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 A857, 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.

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SECTION 502
PILING

DESCRIPTION

502.01 This work consists of furnishing and driving foundation piles, other than sheet piling.

MATERIALS

502.02 Rolled Structural Steel Piles. Steel used in rolled structural steel piles shall conform to the requirements of ASTM A572/A572M or ASTM A992/A992M. Sections of piles shall be of "H" or "W" shape. The flange projection shall not exceed 14 times the minimum thickness of metal in either the flange or the web, and flange widths shall not be less than 80 percent of the depth of the section. The nominal depth in the direction of the web shall not be less than 8 inches. Flanges and web shall have a minimum nominal thickness of 0.375 inches or greater.

502.03 Steel Pipe Piles. Steel pipe piles shall conform to the requirements of ASTM A252, Grade 2 or higher. Ends of closed-end pipe piles shall be closed with a flat plate, forged or cast steel conical point, or other end closure design approved by the Engineer. End plates used on closed-end pipe piles shall be made of ASTM A36/A36M steel or better. End plates shall have a minimum thickness of 0.75 inches. The diameter and thickness of the end plates shall be as shown on the plans. The end plate shall be cut flush with the outer pile wall. The end of the pipe shall be beveled before welding to the end plate using a partial penetration groove weld.

502.04 Protective Coatings. If there is a required protective coating, the Contractor shall restore or repair any damage to the coating.

CONSTRUCTION REQUIREMENTS

502.05 Pile Driving Equipment. All equipment, including the pile driving hammer, hammer cushion, helmet, pile cushion, and other appurtenances to be furnished by the Contractor shall be approved in advance by the Engineer before any driving can begin. Pursuant to obtaining this approval, the Contractor shall submit a description of pile driving equipment to the Engineer at least two weeks before pile driving is to begin. The description shall contain sufficient detail so that the proposed driving system can be evaluated by wave equation analysis. The Contractor shall submit to the Engineer results of a wave equation analysis to show that the piles are drivable.

Hammer efficiencies shown in Table 502-1 shall be used in the wave equation analysis of vertical piles unless better information is available. Hammer efficiencies shall be adjusted for batter driving.

Table 502-1

Hammer Type	Hammer Efficiency (%)
Single-acting steam/air	67
Double-acting steam/air	50
Diesel	80
Hydraulic or diesel with built-in energy measurement	90

For steam, air, and diesel hammers, a minimum manufacturer's rated energy for specific HP Piles sizes shall be used as shown in Table 502-2.

Table 502-2

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 2,500 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.

The criteria that the Contractor and the Engineer will use to evaluate the driving equipment shall consist of both the required number of hammer blows per foot at the required nominal resistance and the pile driving stresses over the entire driving process. The required number of hammer blows indicated by the wave equation analysis at the required nominal driving resistance shall be between 30 and 120 blows per foot for the driving equipment to be deemed acceptable.

In addition, the piles stresses, which are determined by the wave equation analysis for the entire driving operation, shall not exceed 90 percent of the yield point of the steel pile material.

During pile driving operations, the Contractor shall use the approved system. Any change in the driving system shall be considered only after the Contractor has submitted revised pile driving equipment data and wave equation analysis. The Contractor shall be notified of the acceptance or rejection of the driving system changes within two working days of the Engineer's receipt of the requested change. The time required for submission, review, and approval shall not constitute the basis for a contract time extension to the Contractor.

Approval of the piling driving equipment shall not relieve the Contractor of responsibility to drive piles, free of damage, to the required nominal resistance and, if specified, the minimum penetration, shown in the contract documents.

(a) *Pile Hammers.* Steam, air, diesel, or hydraulic impact hammers shall be used to drive all types of piles.

1. Single or Double Acting Steam and Air Hammers

   Proximity switches and an electronic readout device shall be provided prior to driving piling. Hammer performance shall be evaluated by the Contractor at the end of driving each pile by measuring blows per minute and comparing these blows with the manufacturer's recommendations.

2. Diesel Hammers

   If open-end (single-acting) diesel hammers are not equipped with a device to measure impact velocity at all times during pile driving operations, the stroke shall be obtained by the Contractor by measuring the speed of operation either manually or with a device that takes the measurement automatically.

   Closed-end double acting diesel hammers shall be equipped with an accurate bounce chamber pressure gauge. The Contractor shall provide the Engineer a calibrated chart equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer to be used. A copy of calibration records of actual hammer performance performed within 90 days prior to the beginning of the work shall be submitted to the Engineer.

3. Hydraulic Hammers

   Hydraulic hammers shall be equipped with a controlled variable stroke system and a readout device to measure ram energy. The plant and equipment shall be equipped with accurate pressure and velocity gauges and an energy readout device.

4. Vibratory Hammers

   Vibratory or other pile driving methods may be used only when specified in the Contract or in writing by the Engineer. Except when pile lengths have been evaluated from static load test piles, the nominal driving resistance of piles driven with vibratory hammers shall be verified by additional driving of the first pile driven in each group of 10 piles with an impact hammer of suitable energy to measure the nominal resistance before driving the remaining piles in the group. In case of variable soils, additional piles shall be verified by an impact hammer as directed by the Engineer. All piles that rely primarily on point bearing capacity shall be re-driven with an impact hammer.

(b) *Hammer Cushion.* All impact pile driving equipment 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 recommended by the hammer manufacturer shall be used. 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) *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 ensure 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.

(d) *Followers.* Followers shall be used only when specified on the plans or approved in writing by the Engineer. The follower and pile shall be maintained in proper alignment during driving. The follower shall be of such material and dimensions to permit the piles to be driven to the blow count determined to be necessary.

(e) *Jetting.* Jetting is permitted only if specified in the Contract or approved in writing by the Engineer. The Contractor shall determine the number of jets and the volume and pressure of water at the jet nozzles necessary to freely erode the material adjacent to the pile.

The Contractor shall control and dispose of all jet water in accordance with subsection 107.25. If jetting is specified or approved by the Engineer and is performed according to the specifications or as approved by the Engineer, the Contractor shall not be held responsible for any damage to the site caused by jetting operations. If jetting is used for the Contractor's convenience, the Contractor shall be responsible for all damages to the site caused by jetting operations.

Unless otherwise specified by the Engineer or the Contract, jet pipes shall be removed before or when the pile tip is 5 feet above the minimum or final tip elevation, and the pile shall be driven with an impact hammer, without jetting, to the final tip elevation or to the required nominal resistance. If the required nominal resistance is not reached at the final tip elevation, the pile may be set up and the required nominal resistance will be determined by re-striking the pile.

502.06 Driving Piles. Piles shall not be driven until required excavation or fill placement 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 1/4 inch or less per foot from the vertical or from the batter shown on the plans. The tendency of steel piles to twist or rotate shall be prevented and corrected. Foundation piles shall be within 6 inches of the position shown on the plans after driving. No pile shall be closer than 4 inches from an edge of the pile cap. Pulling or pushing laterally on installed piles to correct misalignment, or splicing a properly aligned section on a misaligned section will not be allowed. The at cutoff elevation shall be within 2 inches of plan elevation for bent caps supported by piles.
Piles driven at integral end bents shall be installed so that the axial alignment of the top 10 feet of the pile is within two percent of the specified alignment.

The order of placing individual piles within a pile group shall begin from the center of the group and proceed outward in both directions unless an alternate installation sequence is approved by the Engineer in writing. For a bent with a single row of piles, pile driving shall begin at one end of the bent and proceed toward the opposite end.

If the location or alignment tolerances are exceeded, the extent of overloading shall be investigated. If the Engineer determines that corrective measures are necessary, such corrective measures shall be designed and constructed by the Contractor. Proposed corrective measures will be subject to approval by the Engineer.

502.07 Predrilling to Facilitate Pile Driving. Drilled holes shall be 2 inches smaller than the diameter or diagonal of the pile cross section. If subsurface obstructions, such as boulders or rock layers, are encountered, the hole diameter may be increased to the least dimension which is adequate for pile installation. Except for end bearing piles, drilling shall be stopped at least 5 feet above the pile tip elevation shown on the plans. The pile shall then be driven with an impact hammer to the specified penetration resistance. Where piles are to be end bearing on rock or very dense cobbles and gravels (hardpan), drilling may be carried to the surface of the rock or the hardpan. The piles shall then be driven with an impact hammer to ensure proper seating. Any void space remaining around the pile after completion of driving shall be filled with sand, pea gravel, concrete, or other materials as specified in the Contract. If the diameter of the drilled hole is exceeded due to sloughing, drifting, over-drilling, or other causes, additional material required to fill this added void area will be 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.

When test piles are shown on the plans they shall be used to determine if drilling or jetting holes to facilitate pile driving is required. If the test pile or piles do not reach the minimum tip elevation shown on the plans and do not develop the required nominal resistance as specified in subsection 502.09, holes shall be drilled or jetted to facilitate pile driving.

502.08 Filling and Capping Piles. Steel pipe piles will be inspected after all adjacent piles within a 5-foot radius have been driven. Before concrete is placed in the pipe pile, it shall be inspected by an acceptable method to confirm the full pile length and dry bottom condition. If accumulations of water in the pipe piles are present, the water shall be removed before the concrete is placed. The concrete for concrete-filled pipe piles shall be Class BZ and shall conform to the requirements of section 601.

Concrete shall be placed in each pipe pile in a continuous operation. No concrete shall be placed until all driving within a radius of 15 feet of the pipe pile has been completed, or all driving within a 15-foot radius shall be discontinued until the concrete in the last pipe pile cast has set for at least two days.

502.09 Determination of Nominal Driving Resistance. The Engineer will use one of the following methods as specified to determine the nominal driving resistance of a driven pile.

(a) *Wave Equation Analysis.* The Engineer will use a wave equation analysis to determine the driving criterion necessary to reach the required nominal driving resistance of the pile. Soil and pile properties to be used in this analysis shall be as shown in the Contract or as determined by the Engineer. The Contractor shall supply the Engineer the necessary information on the proposed driving equipment to perform the wave equation analysis.

(b) *Dynamic Testing.* The length of the pile used in the dynamic test shall be a minimum of 10 feet greater than the estimated length of production piles in order to provide for variation in soil conditions. Dynamic monitoring shall be performed to obtain the nominal driving resistance, pile driving stresses, pile integrity, pile driving system performance, and final driving criteria. Dynamic monitoring shall be conducted by Pile Driving Analyzer (PDA) in accordance with ASTM D4945. PDA shall be performed on the first pile driven to the plan requirements.

A minimum of one production pile per bent (abutment or pier foundation) shall be monitored as a test pile. Dynamic monitoring shall be conducted by the Contractor's Engineer. The Contractor’s Engineer conducting the PDA shall be a licensed Professional Engineer who has achieved one of the following certification levels: intermediate, advanced, master, or expert through the Dynamic Measurement and Analyses Proficiency Test conducted by Pile Dynamics, Inc., and the Pile Driving Contractors Association. A Contractor’s Engineer with a lower certification level than intermediate can provide dynamic monitoring as long as this individual is under the direct supervision of an Engineer with intermediate certification level or higher.

The Contractor shall notify the Project Engineer at least seven calendar days before the scheduled date of driving piles to be monitored by PDA. The Contractor shall confirm the driving date three calendar days prior to the scheduled driving date. The Contractor shall indicate at which foundation production pile driving is to begin. The Contractor’s Engineer conducting the PDA will provide final driving criteria for the indicated foundation.

Each pile to be tested shall be instrumented with force and acceleration transducers. The transducers shall be installed before striking the pile. The pile driving may need to be temporarily interrupted for the transducers to be adjusted or replaced, or for the monitoring results to be assessed.

The Contractor shall drive the test pile to the minimum tip elevation and to the penetration depth at which the dynamic test equipment indicates that the nominal driving resistance shown on the plans has been achieved. The Contractor may reduce the driving energy transmitted to the pile by using additional cushions or reducing the energy output of the hammer in order to maintain stresses below the value shown in subsection 502.05. If non-axial driving is indicated by the dynamic test equipment measurements, the Contractor shall immediately realign the hammer system.

If restriking is specified in the Contract documents, the Contractor shall wait at least one hour prior to the restriking of the test pile. The hammer shall be warmed up before restriking begins by applying at least 20 blows to another pile or other fixed object. The maximum amount of penetration required during restrike shall be 3 inches, or the total number of hammer blows shall be 20, whichever occurs first. If the pile does not achieve the required nominal driving resistance during restrike, the Contractor’s Engineer conducting the PDA shall specify additional pile penetration and testing.

If the required nominal driving resistance 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 Contractor’s Engineer conducting the PDA may direct the driving to be continued for 40 additional blows.

Once the dynamic monitoring is complete, the Contractor’s Engineer conducting the PDA shall run Case Pile Wave Analysis Program (CAPWAP) analyses and shall provide the final driving criteria the same day of the test to the Engineer. Production piles driven prior to receipt of the final driving criteria shall be done at the Contractor’s risk. Final driving criteria for additional structures shall be provided within two business days of the test or when multiple test piles are dynamically tested the same day. A detailed report electronically sealed by the Contractor’s Engineer conducting the PDA shall include the pile driving criteria with the PDA and CAPWAP results and shall be submitted to the Engineer for acceptance within two business days after the dynamic monitoring.

If changes are made to the pile driving system (hammer, fuel setting, piling, cushioning, etc.) after the dynamic monitoring

has been completed and driving criteria established, new driving criteria shall be determined using the PDA. New criteria shall be determined at the Contractor's expense. If the Engineer requests additional piles to be monitored, pile monitoring will be paid for in accordance with subsection 502.16.

(c) *Static Load Test.* If a static load test is used to determine the pile axial resistance, the test shall not be performed less than five days after the test pile was driven unless approved by the Engineer or otherwise specified in the Contract. The static load test shall follow the procedures specified in ASTM D1143/D1143M, and the loading procedure shall follow the Quick Load Test Method, unless detailed longer-term load-settlement data are needed, in which case the standard loading procedure shall be used. Testing equipment and measuring systems shall conform to ASTM D1143/D1143M.

The Contractor shall submit detailed documents for the proposed loading apparatus, prepared by a Licensed Professional Engineer, to the Engineer for review. The submittal shall include calibrations for the hydraulic jack, load cell, and pressure gauge conducted within 30 days before mobilization to the job site. Tension (anchor) piles that will later be used as permanent piles in the work shall be of the same type and size as the production piles, and shall be driven at the same time as the test pile in the location of permanent piles where feasible.

While performing the static load test, the Contractor shall provide safety equipment and employ adequate safety procedures. Adequate support for the static load test plates, jack, and ancillary devices shall be provided to prevent them from falling in the event of a release of load due to hydraulic failure, test pile failure, or other cause.

The method of defining failure of the static load test shall be as defined in the Contract. Based on the static load and dynamic test results, the Contractor's Engineer conducting the PDA will provide the final driving criteria for production pile acceptance.

When specified, tension static load tests shall be conducted in accordance with ASTM D3689. When specified, lateral load tests shall be conducted in accordance with ASTM D3966.

502.10 Nominal Driving Resistance of Production Piles Production piles shall be driven to the depth necessary to obtain the required nominal driving resistance as determined by subsection 502.09. If a minimum pile tip elevation is shown on the plans, in addition to obtaining the required nominal driving resistance, production piles shall also be driven to the minimum pile tip elevation.

When the nominal driving resistance is determined in accordance with subsection 502.09(a) or subsection 502.09(b) for acceptance, the Engineer will record the blow count per inch or foot of pile movement and the associated hammer stroke for the last two consecutive feet of driving, and the final pile tip elevation as per the pile driving criteria established through the wave equation analysis or dynamic test.

Practical refusal will be defined as 10 blows per inch of penetration for a maximum of three consecutive inches of pile penetration and with the hammer operated at its maximum fuel or energy setting, or at a reduced fuel or energy setting recommended by the Engineer based on pile installation stress control and less than 1/4 inch rebound per blow. The Contractor shall stop driving as soon as the Engineer determines that the pile has reached practical refusal.

Absolute refusal is defined as 20 blows for 1 inch or less of pile penetration. Driving shall terminate immediately if this criterion is achieved. In the case of hard rock, an absolute refusal criterion of 5 blows per 1/4 inch or 10 blows per 1/2 inch should be adopted to reduce the risk of pile toe or driving equipment damage.

The nominal driving resistance of jetted piles shall be based on impact driving penetration resistance after the jet pipes have been removed. Jetted piles not attaining the nominal driving resistance at the ordered length shall be spliced and driven with an impact hammer until the nominal driving resistance is achieved in accordance with the driving criteria in subsection 502.09.

502.11 Piling Length. The lengths of piles shown on the plans and in the Schedule of Pay Items are estimated lengths and are for bidding purposes only. Piles may be ordered in plan lengths or standard production lengths. The Contractor shall provide the actual length of piles necessary to obtain the nominal driving resistance and penetration depth required as determined from results obtained from driving representative test piles or other pertinent data. There will be expected variations in final tip elevations due to differences in nominal pile driving resistance. The final tip elevation of each pile shall be determined during the driving operation.

A minimum pile penetration of 10 feet below the bottom of the footing elevation 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 minimum tip elevations are specified, the Contractor shall drive piles to a penetration depth that satisfies this requirement in addition to the nominal driving resistance. If the pile cannot be driven to the minimum tip elevation, the Engineer will

determine if pre-drilling is required.

Water jets may be used in conjunction with the hammer to obtain the specified penetration only with approval by the Engineer. The last 5 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 shall not modify any of the requirements of this specification.

502.12 Extensions and Splices. When the American Welding Society (AWS) D1.1 Structural Welding Code is cited in this section, it shall be the current edition.

Full length piles shall be used where practicable. The number of splices shall be kept to a minimum. Commercially available splices may be used if approved by the Engineer.

All welded splices shall be partial joint penetration (PJP) unless designated otherwise on the plans. All welded splices shall be made by using a prequalified joint designation in accordance with AWS D1.1. The CJP design shall include beam copes (weld access holes) through the web of the pile at the junctures with the flanges. Copes shall be made in accordance with AWS D1.1, section 5.17. If backing is used it shall be in accordance with AWS D1.1. Removal of the backing after welding is not required.

Personnel performing welding inspection shall be a certified welding inspector (CWI) in accordance with AWS D1.1, Chapter 6. All welded pile splices shall be made in accordance with a written Welding Procedure Specification (WPS) that shall be reviewed, and approved by the Contractor's CWI, prior to welding any piling splices on the project. The WPS shall list all essential variables of the process in accordance with AWS D1.1. The WPS shall be available for review by the Engineer.

All welded splices shall be made with low hydrogen electrodes. The Contractor shall adhere to the low hydrogen practice for electrodes in accordance with AWS D1.1.

All cuts at splices shall 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.

All welders shall be currently qualified in accordance with AWS D1.1. Welder qualifications shall be approved by the Contractor's CWI prior to the start of welding. The welder shall be requalified if any essential variables listed in AWS D1.1 are not met.

The Contractor shall provide an AWS Certified Welding Inspector (CWI) on the project site for quality control. The CWI shall inspect all production stages of the welded splice, including assembly of the splice joint, during welding, and after welding to ensure that workmanship and materials meet the requirements of the Contract. The CWI shall submit a record of all weld inspection documentation to the Engineer.

The Contractor's inspector performing UT testing of CJP splices shall be qualified in accordance with the current edition of the American Society for Nondestructive Testing Practice No. SNT-TC-1A. Individuals who perform nondestructive testing shall be qualified for NDT Level II.

The first two CJP welded splices shall be ultrasonically tested (UT) for acceptance in accordance with Table 6.3 of AWS D1.1. If both of the UT tested CJP splices are determined to be acceptable, no further UT testing of CJP splices will be required. If either of the first two UT tested CJP splices are not acceptable, UT testing of CJP splices shall continue until two consecutive tests are acceptable.

502.13 Defective Piling. Piles damaged in driving by reasons of internal defects or improper driving shall be corrected 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.

Piles driven below the specified butt elevation shall be corrected by one of the following approved methods:

(1) The pile is spliced or built up as otherwise provided herein.

(2) A sufficient portion of the footing is extended down to properly embed the pile.

A pile driven out of its proper location in accordance with subsection 502.06 shall be corrected by one of the following methods:

(1) One or more replacement piles are driven next to the out-of-position piles.

(2) The footing is extended laterally to incorporate the out-of-location pile.

(3) Additional reinforcement is added.

All such remedial materials and work shall be approved by the Engineer and furnished and performed at the Contractor's expense.

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

502.14 Pile Tips. If difficult driving conditions are encountered, the Engineer may direct the Contractor to furnish and attach pile tips even though tips are not required on the plans.

METHOD OF MEASUREMENT

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

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.

Partial Joint Penetration (PJP) welded splices for piles, when specified on the plans, will be measured as additional length of pile. The additional length for each PJP splice will be measured as follows: steel "H" piles, 3 linear feet; steel pipe piles, 3 linear feet. CJP welded splices, when specified in the plans, will be the actual number completed and accepted per splice.

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

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

BASIS OF PAYMENT

502.16 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
Drilling Hole to Facilitate Pile Driving	Linear Foot
End Plate	Each
Pile Tip	Each
Dynamic Pile Test	Each
Static Pile Load Test	Each
Complete Joint Penetration (CJP) Splice	Each

All costs for providing Certified Welding Inspector (CWI) services for Partial Joint Penetration (PJP) welded splices shall be included in the additional measured length of pile in accordance with subsection 502.12.

Complete Joint Penetration (CJP) splices shall be paid for at the contract unit price for each completed and accepted CJP Splice. All costs for completing the CJP welded splices including, but not limited to, Ultrasonic Testing, Certified Welding Inspector (CWI) services, and required documentation shall be included in the price per each for Complete Joint Penetration (CJP) Splice.

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

Steel 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 109.04.

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

SECTION 503
DRILLED SHAFTS

DESCRIPTION

503.01 This work consists of furnishing all materials, labor, tools, equipment, services and incidentals necessary to construct the drilled shafts (also referred to as drilled caissons, drilled piers, cast-in-place-drilled-holes, or cast-in-situ piles) in accordance with the Contract Documents and this Specification.

SUBMITTALS AND MEETINGS

503.02 Submittals. At least 30 days prior to the start of drilled shaft construction, the Contractor shall submit to the Engineer an electronic file of a project reference list verifying the successful completion by the Contractor of at least three separate foundation projects within the last five years with drilled shafts of similar size (diameter and depth) and construction difficulty to those shown on the Plans in similar subsurface geotechnical conditions. A brief description of each project and the project owner's contact name and current phone number shall be included for each project listed. Work shall not begin until all required submittals have been received by the Engineer.

(a) *Experience and Personnel.* The personnel assigned to the project shall have the following minimum experience:

(1) On-site supervisors shall have a minimum of two years of experience in supervising construction of drilled shaft foundations of similar size (diameter and depth) and installation method to those shown on the Plans and similar geotechnical conditions to those described in the geotechnical report. The work experience shall be direct supervisory responsibility for the on-site drilled shaft construction operations. Project management level positions indirectly supervising on-site drilled shaft construction operations are not acceptable for this experience requirement.

(2) Drill rig operators shall have a minimum of one year of experience in construction of drilled shaft foundations.

The Engineer may request a list identifying on-site supervisors and drill rig operators assigned to the project for review. The list shall contain a detailed summary of each individual's experience in drilled shaft excavation operations. The Contractor shall inform the Engineer in writing of changes to field personnel.

(b) *Drilled Shaft Installation Plan.* At least 30 days prior to the start of drilled shaft construction the Contractor shall submit an electronic file of a Drilled Shaft Installation Plan narrative. In preparing the narrative, the Contractor shall reference the available subsurface geotechnical data provided in the Contract and any geotechnical reports prepared for this project. This narrative shall provide at a minimum the following information:

(1) Description of overall construction operation sequence and the sequence of drilled shaft construction when in groups or lines.

(2) A list, description, and capacities of proposed equipment including but not limited to cranes, drills, augers, bailing buckets, final cleaning equipment and drilling unit. As appropriate, the narrative shall describe why the equipment was selected and suitability to the anticipated site and subsurface conditions.

(3) Details of drilled shaft excavation methods, including proposed drilling methods, methods for cleanout of the bottom of the excavation hole and a disposal plan for excavated material including drilling slurry (if applicable). This shall include means and methods to address subsurface geotechnical conditions including boulder and obstruction removal techniques if such are indicated in the Contract subsurface geotechnical information or Contract Documents.

Details of the methods to be used to ensure drilled shaft hole stability (i.e., prevention of caving, bottom heave, etc. using temporary casing, slurry, or other means) during excavation and concrete placement.

(4) Detailed procedures for mixing, using, maintaining, storing, and disposing of the slurry shall be provided if applicable. A detailed mix design (including all additives and their specific purpose in the slurry mix) and a discussion of its suitability to the anticipated subsurface geotechnical and site conditions shall also be provided for the proposed slurry.

(5) The submittal shall include a detailed plan for process control of the selected slurry including property tests, test methods, and minimum and/or maximum property requirements which must be met to ensure that the slurry functions as intended for the anticipated subsurface conditions and shaft construction methods in accordance with the slurry manufacturer's recommendations and these specifications.

(6) When casings are proposed or required, casing dimensions and detailed procedures for casing installation, removal, advancing the casing, and excavating the drilled shaft hole in accordance with subsection 503.13(b) shall be provided.

When removing casing, detail the method to extract the casing to maintain shaft reinforcement in proper alignment and keep concrete workable during casing extraction.

(7) Details of concrete placement including proposed equipment and procedures for delivering concrete to the drilled shaft, placement of the concrete into the shaft, placement and raising of the tremie or pump line during placement, size of tremie and pump lines, operational procedures for pumping, and a sample uniform yield form to be used by the Contractor for plotting the volume of concrete placed versus the depth of shaft for all shaft concrete placement. Describe the method to be used to form a horizontal construction joint during concrete placement. Include details of procedures to prevent loss of slurry or concrete into waterways, and other areas to be protected.

(8) Describe the method and materials that will be used to fill or eliminate all voids below the top of shaft between the plan shaft diameter and excavated shaft diameter, or between the shaft casing and surrounding soil if permanent casing is specified.

(9) Details of any required load tests or shaft integrity tests including equipment, instrumentation, procedures, calibration data for test equipment, calculations and drawings.

(10) Details and procedures for protecting existing structures, utilities, roadways and other facilities during drilled shaft installation.

(c) *Slurry Technical Assistance.* If slurry is to be used to construct the drilled shafts, the Contractor shall provide or arrange for technical assistance from the slurry manufacturer as specified in subsection 503.13(b)5(1). The Contractor shall submit three copies of the following to the Engineer at least 14 days prior to the start of drilled shaft construction:

(1) The name and current phone number of the slurry manufacturer's technical representative assigned to the project.

(2) The names of the Contractor’s personnel assigned to the project and trained by the slurry manufacturer’s technical representative in the proper use of the slurry. The submittal shall include a signed training certification letter from the slurry manufacturer for each individual including the date of the training.

(d) *Logs of Shaft Construction.* The Contractor’s Quality Control staff shall prepare inspection logs using CDOT Form 1333 – Inspector’s Report of Caisson Installation documenting each shaft construction activity. In addition, the Contractor shall prepare and submit the logs documenting any subsurface investigation borings or rock core holes performed by the Contractor at drilled shaft foundation locations.

In addition to the information required on the Form 1333, the Contractor shall provide the following information: type and dimensions of tools and equipment used, any changes to the tools and equipment; type of drilling fluid if used, the results of slurry tests, any problems encountered, and method used for bottom cleaning.

In addition to the information required on the Form 1333, concrete placement records shall include at least the following information: tremie tip elevation during concrete placement, and concrete yield curve (volume versus concrete elevation, actual and theoretical).

A complete set of shaft inspection logs for an individual drilled shaft shall be submitted to the Engineer within 48 hours of the completion of concrete placement at the shaft.

503.03 Meetings The Engineer will evaluate the Drilled Shaft Installation Plan for conformance with the Contract within ten working days after receipt of the submission. At the option of the Department, a Shaft Installation Plan Submittal Meeting may be scheduled following review of the Contractor’s initial submittal of the Plan. Those attending the Shaft Installation Plan Submittal Meeting, if held, shall include the following: The superintendent, on-site supervisors, and other Contractor personnel involved in the preparation and execution of the Drilled Shaft Installation Plan.

(1) The Project Engineer and Owner’s personnel involved with the structural, geotechnical, and construction review of the Drilled Shaft Installation Plan together with Owner’s personnel who will provide inspection and oversight during the drilled shaft construction phase of project.

The Contractor shall submit to the Engineer updates or modifications to the Drilled Shaft Installation Plan whenever such updates or modifications are proposed. The Engineer will evaluate the new information for conformance with the Contract Plans and Specifications and respond within ten working days after receipt of the submission.

A shaft Pre-construction meeting shall be held at least five working days prior to the Contractor beginning any shaft construction work at the site to discuss investigative boring information, construction procedures, personnel, and equipment to be used, and other elements of the accepted Shaft Installation Plan as specified in subsection 503.02(b). If slurry is used to construct the shafts, the frequency of scheduled site visits to the project site by the slurry manufacturer’s representative shall be discussed. Those attending shall include:

(2) The superintendent, on-site supervisors, and other key personnel identified by the Contractor as being in charge of excavating the shaft, placing the casing and slurry as applicable, placing the steel reinforcing bars, and placing the concrete. If slurry is used to construct the shafts, the slurry manufacturer's representative and a Contractor's employee trained in the use of the slurry, as identified to the Engineer in accordance with subsection 503.04(c)4(1), shall also attend.

The Engineer, key inspection personnel, and appropriate representatives of the Department. If the Contractor's key personnel change, or if the Contractor proposes a significant revision of the approved Drilled Shaft Installation Plan, an additional conference may be held at the request of the Engineer before any additional shaft construction operations are performed.

503.04 Control and Disposal of Materials.
The Contractor shall collect and properly dispose offsite all slurry and water displaced during final cleaning and concrete placement. Open pits for collection of materials may be allowed during construction activities for later disposal. Control all excavated material, slurry, water, and other matter so that at no time it enters or encroaches upon the adjacent travel lanes, railroad, water ways, and environmentally sensitive or restricted areas as shown on the plans. All environmental regulations for handling, discharge, and disposal of all construction materials shall be followed.

MATERIALS

503.05 Concrete. Concrete used in the construction of drilled shafts shall be Class BZ in accordance with Section 601. If the concrete does not meet the requirements of Section 601, price reductions shall be applied to the drilled caisson pay item. The Contractor may elect to use Self Consolidating Concrete (SCC) Class BZ.

503.06 Reinforcing Steel. Reinforcing steel shall be in accordance with Section 602. When necessary, vertical bars shall be bundled in order to maximize clear space between vertical reinforcement. Rolled hoops or bundled spirals shall be used in order to maximize the clear space between horizontal reinforcement. Reinforcing steel cages for drilled shafts with varying shaft and socket diameters shall be designed with a single, uniform diameter. At all times, the reinforcing bars and fabricated steel reinforcing cage shall be supported off the ground surface and shall be protected from contamination of mud, oils and solvents, and other deleterious materials. The steel shall be free of excessive rust (flaking, peeling, and thick coating) at the time of cage placement into the hole. Any contamination or excessive rust shall be cleaned and removed by the Contractor to the Engineer's acceptance prior to placement.

503.07 Casings. All permanent structural casing shall be of steel conforming to ASTM A36/A36M or ASTM A252 Gr 2 unless specified otherwise on the Plans. All splicing of permanent structural casing shall be in accordance with Section 6.13.3, "Welded Connections," of the AASHTO LRFD Bridge Design Specifications, which includes AASHTO/AWS D 1.5M/ D 1.5 Bridge Welding Code. All casing shall be watertight and clean prior to placement in the excavation. Where the minimum thickness of the casing is specified on the Plans, it is specified to satisfy structural design requirements only. The Contractor shall increase the casing thickness from the minimum specified thickness, as necessary and accepted by the Engineer, to satisfy the construction installation requirements.

All permanent casing shall be of ample strength to resist damage and deformation from transportation and handling, installation stresses, and all pressures and forces acting on the casing. For permanent nonstructural casing, corrugated casing may be used. The diameter of permanent casing shall be as shown on the Plans unless a larger diameter casing is approved by the Engineer. When a larger size permanent casing is approved by the Engineer, no additional payment will be made for the increased weight of casing steel or the increased quantity of drilled shaft excavation and concrete.

All temporary casing shall be a smooth wall structure steel except where corrugated metal pipe is shown on the Plans as an acceptable alternative material. All temporary casing shall be of ample strength to resist damage and deformation from transportation and handling, installation and extraction stresses, and all pressures and forces acting on the casing. The casing shall be capable of being installed and removed without deforming and causing damage to the completed shaft and without disturbing the surrounding soil. Temporary casing shall be completely removed, unless otherwise shown on the Plans or approved by the Engineer. The outside diameter of temporary casing shall not be less than the specified diameter of the shaft.

503.08 Mineral Slurry. Mineral Slurry shall be used in accordance with the quality control plan specified in subsection 503.02(b)(5).

Mineral slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64.3 to 72
Viscosity (seconds/quart)	Marsh Funnel and Cup API 13b-1, Section 2.2	28 to 50
pH	Glass Electrode, pH Meter, or pH Paper	8 to 11
Sand Content (%)	API 13B-1, Section 5	4.0 max immediately prior to placing concrete

503.09 Polymer Slurry. Polymer slurries, either natural or synthetic, shall be used in accordance with the manufacturer's recommendations, and shall conform to the quality control plan specified in subsection 503.02(b)(5). The polymer slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64.3 max
Viscosity (seconds/quart)	Marsh Funnel and Cup API 13b-1, Section 2.2	32 to 135
pH	Glass Electrode, pH Meter, or pH Paper	8 to 11.5
Sand Content (%)	API 13B-1, Section 5	1.0 max immediately prior to placing concrete

The sand content of polymer slurry prior to final cleaning and immediately prior to placing concrete shall be less than or equal to 1.0 percent, in accordance with American Petroleum Institute API 13B-1, Section 5. Slurry temperature shall be at least 40 °F when tested.

503.10 Water Slurry. Water may be used as slurry when casing is used for the entire length of the drilled hole, or to stabilize the bedrock below the temporary casing provided that the method of drilled shaft installation maintains stability at the bottom of the shaft excavation. Water slurry shall conform to the following requirements:

Property	Test	Requirement
Density (pcf)	Mud Weight (Density) API 13B-1, Section 1	64 max
Sand Content (%)	API 13B-1, Section 5	1.0 max

503.11 Access Tubes for CSL Testing. Access tubes for CSL testing shall be steel pipe of 0.145-inch minimum wall thickness and at least 1.5 inches inside diameter. The access tubes shall have a round, regular inside diameter free of defects and obstructions, including all pipe joints, in order to permit the free, unobstructed passage of 1.3 inches' maximum diameter source and receiver probes used for the CSL tests. The access tubes shall be non-galvanized, watertight, free from corrosion, and with clean internal and external faces to ensure good bond between the concrete and the access tubes. The access tubes shall be fitted with watertight threaded caps on the bottom and the top. Grout for filling the access tubes at the completion of the CSL tests shall be a neat cement grout with a maximum water/cement ratio of 0.45. Drilled shafts for structures as shown on the CDOT S-Standard drawings shall be excluded from this testing, except as noted on the plans.

CONSTRUCTION REQUIREMENTS

503.12 Drilled Shaft Excavation. The excavation and drilling equipment shall have adequate capacity, including power, torque and down pressure to excavate a hole of both the maximum diameter and to a depth of 20 feet or 20 percent beyond the maximum shaft length shown on the Plans, whichever is greater. Blasting will only be permitted if specifically stated on the Plans or authorized in writing by the Engineer. Once the excavation operation has been started, the excavation shall be conducted in a continuous operation until the excavation of the shaft is completed except for pauses and stops. Pauses or interruptions during this excavation operation will not be allowed except for casing installation, casing splicing and removal of materials or obstructions. Drilled shaft excavation operation interruptions not conforming to this definition shall be considered stops. The Contractor shall provide temporary casing at the site in sufficient quantities to meet the needs of the construction method.

If the drilled shaft excavation is not complete at the end of the shift or series of continuous shifts, the drilled shaft excavation operation may be stopped provided the Contractor protects the shaft as indicated in subsection 503.13(b) before the end of the work day.

If slurry is present in the shaft excavation, the Contractor shall conform to the requirements of subsection 503.13 (b)5(2) regarding the maintenance of the minimum level of drilling slurry throughout the stoppage of the shaft excavation operation, and shall recondition the slurry to the required slurry properties in accordance with subsections 503.09, 503.10, and 503.11 prior to recommencing shaft excavation operations.

Sidewall over-reaming shall be performed when the time for shaft excavation exceeds 24 hours (measured from the beginning of excavation below the casing when casing is used). Sidewall over-reaming shall also be performed when the sidewall of the hole is determined by the Engineer to have softened due to the excavation methods, swelled due to delays in the start of concrete placement, or degraded because of slurry cake buildup. Over-reaming thickness shall be a minimum of 1/2-inch or as directed by the Engineer. Over-reaming may be accomplished with a grooving tool, over-reaming bucket, or other equipment approved by the Engineer. If over-reaming is required as a result of the excavation time exceeding the time limit specified herein, the Contractor shall bear the costs associated with both sidewall over-reaming and additional drilled shaft concrete related to over-reaming.

Excavation to the foundation cap elevation shall be completed before drilled shaft construction begins unless otherwise noted in the Contract Documents or approved by the Engineer. Any disturbance to the foundation cap area caused by shaft installation shall be repaired by the Contractor prior to placing the cap concrete. When drilled shafts are to be installed in conjunction with embankment construction, the Contractor shall construct drilled shafts after placement of the embankment fill unless otherwise shown on the Contract Documents or approved by the Engineer. Drilled shafts installed prior to the completion of the embankment fill shall not be capped until the fill has been placed to the bottom of cap level.

(a) *Dry Construction Method*. The dry construction method consists of drilling the shaft excavation, removing accumulated water and loose material from the excavation, placing the reinforcing cage, and concreting the shaft in relatively dry excavation. The dry construction method may only be used if the shaft excavation demonstrates that the following conditions are met: less than 12 inches of water accumulates above the base of excavation over a period of one hour when no pumping is performed, the sides and bottom of the hole remain stable without detrimental caving, sloughing, or swelling between the completion of excavation and concrete placement, all loose material and water can be satisfactorily removed prior to inspection and concrete placement (no more than 2 inches of water will be permitted in the bottom of the shaft excavation at the time of concrete placement), and the Engineer can visually inspect the sides and bottom of the shaft prior to placing the concrete. The drilled shaft excavations shall not be left open overnight unless cased full depth or otherwise protected against sidewall instability. An open excavation is defined as a drilled shaft that has not been filled with concrete, or temporarily backfilled with a material approved by the Engineer in accordance with subsection 503.02(b) or protected in accordance with subsection 503.13(b). The use of slurry to protect a drilled shaft during a drilling stoppage or overnight shutdown shall be approved by the Engineer. The excavation shall be protected with a suitable cover which will prevent persons or materials from falling into the hole. Casing of drilled shafts in stable rock formations during stoppages is not required if accepted by the Engineer unless shown on the Plans or specified herein.

(b) *Protection Methods*. The Contractor bears full responsibility for selection and execution of the methods of stabilizing and maintaining the drilled shaft excavation. The walls and bottom of the drilled shaft excavation shall be protected so that sidewall caving and bottom heaves are prevented from occurring. For shafts where the soils above the bedrock do not contribute to the bearing calculations as shown on the Plans, the soils surrounding the temporary casing may be disturbed during the installation of temporary casing using uncontrolled in-situ slurries.

Acceptable protection methods include the use of casing, drilling slurry, or both:

1. Temporary Casing Construction Method. The Contractor shall conduct casing installation and removal operations and drilled shaft excavation operations such that the adjacent soil outside the casing and drilled shaft excavation for the full height of the drilled shaft is minimally disturbed. For shafts where the soils above the bedrock do not contribute to the bearing calculations as shown on the Plans, the soils surrounding the temporary casing may be disturbed during the installation of temporary casing using uncontrolled in-situ slurries.

   If the Contractor is utilizing casing that is sealed into the underlying bedrock, water may infiltrate the shaft below the casing. Excavation of the bedrock may continue without the use of casing or slurry if the shaft remains stable.

   The Contractor shall remove all temporary casings from the excavation as concrete placement is completed, unless approval has been received from the Engineer to leave specified temporary casings in place. As the temporary casing is withdrawn, sufficient head of fluid concrete must be maintained to ensure that water or slurry outside the temporary casing will not breach the column of freshly placed concrete. Casing extraction shall be at a slow, uniform rate with the pull in line with the shaft axis. Excessive rotation of the casing shall be avoided to limit deformation of the reinforcing steel cage.

2. Permanent Casing Construction Method. After the casing has been filled with concrete, all void space occurring between the casing and drilled shaft excavation shall be filled with a material which approximates the geotechnical properties of the in-situ soils, in accordance with the Drilled Shaft Installation Plan specified in subsection 503.02(b).

   Tops of permanent casings for the drilled shafts shall be removed to the top of the drilled shaft or finished ground line, whichever is lower, unless the top of permanent casing is shown in the Plans at a different elevation. For those drilled shafts constructed within a permanent body of water, tops of permanent casings for drilled shafts shall be removed to the low water elevation unless otherwise shown on the Plans or directed by the Engineer. Casing used for forming shafts installed through a body of water shall not be removed.

3. Alternative Casing Methods. When approved by the Engineer, installation of casing using rotating or oscillating methods will be permitted. Use of this alternative casing method shall be in accordance with the equipment and procedures shown in the approved Drilled Shaft Installation Plan, and shall comply with all other requirements specified herein. Drilled shaft casing shall be equipped with cutting teeth or a cutting shoe and installed by either rotating or oscillating the casing.

4. Uncontrolled In-Situ Slurry. The uncontrolled in-situ slurry consists of in-situ soils from the drilled shaft mixed with water. For shafts where the soils above the bedrock do not contribute to the bearing calculations as shown on the Plans, the Contractor may use uncontrolled in-situ slurry to install temporary casing. For shafts where the soils above the bedrock do contribute to the bearing calculations, the use of uncontrolled in-situ slurry to install temporary casing shall not be allowed. Slurry in accordance with subsections 503.09, 503.10, and 503.11 or temporary casing in accordance with subsection 503.13 is required if the drilled shaft does not remain stable using uncontrolled in-situ slurry.

5. Slurry. The Contractor may use slurry in accordance with subsections 503.09, 503.10, and 503.11 to maintain a stable excavation during drilled shaft excavation and concrete placement operations once water begins to enter the drilled shaft excavation and remain present.

   The Contractor may use slurry to maintain stability during drilled shaft excavation and concrete placement operations in the event that water begins to enter the drilled shaft excavation at a rate of greater than 12 inches per hour, or if the Contractor is not able to restrict the amount of water in the drilled shaft to less than 3 inches prior to concrete placement, or to equilibrate water pressure on the sides and base of the drilled shaft excavation when groundwater is encountered or anticipated based on the available subsurface data.

   A. Slurry Technical Assistance

   If slurry is used, the manufacturer's representative, as identified to the Engineer in accordance with subsection 503.02(c), shall provide technical assistance for the use of the slurry.

   The manufacturer’s representative or the Contractor’s employee trained in the use of the slurry, as identified to the Engineer in accordance with subsection 503.02(c), shall be present at the site throughout the shaft slurry operations for this project to perform the duties specified above.

   B. Minimum Level of Slurry in the Excavation

   When slurry is used to maintain a stable excavation, the slurry level in the excavation shall be maintained to obtain hydrostatic equilibrium throughout the construction operation at a height required to provide and maintain a stable hole, but not less than 5 feet above the water table.

   Slurry levels shall be as follows:

   1. Not less than five feet above the water table for mineral slurries

   2. Not less than ten feet above the water table for water slurry and uncontrolled in-situ slurries

   3. Not less than ten feet above the water table for polymer slurries, except when a lesser dimension is specifically recommended by the slurry manufacturer for the site conditions and construction methods.

   The Contractor shall provide casing, or other means, as necessary to meet these requirements.

   The slurry level shall be maintained above all unstable zones a sufficient distance to prevent bottom heave, caving, or sloughing of those zones.

Throughout all stops in drilled shaft excavation operations, the Contractor shall monitor and maintain the slurry level in the excavation the greater of the following elevations:

1. No lower than the groundwater level elevation outside the drilled shaft

2. Elevation as required to provide and maintain a stable hole

C. Cleaning Slurry

The Contractor shall clean, re-circulate, de-sand, or replace the slurry, as needed, in order to maintain the required slurry properties. Sand content will only be required to be within specified limits immediately prior to concrete placement.

503.13 Obstructions. When obstructions are encountered, the Contractor shall notify the Engineer promptly. An obstruction is defined as a specific object not identified on the Plans or Geotechnical Report in accordance with subsection 102.05 (including, but not limited to, boulders, logs, and manmade objects) encountered during the drilled shaft excavation operation which prevents or hinders the advance of the drilled shaft excavation. When efforts to advance past the obstruction to the design drilled shaft tip elevation result in the rate of advance of the drilled shaft drilling equipment being significantly reduced relative to the rate of advance for the portion of the drilled shaft excavation in the geological unit that contains the obstruction, then the Contractor shall remove, bypass or break up the obstruction under the provisions of subsection 503.24. Blasting will not be permitted unless approved in writing by the Engineer.

Drilling tools that are lost in the excavation will not be considered obstructions, and shall be promptly removed by the Contractor. All costs due to lost tool removal will be borne by the Contractor including, but not limited to, costs associated with the repair of hole degradation due to removal operations or an excessive time that the hole remains open.

503.14 Protection of Existing Structures and Drilled Holes. The Contractor shall control operations to prevent damage to existing structures and recently drilled holes, utilities, roadways and other facilities. Preventative measures shall include, but are not limited to, selecting construction methods and procedures that will prevent excessive caving of the drilled shaft excavation and monitoring and controlling the vibrations from the driving of casing or sheeting, drilling of the shaft, or from blasting, if permitted.

503.15 Slurry Sampling and Testing. Mineral slurry and polymer slurry shall be mixed and thoroughly hydrated in slurry tanks, lined ponds, or storage areas. The Contractor shall draw sample sets from the slurry storage facility and test the samples for conformance with the appropriate specified material properties before beginning slurry placement in the drilled hole. Slurry shall conform to the quality control plan included in the Drilled Shaft Installation Plan in accordance with subsection 503.02(b)(5) and approved by the Engineer. A sample set shall be composed of samples taken at mid-height and within 2 feet of the bottom of the storage area.

The Contractor shall sample and test all slurry in the presence of the Engineer, unless otherwise approved by the Engineer. The date, time, names of the persons sampling and testing the slurry, and the results of the tests shall be recorded. A copy of the recorded slurry test results shall be submitted to the Engineer at the completion of each drilled shaft, and during construction of each drilled shaft when requested by the Engineer.

Slurry samples shall be taken at mid-height and within 2 feet of the bottom of the drilled shaft and tested during drilling as necessary to verify the control of the properties of the slurry. As a minimum, sample sets of polymer slurry shall be taken and tested at least once every four hours after beginning its use during each shift. Sample sets of all slurry shall be taken and tested immediately prior to placing concrete.

503.16 Drilled Shaft Excavation Inspection. The Contractor shall use best methods such as a cleanout bucket, air lift, or hydraulic pump to clean the bottom of the excavation of all drilled shafts. For wet drilled shaft excavation in soils, the base of the excavation shall be covered with not more than 3 inches of sediment or loose or disturbed material just prior to placing concrete. For dry drilled shaft excavations in soils, the base of excavation shall be covered with not more than 1.5 inches of sediment or loose or disturbed material just prior to placing concrete. For wet and dry drilled shaft excavations in rock, the base of the excavation shall be covered with not more than 0.5 inch for 50 percent of the base area of sediment or loose or disturbed material just prior to placing concrete.

The excavated drilled shaft will be inspected and approved by the Engineer prior to proceeding with construction. The bottom of the excavated drilled shaft shall be sounded with an airlift pipe, a tape with a heavy weight attached to the end of the tape, a borehole camera with visual sediment depth measurement gauge, or other means acceptable to the Engineer to determine that the drilled shaft bottom meets the requirements in the Contract. The Contractor shall supply all needed equipment required to inspect the drilled shaft excavation.

503.17 Assembly and Placement of Reinforcing Steel. The Contractor shall show bracing and any extra reinforcing steel required for assembling, transportation, or placement of the cage on the shop drawings. The Contractor shall be responsible for engineering the temporary support and bracing of the reinforcing cages to ensure that they maintain their planned configuration during assembly, transportation, and installation.
The reinforcing cage shall be rigidly braced to retain its configuration during handling and construction. Individual or loose bars will not be permitted. All intersections of vertical and horizontal bars shall be tied. At least four vertical bars of each cage, equally spaced around the circumference, shall be tied at all reinforcement intersections with double wire ties. The remaining reinforcement intersections in each cage shall be tied with single wire ties.

The reinforcement shall be carefully positioned and securely fastened to provide the minimum clearances specified or shown on the Plans, and to ensure that no displacement of the reinforcing steel cage occurs during placement of the concrete. Splicing of the reinforcement cage during placement of the cage in the shaft excavation will not be permitted unless otherwise shown on the Plans or approved by the Engineer. If the reinforcing cage is spliced during placement of the cage into the drilled shaft excavation, the splice details and location of the splices shall be in accordance with the Plans and the accepted Drilled Shaft Installation Plan. In addition, the work shall be performed within the time limits specified in subsection 503.13.

The steel reinforcing cage shall be securely held in position throughout the concrete placement operation. 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. The reinforcing steel in the drilled shaft shall be tied and supported so that the location of the reinforcing steel will remain within allowable tolerance. Concrete spacers or other approved non-corrosive spacing devices shall be used at sufficient intervals (near the bottom, the top, and at intervals not exceeding 10 feet vertically) to ensure concentric spacing for the entire cage length. The number of spacers required at each level will be one spacer for each foot of excavation diameter, with a minimum of four spacers at each level. The spacers shall be of adequate dimension to ensure an annular space between the outside of the reinforcing cage and the side of the excavation along the entire length of the drilled shaft as shown on the Plans. Acceptable feet made of plastic or concrete (bottom supports) shall be provided to ensure that the bottom of the cage is maintained at the proper distance above the base of the excavation unless the cage is suspended from a fixed base during the concrete pour.

Minimum concrete cover to reinforcing steel shall be as follows:

Drilled Shaft Diameter	Maximum Horizontal Tolerance
Less than or equal to 3 feet	3 inches
Greater than 3 feet and less than 5 feet	4 inches
Greater than or equal to 5 feet	6 inches

Drilled shafts for structures as shown on the CDOT S-Standard drawings shall be excluded from the minimum cover concrete requirements, except as noted on the plans.
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.

Bracing steel which constricts the interior of the reinforcing cage shall be removed after lifting the cage if freefall concrete or wet tremie methods of concrete placement are to be used.

The elevation of the top of the steel cage shall be checked before and after the concrete is placed. If the upward displacement of the rebar cage exceeds 2 inches, or if the downward displacement exceeds 6 inches, the drilled shaft shall be considered defective. No additional drilled shafts shall be constructed until the Contractor has modified the rebar cage support in a manner satisfactory to the Engineer.

503.18 Concrete Placement, Curing, and Protection Concrete placement shall be in accordance with Section 601 and shall commence as soon as possible after completion of drilled shaft excavation by the Contractor and inspection by the Engineer. Immediately prior to commencing concrete placement, the drilled shaft excavation and the properties of the slurry (if used) shall be in accordance with subsections 503.09, 503.10, and 503.11. The CSL access tubes shall be filled with potable water before concrete placement and the top watertight threaded caps shall be reinstalled. Concrete placement shall be one continuous placement to the top of the drilled shaft, or as shown on the Plans.

If water is not present the concrete shall be deposited through the center of the reinforcement cage by tremie, pump or free-fall preventing segregation of aggregates. The concrete shall be placed such that the free-fall is vertical down the center of the drilled shaft without hitting the sides or steel reinforcing cage.

If water exists in amounts greater than 2 inches in depth or enters at a rate of more than 12 inches per hour, then the drilled shaft concrete shall be placed in accordance with subsection 601.12(f).

Before placing any fresh concrete against concrete deposited in water or slurry (construction joint), the Contractor shall remove all scum, laitance, loose gravel, and sediment on the surface of the concrete deposited in water or slurry, and chip off any high spots on the surface of the existing concrete that would prevent any steel reinforcing bar cage from being placed in the position as shown on the Plans.

The Contractor shall not perform foundation piling driving or casing installation using oscillation method within a radius of 20 feet, or drilled shaft excavation operations within a clear distance of 3 diameters of a newly poured drilled shaft until a minimum of 24 hours has passed after the placement of concrete and the concrete has reached a minimum compressive strength of 1,800 psi.

For any portion of the caisson socketed in fine grained bedrock susceptible to slaking and degradation such as, but not limited to, claystone, siltstone, or shale and provided the proper slurry properties have been achieved. If the concrete is not placed within four hours of drilling, the Contractor shall drill into the bedrock an additional 1/3 of the plan specified rock socket prior to placing the concrete. The reinforcing cage shall extend to the new tip elevation. For the use of polymer slurry this requirement will be waived.

503.19 Drilled Shaft Construction Tolerances. Drilled shafts shall be constructed so that the center of the poured shaft at the top of the drilled shaft or mudline, whichever is lower, is within the following horizontal tolerances:

Drilled Shaft Diameter	Minimum Concrete Cover
Less than or equal to 2 feet	3 inches
Greater than 2 feet and less than 5 feet	4 inches
Greater than or equal to 5 feet	6 inches

Drilled shafts in soil and rock shall be within 1.5 percent of plumb. Plumbness shall be measured from the top of poured drilled shaft elevation or mudline, whichever is lower. During drilling or excavation of the drilled shaft, the Contractor shall make frequent checks on the plumbness, alignment, and dimensions of the drilled shaft. Any deviation exceeding the allowable tolerances shall be corrected with a procedure approved by the Engineer.
Drilled shaft steel reinforcing bars shall be no higher than 6 inches above or 3 inches below the plan elevation.

The reinforcing cage shall be concentric with the drilled shaft excavation within a horizontal tolerance of 1-1/2 inches.

The top elevation of the completed drilled shaft shall have a tolerance of plus 1 inch or minus 3 inches.

The diameter of the drilled shaft shall not be less than the diameter shown on the Plans.

Tolerances for casings shall be in accordance with American Pipe Institute tolerances applicable to regular steel pipe.

Drilled shaft excavations and completed drilled shafts not constructed within the required tolerances will be considered defective. The Contractor shall be responsible for correcting all defective drilled shafts to the satisfaction of the Engineer. Materials and work necessary, including engineering analysis and redesign, to complete corrections for out-of-tolerance drilled shafts shall be furnished without cost to the Owner or an extension of the completion date of the project. The Contractor shall submit redesign drawings electronically sealed by the Contractor's Engineer.

TESTING AND VERIFICATION

503.20 Integrity Testing. Crosshole Sonic Log (CSL) testing shall be performed in accordance with ASTM D6760. The minimum number of shafts tested shall be indicated on the plans. CSL testing shall be performed on shafts constructed using tremie concrete placement methods and drilled shafts selected by the Engineer. Drilled shafts for structures as shown on the CDOT S-Standard drawings shall be excluded from this testing, except as shown on the plans. The Engineer may increase the number of shafts tested as deemed necessary. The Contractor shall accommodate the CSL testing by furnishing and installing access tubes in accordance with subsection 503.12.

The Contractor shall install access tubes for CSL testing in drilled shafts as shown on the plans selected by the Engineer to permit access for the CSL test probes. If the condition of the drilled shaft excavation permits drilled shaft construction in the dry, the Engineer may specify that the testing be omitted.

The Contractor shall securely attach the access tubes to the interior of the reinforcement cage of the drilled shaft. One access tube shall be furnished and installed for each foot of drilled shaft diameter, rounded up to the nearest whole number, unless otherwise shown on the Plans. A minimum of three tubes will be required. The access tubes shall be placed around the drilled shaft, inside the spiral or hoop reinforcement and 3 inches clear of the vertical reinforcement, at a uniform spacing measured along the circle passing through the centers of the access tubes. If these minimums cannot be met due to close spacing of the vertical reinforcement, then the access tubes shall be bundled with the vertical reinforcement.
If trimming the cage is required and access tubes for CSL testing are attached to the cage, the Contractor shall either shift the access tubes up the cage, or cut the access tubes provided that the cut tube ends are adapted to receive the watertight cap as specified.

The access tubes shall be installed in straight alignment and as near to parallel to the vertical axis of the reinforcement cage as possible. The access tubes shall extend from the bottom of the drilled shaft to at least 2 feet above the top of the drilled shaft. Couple tubes as required with threaded couplers, such that inside of tube remains flush. The Contractor shall clear the access tubes of all debris and extraneous materials before installing the access tubes. Care shall be taken to prevent damaging the access tubes during reinforcement cage installation and concrete placement operations in the drilled shaft excavation.

The access tubes shall be filled with potable water before concrete placement, and the top watertight threaded caps shall be reinstalled.

Prior to performing CSL testing operations, the Contractor shall remove the concrete at the top of the drilled shaft down to sound concrete.

The Contractor shall engage a qualified Specialty Engineer to perform the CSL testing. The qualified CSL Specialty Engineer shall have a minimum three years of experience of CSL testing and have a Colorado Licensed Professional Engineer supervising the collection and interpretation of data. The Contractor shall provide all necessary assistance to the CSL Specialty Engineer to satisfactorily perform the testing.

The testing shall be performed after the drilled shaft concrete has cured at least 96 hours. Additional curing time prior to testing may be required if the drilled shaft concrete contains admixtures, such as set retarding admixture or water reducing admixture. The additional curing time prior to testing required under these circumstances shall not be grounds for additional compensation or extension of time to the Contractor. No subsequent construction shall be performed on the completed drilled shaft until the CSL tests are approved and the drilled shaft accepted by the Engineer.

After placing the drilled shaft concrete and before beginning the CSL testing of a drilled shaft, the Contractor shall inspect the access tubes. Each access tube that the test probe cannot pass through shall be replaced, at the Contractor’s expense, with a 2-inch diameter hole cored through the concrete for the entire length of the drilled shaft. Unless directed otherwise by the Engineer, cored holes shall be located approximately 6 inches inside the reinforcement and shall not damage the drilled shaft reinforcement. Descriptions of inclusions and voids in cored holes shall be logged and a copy of the log shall be submitted to the Engineer. Findings from cored holes shall be preserved, identified as to location, and made available for inspection by the Engineer.

The Engineer will approve the continuation of drilled shaft construction prior to approval and acceptance of the first shaft if the Engineer’s observations of the construction of the first shaft are satisfactory, including, but not limited to, conformance to the Drilled Shaft Installation Plan as approved by the Engineer, and the Engineer’s review of Contractor’s daily reports and inspector’s daily logs concerning excavation, steel reinforcing bar placement, and concrete placement.

Drilled shafts with velocity reduction exceeding 30 percent are not acceptable without additional offset CSL testing and three-dimensional (3D) Tomography analysis.

If subsequent testing at a drilled shaft indicates the presence of a defect in the drilled shaft, the testing costs and the delay costs resulting from the additional testing shall be borne by the Contractor. If this additional testing indicates that the drilled shaft has no defect, the testing costs and the delay costs resulting from the additional testing will be paid by the Owner. If the drilled shaft construction is on the critical path of the Contractor’s schedule, a time extension equal to the delay created by the additional testing will be granted.

If the Engineer determines a drilled shaft is unacceptable based on the CSL tests and tomographic analyses, or observes problems during drilled shaft construction, coring of the shaft to allow further evaluation and repair shall be required, or the shaft shall be replaced. If coring to allow further evaluation of the shaft and repair is chosen, one or more core samples shall be taken from each unacceptable shaft for full depth of the shaft or to the depth directed by the Engineer. The Engineer will determine the number, location, and diameter of the cores based on the results of 3D tomographic analysis of offset and horizontal CSL data. The Contractor shall provide an accurate log of cores, label and place the cores in a crate showing the shaft depth at each interval of core recovery, transport the cores along with five copies of the coring log to the Engineer, and perform strength testing by an AASHTO certified lab on portions of the cores that exhibit questionable concrete as determined by the Engineer.

If the coring or testing indicates the shaft is defective, the Contractor shall propose remedial measures for approval by the Engineer, repair all detected defects, and conduct post repair integrity testing using horizontal and offset CSL testing and 3D tomographic imaging as described herein. The coring costs and remedial measure costs shall be borne by the Contractor. If the additional coring indicates that the drilled shaft has no defect, the coring costs resulting from the additional coring will be paid by the Owner. If the drilled shaft construction is on the critical path of the Contractor's schedule, a time extension equal to the delay created by the additional testing will be granted.

All access tubes and cored holes shall be dewatered and filled with a 4,000 psi grout after tests are completed and the drilled shaft is accepted. The access tubes and cored holes shall be filled using grout tubes that extend to the bottom of the tube or hole or into the grout already placed.

503.21 Drilled Shafts Load Tests. Test shafts shall be installed at the locations shown on the Plans unless otherwise directed or approved by the Engineer.

Test shafts shall be installed to the same dimensions, details, and elevations shown on the Plans, and shall be installed using the same equipment and installation procedures proposed for installation of the foundation drilled shafts.

If the methods or procedures are changed following the completion of load testing, the Contractor shall install additional load test shafts, and conduct additional load tests as directed by the Engineer at no additional cost to the Owner.

An electronically sealed report of load test results shall be submitted within five business days of the testing completion. Load testing results will be evaluated by the Engineer before installing any production drilled shafts, to allow for design modifications based on the load test results. Load test data as reported shall conform to the Drilled Shaft Foundation Testing (DSHAFT) and be available in electronic form at the project website (http://srg.cce.iastate.edu/shaft).

(a) *Static Load Tests.* Static load tests shall be performed in accordance with the procedures specified in ASTM D1143.

(b) *Force Pulse (Rapid) Load Tests.* Force pulse (rapid) load tests shall be performed in accordance with the procedures specified in ASTM D7383.

METHOD OF MEASUREMENT

503.22 Drilled shafts 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 shaft will be measured as ½ linear foot of additional length of drilled shaft.

BASIS OF PAYMENT

503.23 The unit price of drilled shafts shall be full compensation for making all excavations; hauling and disposal of excavated material; provision and disposal of slurry, performing all necessary pumping; furnishing and placing required concrete and reinforcement steel, including the reinforcement projecting above the tops of the drilled shafts necessary for splicing and any intermediate reinforcement splices; furnishing and placing of CSL tubes; all backfilling; furnishing, placing, and removing temporary casings; furnishing permanent casing if required to complete the work; and for furnishing all tools, labor, equipment, and incidentals necessary to complete the work. Costs associated with repairing defects found in the drilled shaft shall be included in the cost of the drilled shaft.

(a) *Payment.* The accepted quantities for drilled shafts 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 Shaft (Inch)	Linear Foot
Drilled Shaft Load Test	Each
CSL Testing	Each

Obstruction Encounter and Removal will not be measured, and will be paid for in accordance with subsection 109.04 under Force Account item Obstruction Encounter and Removal.

(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
Less than or equal to 5 feet	Contract Unit Price
Greater than 5 feet and less than 15 feet	Contract Unit Price plus 15%
Greater than or equal to 15 feet	As provided in subsection 109.04

Additional compensation will not be paid for the portions of a drilled shaft 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.

Soil Nail Wall. This work consists of constructing a permanent soil nailed wall (also referred to as ground nail wall) as specified herein, and as shown on the plans. Temporary soil nail walls and the final facing are not covered in this specification. The work includes:

(1) Excavating staged lifts in accordance with the plans and approved submittals.

(2) Drilling soil nail holes to the diameter and length required to develop the specified capacity as shown on the plans.

(3) Installing soil nails including placement and grouting.

(4) Performing soil nail testing and providing test results to the Engineer.

(5) Providing and installing the specified drainage features.

(6) Providing and installing bearing plates, washers, nuts, couplers, and other required miscellaneous materials.

(7) Constructing the initial shotcrete face.

MATERIALS

504.02 Shop Drawings. The Contractor shall submit one electronic submittal of shop drawings and certified material test reports for review prior to construction of the wall. See subsection 504.07, 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 TULT (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 front face of wall for panel less than 12 inches deep and from the back face of wall for panel greater than 12 inches deep to the end of the soil reinforcement as measured to the neat end. Soil reinforcement lengths shall not be less than the lengths specified on the plans.

The Reinforcement Lengths shown on the shop drawings shall be the reinforcement length required for internal stability and pull-out only. External stability (bearing pressure, sliding, and overturning) and global stability shall already be checked by the design Engineer.

(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 40 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 40 feet shall be approved by the Engineer.
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 shall be 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 1/2 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 1 Geotextile is installed behind the joints as shown in the shop drawings. Geotextile (Class 1) and crushed rock will not be measured and paid for separately, but shall be included in the work. Neoprene cushions shall be provided at 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 block connection shall be used for the sacrificial thickness calculation. The following minimum sacrificial thickness for reinforcement shall be applied to 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

Steel Soil Reinforcement

$$LTDS = \frac{\phi A_c F_y}{b}$$

Where:

Φ = 0.75 (Strip reinforcement)
= 0.65 (Grid reinforcement)

A_c = Area of reinforcement corrected for corrosion loss (in^2)
F_y = minimum yield strength of steel (ksi)

b = unit width of reinforcement (ft)

3. Geosynthetic Soil Reinforcement. Geosynthetic soil reinforcement shall be either a geogrid or woven geotextile. For polyester (PET), polypropylene (PP), and polyethylene (PE) reinforcement, the LTDS of material shall be determined using the following K percentages 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)

   $$Where\ K = \frac{\phi}{RF(ID)\ \text{X}\ RF(D)\ \text{X}\ RF\ (CR)}$$

   RF(ID): Installation damage reduction factor

   RF(D): Durability reduction factor

   RF(CR): Creep reduction factor

   Meet AASHTO LRFD and/or FHWA GRS design method for 75 years' design life.

   (1) Geogrid or Geotextile sheet reinforcement (PE, PET, PP):

Products	K (Geogrid)	K (Geotextile)
PE and PP	27%	18%
PET	35%	30%

   (2) Woven Geotextile shall meet minimum bi-axial MARV of ultimate tensile of 4,800 LB/FT and a minimum tensile strength of 2,400 LB/FT at 5 percent strain based on ASTM D4595.

   (3) All products not listed above: Follow AASHTO equations 11.10.6.4.3b-1 and 11.10.6.4.3b-2 using independently certified test results.

(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 GRS 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 504.13.

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 as shown on the plans. 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.

504.05 Geomembrane and Joints. 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 712.07 for geomembrane, and be LLDPE with a minimum thickness of 30 mils. It shall be spliced with a dual track field seamed joint in accordance with ASTM D4437 and ASTM D5820. 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 Pay Length for Geomembrane (PLG) as shown on the plans. The membrane shall be installed with a slope between 20:1 (minimum) and 10:1 (maximum), as shown on the plans, from the block facing to a drainage system located at the cut or pre-filled slope as shown on the plans. The Contractor shall provide a site-specific working drawing that indicates sheet splices, pattern, slope, and daylight location. Prior to membrane installation, the working drawing shall be submitted by the Contractor and approved by the Engineer.

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 excavation 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 1 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 an approved Class D or G Concrete and shall conform to the requirements of Section 601. The Contractor may elect to use an approved self-consolidating Class D or G Concrete. Pre-cast panels shall be cured in accordance with AASHTO M170.

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. The Contractor's Engineer shall electronically seal all engineering calculations, as stated in subsections 504.02(f), 504.02(g), 504.02(j), 504.02(k), 504.07(e), 504.07(f), 504.07(g), and 504.07(h) .

(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. Before panel shipping from precast yard to wall site, the Engineer will approve the time of shipping, method of lifting and 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 current AASHTO LRFD or latest interim requirements.

(i) *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.

(j) *Submittal Checklist*. The Contractor shall submit the wet cast facing or 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 or Smaller Panel 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 shall 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 modular facing and be stabilized by a counterfort or a coherent mass such as interlocked wire basket system. 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 or coherent mass long-term connection test.

(2) 75-year design of wire basket and filter fabrics for avoiding migration of fine soil.

The Contractor shall submit the dry cast facing MSE Wall Submittal Checklist, Form 1401, or the wet cast facing MSE Wall Submittal Checklist, Form 1402, with the Certifications, Calculations, and Testing Report submittal package included with the shop drawing submittal.

504.09 Materials shall meet the following requirements:

(1) Concrete shall be Class D, conforming to the requirements of Section 601.

(2) Reinforcing Steel shall conform to the requirements of Section 602.

(3) Shotcrete shall conform to the requirements of Section 641.

(4) Forms and falsework shall conform to the requirements of subsections 601.09 and 601.11.

(5) Geocomposite strip drains shall comply with Section 712.12.

(6) Underdrains and pipes shall comply with Sections 712.11 and 712.13.

504.10 Soil Nails

(a) *Solid Bar Soil Nail.* Bars shall conform to AASHTO M31 for Grade 75 or ASTM A 722 for Grade 150. Bars shall be threaded, continuous without splices or welds, new, straight, undamaged, epoxy-coated or encapsulated as shown on the plans. Bars shall be threaded a minimum of 6 inches on the wall anchorage end to allow proper attachment of bearing plate and nut. Threading may be continuous spiral deformed ribbing provided by the bar deformations (continuous thread bars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, the next larger bar number designation from that shown on the plans shall be provided at no additional cost.

(b) *Bar Coupler.* Bar couplers, where allowed by the plans, shall be designed to develop the full ultimate tensile strength of the bar as certified by the manufacturer.

(c) *Fusion Bonded Epoxy Coating.* Epoxy coating for bars and end hardware shall conform to ASTM A775 or A934. The minimum thickness shall be 0.012 inch and shall be electrostatically applied. Bend test requirements are waived. Coating at the wall anchorage end of epoxy-coated bars may be omitted over the length provided for threading the nut against the bearing plate. Coating at the end of the bar of epoxy-coated bars may be omitted over the length provided for threading a coupler if bars are to be joined. Galvanization may be substituted for epoxy. Bars should be galvanized according to ASTM A767/A767M. A minimum galvanization coating of 3.4-mil thickness is required. Galvanization shall be applied in accordance with ASTM A153 for nuts, plates, and other hardware.

(d) *Encapsulation.* Encapsulation shall be a sheathing of either corrugated HDPE tube with a minimum 0.06-inch thickness conforming to AASHTO M252 or corrugated PVC tube with a minimum 0.04-inch thickness conforming to ASTM D1784, Class 13464-B. The level of corrosion protection shall be as shown on the plans.

(e) *Centralizer.* Centralizers shall be manufactured from Schedule 40 PVC pipe or tube, or other material not detrimental to the soil nail steel or corrosion protection. Wood shall not be used. Centralizers shall be
   (1) Securely attached to the soil nail bar.
   (2) Sized to position the soil nail bar within 1 inch of the center of the drill hole.
   (3) Sized to allow tremie pipe, grout tube, or casing insertion along the full length of the drill hole.
   (4) Sized to allow grout to freely flow up the drill hole.

(f) *Soil Nail Grout.* The minimum compressive strength for grout should be 1,500 pounds per square inch (psi) at 3 days, and 3,000 psi at 28 days, as tested in accordance with ASTM C109. If sand is used in the grout mixture, it shall meet the requirements of subsection 703.01. A batch ticket shall be supplied for each grout delivery to be used during construction of the soil nail wall. If grout is mixed on site, all materials shall be weighed and recorded prior to mixing or incorporation into the mixer. The water/cementitious ratio and specific gravity may be used as a primary quality control of the neat cement grout mix if the Contractor can demonstrate the materials and mix design consistently produce a grout of the minimum specified strength. Neat cement grout cubes shall be molded by the Contractor in the presence of the Engineer and tested by the Department on the grout used in production soil nails and the adjacent test soil nail.

(g) *Fine Aggregate*. Fine aggregate shall conform to subsection 703.01.

(h) *Cementitious* Materials. Cementitious materials shall conform to Section 701. The cement used for shotcrete and grout shall meet the sulfate resistance requirements of subsection 601.04.

(i) *Admixtures.* Admixtures shall conform to Section 711. Admixtures that control bleed, improve flowability, reduce water content, reduce washout, and retard set may be used in the grout as approved by the Engineer. Accelerators are not permitted. Expansive admixtures may be used only in grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer's recommendations.

(j) *Film Protection.* Polyethylene film for moisture loss control shall conform to AASHTO M171.

504.11 Bearing Plates, Washers, Nuts, and Headed Studs.

(a) *Bearing Plates.* Bearing plates shall conform to AASHTO M183/ASTM A36.

(b) *Beveled Washers*. Beveled washers shall conform to ASTM F436, with an angle matching the inclination of the soil nail to provide uniform bearing.

(c) *Nuts.* Nuts shall be hexagonal and fitted with beveled washer or spherical seat to provide uniform bearing to develop the full ultimate tensile strength of the bar as certified by the manufacturer and conform to AASHTO M292/ASTM A194. ,.

(d) *Headed Studs*. Headed studs on the bearing plate shall conform to requirements of Section 509.12.

504.12 Welded Wire Fabric. Welded Wire Fabric shall conform to AASHTO M55, AASHTO M221, or ASTM A1064.

CONSTRUCTION REQUIREMENTS

504.13 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 shall 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.

504.14 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 five elements listed in subsection 504.11. 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.

504.15 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.

504.16 Facial Panel Quality 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 quality control 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 5,500 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.

504.17 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 offsets as recommended by the manufacturer. 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, to avoid panels with random cracks.

504.18 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 of AASHTO T 180 for walls higher than 16 feet. 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 3/8-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 3/4 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 T180.

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 and 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 stormwater 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.

504.19 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.

504.20 Leveling Pad. The foundation of the leveling pads shall meet the requirement of subsection 504.04 for steel and concrete. The leveling pad shall be level within the tolerance of 1/8 inch for any two points along the length of a panel, and within 1/4 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 two shims (each 3/16 inch thick) shall be required to level the panels on the leveling pad.

504.21 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.

504.22 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 1/2 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.

504.23 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.

504.24 Contractor Qualifications. The Contractor shall provide on-site supervisors and drill operators with experience installing permanent soil nails on at least 3 permanent soil nail retaining wall projects during the past 3 years totaling at least 10,000 square feet of wall face area and at least 500 permanent soil nails.

504.25 Submittals. The following documents shall be submitted in accordance with subsection 105.02. No work relating to soil nail wall construction including ordering materials shall be performed before the following submittals have been reviewed and reviewed by the Engineer.

(a) *Qualifications*. The soil nailing Contractor shall submit a brief description of at least 3 completed projects, including the owning agency's name, address, current phone number, location of project, project contract value, square foot of wall, the number of nails, scheduled completion date, and actual completion date for the project.

(b) *Personnel*. At least 14 calendar days before starting soil nail work, the soil nailing Contractor shall identify on-site supervisors and drill operators assigned to the project, and submit a summary of each individual's experience. Only those individuals designated as meeting the qualifications requirements shall be used for the project. The soil nailing Contractor shall not substitute for any of these individuals without written approval by the Engineer. The Engineer will review the soil nailing Contractor qualifications and staff within 15 working days after receipt of the submission. The Engineer may suspend the work if the soil nailing Contractor substitutes unqualified personnel for qualified personnel during construction. If work is suspended due to the substitution of unqualified personnel per subsection 504.06, the Contractor shall be fully liable for additional costs resulting from the suspension of work and no adjustment in contract time resulting from the suspension of the work will be allowed.

(c) *Construction Plan*. At least 14 days before starting soil nail work, the soil nailing Contractor shall submit a Construction Plan to the Engineer for review that includes the following:

(1) The start and finish date and proposed detailed wall construction sequence. Include schedule entries and anticipated durations for each lift excavation, soil nail installation for each lift, grout curing, soil nail testing, and shotcrete placement and curing.

(2) Drilling and grouting methods and equipment, including the drill hole diameter proposed to achieve the specified pullout resistance values shown on the plans and any proposed variation of these along the wall alignment.

(3) Soil nail grout mix design, including compressive strength test results supplied by a qualified independent testing lab verifying the specified minimum 3-day and 28-day grout compressive strengths. Previous test results for the same grout mix completed within one year of the start of grouting may be submitted for verification of the required compressive strengths.

(4) Soil nail grout placement procedures and equipment.

(5) Shotcrete materials and methods including methods to address soil fall out, perched water, and anti-washout as needed based on site condition or review of the Geotechnical Report in accordance with subsection 102.05.

(6) All materials, methods, and control procedures for the initial shotcrete facing.

(7) Soil nail testing methods and equipment setup.

(8) Identification number and certified calibration records for each test jack, pressure gauges, and load cell to be used. Jack, load cell, and pressure gauge shall be calibrated as a unit. Calibration records shall include the date tested, the device identification number, and the calibration test results and shall be certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 6 months prior to submittal.

(9) Certificates of Compliance for:

(i) The soil nail bar yield or ultimate tensile strength.

(ii) Soil nail bar steel type.

(iii) Bearing plates, washers, nuts, and couplers.

(iv) Corrosion protection.

(v) Geocomposite strip drain and underdrain material.

The Engineer will review the soil nailing Contractor's Construction Plan within 10 working days after the submission.

504.26 Protection and Cleanup. During work operations, the Contractor shall take such precautions as may be necessary to prevent shotcrete overspray, drill cuttings, equipment exhaust, oil, wash water, and other materials from defacing or damaging private and public property including adjacent landscaping in accordance with subsections 107.12 and 107.25. The Contractor shall furnish all equipment as may be necessary to handle wastewater and material from the operations, and clean up all waste resulting from the operations. The Contractor is responsible for the stability of the highway facility and nearby structures.

504.27 Storage and Handling. Soil nail bars shall be stored and handled in a manner to avoid damage, excessive bending, permanent deformation, or corrosion. Bars exhibiting abrasions, cuts, welds, weld splatter, corrosion, or pitting shall be replaced. Bars exhibiting damage to encapsulation or epoxy coating shall be repaired or replaced. Repaired epoxy coating areas shall have a minimum 0.012-inch thick coating. Bars exhibiting damage shall be repaired or replaced at the Contractor's expense.

504.28 Excavation. The Contractor shall be responsible for providing the necessary survey and alignment control during the excavation for each lift, locating drill holes, and verifying limits of the soil nail wall installation. Prior to any excavation, surface water controls shall be installed around the wall area as needed to prevent surface water, seepage, or springs from flowing within or into the excavation or as determined by the Engineer. The Engineer shall be notified 14 days prior to the beginning of excavation to allow scheduling of qualified representatives of the soil nail wall design professional engineer to observe the excavation and drilling as needed. The Engineer and the soil nail wall design engineer shall be contacted immediately if the Contractor encounters any ground conditions or materials during the excavation or drilling that is not shown on the plan set or unanticipated seepage, springs, or other sources of groundwater to allow for review of the design. The Contractor shall reference available Geotechnical Reports or other site condition reports in accordance with subsection 102.05 for additional information concerning the ground conditions that are anticipated during excavation.

During construction of the soil nail wall, excavation not associated with the soil nail wall construction shall not be performed within a horizontal distance equal to the total height of the final soil nail wall face excavation. The height of the exposed unsupported final excavation face cut shall not exceed the vertical soil nail spacing plus the required reinforcing lap or the short-term stand-up height of the ground, whichever is less. Each lift excavation shall be completed to the final wall excavation line and shotcrete applied in the same work shift, unless otherwise approved by the Engineer. Application of the shotcrete may be delayed up to 24 hours if the Contractor can demonstrate that the delay will not adversely affect the excavation face stability.

The Contractor shall modify excavation procedures and soil nail wall installation procedures to prevent the loss of material from the excavation face or from behind the previously installed shotcrete lift (chimneying). This may require adjustments to the sequencing between excavation, soil nail drilling and shotcreting to shorten the time the excavation lift is unsupported, drilling and installing the soil nails through temporary berms prior to final excavation and/or installing the initial shotcrete prior to drilling the soil nails. All voids that develop behind the shotcrete shall be filled with grout at no additional cost to the Department.

Excavation of the next-lower lift shall not proceed until soil nail installation, initial shotcrete face placement, attachment of bearing plates and nuts, and soil nail testing have been completed and accepted per subsection 504.17 in the current lift. Soil nail grout and shotcrete shall have achieved a compressive strength of at least 1000 psi before excavation of the next underlying lift.

Where the Contractor's excavation and installation methods result in a discontinuous wall along any soil nail row, the ends of the upper lift excavation shall extend beyond the ends of the next lower excavation lift by at least 10 feet. Slopes at these discontinuities shall be constructed to prevent sloughing or failure of the temporary slopes. If sections of the wall are to be constructed at different times, the Contractor shall prevent sloughing or failure of the temporary slopes at the end of each wall section.

The Contractor shall remove all or portions of cobbles, boulders, rubble or other subsurface obstruction encountered at the cut line which will protrude in to the shotcrete facing including a method to safely secure remnant pieces remaining behind the excavation face and promptly backfilling voids resulting from removal of protrusions extending behind the excavation face. Voids, over-break or over-excavation beyond the plan wall excavation line resulting from the removal of face protrusions or the excavation operation shall be backfilled with shotcrete, concrete, or grout.

504.29 Soil Nail Installation. Soil nail length and drill hole diameter used shall be those necessary to develop the specified load capacity to satisfy the acceptance criteria, but not less than the lengths or diameters shown on the plans. The Contractor shall modify their drilling procedures, as needed, to achieve the required soil nail pullout resistance specified in the plans. All work required to achieve the required soil nail pullout resistance including modifications to the drilling procedures will not be measured separately but shall be included in the unit price of the work. Holes shall be drilled for the soil nails at the

locations, elevations, orientations, and minimum lengths shown on the plans. Drilling equipment and methods shall be suitable for the ground conditions and conform to the installation methods submitted by the soil nailing Contractor. Drilling muds or other fluids shall not be used to remove cuttings. If caving ground is encountered, cased drilling methods shall be used to support the sides of the drill holes. Self-drilling soil nail bars (also known as hollow, self-grouting or pressure grouted soil nail bars) shall not be used unless indicated on the plans. Soil nail bars shall be as shown on the plans. Provide centralizers per Section 504.03 (e).

504.30 Grouting. The drill hole shall be grouted after installation of the soil nail bar and within 2 hours of completion of drilling. The grout shall be injected at the lowest point of each drill hole through a tremie pipe, grout tube, or casing. The outlet end of the grout tube or casing shall be kept below the surface of the grout as the conduit is withdrawn to prevent the creation of voids. The drill hole shall be completely filled in one continuous operation. Cold joints in the grout column are not allowed except at the top of the test bond length of proof tested production soil nails. Excessive grout take is defined as twice the theoretical grout volume to grout the drill hole. The Engineer shall be notified of excessive grout take to allow for modification of the wall design and construction. The Contractor shall maintain the stability of borings through the temporary unbonded length of proof test soil nails for subsequent grouting. If the unbonded test length of production proof test soil nails cannot be satisfactorily grouted subsequent to testing, the Contractor shall install a new soil nail in its place.

In some granular soils with an open matrix with no cohesion, the potential for drill hole collapse or grout leakage may be large. In this case, a grout containment device or “sock” may be used as approval by the Engineer to reduce excessive grout take in the highly permeable soil.

504.31 Underdrain. The underdrain shall be installed in accordance with Section 605.03. The underdrain should be installed as part of the soil nail wall construction. If the underdrain is to be installed at a time after construction of the soil nail wall, the Contractor shall notify the Engineer to review any proposed excavation at the foot of the wall for stability.

504.32 Soil Nail Testing. Both verification and proof testing of designated test soil nails shall be performed. Proof tests shall be performed on production soil nails at locations selected by the Engineer or as shown on the plans. Testing of a soil nail shall not be performed until the soil nail grout and shotcrete facing have cured for at least 72 hours or attained their specified 3-day compressive strength.

The Contractor shall provide all necessary equipment to perform the soil nail testing including, but not limited to, dial gauges, dial gauge support, jack and pressure gauge, electronic load cell with machined platens placed at either end of the load cell, and a reaction frame. In non-creep susceptible soils and as approved by the Engineer, the use of a load cell may be replaced with a dual pressure gauge system with the low reading gauge being used for soil nail acceptance.

The pressure gauge shall be graduated in 100-psi increments or less. The soil nail head movement shall be measured with a minimum of two dial gauges capable of measuring to 0.001 inch. The Contractor shall have available calibrated back up gauges and test loading equipment to minimize down time due to testing equipment failure.

The Contractor shall not apply loads greater than 80 percent of the minimum ultimate tensile strength of the tendon for Grade 150 bars or 90 percent of the yield strength of the tendon for Grade 75 bars. Preliminary results shall be submitted to the Engineer within 24 hours of the test completion. A full report containing test load results shall be submitted to the Engineer within 5 working days of the test completion.

504.33 Verification Testing Of Sacrificial Soil Nails. Verification testing shall be performed on sacrificial test soil nails as shown on the plans. Verification testing shall be performed prior to installation of production soil nails to confirm the appropriateness of the Contractor’s drilling and installation methods, and verify the required soil nail pullout resistance.

Verification test soil nails shall have both bonded and unbonded lengths. Along the unbonded length, the soil nail bar shall not be grouted. The unbonded length of the test soil nails shall be at least 3 feet as measured from the back of the bearing plate to the top of the grout.

Verification tests shall be conducted according to the loading schedule of Table 504-1. Each load increment shall be held for at least 10 minutes. The Contractor shall record soil nail movements at each load increment and the time intervals shown in the table for each load step. Creep tests shall be performed at 0.75 VTL. The alignment load (AL) should be the minimum load required to align the testing apparatus and shall not exceed 5 percent of the VTL. The dial gauges shall be set to “zero” after applying the alignment load. Following application of the maximum load, the load shall be reduced to the alignment load and the dial gauge readings recorded as the permanent set.

Each load increment shall be held for at least 10 minutes. The Contractor shall monitor the verification test soil nail for creep at the 0.75 VTL load increment by measuring and recording soil nail movement. The load shall be maintained during the creep test within 2 percent of the intended load by use of the load cell. The test results shall be presented for the Engineers review and acceptance prior to production. The Engineer shall have 10 working days to review the report and based on the results, design modifications may be required.

The bonded length of the soil nail during verification tests ($L_{B\ VT}$) shall be:

(a) For Grade 75 and other mild steel in accordance with ASTM A615, the maximum bond length ($L_{B\ VTmax}$), is defined as:

$$L_{B\ VTmax} = \frac{A_t \cdot f_y \cdot C_{RTY}}{r_{PO}}$$

(b) For Grade 150 and other high-strength steel in accordance with ASTM A722, the maximum bond length ($L_{B\ VTmax}$), is defined as:

$$L_{B\ VTmax} = \frac{A_t \cdot f_u \cdot C_{RTU}}{r_{PO}}$$

where:

C_{RTY} = reduction coefficient for mild-grade steel = 0.9
C_{RTU} = reduction coefficient for high-strength steel = 0.8
A_t = cross-sectional steel area of the test soil nail in square inches
f_y = nominal yield strength of test soil nail (mild steel) in kips per square inch
f_u = nominal tensile strength of test soil nail (high-strength steel) in kips per square inch
r_{PO} = nominal pullout resistance in kips per foot of test soil nail per plans = $\pi \times q_u \times D_{DH}$
q_u = nominal bond strength in kips per square foot
D_{DH} = drill hole diameter in feet

(c) If $L_{B\ VTmax} > 10$ feet, select $L_{B\ VT}$ to be 10 feet $\leq L_{B\ VT} \leq L_{B\ VTmax}$.

(d) If $L_{B\ VTmax} < 10$ feet, to avoid tensile breakage, select $L_{B\ VT} = 10$ feet and increase the test soil nail bar size as needed, and recalculate $L_{B\ VTmax}$ until $L_{B\ VTmax} > 10$ ft.

(e) The maximum (nominal) load during the verification test is defined as the Verification Test Load (VTL) and is calculated as VTL = $L_{B\ VT} \times r_{PO}$

Table 504-1
VERIFICATION TEST LOADING SCHEDULE

Load	Hold Time (minutes)[2]
AL[1]	1
0.13 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.25 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.38 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.50 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.63 VTL	10 (recorded at 1, 2, 4, 5, 10)
0.75 VTL (Creep Test)[3]	60 (recorded at 1, 2, 4, 5, 6, 10, 20, 30, 50, 60)
0.88 VTL	10
1.00 VTL[4]	10
AL	1[5]

[1] AL = alignment load, which is less than or equal to 0.05 VTL.
[2] Soil nail movement shall be measured after each load increment has been achieved and at each time step.
[3] Maintain the load during the creep test within 2 percent of the intended load by use of the load cell.
[4] The Engineer may allow loading to failure to determine nominal soil conditions.
[5] Permanent soil nail movement shall also be recorded

.

504.34 Proof Testing Of Production Soil Nails. Successful proof testing shall be performed on 5 percent of the production soil nails in each soil nail row or a minimum of one per row. Verification tests shall not be included in the 5 percent; except that the Engineer may allow the verification tests to be included based on the plans and site conditions. The Engineer will determine the locations and number of proof tests prior to soil nail installation in each row unless otherwise shown on the plans. Production proof test soil nails shall have both bonded and temporary unbonded lengths. Fully grouted test soil nails shall not be proof tested. The Contractor shall maintain the stability of the hole for the temporary unbonded test length for subsequent grouting. If the unbonded test length of production proof test soil nails cannot be satisfactorily grouted subsequent to testing, the proof test soil nail shall become sacrificial and shall be replaced with an additional production soil nail installed at the Contractor's expense. The temporary unbonded length of the test soil nail shall be at least 3 feet as measured from the back of the bearing plate to the top of the grout.

Proof tests shall be conducted according to the loading schedule of Table 504-2. Unless the soil is susceptible to creep per subsection 504.15, each load increment shall be held until readings are stable as defined by three readings within 0.005 inches taken one per minute over three minutes. The Contractor shall record soil nail movements at each load increment and the time intervals shown in the table for each load step. Creep tests shall be performed at 1.00 PTL. The alignment load (AL) shall be the minimum load required to align the testing apparatus and shall not exceed 5 percent of the PTL. Set dial gauges to “zero” after applying the alignment load. Following application of the maximum load, reduce the load to the alignment load and record the permanent set.

The creep period shall start as soon as the maximum test load (1.0 PTL) is applied and the soil nail movement shall be measured and recorded at 1 minute, 2, 3, 5, 6, and 10 minutes. Where the soil nail movement between 1 minute and 10 minutes exceeds 0.04 inch, the maximum test load shall be maintained for an additional 50 minutes and movements recorded at 20 minutes, 30, 50, and 60 minutes. All load increments shall be maintained within 5 percent of the intended load.

The bonded length of the soil nail during verification tests, $L_{B\ PT}$, shall be:

(a) For Grade 75 and other mild steel in accordance with ASTM A615, the maximum bond length ($L_{B\ PTmax}$), is defined as:

$$L_{B\ PTmax} = \frac{A_t \cdot f_y \cdot C_{RTY}}{r_{PO} \cdot 0.75}$$

(b) For Grade 150 and other high-strength steel in accordance with ASTM A722, the maximum bond length ($L_{B\ PT\ max}$), is defined as:

$$L_{B\ PTmax} = \frac{A_t \cdot f_u \cdot C_{RTU}}{r_{PO} \cdot 0.75}$$

(c) Select $L_{B\ PT}$ to be 10 ft or $L_{B\ PTmax}$, whichever is smaller, to avoid tensile breakage.

(d) Production proof test soil nails that are shorter than 13 feet may be tested with less than the minimum 10 feet bond length. The maximum load in the proof test (PTL) is calculated as PTL = $L_{B\ PT} \times r_{PO} \times 0.75$

Table 504-2
PROOF TEST LOADING SCHEDULE

Load	Hold Time (minutes)[2]
AL[1]	1
0.17 PTL	Until Movement Stabilizes[3]
0.33 PTL	Until Movement Stabilizes
0.50 PTL	Until Movement Stabilizes
0.67 PTL	Until Movement Stabilizes
0.83 PTL	Until Movement Stabilizes
1.0 PTL (Creep Test)[4]	10 (recorded at 1, 2, 4, 5, 6, and 10)
AL	1

Notes:
1 AL = alignment load, which is less than or equal to 0.05 PTL.
2 Times are measured after the target load has been achieved in each increment.
3 If the soils reinforced with soil nails are relatively susceptible to deformation of creep, it is recommended to hold each load increment for 10 minutes and to record the soil nail movement at 1, 2, 5, and 10 minutes.
4 If the soil nail movement measured between 1 and 10 minutes exceeds 0.04 in., PTL must be maintained for 50 additional minutes and movements must be recorded at 20, 30, 50, and 60 minutes. The permanent soil movement must also be recorded.

504.35 Test Soil Nail Acceptance Criteria. A test soil nail shall be considered acceptable when the following criteria are met.

(a) *Verification testing*. The following criteria shall be met for acceptance of the soil nail:

(1) Pullout shall not occur at loads less than 1.00 VTL.

(2) The total movement (Δ_{VTL}) measured at VTL shall exceed 80 percent of the theoretical elastic elongation of the unbonded length (L_{UB}), as defined by:

$$\Delta_{VTL} > 0.8 \frac{VTL \cdot L_{UB}}{E \cdot A_t}$$

where E = Young's modulus of steel (29,000 ksi).

(3) The creep movement between the 1 and 10-minute readings at 0.75 VTL shall be less than 0.04 in.

(4) The creep movement between the 6 and 60-minute readings at 0.75 VTL shall be less than 0.08 in.

(5) The creep rate shall be linear or decreasing throughout the creep test load-hold period.

(b) *Proof testing*. The following criteria shall be met to acceptance of the soil nail:

(1) No pullout occurs.

(2) The total soil nail movement (Δ_{PTL}) measured at PTL shall be greater than 80 percent of the theoretical elastic elongation of the unbonded length, as defined by:

$$\Delta_{PTL} > 0.8 \frac{PTL \cdot L_{UB}}{E \cdot A_t}$$

(3) The creep movement shall be less than 0.04 in. between the 1 and 10-minute readings.

(4) If this movement is exceeded, PTL shall be maintained for an additional 50 minutes with readings recorded at 20, 30, 50, and 60 minutes.

(5) If the creep test is extended, the creep movement between the 6 and 60-minute readings shall be less than 0.08 in.

504.36 Test Soil Nail Rejection. If a test soil nail does not satisfy the acceptance criterion in subsection 504.17**:**

(a) *Verification test soil nails*. The Engineer will evaluate the results of each verification test. The Contractor shall propose and provide plans and calculations for alternative methods for review and acceptance by the Engineer and shall install replacement verification test soil nails. Replacement test soil nails shall be installed and tested at the Contractor's expense. The production soil nails shall be installed using the same installation procedures (drill equipment, drill tooling, drill hole diameter, grouting, etc.) used to provide successful verification tests at no additional cost to the Department.

(b) *Proof test soil nails*. The Engineer may require the Contractor to replace some or all of the installed production soil nails between a failed proof test soil nail and the adjacent passing proof test soil nail. Alternatively, the Engineer may require the installation and testing of additional proof test soil nails to verify that adjacent previously installed production soil nails have sufficient load carrying capacity. Installation and testing of additional proof test soil nails or installation of additional or modified soil nails as a result of proof test soil nail failures shall be at the Contractor's expense.

504.37 Wall Drainage Network. All elements of the wall drainage network shall be installed and secured as shown on the plans. The drainage network shall consist of installing geocomposite strip drains, PVC connection pipes, wall footing drains, and weepholes as shown on the plans. Exclusive of the wall footing drains, all elements of the drainage network in the current lift shall be installed prior to shotcreting.

(a) *Geocomposite Strip Drains.* Geocomposite strip drains shall be centered between the columns of soil nails as shown on the Plans. The strip drains shall be at least 12 inches wide and placed with the geotextile side in contact with excavation face. The strips shall be secured to the excavation face and shotcrete shall be prevented from contaminating the geotextile. Strip drains shall be vertically continuous. Splices shall be made with a 12-inch minimum overlap such that the flow of water is not impeded. Drain plate and connector pipe shall be installed at the base of each strip as shown on the plans. Damage to the geocomposite strip drain which may interrupt the flow of water shall be repaired.

(b) *Underdrains.* Underdrains shall collect groundwater from the drainage network and be installed at the bottom of each wall as shown on the plans. The drainage geotextile shall envelope the footing drain aggregate and pipe and conform to the dimensions of the trench. The drainage geotextile shall overlap on top of the drainage aggregate as shown on the plans. Damaged or defective drainage geotextile shall be repaired or replaced.

504.38 Initial Shotcrete Facing. The initial shotcrete facing shall be installed in accordance with Section 641. Membrane curing compound shall not be used. Maturity meters shall be used to monitor all shotcrete in accordance with subsection 641.05.

(a) *Initial Face Finish.* Shotcrete finish shall be either an undisturbed gun finish as applied from the nozzle or a rod, broom, wood float, rubber float, steel trowel or rough screeded finish as shown on the Plans.

(b) *Attachment of Soil Nail Head Bearing Plate and Nut.* Bearing plate, washers, and nut shall be attached to each soil nail head as shown on the plans. While the initial shotcrete facing is still plastic and before its initial set, the plate shall be uniformly seated on the shotcrete by hand-wrench tightening the nut. Where uniform contact between the plate and the shotcrete cannot be provided, the plate shall be set in a bed of grout. After grout has set for 24 hours, the nut shall be hand-wrench tightened. Bearing plates and headed studs shall be located within the tolerances shown on the Plans.

(c) *Shotcrete Facing Tolerances.* Construction tolerances for the shotcrete facing from plan location and plan dimensions shall be as shown in Table 504-3.

Table 504-3
INITIAL SHOTCRETE FACING TOLERANCES

Item	Tolerance
Horizontal location of welded wire mesh, reinforcing bars, and headed studs measured horizontally from wall face	3/8 in.
Location of headed-studs on bearing plate	1/4 in.
Spacing between reinforcing bars	1 in.
Reinforcing lap length	1 in.
Thickness of shotcrete, if troweled or screeded	9/16 in. [approximation of 0.6 in.]
Thickness of shotcrete, if left as shot	1-1/8 in. [approximation of 1.2 in.]
Planeness of finish face surface, gap under 10-ft straightedge, if troweled or screeded	9/16 in. [approximation of 0.6 in.]
Planeness of finish face surface, gap under 10-ft straightedge, if left as shot	1-1/8 in. [approximation of 1.2 in.]
Soil nail head bearing plate deviation from parallel to wall face	10 degrees

504.39 Forms and Falsework. Forms and falsework shall conform to subsections 601.09 and 601.11 respectively.

504.40 Reinforcing Steel. Reinforcing steel shall be installed in accordance with this specification and Section 602.

504.41 Structural Concrete. Structural concrete shall be placed in accordance with this specification and Section 601.

504.42 Acceptance. Material for the soil nail retaining wall will be accepted based on the manufacturer production certification or from production records. Construction of the soil nail retaining wall will be accepted based on survey, visual inspection, and the relevant production testing records.

METHOD OF MEASUREMENT

504.43 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.

504.43 Soil nail walls will be measured by the quantities for the five major components of the wall: soil nail, initial shotcrete facing, verification testing, excavation and underdrain.

Soil nail will be measured by the linear foot of nail installed and accepted.

Verification testing will be measured by the number of verification tests performed.

BASIS OF PAYMENT

504.44 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, 1/4 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.

504.45 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 1/4 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 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 deviate from even by more than 1/4 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. If the finished wall facing profile outside of acceptable zone or into negative batter is not repairable, the non-repairable portion shall receive a 21 percent price reduction for each wall pay item. 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 five, the Engineer will reject the entire wall or portions thereof. The Contractor shall replace the rejected wall at his own expense.

504.46 The accepted quantities, measured as provided above, will be paid for at the contract unit price for the pay items listed below that are shown on the bid schedule. Payment will be made under:

Payment will be made under:

Pay Item	**Pay Unit**
Soil Nail	Linear Foot
Verification Testing	Each

Payment for Soil Nail Wall will be full compensation for all work and materials required to complete soil nail wall. This work shall include but is not limited to soil nails, geocomposite strip drains, proof testing, drilling, grouting, bearing plates, end hardware (nuts, washers, couplers), certificates of compliance, and incidentals necessary to acceptably fabricate and construct the soil nail walls exclusive of any final facing items that may be tabulated on the plans.

All excavation work required to construct the soil nail wall and the initial shotcrete facing to the lines and grades indicated on the plans will be measured and paid for in accordance with Section 203 or 206. Additional earthwork outside of excavation for the wall installation and backfilling prior to or post wall construction will not be measured and paid for separately, but shall be included in the work.

Underdrain will be measured and paid for in accordance with Section 605.

Initial Shotcrete Facing will be measured and paid for in accordance with Section 641under Pay Item Initial Shotcrete Facing.

Incidental shotcrete required for over-break will be measured and paid for in accordance with Section 641 under Pay Item Shotcrete.

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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 C535	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 truckloads 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 1 1/2- 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 1 1/2-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.

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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 1,000 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 or by the American Wood Protection Association (AWPA) standards.

508.04 Inspection. All timber furnished shall be covered by a certificate of inspection issued by the American Lumber Standard Committee (ALSC) or the International Accreditation Service (IAS) accredited inspection agency. Inspection approval shall be marked on each piece.

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 1/2 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 1/4 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 1/4 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 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.

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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 A709) 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 A673). 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 A709)
High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 inches thick	AASHTO M 270 (ASTM A709)

Steel conforming to AASHTO M 270 (ASTM A709) 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 A847, 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 A307 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 A668, 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 1-1/2 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 A449 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 C2.23, 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 A108, 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 work 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 and 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 1/6 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 A578. Plates greater than 3/4 inch thick shall be tested using 2.25 MHZ 1-inch diameter transducers. Plates less than and including 3/4 inch thick shall be tested with a 5 MHZ 1/2 -inch diameter transducer. Supplementary requirement S2 shall be used as the acceptance standard.

(c) *Dye Penetrant Testing.* Dye penetrant testing in accordance with ASTM E165 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 E709 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 E709, 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 E18. 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 5/8-inch-thick and carrying calculated stress shall be milled or sawn to a depth of 1/4 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 1,200 °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 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 1,000 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 1/4 inch thick shall be placed against the web before applying heat to the inside flange surface. When the radius of curvature is 1,000 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 1,000 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 1 1/4 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 2 1/2 inches and the radius of curvature is greater than 1,000 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 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 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 1/16 inch smaller than the nominal diameter of the fastener and reamed to 1/16 inch larger than the nominal diameter of the fastener, or drilled to 1/16 inch larger than the nominal diameter of the fastener. Subsized holes prior to reaming shall not be offset more than 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 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 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 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 1/50 inch for pins 5 inches or less in diameter, or 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 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 1/4 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 E110. 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 1 1/2 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 1/2 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 1/4 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 A780, 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 A709 Grade 50W steel, prior to shipping.

(a) *Cleaning of Unpainted ASTM A709 Grade 50W Steel.* The exterior surfaces of unpainted ASTM A709 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 topcoat 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 A709 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 electronically 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 1,200 °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 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 F959.

Bolts shall be AASHTO M164 Type 1 for connections which are painted. Bolts for unpainted ASTM A709 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 A709 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 LRFD Bridge Design Specifications

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 F606 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 F606 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 LRFD Bridge Design Specifications, 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 A709 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 A709 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 A709) Grade 36 unless otherwise required in the Contract. ASTM A709 Grade 50W or ASTM A709 Grade 50 may be substituted for ASTM A709 Grade 36. Anchor bolts shall be ASTM A449 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 3/4 inch or less in thickness may be either laminated or plain. Pads over 3/4 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 1/2 inch, plus or minus 1/8 inch in thickness. Unless otherwise noted on the plans, the top and bottom layers of metal shall be uniformly covered with a maximum of 1/8 inch of elastomer. The edges of the metal shall be uniformly covered with a minimum of 1/8 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 1/8 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 1,000 psi, shall not exceed 0.06.

Pads less than 3/4 inch in thickness may be either laminated or plain. Pads 3/4 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 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 1/4 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 3,500 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 half 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, 1,000 to 2,999 kips, and 3,000 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 1/16 inch for bearing seats up to 30 inches, 3/32 inch for bearing seats over 30 inches and under 45 inches, and 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 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 Devices 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.

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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 A53, 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 A709 Grade 36.

(3) Bolts shall conform to the requirements of ASTM A307.

(4) Zinc coating shall conform to the requirements of ASTM A123, A153, A385 and A386.

(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 A847 for structural steel tubing and ASTM A709 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 1/4 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 setscrew 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 3/8 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.

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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 1/8 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

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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.

This work consists of furnishing and placing a Polyester Concrete End Dam system which includes Polyester-based Polymer Concrete (PPC) and High-Molecular-Weight Methacrylate (HMWM) resin primer. The system shall be used for Portland Cement Concrete blockouts (PCC) of bridge expansion devices on the concrete bridge deck, abutment backwalls, and approach slabs as shown on the plans.

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. The Contractor shall provide calculations electronically sealed by the Contractor's Engineer to the Engineer.

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

Structural Steel (except center beams, edge beams and support bars)	AASHTO M 270 (ASTM A709) Grade 36
Center Beams, Edge Beams and Support Bars	AASHTO M 270 (ASTM A709) Grade 50 or AASHTO M 270 (ASTM A709) 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 Polyester Concrete End Dam.

(a) *Submittals.* 15 days prior to the Polyester Concrete Pre-placement Conference the Contractor shall submit the following:

(1) Polyester Concrete End Dam System. The Contractor shall submit to the Engineer two copies of the Manufacturer's written instructions for the installation of the Polyester Concrete End Dam system. The literature shall contain pertinent materials and installation data for the PPC supplied on the project. The Contractor shall submit the proposed testing procedures, mix design, form installation, and criteria for all PPC materials.

(2) Manufacturer Qualifications. The Contractor shall install a Polyester Concrete End Dam system with all components of PPC provided through a single manufacturer. The manufacturer shall have documented experience supplying five successful projects of similar size and scope within the past five years. The Contractor shall submit documentation of the manufacturer's project experience including the following:

(i) Project construction dates.
(ii) PPC quantities.
(iii) Reference names and contact information for owner representatives.

(3) Contractor Qualifications. The Contractor shall submit documentation of at least 10 successful projects with one or more of the following: (1) Thin Bonded Overlay (Polyester Concrete), and (2) Polyester Concrete End Dam, to established grade lines using similar equipment as specified in subsection 518.11(c) below within the past five years. The documentation of Contractor qualifications shall include the following:

(i) Project construction dates.
(ii) PPC quantities.
(iii) Reference names and contact information for owner representatives.

If the Contractor does not have at least 10 documented successful projects of experience with placing PPC systems, the Contractor shall arrange for a qualified Manufacturer's Technical Representative with at least five documented successful projects of experience with PPC system placements within the past five years to be on-site throughout the duration of the project to provide technical support for the material mixing and placement.

If the Contractor has at least 10 documented successful projects of experience with placing PPC systems, the qualified Manufacturer's Technical Representative with at least five documented successful projects of experience with PPC system placements within the past five years shall, at a minimum, be on-site the first day of PPC placements, and shall be available as requested by the Engineer if necessary.

(4) Manufacturer's Technical Representative Qualifications. The Manufacturer's Technical Representative shall have at least five documented successful projects of experience of similar size and scope with PPC system placements using similar equipment as specified herein within the past five years, and be competent in all aspects of the work including all materials to install the PPC systems. This includes, but is not limited to, surface preparation, PPC application and PPC curing. The Technical Representative shall be available on-site for the first day of PPC placement to facilitate the installation.

The Contractor shall submit documentation of the Technical Representative's experience including the following:

(i) Years of experience with PPC systems.
(ii) Project construction dates.
(iii) PPC quantities.
(iv) Reference names and contact information for owner representatives.

(5) Certified Test Report. The Contractor shall furnish a Certified Test Report, in accordance with subsection 106.13, confirming that all materials required for a Polyester Concrete End Dam system have been pretested, and meet all requirements.

(6) Placement Plan. The Contractor shall submit a Polyester Concrete Placement Plan that includes the following:

(i) Schedule of work and required testing.
(ii) Placement sequence and procedure.
(iii) Description of all equipment used.
(iv) Method for preventing leakages of HMWM primer and Polyester Concrete.
(v) Method for measuring, and maintaining thickness and profile for each lift.
(vi) Finishing surface method including sequence and repair of damaged sections.
(vii) Cure time for Polyester Concrete.
(viii) Storage and handling of resin and PPC components.
(ix) Procedure for disposal of excess resin, PPC and containers.
(x) Procedure for cleanup of mixing and placement equipment.

(7) Equipment. The Contractor shall submit documentation of certification of scales that will be used to calibrate the mobile mixing truck. The certification shall be dated within the last month. A new certification shall be done if any adjustments are made to the scales.

(8) Material Samples. Representative material samples used for the project shall be submitted to the Engineer a minimum of 30 days prior to the PPC application. The exact samples of materials from the same lots used for the project, for all components of the PPC system shall be submitted by the manufacturer, if requested, a minimum of 15 days prior to the PPC application. The quantities of the material samples shall consist of one 4-liter sample for each liquid with corresponding amounts of catalysts and accelerators, and a 50-pound sample for each dry component.

(b) *Material Requirements.* Materials for the Polyester Concrete End Dam shall be as follows:

(1) PPC. The PPC shall consist of Polyester Resin Binder, catalysts and dry aggregate specified in Table 518-3. It shall also include a compatible primer applied on the prepared concrete areas, which when mixed with other specified materials and applied as specified herein, shall produce a PPC meeting the requirements of this specification. Accelerators may be required to speed up the chemical reaction, and achieve proper Set Time of the PPC. They shall be used as

recommended by the PPC Manufacturer.

(2) Polyester Resin Binder. Polyester Resin Binder shall have the following properties:

(i) Be an unsaturated Isophthalic Polyester-styrene Co-polymer. The Polyester Resin content shall be 12 percent ±1 percent of the weight of the dry aggregate.
(ii) Contain at least 1.0 percent by weight Gamma-methacryloxypropyltrimethoxysilane, an Organosilane Ester Silane coupler.
(iii) Be used with a promoter that is compatible with suitable Methyl Ethyl Ketone Peroxide and Cumene Hydroperoxide initiators.
(iv) Have the values for the material properties shown in Table 518-1.

Table 518-1
POLYESTER RESIN BINDER PROPERTIES
(Tested each lot sent to the job)

Property	Test Method	Value
Viscosity*	ASTM D2196	$0.1x10^{-5}$ to $2.9x10^{-5}$ psi-sec (0.075 to 0.20 Pa-s) RVT No.1 Spindle, 20 RPM at 77 °F
Specific Gravity*	ASTM D1475	1.05 to 1.10 at 77 °F
Elongation	ASTM D638	35% minimum Type I specimen, thickness 0.25 ± 0.03" at Rate = 0.45 inch/minute.
	ASTM D618	Sample Conditioning: 18/25/50+5/70
Tensile Strength	ASTM D638	2,500 psi, minimum Type I specimen, thickness 0.25 ± 0.03" at Rate = 0.45 inch/minute.
	ASTM D618	Sample Conditioning: 18/25/50+5/70
* Test shall be performed before adding initiator.		

(3) Primer. Primer for the concrete blockout surfaces shall be a wax-free low odor, High-molecular-weight Methacrylate primer (HMWM), and consist of a resin, initiator, and promoter.

When initiators and promotors are required to achieve proper modifications for working under different temperature conditions and applications of the primer, they shall be used as recommended by the PPC Manufacturer.

HMWM primer shall be applied to bond in PCC surfaces and promote adhesion to the PPC materials. The primer shall be tested for the Bond Strength in accordance with CP-L4302. The primer shall have a maximum volatile content of 30 percent prior to adding the initiator, when tested in accordance with ASTM D2369, and conform to Table 518-2.

Initiators for the Methacrylate Resin shall consist of a metal drier and Peroxide. If supplied separately from the resin, the metal drier shall not be mixed with the Peroxide directly. The containers shall not be stored in a manner that allows leakage or spilling to contact the containers or materials of the other.

Table 518-2
HIGH MOLECULAR WEIGHT METHACRYLATE RESIN PROPERTIES
(Tested yearly)

Property	Test Method	Value
Viscosity*	ASTM D2196	$4.0x10^{-5}$ psi-sec (0.025 Pa-s) maximum (Brookfield RVT with UL adapter, 50 RPM at 77 °F)
Volatile Content*	ASTM D2369	30% maximum
Specific Gravity*	ASTM D1475	0.90 minimum at 77 °F
Flash Point*	ASTM D3278	180 °F minimum
Vapor Pressure*	ASTM D323	0.04 inch Hg, maximum at 77 °F
PCC Saturated Surface-Dry Bond Strength (Adhesive)	CP-L4302	700 psi, minimum at 24 hours and 70 ± 1 °F (with Polyester Concrete at 12 % resin content by weight of the dry aggregate)
* Test shall be performed before initiator is added		

(4) Aggregate. Aggregate for Polyester Concrete shall:

(i) Have not more than 45 percent crushed particles retained on the No. 8 sieve when tested in accordance with AASHTO Test Method T335.
(ii) Provide fine aggregate consisting of natural sand.
(iii) Have a weighted-average aggregate absorption of no more than 1.0 percent when tested under AASHTO Test Methods T84 and T85.
(iv) At the time of mixing with resin, have moisture content of not more than one-half of the weighted-average aggregate absorption when tested under AASHTO Test Method T255.
(v) Comply with the requirements for the aggregate gradation shown in Table 518-3.

Table 518-3
AGGREGATE GRADATION
(Tested yearly)

Sieve Size	Percent Passing
3/8”	100
No. 4	62 - 85
No. 8	45 - 67
No. 16	29 - 50
No. 30	16 - 36
No. 50	5 - 20
No. 100	0 - 7
No. 200	0 - 3

(5) Sand. Sand for abrasive sand finish shall:

(i) Be commercial-quality blast sand.
(ii) Have not less than 95 percent pass the No. 8 sieve, and not less than 95 percent retained on the No. 20 sieve when tested under AASHTO Test Method T27.
(iii) Have an average absorption of not more than 1.0 percent when tested under AASHTO Test Method T85.

(6) Composite System Properties. Polyester Concrete End Dam system shall have the values for the composite system properties shown in Table 518-4:

Table 518-4
COMPOSITE SYSTEM PROPERTIES
(Tested every 2 years)

Property	Test Method	Values
Abrasion Resistance	CP-L4301	< 2g weight loss (at 12% resin content by weight of the dry aggregate)
Modulus of Elasticity	ASTM C469	1,000,000 psi to 2,000,000 psi (at 12% resin content by weight of the dry aggregate)
PPC (Bond Strength)	CP-L4302	500 psi minimum at minimum of 24 hours and 70 °F (without Primer, at 12% resin content by weight of the dry aggregate, and saturated surface dry specimen)
Compressive Strength at Final Set Time	ASTM C805	3,000 psi at minimum of 4 hours
Compressive Strength at Cure Time	ASTM C39	4,500 psi at minimum of 24 hours

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 1/4 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 Polyester Concrete End Dam.

(a) *Pre-placement Conference*. A Polyester Concrete Pre-placement Conference shall be held at least 15 days before any PPC placement operation begins. Attendees shall include all parties involved in the work.

(b) *Trial Application.* The Contractor shall construct a test box for a test pour. The test box shall be at least 2 feet long, the depth of the Polyester Concrete End Dams, and the maximum width of the End Dams, or as approved by the Engineer. Prior to constructing the Polyester Concrete End Dams, one or more trial applications shall be placed in the test box to determine the Initial Set Time (Gel Time), Final Set Time, and Cure Time and to demonstrate the effectiveness of the mixing, placing, and finishing equipment proposed. The Final Set Time can be determined when the in-place PPC cannot be deformed by pressing with a finger, indicating the resin binder is no longer in a liquid state.

The trial application shall replicate field conditions and be constructed using the same installer and equipment as the production work. The location of the trial application shall be as approved by the Engineer. Trial applications shall be properly disposed of off-site by the Contractor.

The number of trial applications required shall be as many as necessary for the Contractor to demonstrate the ability to construct an acceptable trial end dam section and competency in ability to perform the work. All Set Times are based on anticipated application temperatures, conditions, and lane closure timing. The Contractor shall adjust the mix design, and construct a test box and demonstrate that the adjusted mix consolidates and sets properly. The methods, installer, or the PPC system may be rejected after three trial applications if not shown to be adequate or in compliance with this specification as directed by the Engineer.

Acceptable test results shall be achieved on a trial application before installation may proceed.

(c) *Equipment.* All equipment for cleaning the existing concrete surface, and mixing and applying the PPC system shall be in accordance with the Material Manufacturer's recommendations as approved by the Engineer prior to commencement of any work.

(1) Measuring Equipment. The following equipment shall be provided:
  (i) Certified Scales used to calibrate the mobile truck mixing equipment.
  (ii) Means to measure the resin levels in the tank of the mobile truck mixer during PPC placement operations and access to the resin tank.

(2) Mixing Equipment. A continuous mixer shall be used for all PPC applications. The continuous mixer shall:
  (i) Employ an auger screw/chute device.
  (ii) Be equipped with an automatic metering device that measures and records aggregate and resin volumes. Record volumes at least every five minutes, including time and date. Submit recorded volumes at the end of the work shift.
  (iii) Have a visible readout gage that displays volumes of aggregate and resin being recorded.
  (iv) Produce a satisfactory mix consistently during the entire placement.
  (v) Be calibrated by certified scales provided by the Contractor. Calibration shall be demonstrated by comparing the computer tickets to three consecutive batches of aggregate verified to be within 2 percent of one another. The process shall be repeated for three consecutive batches of resin, also verified to be within 2 percent of one another. This calibration process shall be witnessed by the Engineer, and the calibration shall be done every 90 days.

  A portable mechanical mixer of appropriate size for proposed batches, as recommended by the manufacturer and approved by the Engineer, may be used for all PPC applications and for smaller area applications of less than 2,000 cubic feet per contract.

(3) Finishing Equipment: PPC materials shall be placed using hand tools such that the finish shall match the adjacent deck or pavement surfaces, and meet the requirements of the project.

(d) *Surface Preparation.* Prior to HMWM primer and PPC applications, the concrete surfaces to be treated shall be cleaned by shot-blasting, scarifying, chipping, or sandblasting until all unsound materials and contaminants which may interfere with the primer and PPC have been removed from the concrete blockouts. Exposed concrete surfaces shall be protected from precipitation and heavy dew during and after the application of the primer.

(e) *Forms.* Forms of the concrete blockouts shall be tight, and sufficiently rigid to prevent distortion due to the pressure of the PPC and other loads incidental to the PPC. The formwork shall be inspected by the Engineer prior to the PPC placements. The forms shall be sealed water tight so that there is no leakage.

(f) *HMWM Primer Application.* Prior to placing HMWM primer in the concrete blockouts, the exposed surfaces of the existing concrete shall be completely dry and blown clean with oil-free compressed air. However, the primer shall be placed after 28-day curing time of new concrete.

After the exposed concrete surfaces have been prepared and cleaned, the primer shall be applied in accordance with the Manufacturer's recommendations. The primer shall be applied within five minutes of mixing at a spread rate of approximately 90 square feet per gallon, and uniformly spread to completely cover any surfaces which PPC materials will bond. The primer shall be reapplied to any areas that appear dry after 15 minutes of absorbing the materials. The concrete surface temperature shall be at 40 °F and rising to 95 °F maximum, and the relative humidity shall be not more than 85 percent.

(g) *Polyester Concrete Application.* The Polyester Concrete shall be applied in the concrete blockouts within two hours after the primer has been applied. Prior to PPC placement, the surface temperature of the concrete blockouts to receive PPC shall be at 40 °F and rising to 95 °F maximum.

The PPC shall be placed prior to the Initial Set Time and 15 minutes following addition of an initiator, whichever occurs first, or within a more restrictive temperature range if recommended by the manufacturer. After placing PPC in the concrete blockouts, if the Initial Set time of the PPC has exceeded 120 minutes, the materials shall be removed and replaced at the Contractor's expense.

Two-unit weight tests shall be performed on site for each lift and/or each day's production of PPC material using 4"x8" cylinders. The average of the two test results shall be within 135 +/- 5 pounds per cubic foot. If the average of the unit weight tests is not within this specified range, adjustments shall be made to the PPC and the tests performed again. Any material placed that is outside the specified range shall be removed and replaced at the Contractor's expense.

After a minimum of four hours and prior to opening to traffic, the Compressive Strength Test for Polyester Concrete End Dams shall be performed in accordance with the Rebound Hammer of Hardness Concrete, ASTM C805. The test results shall achieve the Compressive Strength of 3,000-psi minimum prior to opening traffic. In addition, one-unit weight test cylinder shall be stripped after 90 minutes and examined for evidence of poor consolidation. If uncured or unconsolidated material is determined to be present, the in-place end dam material shall be removed and replaced at the Contractor's expense.

If the depth of the Polyester Concrete End Dams exceeds 6 inches, the PPC materials shall be placed in lifts. The maximum thickness of each lift shall be recommended by the manufacturer or approved by the Engineer. Each lift of the PPC shall be consolidated and achieve a relative compaction in the concrete blockouts to the satisfaction of the Engineer.

A minimum of two 4-inch x 8-inch test cylinders shall be made for each day's production of PPC for expansion joint end dams. The test cylinders shall be broken at intervals as directed by the Engineer to verify a minimum compressive strength of 4,500 psi has been achieved. If the material has not reached 4,500 psi at 28 days, the Engineer has the option of price reducing the material or remove and replace in accordance with subsection 601.17.

(h) *Surface Finishing.* The proposed surface of Polyester Concrete End Dams shall be consolidated and finished to the required grade and cross slope using finishing equipment as approved by the Engineer.

Sand finish shall be applied by either mechanical means or hand broadcasting onto the glossy surface at a minimum rate of 2.2 lbs. per square yard immediately after finishing and before the Initial Set Time occurs. The smoothness of the PPC surface shall be tested with a 10-foot straightedge transversely and longitudinally. Deviations greater than 3/8 of an inch shall be diamond ground to the proposed finish grade. The thickness of the PPC shall not be reduced by more than 3/8 of an inch. Where there is a low spot reduced by more than 3/8 of an inch on the PPC surface, the low area shall be removed at least ¾" and replaced with new PPC system to the proposed finish grade as directed by the Engineer. If there is a damaged surface on the PPC, the Contractor shall remove unsound PPC surface and replace it with new PPC system in accordance with the Finishing Surface Method.

After final surface finishing, traffic or equipment shall not be allowed on the treated surface until the PPC has achieved the Final Set Time. The Polyester Concrete End Dams shall be protected from moisture until Final Set Time has been obtained. The Contractor shall follow all Manufacturer's recommendations including surface preparation and all Set Times prior to opening treated surfaces to traffic or completing the work.

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.

Polyester Concrete End Dam will not be measured, but will be the quantity designated on the plans.

Exceptions for each structure will be:

(1) when field changes are ordered, OR
(2) when it is determined that there are discrepancies on the plans in an amount plus or minus 2 percent of the plan quantity for the structure.

Polyester Concrete End Dam will be measured by the number of cubic feet completed in place and accepted. The pay volume for each discrete location (a contiguous treated area not touching other treated areas) shall be rounded up to the next whole cubic foot.

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 Polyester 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 surface preparation, HMWM primer application, PPC application, surface finishing, trial application test boxes, testing, the on-site Technical Representative 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
Polyester Concrete End Dam	Cubic Foot

Polyester Concrete End Dam Cubic Foot

NOTES