SECTION 509
STEEL STRUCTURES

DESCRIPTION

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

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

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

MATERIALS

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

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

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

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

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

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

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

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

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

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

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

509.09 Pins and Rollers. Steel for pins and rollers shall conform to ASTM A 668, Class C, D, F, or G as specified in the Contract. They shall be accurately manufactured to the dimensions shown in the Contract. Pins larger than 9 inches in diameter shall have a hole not less than 2 inches in diameter bored longitudinally through their centers. The hole shall be bored before the pin is subjected to heat treatment. Threads for all pins shall conform to the United Standard Series UNC-ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 1½ inches or more shall have six threads per 1 inch.

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

509.11 Galvanized and Metallized Steel. When shown in the Contract, structural steel shall be galvanized in accordance with AASHTO M 111. Steel surfaces to be

metallized shall be coated in accordance with AWS C2.2, Recommended Practice for Metallizing with Aluminum and Zinc for Protection of Iron and Steel. When the Contract specifies galvanizing, metallizing may be substituted.

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

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

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

SHOP FABRICATION AND INSPECTION REQUIREMENTS

509.14 Notice of Fabrication.

(a) *Quality Control and Quality Assurance.* Quality control (QC) of structural steel fabrication is the responsibility of the Contractor. The QC 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. QC 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 QC 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 quality 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) *Quality Control Plan.* The fabricator shall submit a written quality control plan to the QA inspector prior to the beginning of fabrication. The quality control plan shall outline the quality 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 quality 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 quality 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 quality control. Operations shall not resume until the fabricator has made a significant change in procedure. Proposed changes shall be defined and submitted in writing and approved by the QA inspector prior to resuming fabrication.

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

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

(f) *Reports.* The QC 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 quality 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 reinspection prior to shipment. Reinspection will normally be made at the next regular inspection; however, if no regular inspection is scheduled, and reinspection 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 reinspection. A deduction shall be made from the bid item cost for the item requiring reinspection.

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 quality 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 QC 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	(1) Tension-Compression	(2) Weld Orientation	(3) Percent Inspection
Flange	Tension	Transverse	100
Flange	Tension	Longitudinal	25
Flange	Compression	Transverse	25
Flange	Compression	Longitudinal	10
	(4)		
Web	Tension	Transverse	100
Web	Tension	Longitudinal	25
Web	Compression	Transverse	25
Web	Compression	Longitudinal	10
	Tension	Transverse	100
Pier & End	Tension	Longitudinal	25
Diaphragms	Compression	Transverse	25
	Compression	Longitudinal	10

Note:

(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 rewelding of the joint, or alternative nondestructive testing methods, as determined by the QA inspector. The testing procedures established in AWS D1.5, section 6.19 shall be amended as follows:

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

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

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

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

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

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

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

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

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

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

4. *Through Thickness Tension Plate.* Ultrasonic testing of plates as identified in the plans as exhibiting tension in the through thickness direction shall be performed in accordance with ASTM A 578. Plates greater than ¾ inch thick shall be tested using 2.25 MHZ 1 inch diameter transducers. Plates less than and including ¾ inch thick shall be tested with a 5 MHZ ½ inch diameter transducer. Supplementary requirement S2 shall be used as the acceptance standard.

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

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

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

Magnetic particle tests shall be performed at the following locations:

(1) *Base metal.* All areas contacted by the carbon arc gouge electrode, the electrode cup, and the welding electrode. All three conditions are arc strikes.
(2) *Fillet Welds.* Each design weld size on main member to main member and secondary member to main member weldments. All stop-starts and weld termini. All linear indications shall further be evaluated with 10x or 30x magnification. Verification shall be resolved by excavation.
(3) *Groove welds.* All through thickness edges on transverse butt joint weldments in tension areas.
(4) *Repairs.* All repair welds to correct: defects in groove and fillet welds, plate cut edges, correction of fabrication errors in cutting, punching, drilling, or fitting, and members which are tacked or welded and subsequently cut apart and rewelded.

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

1. *Contract Number.*

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

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

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

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

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

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

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

Production Quality 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 Quality control tests shall include the first production cut of the thickest fabricated flange. A minimum of 50 percent of production Quality 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 ¼ inch. Reentrant corners shall be pre-cut to a minimum radius of 1 inch before cutting. The procedure for cutting plate edges of tension flanges shall be qualified in accordance with subsection 509.18(f).

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

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

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

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

1. *Rolling Direction.* The bendline will be at right angles to the direction of rolling.

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

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

4. *Corner Radii.* The corners of the plate shall be rounded to a radius of $^{1}/_{16}$ 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.

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

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

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

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

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

   For the V-type heating, the apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached. To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so the heat is not applied directly to the web. Asbestos sheet material ¼ inch thick shall be placed against the web before applying heat to the inside flange surface. When the radius of curvature is 1000 feet or more, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend to the juncture of the flange and web. When the radius of curvature is less than 1000 feet, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to $^1/_8$ of the flange or 3 inches, whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees, but the base of the triangle shall not exceed 10 inches. Variations in the patterns prescribed above may be made upon approval by the QA inspector.

   For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is only mandatory when the flange thickness is

1¼ inches or greater, in which case, the two surfaces shall be heated concurrently. The minimum temperature shall be as prescribed below.

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

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

4. *Position for Heating.* The girder may be heat curved with the web in either a vertical or a horizontal position. When curved in the vertical position, the girder must be braced or supported in such a manner that the tendency of the girder to deflect laterally during the heat curving process will not cause the girder to overturn.

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

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

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

   A. Attachment of end bearing stiffeners.
   B. Attachment of lateral gusset plates.
   C. Attachment of longitudinal stiffeners.
   D. Welding of intermediate stiffeners and connection plates to the flanges. When longitudinal stiffeners are required, they shall be heat

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

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

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

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

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

The maximum deviation from flatness of the contact area of every steel bearing surface shall not exceed $^{1}/_{32}$ 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 in 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 QC inspector. Undercut may be prepared by contour grinding when approved by the Engineer. Areas repaired shall be recorded in accordance with AWS D 1.5, paragraph 6.5.8. Surfaces that are air carbon arc gouged shall be ground to bright metal prior to welding. Repair areas shall be preheated to a temperature of 200 to 300 °F prior to welding. Cracks removed prior to welding shall be penetrant tested or magnetic particle tested to assure their complete removal before welding. All repairs shall be penetrant or magnetic particle tested for soundness. This requirement applies equally to tack welds.

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

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

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

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

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

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

2. *Production Tests.* The first two studs welded on each beam or girder, after being allowed to cool, shall be bent 45 degrees by striking the stud with a hammer. If failure occurs in the weld of either stud, the weld procedure shall be corrected and two successive studs successfully welded and tested before any more studs are welded to the beam or girder. The QA inspector shall be promptly informed of all changes in the welding procedure at any time during fabrication.

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

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

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

509.21 Shop Assembly.

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

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

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

(d) *Full Chord Assembly.* Full chord assembly shall consist of assembling, with geometric angles at the joints, the full length of each chord of each truss or open spandrel arch, or each leg of each bent or tower, then reaming the field connection holes while the members are assembled, and reaming the web member connections to steel templates set at geometric (not cambered) angular relation to chord lines. Field connection holes in web members shall be reamed to steel templates. At least one end of each web member shall be milled or scribed normal to the longitudinal axis of the member and the templates at both ends of the member shall be accurately located from one of the milled ends or scribed lines.

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

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

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

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

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

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

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

+L/1200 -L/2880

Where: L = length in feet between supports

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

FIELD CONSTRUCTION REQUIREMENTS

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

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

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

509.27 Erection of Steel Structures.

Structural steel members shall be erected in a manner that will provide safety to the Contractor's forces, inspectors and the traveling public. Structural steel members shall be erected in a manner to prevent damage to all elements of the structure. 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 designed to resist all loads imposed during each stage of construction until completion of the deck concrete.

At least four weeks prior to erection, the Contractor shall approve, sign and submit a proposed plan of erection to the Engineer for record purposes only. The Erection Plan shall be approved by, and contain the seal and signature of, the Contractor's Professional Engineer registered in the State of Colorado. The Erection Plan will not be approved by the Engineer. If falsework drawings are required, they shall be submitted in accordance with subsection 601.11.

The Erection Plan and procedure shall provide complete details of the erection process including but not limited to:

(1) Temporary falsework support, bracing, guys, deadmen, connection details and attachments to other structure components or objects;
(2) Procedure and sequence of operation including a detailed schedule that shall comply with the working hour limitations;
(3) Cranes make and model, weight, geometry, lift capacity, outrigger size and reactions;
(4) Girder weights, lift points, lifting devices, spreaders, and angle of lifting cables.
(5) Assumed loads and girder stresses during progressive stages of lifting and erection to substantiate the structural integrity and stability of the girders prior to completion of the entire structure;
(6) Girder launcher or trolley details and capacity (if intended for use); and
(7) Locations of cranes, trucks delivering girders, and the location of cranes and outriggers relative to other structures, including retaining walls, wing walls and utilities.
(8) Material properties and specifications for temporary works.
(9) Drawings, notes, catalog data showing the manufacturer's recommendations or performance tests, and calculations clearly showing the above listed details, assumptions, and dimensions.

A Pre-Erection Conference will be held at least two weeks prior to the beginning of erection. The Contractor and the Contractor's Professional Engineer shall attend the meeting.

The Contractor's Professional Engineer shall inspect and provide written approval of each phase of the installation prior to allowing vehicles or pedestrians on or below the structure. The Contractor's Professional Engineer shall approve all changes to the Erection Plan. The Contractor shall submit all changes to the Erection Plan to the Engineer for record purposes only. The Contractor shall demonstrate his knowledge and familiarity with the location of the piece marks and the piece mark convention used by the girder fabricator at the Pre-Erection Conference. This is required to assure the structural components are assembled in accordance with the reviewed shop drawings.

The Contractor shall perform daily inspections of the erected girders until completion of the deck concrete. The Contractor shall provide the Engineer with written documentation of these inspections within 24 hours.

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 and to the following:

Falsework and forms shall be constructed so that any loads applied to girder webs will be applied within 6 inches of a flange or stiffener and will be distributed in a manner that will not produce local distortion of the web. Temporary struts and ties shall be provided as necessary to resist lateral loads applied to the girder flanges and to prevent appreciable relative movement between the edge of deck form and the adjacent steel girder.

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

(f) *Anchorage.* Anchor bolts in piers, abutments, or pedestals shall be accurately set either in the concrete as it is being placed, or in holes formed while the concrete is being placed, or in holes drilled after the concrete has set. Bolts placed in formed or drilled holes shall be grouted in place with a nonshrink or epoxy grout which shall completely fill the holes. Location of anchors and setting of rockers shall take into account any variation from mean temperature at time of setting and anticipated lengthening of bottom flange due to dead load after setting. At mean temperature and under dead load the rockers shall be set vertical and anchor bolts at expansion bearings shall be centered in their slots. Care shall be taken that full and free movement at the movable bearings is not restricted by improper setting or adjustment of bearings or anchor bolts and nuts.

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

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

(i) *Handling and Installation.* During erection the parts shall be accurately assembled, as shown on the plans, and match-marks shall be followed. The material shall be so handled that parts will not be bent, broken, or otherwise damaged. Hammering which will damage or distort the members will not be permitted. Bearing surfaces and surfaces to be in permanent contact shall be

cleaned before the members are assembled. Splices and field connections of main stress carrying members shall have a minimum of one half of the holes filled with high strength bolts and cylindrical erection pins, with the bolts fully tightened before external support systems are removed and the connections completed by belting, unless otherwise specified.

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

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

(k) *Misfits.* The correction of minor misfits involving minor reaming, cutting, and chipping will be considered a legitimate part of the erection. However, any error in shop fabrication or deformation resulting from handling and transportation which prevents proper assembling and fitting up of parts by moderate use of drift pins or by a moderate amount of reaming and slight chipping or cutting shall be reported immediately to the Engineer. The Engineer's approval shall be obtained for methods of correction and the correction shall be made in the Engineer's presence.

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

509.28 Connections Using High-Strength Bolts.

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

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

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

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

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

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

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

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

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

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

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

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

5. *Snug Tight.* Installation of all high strength bolts shall be in accordance with AASHTO Standard Specifications for Highway Bridges, paragraph

10.17.4. The "snug tight" condition as defined in paragraph 10.17.4.3 or 10.17.4.6 shall be accomplished for any method of tightening.

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

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

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

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

2. *Washer 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 then 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 Lockwashers.* Subsections 509.28 (c), (e), and (f) shall not apply to bolts for which the plans specify lockwashers or locknuts. Fasteners with lockwashers 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
5/8	19,000
¾	28,000
7/8	39,000
1	51,000
1 1/8	56,000
1 ¼	71,000
1 3/8	85,000
1 ½	103,000

509.29 Field Cleaning and Painting of Steel.

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

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

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

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

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

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

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

METHOD OF MEASUREMENT

509.32

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

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

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

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

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

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

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

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

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

TABLE 509-4

Nominal Bolt Size (In Inches)	Weight of 100 Bolts in Pounds
5/8 - 11 UNC	32
¾ - 10 UNC	53
7/8 - 9 UNC	81
1 - 8 UNC	117
1 1/8 - 7 UNC	165
1¼ - 7 UNC	212
1 3/8 - 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 implementing the Erection Plan will not be 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 preconstruction 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.

Unless otherwise specified, bolt holes along those edges of the plates that will form longitudinal seams in the finished structure shall be staggered in rows 2 inches apart, with one row in the valley and one in the crest of the corrugations.

Where the bolting plan used by the fabricator requires the longitudinal seams to have a minimum of six bolts per linear foot of seam, the holes shall be punched in rows 2 inches apart with two holes in the crest and one hole in the valley on both edges of the plates.

Where the bolting plan used by the fabricator requires the longitudinal seams to have a minimum of eight bolts per linear foot of seam, the holes shall be punched in rows 2 inches apart with two holes in the crest and two holes in the valley along both edges of each plate.

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 preforming to an elliptical shape. This elongation shall

approximate five 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.

Damage to the pipe due to Contractor's operations shall be repaired or replaced at the Contractor's expense.

METHOD OF MEASUREMENT

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

BASIS OF PAYMENT

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

Payment will be made under:

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

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

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

SECTION 512
BEARING DEVICE

DESCRIPTION

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

MATERIALS

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

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

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

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

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

Structural steel elements of Type II bearing devices shall be painted in accordance with Section 509.

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

FABRICATION

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

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

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

Laminated pads shall be individually molded and shall consist of alternate laminations of elastomer and metal laminates. The bearings shall be vulcanized under heat and pressure. The mold finish shall conform to standard shop practice. The internal steel laminates shall be sandblasted and cleaned of all surface coatings, rust, mill scale, and dirt before bonding, and shall be free of sharp edges and burrs. Laminations of elastomer shall be ½ inch, plus or minus $^{1}/_{8}$ 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 1000 psi, shall not exceed 0.06.

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

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

512.05 Type III Bearing Device. The manufacturer of Type III bearings shall be preapproved and listed in the Contract. Type III bearing devices are designed as Pot type or Disc type. Bearing devices shall be fabricated as fixed, guided expansion, or non-guided expansion bearings as designated in the Contract. Bearings shall satisfactorily provide for thermal expansion and contraction, rotation, camber changes, and creep and shrinkage of the structural members they support. Bearings

shall be designed and fabricated so that they can be readily inspected and easily removed and replaced during the service life of the bridge. This shall include provisions to allow removal and replacement of all components of the bearing device, excluding sole plates, by lifting the superstructure no more than ¼ inch. The static coefficient of friction shall be determined based on the force required to cause first movement under the vertical load applied during the test. The operating coefficient of static friction or sliding friction between the stainless steel and the PTFE sheet, when subjected to a 3500 psi load, shall not exceed 0.03.

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

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

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

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.

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.

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

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

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

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

512.06 Reserved

512.07 Reserved.

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

512.09 Testing and Acceptance. The materials for elastomeric bearings and finished bearings shall be subjected to the tests described in this section. 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. The Engineer or the Engineer's representative shall be allowed free access to the necessary parts of the manufacturer's plant and test facility.

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

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

2. One lot shall not exceed 25 bearings.

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

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

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

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

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

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

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

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

5. *Rotational Test (Type III).* This test consists of applying a vertical load to the bearing device equal to 150 percent of its rated capacity and subjecting the bearing to the greater value of either rotation of 0.02 radians or the designed rotation for a period of one hour. During the testing of pot bearings, if the confined elastomer extrudes beyond the sealing mechanism,

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

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

A. *ShortDuration 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. *LongDuration 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 nonparallelism 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 bear-ings
   (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.

SECTION 514
PEDESTRIAN AND BIKEWAY RAILING

DESCRIPTION

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

MATERIALS

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

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

(1) Steel tubes shall conform to the requirements of ASTM A500 Grade B.
(2) Steel plates and bars shall conform to the requirement of ASTM A 709 Grade 36.
(3) Bolts shall conform to the requirements of ASTM A 307.
(4) Zinc coating shall conform to the requirements of ASTM A 123, A 153, A 385 and A 386.
(5) Welding shall conform to the American Welding Society Structural Welding Code - Steel, D1.1.

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

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

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

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

CONSTRUCTION REQUIREMENTS

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

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

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

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

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

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

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

METHOD OF MEASUREMENT

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

BASIS OF PAYMENT

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

Payment will be made under:

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

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

SECTION 515
WATERPROOFING MEMBRANE

DESCRIPTION

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

MATERIALS

515.02 The waterproofing membrane shall consist of one of the following:
(1) A prefabricated reinforced membrane and primer or,
(2) A single component, hot applied, elastomeric membrane and primer if required.

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

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

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

CONSTRUCTION REQUIREMENTS

515.04 Waterproofing Membrane.

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

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

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

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

(e) *Application of Protective Covering*. As soon as practical, but in all cases the same day as membrane application, protective covering shall be placed from gutter line to gutter line. Protective covering shall be laid parallel to the centerline of the bridge. The protective covering shall be butted together at longitudinal and transverse joints. Overlapping will not be permitted. The maximum allowable space between adjoining sections of protective covering shall be 1 inch. Following placement of protective covering, a bead of compatible mastic or hot applied membrane shall be applied where the protective covering contacts the curbs, and in cracks between adjoining sections that are apart by more than $^{3}/_{8}$ 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 a minimum rate of 1 gallon per 100 square feet of surface area. The sealer shall be applied to the surface of the concrete bridge deck, approach slabs, curbs including the face of concrete bridge rail for 6 inches above the bridge deck, sidewalks, and the interior concrete surface of drains. Two copies of the manufacturer's literature for the sealer including the recommended application procedure shall be provided to the Engineer prior to application. The literature shall include a product material safety data sheet.

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

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

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

METHOD OF MEASUREMENT

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

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

BASIS OF PAYMENT

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

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

Payment will be made under:

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

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

SECTION 516
DAMPPROOFING

DESCRIPTION

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

MATERIALS

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

CONSTRUCTION REQUIREMENTS

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

The surface which is to be protected by dampproofing shall be thoroughly cleaned before the primer is applied. The surface shall then be brush or spray painted with two coats of asphalt for primer treatment at a rate of $^{1}/_{8}$ 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

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	D 41	Primer under asphalt mop coats
*Asphalt Mop Coat	D 449	Mop coats with or without membrane
Woven Cotton Fabric	D 173	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 bituminous 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 not less than 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 not less than 15 gallons for each 100 square feet of vertical surface for each mop coat. The work shall be so regulated that, at the close of a day's work, all fabric that has been laid shall have received the final mopping of asphalt and the edges of all laps shall be thoroughly sealed down.

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

METHOD OF MEASUREMENT

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

BASIS OF PAYMENT

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

Payment will be made under:

Pay Item	Pay Unit
Waterproofing (Asphalt)	Square Yard

SECTION 518
WATERSTOPS AND EXPANSION JOINTS

DESCRIPTION

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

MATERIALS

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

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

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

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

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

518.04 Elastomeric Expansion Devices. This device consists of an elastomeric expansion joint device and curb cover plates as shown on the plans and in accordance with these specifications. The expansion joint device shall seal the deck surface as indicated on the plans, and prevent water from seeping through the superstructure slab. Seeping of water through the joint will be cause for rejection of the expansion device. The Contractor shall state at the preconstruction 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 not in contact with elastomers or embedded in concrete shall be painted or galvanized, in accordance with Section 509. Either painting or galvanizing may be used, unless noted otherwise on the plans. Portions of structural steel in contact with elastomeric seals or embedded in concrete shall not be painted, but may be galvanized. All paint coats shall be shop applied.

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 preconstruction 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 24 inches.

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

Only a continuous full length modular joint device supplied will be acceptable. 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, either box seals or 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) Center beams, support bars, and their connections shall satisfy the applicable design requirements of the AASHTO Standard Specifications for Highway Bridges. In addition, to help limit fatigue stresses at center beam to support bar connections, center beams and support bars shall satisfy the minimum criteria given in the following paragraph.

The maximum spacing of the support bars connected to a center beam shall not exceed 4 feet 0 inch along the center beam. The minimum area of a center beam shall be 4.9 square inches. The minimum section modulus about the horizontal axis for the bottom fiber of a center beam shall be 5.9 cubic inches. For the support bar, the minimum area (A) and minimum section modulus, about the horizontal axis for the top fiber (S), shall be as follows:

Rated Movement

	0-6"	0-9"	0-12"	0-15"	0-18"	0-21"	0-24"
A	5.1	6.2	7.0	7.7	8.5	9.1	9.7
S	2.9	4.2	5.5	6.7	8.0	9.3	10.4

The center beams and support bars shall be sufficiently detailed in the shop drawings so that the above minimum section properties can be independently verified using the information contained in the shop drawings.

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

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

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

All structural steel not in contact with elastomers or embedded in concrete shall be painted or galvanized, in accordance with Section 509. Either painting or galvanizing may be used, unless noted otherwise on the plans. Portions of structural steel in contact with elastomeric seals or embedded in concrete shall not be painted, but may be galvanized. All paint coats shall be shop applied.

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

by the manufacturer. The material designations for all components shall be shown on the shop drawings.

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

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

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

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

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

CONSTRUCTION REQUIREMENTS

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

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

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

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

The bridging plate shall be centered and secured over the joint opening according to the manufacturer's directions.

The joint binder, polymer modified asphalt, and aggregate shall be placed in the sequence and by the methods recommended by the manufacturer. The completed joint shall be compacted by the methods recommended by the manufacturer.

The final grade of the joint after compaction shall match the finished grade of the deck. The final thickness of the joint shall be 2.5 inches minimum.

A representative of the joint manufacturer shall be on site during the installation of each of the joint components. The representative shall certify that the joint was installed in accordance with manufacturer's recommended procedures and in accordance with the attached details. If a joint fails to meet the manufacturer's specifications, it shall be removed and replaced with a properly installed joint at the expense of the Contractor.

Two copies of the manufacturer's product literature, specifications and installation instructions shall be provided to the Engineer.

518.09 Elastomeric Expansion Devices. The Contractor shall submit working drawings as specified in subsection 105.02. The manufacturer's instructions for proper installation of the expansion joint device shall be included in the working drawings. Working drawings which lack manufacturer's installation instructions shall be returned for resubmittal.

Where applicable according to the plans, details of the expansion device through the curb, and details of the curb cover plates and connections, shall be shown on the working drawings.

At the discretion of the Engineer, the manufacturer may be required to furnish facilities for testing and inspecting of the completed device or a representative sample in the plant or at an independent test facility. The inspectors shall be allowed free access to the necessary parts of the manufacturer's plant and test facility.

The manufacturer shall provide a technical representative to be present at all times while the expansion device is being installed. The expansion device shall be installed in strict accordance with the manufacturer's written instructions and these specifications.

The expansion device shall be anchored as shown on the plans. Curb cover plates, where called for by the plans, shall be anchored to the concrete with castinplace 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 recleaned 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 nonacceptance.

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 includes 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. Shop drawings shall include manufacturer's installation instructions.

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 furnish facilities for testing and inspecting 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 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 their technical representative, and these specifications. The permanently installed expansion joint device shall match exactly the finished roadway profile and grade.

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 seal 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 and securely supported at the correct grade and elevation and the correct joint opening as shown on the plans and on the shop drawings. If the maximum time between setting the joint opening and placing concrete exceeds four hours, the opening shall be checked and adjusted as necessary.

(b) The structure temperature shall be measured by recording the surface temperature of the concrete, steel, or both with a surface thermometer as described below.

1. *Concrete Bridges*: Record the temperature of the underside of the concrete slab at each end of the superstructure element adjacent to the expansion joint. Take the average of the readings to use with the temperature chart shown on the plans. In lieu of surface readings, internal slab readings may be taken by drilling a ¼ inch diameter hole 3 inches into the concrete slab, filling the hole with water, and inserting a probe thermometer.

2. *Steel Bridges*: Record the concrete slab temperature as described above. In addition, record the surface temperature of the shaded portion of the girder web at each location. Average the readings of the steel and concrete to use with the temperature chart.

(c) All nongalvanized 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 (SSPCSP6, 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. Prior to concrete placement, all existing concrete surfaces shall be primed with a CDOT approved epoxy polysulfide grout. The grout shall be placed according to the manufacturer's instructions. 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 nonacceptance.

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 includes completion of the portions of the curb and deck that cannot be constructed until after the expansion device is installed. This applies even though this work is to be paid for under other items of the Contract.

(e) The Contractor shall provide written certification to the Engineer that the expansion joint device was installed in accordance with the manufacturer's instructions, the advice of their technical representative, and these specifications. Any certification from the joint manufacturer's technical representative, provided by the Contractor to the Engineer, shall be in writing.

518.11 Elastomeric Concrete End Dam. The material supplier shall supply a representative who is completely competent in all aspects of the work, including all material and all equipment necessary to install the elastomeric concrete end dam properly.

The representative shall remain on site until the job is completed. The representative shall be responsible for:

(1) Advising the Engineer and the Contractor to insure that the correct installation method is being followed.

(2) Training assigned personnel in the correct methods of installation.

(3) Certifying to the Engineer that the material has been installed correctly.

All certifications from the supplier's representative to the Engineer shall be in writing and shall be signed and dated by the supplier's representative and the Contractor.

METHOD OF MEASUREMENT

518.12 Waterstop will be measured by the number of linear feet installed and accepted.

Asphaltic expansion devices will be measured by the number of linear feet from curb face to curb face along the joint installed and accepted.

Elastomeric expansion device will be measured by the linear foot between faces of curbs, parallel to the expansion device, completely installed, tested, and accepted. Portions of devices required in faces of curbs, including cover plates and hardware, will not be measured for payment.

Modular expansion device will be measured by the linear foot between faces of curbs, parallel to the expansion device, completely installed and accepted. Portions of devices required in faces of curbs, including cover plates and hardware, will not be measured for payment. The words "completely installed" shall be interpreted to mean the expansion joint device is in place with the following operations completed:

(1) Concrete placed and finished.
(2) Watertight integrity test performed.

Elastomeric Concrete End Dam will be measured by the cubic foot completed and accepted.

BASIS OF PAYMENT

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

The accepted quantity of asphaltic expansion joint will be paid for at the contract unit price per linear foot and shall include all preparation materials, installation, compacting and final treatments associated with the particular joint provided.

The accepted quantity of elastomeric expansion device will be paid for at the contract unit price per linear foot and shall include all work necessary to complete the item, including furnishing and installing steel extrusions, steel angles, steel anchors, cover plates and hardware, bolts, inserts, epoxy grout, lubricant adhesive, premolded elastomeric joint seal and all miscellaneous hardware required.

The accepted quantity of modular expansion device will be paid for at the contract unit price per linear foot and shall include all work necessary to complete the items, including furnishing and installing modular expansion device, steel angles, concrete anchorages, cover plates and hardware, bolts, inserts, lubricant adhesive and all miscellaneous hardware required.

The accepted quantity of Elastomeric Concrete End Dam will be paid for at the contract unit price per cubic foot and shall include all work and materials necessary to

complete the item including saw cutting existing bituminous pavement, removing bituminous pavement, light sandblasting of existing concrete and any existing steel, and all miscellaneous work required.

Payment will be made under:

Pay Item	**Pay Unit**
Waterstop (Inch)	Linear Foot
Bridge Expansion Device (2 Inch)	Linear Foot
Bridge Expansion Device (0 - 4 Inch)	Linear Foot
Bridge Expansion Device (0 - __Inch)	Linear Foot
Elastomeric Concrete End Dam	Cubic Foot