne Preservatives of the AWPA Standards shall be utilized and total absorption shall be 0.4 pounds per cubic foot of timber. Redwood or cedar will not require a preservative treatment.

All steel hardware and bolts for timber railing shall be galvanized or zinc coated.

514.05 Combination Railing. Pedestrian or bikeway railing combined with traffic railing shall conform to the requirements of this section. Traffic Railing and Traffic portion of Combination Railing shall conform to the plans and shall be in accordance with Section 606.

CONSTRUCTION REQUIREMENTS

514.06 Prior to construction of any type of railing, the Contractor shall submit working drawings in accordance with Sections 101 and 105.

Posts shall be aligned and plumb within a tolerance of ¼ inch. The finished rail shall be rigidly braced and secured to surrounding construction and shall be tight, and free of rattle, vibration, or noticeable deflection.

Rail elements shall be erected in a manner resulting in a smooth continuous installation. All bolts in the finished rail shall be drawn tight. Bolts shall be of sufficient length to extend beyond the nuts. Fasteners projecting toward the pathway shall be carriage bolts with smooth, round heads with nuts oriented away from the pathway. Bolts in timber rails shall be recessed. Hand rails and rub rails shall not have projecting fasteners.

Welding shall be in accordance with Section 509 and AWS D1.1. Gas Metal-Arc Welding (GMAC) will be permitted. Where welds are designated, connections shall be continuously welded. All cut edges shall be rounded and all welds ground smooth. Punched, cut, drilled, or tapped holes shall be free of burs and sharp edges. After field welding, damaged paint and galvanized coatings shall be repaired.

Electrolytic isolation shall be provided to prevent contact of dissimilar metals. Asphaltic paint shall not be permitted to remain on surfaces to be exposed or to receive a sealant or paint.

Pipe railing with threaded fittings shall screw into end fittings but may slide through intermediate fittings. Splices shall be made inside of fittings and clearance shall be allowed for expansion. Each piece of railing shall be securely fastened at one end by a set screw in the fittings or by sufficient threads to develop its strength.

All steel railing shall be galvanized or painted in accordance with Section 509 unless uncoated railing of corrosion resistant steel is specified. The color of paint shall be as shown on the plans or as directed.

METHOD OF MEASUREMENT

514.07 Railing will be measured by the linear foot from end to end of the railing. Payment will be full compensation for all work and materials required to complete the installation including foundations, anchorages, attachments, fabrication, painting, and installation.

BASIS OF PAYMENT

514.08 The accepted quantities of railing will be paid for at the contract unit price per linear foot.

Payment will be made under:

Pay Item	Pay Unit
Bikeway Railing (____)	Linear Foot
Hand Railing	Linear Foot
Pedestrian Railing (____)	Linear Foot
Pipe Railing	Linear Foot
Pipe and Redwood Railing	Linear Foot

Payment for Traffic Railing, Combination Pedestrian and Traffic Railing, and Combination Railing shall be in accordance with Section 606 for the applicable type of bridge railing or guardrail.

SECTION 515
WATERPROOFING MEMBRANE

DESCRIPTION

515.01 This work consists of furnishing and placing an approved waterproofing membrane and protective covering over a prepared concrete bridge deck surface or furnishing and placing an approved chemical concrete sealer (sealer) on the surface of a concrete bridge deck, approach slabs, and all adjacent sidewalk and curb, and other applications designated on the plans.

MATERIALS

515.02 The waterproofing membrane shall consist of one of the following:

(1) A prefabricated reinforced membrane and primer or,

(2) A single component, hot-applied elastomeric membrane and primer if required.

Materials for the waterproofing membrane shall meet the requirements specified in the following subsections:

Protective Covering	705.07
Prefabricated, Reinforced Membrane and Primer	705.08
Single Component, Hot Applied, Elastomeric Membrane	705.09

515.03 Concrete sealer shall consist of an alkyl-alkoxy silane and shall be a penetrating type with 40 percent solids in water or a high flash organic solvent. The sealer shall be compatible with the curing compound used on the concrete and shall be one that is included on the approved products list of the Department. A certificate of compliance shall be provided with each shipment of sealer.

CONSTRUCTION REQUIREMENTS

515.04 Waterproofing Membrane.

(a) *Condition of Concrete Deck for Application of Waterproofing Membrane.* The entire deck and the sides of the curbs for a height of 2 inches above the plan thickness of the hot mix asphalt shall be free of all foreign material such as dirt, grease, old pavement and primer. All decks shall be sand blasted or shot blasted. Immediately prior to the application of primer or any type of membrane, all dust and loose material shall be removed. The deck condition will be approved before application of the membrane.

(b) *Weather and Moisture Limitations for Application of Waterproofing Membrane.* Application of primer or membrane shall not be done during inclement weather conditions, or when deck and ambient air temperatures are below 50 °F. The deck surface shall be dry at the time of application of primer and membrane.

(c) *Application*, Prefabricated, Reinforced Membrane. Primer shall be applied to the prepared concrete surface at the rate and according to the procedure recommended by the membrane manufacturer. Placement of the membrane shall not begin until the volatile material in the primer has dissipated. The membrane shall be placed in such a manner that a shingling effect will be achieved and any accumulation of water will be directed toward curbs and drains. Primer and membrane shall be placed on the curb faces for a height of 2 inches above the plan thickness of the hot mix asphalt. The entire membrane shall be essentially free of wrinkles, air bubbles and other placement defects. Blisters or bubbles larger than 2 inches in diameter, which develop after placement of the membrane and before placement of protective covering, shall be punctured, the air expelled and membrane patched in a manner satisfactory to the Engineer. At all expansion joints, and other joints, membrane shall be flashed up to the top of the joint and secured with primer. At drain pipes, membrane shall be placed in such a manner that it extends down inside the drain and is secured with primer.

(d) *Application, Single Component, Hot Applied, Elastomeric Membrane.* Hot applied membrane shall be applied to the prepared deck surface at a uniform minimum rate of ½ gallon per square yard thickness of 90 to 110 mils, 1 mil = 0.001 inch. During application the thickness may be measured by the Engineer. Lack of uniform application shall be cause for termination of the work until remedial measures are taken. Primer, if required, and membrane shall be placed up the curb faces for a height of 2 inches above the plan thickness of hot mix asphalt.

(e) *Application of Protective Covering.* As soon as practical, but in all cases the same day as membrane application, protective covering shall be placed from gutter line to gutter line. Protective covering shall be laid parallel to the centerline of the bridge. The protective covering shall be butted together at longitudinal and transverse joints. Overlapping will not be permitted. The maximum allowable space between adjoining sections of protective covering shall be 1 inch. Following placement of protective covering, a bead of compatible mastic or hot applied membrane shall be applied where the protective covering contacts the curbs, and in cracks between adjoining sections that are apart by more than ⅜ inch. The bead shall fill the void preventing water from entering at this point.

(f) *Inspection.* Upon completion of the membrane and protective covering the Engineer will inspect the membrane system.

Approval in writing from the Engineer shall be obtained before application of hot mix asphalt. The Contractor shall be responsible for maintaining the condition of the membrane system on the bridge deck until covered with hot mix asphalt to the thickness required by the Contract.

(g) *Overlay.* Hot mix asphalt shall be placed, spread and compacted, in accordance with the specifications or as approved.

515.05 Concrete Sealer.

(a) *Condition of Surface for Application of Sealer.* The surface of bridge deck, approach slabs, sidewalks, and curbs and the interior concrete surface of drains shall be free of all residue and other surface contaminants. Within 48 hours prior to the application of the sealer these surfaces shall be cleaned with dustless abrasive shot blasting. Other methods of blasting, power washing, or cleaning may be used if approved. The amount of shot blasting or cleaning shall be sufficient to remove all visual evidence of curing compound residue, dirt, grease, and surface contaminants. When wet methods are used the surface shall be dried in accordance with subsection 515.04.

(b) *Weather and Moisture Limitations for Application of Sealer.* Sealer shall not be applied when the deck or ambient air temperature is below 40 °F, above 90 °F, or outside the manufacturer's recommended temperature range. The concrete shall have aged a minimum of 28 days and the surface shall be dry at the time of application of the sealer. When the surface is wet because of inclement weather, power washing, or other moisture it shall be permitted to dry at least 24 hours before the sealer is applied.

(c) *Application of Sealer.* Sealer shall be applied uniformly at the manufacturer's recommended rate. The sealer shall be applied to the surface of the concrete bridge deck, approach slabs, curbs including the face of concrete bridge rail for 6 inches above the bridge deck, sidewalks, and the interior concrete surface of drains. Two copies of the manufacturer's literature for the sealer including the recommended application procedure shall be provided to the Engineer prior to application. The literature shall include a product material safety data sheet.

All solvents, coatings, or other chemical products, or solutions, shall be mixed, handled, applied, stored and disposed of in such a manner that spills, splashes, and drips shall be contained without contamination of the soil, vegetation, streams, or other water bodies.

The Contractor shall provide two approved respirators for use by Department personnel.

Traffic shall not be allowed on the treated surface until the sealer has penetrated the concrete and the liquid sealer is no longer visible on the surface. The Contractor shall follow all the manufacturer's recommendations, including penetration time, prior to opening to traffic.

METHOD OF MEASUREMENT

515.06 Waterproofing membrane including protective covering, complete in place, will be measured by the number of square yards of bridge deck covered. Material placed on curb faces will not be measured.

Concrete sealer will be measured by the number of square yards of concrete surface covered, except material placed on drains will not be measured.

BASIS OF PAYMENT

515.07 The accepted quantities of waterproofing membrane including protective covering will be paid for at the contract unit price per square yard.

The accepted quantities of concrete sealer, including surface preparation, will be paid for at the contract unit price per square yard of concrete surface covered. Preparation and sealing of drains will not be paid for separately but shall be included in the work.

Payment will be made under:

Pay Item	Pay Unit
Waterproofing (Membrane)	Square Yard
Concrete Sealer	Square Yard

Hot mix asphalt will be measured and paid for in accordance with Section 403.

SECTION 516
DAMPPROOFING

DESCRIPTION

516.01 This work consists of dampproofing concrete surfaces in accordance with these specifications and in conformity with the plans or as ordered.

MATERIALS

516.02 Materials for dampproofing with asphalt shall conform to the requirements of subsection 702.01.

CONSTRUCTION REQUIREMENTS

516.03 Surfaces to be dampproofed shall be cured, dry and free of all frost, loose material and dirt.

The surface which is to be protected by dampproofing shall be thoroughly cleaned before the primer is applied. The surface shall then be brush or spray painted with two coats of asphalt for primer treatment at a rate of ⅛ gallon per square yard for each coat. After the primed surface has dried one application of asphalt dampproofing material shall be applied by brush, at a rate of 1/10 gallon per square yard.

Care shall be taken to prevent discoloration of other parts of the structure not to be dampproofed, by the dripping or spreading of asphalt.

METHOD OF MEASUREMENT

516.04 Dampproofing will be measured by the square yard of surface area dampproofed.

BASIS OF PAYMENT

516.05 The accepted quantities of dampproofing, including absorptive primer coats, will be paid for at the contract unit price per square yard.

Payment will be made under:

Pay Item	Pay Unit
Dampproofing (Asphalt)	Square Yard

SECTION 517
WATERPROOFING

DESCRIPTION

517.01 This work consists of waterproofing concrete surfaces in accordance with these specifications and in conformity with the plans or as directed.

MATERIALS

517.02 Materials for waterproofing shall conform to the following:

Item	ASTM Designation	Use
Asphalt Primer	D41	Primer under asphalt mop coats
*Asphalt Mop Coat	D449	Mop coats with or without membrane
Woven Cotton Fabric	D173	With asphalt membrane

* Type I is for use below ground and shall be heated to a temperature of between 225 and 275 °F. Type II is for use above ground and shall be heated to a temperature of between 275 and 325 °F. Type II shall be used unless otherwise specified.

For hot application, materials for waterproofing shall be heated to a temperature of between 175 and 225 °F in a heating kettle or tank constructed as a double boiler, with a space between the inner and outer shells filled with oil, asphalt, or other material for heat transfer and for positive temperature control. Heating kettles shall be equipped with thermometers and the material shall be stirred continuously to avoid overheating.

CONSTRUCTION REQUIREMENTS

517.03 All concrete surfaces to be waterproofed shall be free of loose material and dirt and shall be reasonably smooth and free of projections or holes. Waterproofing shall not be started without approval in wet weather or when the temperature is below 35 °F.

The waterproofing shall in all cases be started at the low point of the surface to be treated so that water will run over and not against or along the laps.

Beginning at the low point of the properly prepared surface to be waterproofed, a priming coat shall be brushed or sprayed on the surface to penetrate and prepare it for the first mop coat of hot asphalt coating.

After the primer has cured, a section about 20 inches wide and the full length of the surface shall be mopped with the hot asphalt. The first strip of half-width fabric shall be rolled into the mop coat immediately after it is placed. The first strip and all following strips shall be rolled into place to eliminate air bubbles and obtain close conformity with the surface being treated. The first strip and an adjacent

section of the surface, of a width equal to slightly more than half the width of fabric being used, shall then be mopped with hot asphalt and a second strip shall then be rolled into it. The second strip shall completely cover the first strip. The second strip and an adjacent surface of concrete shall then be mopped with hot asphalt and a third strip of fabric "shingled" on. The third strip shall lap the first strip by at least 2 inches. This process shall be continued until the entire surface to be treated is covered and each strip of fabric shall lap at least 2 inches over the next to last strip. The entire surface shall then be given a final mopping of hot asphalt.

The completed waterproofing shall consist of a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt, together with the required prime coat. Each layer must be separated from the concrete surface or other layers of fabric by an intervening mop coat.

The mopping on the concrete shall cover the surface so that no gray spots appear and on the fabric it shall be sufficiently heavy to completely conceal the weave. At least 12 gallons of asphalt shall be used for each 100 square feet of horizontal surface and at least 15 gallons for each 100 square feet of vertical surface for each mop coat. The work shall be so regulated that, at the close of a day's work, all fabric that has been laid shall have received the final mopping of asphalt and the edges of all laps shall be thoroughly sealed down.

Suitable provisions shall be made to prevent water from getting between the waterproofing and waterproofed surface at the edges of the membrane and at any point where it is punctured by such appurtenances as drains or pipes.

METHOD OF MEASUREMENT

517.04 The accepted quantities of waterproofing will be measured by the square yard based on the surface area waterproofed.

BASIS OF PAYMENT

517.05 The accepted quantities of waterproofing will be paid for at the contract unit price per square yard.

Payment will be made under:

Pay Item	Pay Unit
Waterproofing (Asphalt)	Square Yard

SECTION 518
WATERSTOPS AND EXPANSION JOINTS

DESCRIPTION

518.01 This work consists of furnishing and installing waterstops, expansion joints, and end dams of the sizes and types required in accordance with these specifications and in conformity with the details shown on the plans, or as directed.

MATERIALS

518.02 Waterstops. Waterstops shall be manufactured either from neoprene or polyvinyl chloride (PVC) meeting the requirements described in subsection 705.10. The Contractor will have the option of furnishing either material unless otherwise specified.

The Contractor shall submit a certificate of compliance for each type of waterstop proposed for use on the project to the Engineer.

518.03 Asphaltic Expansion Devices. This device consists of an expansion joint system composed of a blended polymer modified asphalt and special aggregate in accordance with these specifications and in conformity with the details shown on the plans or established. The joint system shall be installed in a prepared expansion joint blockout and shall be designed for a rated joint movement of 0 to 2 inches including rotations.

The polymer modified asphalt, aggregate, backer rod, bridging plate, and joint binder shall conform to recommendations of the manufacturer of the approved joint system installed. Approved joint systems shall be those shown on the plans.

The Contractor shall furnish manufacturer's certification that all materials furnished have been pretested and meet the requirements set forth in the specifications and conform to the materials listed in the latest product literature. No substitution of materials will be permitted.

518.04 Elastomeric Expansion Devices. This device consists of an elastomeric expansion joint device and curb cover plates as shown on the plans and in accordance with these specifications. The expansion joint device shall seal the deck surface as indicated on the plans, and prevent water from seeping through the superstructure slab. Seeping of water through the joint will be cause for rejection of the expansion device. The Contractor shall state at the Pre-construction Conference the specific manufacturer and model number of the device the Contractor intends to furnish and install.

The device shall consist of a continuous premolded elastomeric expansion joint seal, embedded steel angles and steel extrusions as shown on the plans, required by the manufacturer, or specified herein for attaching the elastomeric expansion joint seal to the steel armor. The expansion device shall have a rated movement of 0 to 4 inches including rotations.

The Contractor shall furnish manufacturer's certification that the materials proposed for use on the project have been pretested and will meet the requirements as set forth in these specifications and the manufacturer's current literature. The materials shall not be installed in the work prior to the Engineer's approval.

Structural steel sections shall conform to the specifications of AASHTO M 270 (ASTM A709 Grade 36). Fabrication and welding of structural steel shall conform to the requirements of Section 509. The material designations for all steel components shall be shown on the Contractor's working drawings.

All structural steel elements of the bridge expansion device, including cover plates, shall be galvanized after fabrication in accordance with Section 509, whether or not they are in contact with the elastomeric seals.

518.05 Modular Expansion Devices. This device consists of a modular expansion joint device and curb cover plates at the locations shown on the plans and in accordance with these specifications. The modular expansion joint device shall seal the deck surface, gutters, curbs, and walls as indicated on the plans, and prevent water from seeping through the bridge deck. Seeping of water through the joint will be cause for rejection of the expansion device. The Contractor shall state at the Pre-construction Conference the specific manufacturer and model number of the device the Contractor intends to furnish and install.

The expansion device shall have a rated movement greater than 4 inches but not exceeding 28 inches.

The modular expansion joint device supplied shall be one of the approved devices as shown on the plans.

The modular expansion device system shall be designed, fabricated, and delivered to the jobsite as a continuous unit, unless otherwise approved by the Engineer. Field splices shall not be located on the vehicle wheel path. The maximum length of completed expansion device assemblies shall be determined by practical shipping limitations. Handling and storage of the expansion joint device shall be in accordance with the manufacturer's written recommendations and as approved by the Engineer.

Only one type of modular joint device will be permitted to be installed at all locations. The installation of two different types at separate locations will not be permitted.

The device shall consist of premolded elastomeric expansion joint seals (strip seals) mechanically held in place by steel center beams and edge beams. Each transverse center beam shall be individually supported by, and connected by full penetration weld to an independent support bar. The device shall provide equal-distance control of the premolded elastomeric seals.

(a) The transverse separation beams (center beams), support bars, and other structural elements shall be fatigue tested and designed following the guidelines provided in NCHRP Report 402, "Fatigue Design of Modular Bridge Expansion Joints" as well as the provisions included in Chapter 14 of the latest edition of the AASHTO LRFD Design Specification.

(b) The following components shall meet the listed requirements:

Structural Steel (except center beams, edge beams and support bars)	AASHTO M 270 (ASTM A 709) Grade 36
Center Beams, Edge Beams and Support Bars	AASHTO M 270 (ASTM A 709) Grade 50 or AASHTO M 270 (ASTM A 709) Grade 50W
Headed Studs	ASTM A108
Premolded Seals, Lubricant Adhesive, and Sliding Surfaces	Conforming to manufacturer's current literature
Stainless Steel Bearing Surfaces	Subsection 705.06

Structural steel shall conform to the requirements of Section 509 except the steel fabricator shall be certified under the AISC Quality Certification Program in Simple Steel Bridges, as a minimum.

All structural steel elements of the bridge expansion device, including cover plates, shall be galvanized after fabrication in accordance with Section 509, whether or not they are in contact with the elastomeric seals.

The manufacturer shall furnish certification that the materials proposed for use on the project have been pretested and will meet the requirements as set forth in these specifications and the manufacturer's current literature. The material shall not be installed in the work prior to the Engineer's approval. All components of the expansion joint device, including stiffening plates and anchorages, shall be supplied by the manufacturer. The material designations for all components shall be shown on the shop drawings.

518.06 Elastomeric Concrete End Dam. Elastomeric concrete end dam shall be an elastomeric concrete of either field vulcanized, fusion bonded synthetic elastomer and precision blended aggregates or an approved polyurethane binder and precision blended aggregates bonded to all adjacent surfaces of the existing structure.

The Contractor shall furnish a manufacturer's certification that the materials proposed for use on the project have been pretested and will meet the requirements as set forth in the manufacturer's current literature.

The material shall not be installed in the work prior to the Engineer's approval.

Two copies of the product literature containing pertinent materials and installation data for the elastomeric concrete supplied on this project shall be furnished to the Engineer at least two weeks prior to the installation of the elastomeric concrete end dam.

Material for this work will either be one of the approved products shown on the plans or approved by the Engineer. The Contractor shall state at the Pre-construction Conference the specific material the Contractor intends to furnish and install. No other material will be considered or allowed.

CONSTRUCTION REQUIREMENTS

518.07 Waterstops. Waterstops shall be furnished full length for each straight portion of the joint, without field splices. Field splices shall have a full size tensile strength of 100 pounds per inch of width. Waterstops, when being installed, shall be cut and spliced at changes in direction as may be necessary to avoid buckling or distortion of the web or flange.

If, after placing concrete, waterstops are substantially out of position or shape, the surrounding concrete shall be removed, the waterstop reset or replaced if damaged, and the concrete replaced at the Contractor's expense.

518.08 Asphaltic Expansion Devices. The joint system shall be installed according to the manufacturer's recommendation and specifications and according to the details on the plans.

The backer rod shall be secured and sealed in the joint opening according to the manufacturer's directions.

The bridging plate shall be centered and secured over the joint opening according to the manufacturer's directions.

The joint binder, polymer modified asphalt, and aggregate shall be placed in the sequence and by the methods recommended by the manufacturer. The completed joint shall be compacted by the methods recommended by the manufacturer.

The final grade of the joint after compaction shall match the finished grade of the deck. The final thickness of the joint shall be 2.5 inches minimum.

A representative of the joint manufacturer shall be on site during the installation of each of the joint components. The representative shall certify that the joint was installed in accordance with manufacturer's recommended procedures and in accordance with the attached details. If a joint fails to meet the manufacturer's specifications, it shall be removed and replaced with a properly installed joint at the expense of the Contractor.

Two copies of the manufacturer's product literature, specifications and installation instructions shall be provided to the Engineer.

518.09 Elastomeric Expansion Devices. The Contractor shall submit working drawings as specified in subsection 105.02. The manufacturer's instructions for proper installation of the expansion joint device shall be included in the working drawings. Working drawings which lack manufacturer's installation instructions shall be returned for resubmittal.

Where applicable according to the plans, details of the expansion device through the curb, and details of the curb cover plates and connections, shall be shown on the working drawings.

At the discretion of the Engineer, the manufacturer may be required to furnish facilities for testing and inspecting of the completed device or a representative sample in the plant or at an independent test facility. The inspectors shall be allowed free access to the necessary parts of the manufacturer's plant and test facility.

The manufacturer shall provide a technical representative to be present at all times while the expansion device is being installed. The expansion device shall be installed in strict accordance with the manufacturer's written instructions and these specifications.

The expansion device shall be anchored as shown on the plans. Curb cover plates, where called for by the plans, shall be anchored to the concrete with cast-in-place inserts. Bolts shall be zinc or cadmium plated. The expansion device shall be accurately set and securely supported at the correct grade and elevation and the correct joint opening as shown on the plans and on the working drawings.

If portland cement concrete end dams are specified on the plans, the area beneath the expansion device angles shall be pressure injected by approved methods with an approved epoxy grout until all voids beneath the angles are eliminated. This shall be performed prior to the installation of the elastomeric expansion joint seal and after the concrete end dams have cured for a minimum of 120 hours.

Epoxy grout shall not be placed when the ambient temperature is 35 °F or below, or when temperatures are expected to fall to or below 35 °F at any time during the period of 12 hours following placement, unless the entire expansion device is protected from freezing by a heating enclosure.

Before the premolded elastomeric expansion joint seal is installed, the contact surfaces of the adjacent steel shall be thoroughly cleaned of mill scale and foreign material that will affect the installation or the sealing capabilities of the elastomeric expansion joint seal.

The cleaned metal surfaces shall be protected from rusting until the premolded elastomeric expansion seal and lubricant adhesive are placed against the metal surface. All cleaned metal surface on which rusting appears shall be re-cleaned at no additional expense to the State.

After the expansion joint device has been permanently installed the Contractor shall test the full length of the device for watertight integrity. The Contractor shall employ a method satisfactory to the Engineer. The entire joint system shall be covered with water, either ponded or flowing, for a minimum duration of 15 minutes. The concrete surfaces under the joint shall be inspected, during this 15 minute period and also for a minimum of 45 minutes after the supply of water has stopped, for any evidence of dripping water or moisture. Water tightness shall be interpreted to be no free dripping water on any surface on the underside of the joint. Patches of moisture shall not be cause for non-acceptance.

If the joint system exhibits evidence of water leakage at any place whatsoever, the Contractor shall locate the leakage and correct the leakage as approved by the Engineer. Subsequent to corrective measures, the watertight integrity test shall be

performed subject to the same conditions as the original test. This work and subsequent tests shall be done at the Contractor's expense. The watertight integrity test is not required for joints at the ends of approach slabs.

The words "permanently installed" as used above include completion of the portions of the curb and deck that cannot be constructed until after the expansion device is installed. This applies even though this work is to be paid for under other items of the Contract.

The Contractor shall provide written certification to the Engineer that the expansion joint device was installed in accordance with the manufacturer's instructions, the advice of their technical representative, and these specifications. Any certification from the joint manufacturer's technical representative, provided by the Contractor to the Engineer, shall be in writing.

518.10 Modular Expansion Device.

(a) The Contractor shall submit shop drawings as specified in subsection 105.02. The manufacturer's instructions for proper installation of the expansion joint device shall be included in the shop drawings.

Details of the expansion device through the curb, and details of the curb cover plates and connections, shall be shown on the shop drawings.

At the discretion of the Engineer, the manufacturer may be required to allow inspection of the completed device in the plant. The inspectors shall be allowed full access to the parts of the manufacturer's plant necessary for the fabrication and assembly of the expansion joint device. The Contractor and Engineer shall ensure that the time of inspection does not result in a delay in fabrication.

The manufacturer shall provide a technical representative to be present at all times while the expansion device is being installed. The Contractor shall notify the expansion device manufacturer of the scheduled installation a minimum of two weeks prior to the installation date.

The modular expansion joint device shall be installed in strict accordance with the manufacturer's written instructions, the advice of the manufacturer's technical representative, and these specifications. The permanently installed expansion joint device shall match exactly the finished roadway profile and grade, and specified recesses as shown on the plans.

Immediately prior to installation, the expansion joint device shall be inspected by the Engineer for proper alignment, and complete bond between the premolded elastomeric seals and the steel, and proper stud placement and effectiveness. Premolded elastomeric seals not fully bonded to the steel shall be made fully bonded at the expense of the Contractor. All bolted connections shall be checked and tightened if found to be loose.

Bends or kinks in the expansion joint device steel will not be allowed (except as necessary to follow the roadway grades). Straightening of bends or kinks will not be allowed. If an expansion joint device exhibits bends or kinks, it

shall be removed from the work site, and replaced by a new expansion joint device, at the expense of the Contractor.

The expansion joint device shall be preset by the manufacturer prior to shipment. Presetting shall be done in accordance with the joint opening at 70 ºF as indicated on the Contract Plans. Mechanical devices, supplied to set the expansion joint device to the proper width shall be disposed of by the Contractor following final adjustment for temperature.

Concrete anchorages shall be inspected visually, and shall be given a light blow with a 4 pound hammer. If an anchorage does not have a complete weld, or does not emit a ringing sound when struck with a light blow of a hammer, it shall be replaced. All anchorage replacements shall be at the expense of the Contractor.

Stainless steel sheet shall be welded to the support member. Adhesive will not be permitted.

The expansion device shall be anchored as shown on the plans. Curb cover plates shall be anchored to the concrete with cast-in-place inserts. Bolts shall be zinc or cadmium plated. The expansion device shall be accurately set for the correct joint opening and field conditions prior to placement in the blockout, and then secured at the correct grade and elevation and the correct joint opening as shown on the plans and on the shop drawings.

(b) The structure temperature shall be measured by recording the surface temperature of the concrete, steel, or both with a surface thermometer as described below.

1. *Concrete Bridges:* Record the temperature of the underside of the concrete slab at each end of the superstructure element adjacent to the expansion joint. Take the average of the readings to use with the temperature chart shown on the plans. In lieu of surface readings, internal slab readings may be taken by drilling a ¼ inch diameter hole 3 inches into the concrete slab, filling the hole with water, and inserting a probe thermometer.

2. *Steel Bridges:* Record the concrete slab temperature as described above. In addition, record the surface temperature of the shaded portion of the girder web at each location. Average the readings of the steel and concrete to use with the temperature chart.

(c) All non-galvanized metal surfaces to come in contact with the premolded elastomeric seal shall be blast cleaned in accordance with the requirements of Steel Structures Painting Council Surface Preparation Specification No. 6 (SSPC-SP6, Commercial Blast Cleaning). After cleaning, all cleaned surfaces shall exhibit a clean quality of CSA2, or better, as defined by Steel Structures Painting Council Standard SSPC-VIS l.

The cleaned metal surfaces shall be protected from rusting until the premolded elastomeric seal and lubricant adhesive are placed against the metal surface.

Any cleaned metal surface on which rusting appears shall be recleaned in accordance with the foregoing, at no additional expense to the State.

In order to perform the work of installing the expansion joint device in a proper manner, some portions of the curb and bridge deck cannot be constructed until after the expansion device is installed. After the modular expansion joint device has been set to its final line and grade, recess openings in the deck and curb shall be filled with concrete Class D or S. Grout shall be required below the support bar boxes where clearance will not allow proper consolidation of concrete Class D or S. In such cases, grout shall be placed prior to pouring concrete, and techniques utilized which will assure full support of the support bar boxes. This shall be verified by visual inspection. The grout shall be a CDOT-approved grout, and strict adherence to the grout manufacturer's instructions shall be followed. The uppermost surface of the concrete placement shall have a broom finish. The cost of this work including grout placement shall be included in the unit price bid for concrete Class D or S.

(d) After the expansion joint device has been permanently installed the Contractor shall test the full length of the device for watertight integrity. The Contractor shall employ a method satisfactory to the Engineer.

The entire joint system shall be covered with water, either ponded or flowing, for a minimum duration of 15 minutes. The concrete surfaces under the joint shall be inspected, during this 15 minute period and also for a minimum of 45 minutes after the supply of water has stopped, for any evidence of dripping water or moisture. Water tightness shall be interpreted to be no free dripping water on any surface on the underside of the joint. Patches of moisture shall not be cause for non-acceptance.

If the joint system exhibits evidence of water leakage at any place whatsoever, the Contractor shall locate the leakage and take measures to correct the leakage as approved by the Engineer. Subsequent to corrective measures, the watertight integrity test shall be performed subject to the same conditions as the original test. This work shall be done at the Contractor"s expense.

The words "permanently installed" as used above include completion of the portions of the curb and deck that cannot be constructed until after the expansion device is installed. This applies even though this work is to be paid for under other items of the Contract.

(e) The Contractor shall provide written certification to the Engineer that the expansion joint device was installed in accordance with the manufacturer's instructions, the advice of their technical representative, and these specifications. Any certification from the joint manufacturer's technical representative, provided by the Contractor to the Engineer, shall be in writing.

518.11 Elastomeric Concrete End Dam. The material supplier shall supply a representative who is completely competent in all aspects of the work, including all material and all equipment necessary to install the elastomeric concrete end dam properly.

The representative shall remain on site until the job is completed. The representative shall be responsible for:

(1) Advising the Engineer and the Contractor to insure that the correct installation method is being followed.

(2) Training assigned personnel in the correct methods of installation.

(3) Certifying to the Engineer that the material has been installed correctly.

All certifications from the supplier's representative to the Engineer shall be in writing and shall be signed and dated by the supplier's representative and the Contractor.

METHOD OF MEASUREMENT

518.12 Waterstop will be measured by the number of linear feet installed and accepted.

Asphaltic expansion devices will be measured by the number of linear feet from curb face to curb face along the joint installed and accepted.

Elastomeric expansion device will be measured by the linear foot between faces of curbs, parallel to the expansion device, completely installed, tested, and accepted. Portions of devices required in faces of curbs, including cover plates and hardware, will not be measured for payment.

Modular expansion device will be measured by the linear foot between faces of curbs, parallel to the expansion device, completely installed and accepted. Portions of devices required in faces of curbs, including cover plates and hardware, will not be measured for payment. The words "completely installed" shall be interpreted to mean the expansion joint device is in place with the following operations completed:

(1) Concrete placed and finished.

(2) Watertight integrity test performed.

Elastomeric Concrete End Dam will be measured by the cubic foot completed and accepted.

BASIS OF PAYMENT

518.13 The accepted quantities of waterstop will be paid for at the contract unit price per linear foot.

The accepted quantity of asphaltic expansion joint will be paid for at the contract unit price per linear foot and shall include all preparation materials, installation, compacting and final treatments associated with the particular joint provided.

The accepted quantity of elastomeric expansion device will be paid for at the contract unit price per linear foot and shall include all work necessary to complete the item, including furnishing and installing steel extrusions, steel angles, steel anchors, cover plates and hardware, bolts, inserts, epoxy grout, lubricant adhesive, premolded elastomeric joint seal and all miscellaneous hardware required.

The accepted quantity of modular expansion device will be paid for at the contract unit price per linear foot and shall include all work necessary to complete the items, including furnishing and installing modular expansion device, steel angles, concrete anchorages, cover plates and hardware, bolts, inserts, lubricant adhesive and all miscellaneous hardware required.

The accepted quantity of Elastomeric Concrete End Dam will be paid for at the contract unit price per cubic foot and shall include all work and materials necessary to complete the item including saw cutting existing asphalt pavement, removing asphalt pavement, light sandblasting of existing concrete and any existing steel, and all miscellaneous work required.

Payment will be made under:

Pay Item	**Pay Unit**
Waterstop (Inch)	Linear Foot
Bridge Expansion Device (2 Inch)	Linear Foot
Bridge Expansion Device (0 - 4 Inch)	Linear Foot
Bridge Expansion Device (0 - __Inch)	Linear Foot
Elastomeric Concrete End Dam	Cubic Foot