# REVISION OF SECTION 509

# STEEL STRUCTURES

**Delete Section 509 and replace with the following:**

# DESCRIPTION

1. This work consists of furnishing, fabricating, erecting, and painting structural steel per 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.

1. 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

1. **Structural Carbon Steel.** Structural carbon steel for bolted or welded construction shall conform to AASHTO M270 (ASTM A709) Grade 36. Material supplied for main members in tension as designated in the Contract shall meet a longitudinal Charpy V-notch (CVN per AWS D1.5. Testing shall be per AASHTO T 243 (ASTM A673). The H frequency of heat testing shall be used.
2. **High-Strength Low-Alloy Structural Steel.** High-strength low-alloy structural steel for welding shall conform to the following specifications:

High-Strength Low-Alloy Columbian-Vanadium Steels of Structural Quality, Grade 50 shall meet the requirements of AASHTO M270 (ASTM A709).

High-Strength Low-Alloy Structural Steel with 50 ksi Minimum Yield Point to 4 inches thick shall meet the requirements of AASHTO M270 (ASTM A709).

Steel conforming to AASHTO M270 (ASTM A709) Grade 50W shall not be painted unless otherwise shown on the plans.

Material supplied for main members in tension, as designated in the Contract, shall meet the longitudinal Charpy V-notch (CVN) tests as specified for Zone 2 in AASHTO M270.

1. **Self-Weathering Tubing.** Self-weathering structural steel tubing shall conform to ASTM A847, Cold-Formed Welded and Seamless High Strength, Low Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance.
2. **Structural Tubing.** Steel base metal to be used for tubular structures, including bridge rail, shall conform to the plans or AWS D1.1. The grade and specification to be used shall be specified in the Contract.
3. **Bolts.** Bolts not otherwise specified in the Contract shall be zinc plated and meet the requirements of ASTM A307 for Grade A Bolts. Bolts shall have single self-locking nuts or double nuts unless otherwise specified in the Contract. Beveled washers shall be used when bearing surfaces have a slope exceeding 1:20 with respect to a plane normal to the bolt axis.
4. **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 ASTM F3125. In general, Type 1 bolts shall be used and bolts for self-weathering steel shall be Type 3, unless otherwise shown in the Contract.

Bolt and nut dimensions shall conform to the current edition RCSC unless otherwise noted. 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. Sufficient thread must be provided to prevent the nut from encountering thread runout.

Nuts shall conform to ASTM A563.

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.

1. **Pins and Rollers.** Steel for pins and rollers shall conform to ASTM A668, Class C, D, F, or G as specified in the Contract. They shall be accurately manufactured to the dimensions shown in the Contract. Pins larger than 9 inches in diameter shall have a hole at least 2 inches in diameter bored longitudinally through their centers. The hole shall be bored before the pin is subjected to heat treatment. Threads for all pins shall conform to the United Standard Series UNC-ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 1 1/2 inches or more shall have six threads per 1 inch.
2. **Anchor Bolts.** Unless otherwise shown in the Contract, all anchor bolts shall conform to ASTM F1554 and shall be zinc plated.
3. **Galvanized and Metallized Steel.** When shown in the Contract, structural steel shall be galvanized per AASHTO M111. Steel surfaces to be metallized shall be coated per 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.
4. **Welded Stud Shear Connectors.** Studs shall meet the requirements of ASTM A108, grades 1010 through 1020, killed or semi-killed. In addition, studs shall conform to the current edition of AWS D1.5 unless otherwise noted. Furnishing, testing, and qualifying of stud welding procedures shall be at the Contractor's expense. Manufacturer shall furnish the Engineer certification as required by AWS D1.5.
5. **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 before 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**.**

Rotational-Capacity Test Reports (RC). RC testing by the Manufacturer shall be required for all fastener assemblies per AASHTO. RC testing reports shall be furnished with shipment of assemblies.

Proof Load Tests.Proof load tests (ASTM F606 Method 1) are required for the bolts. Wedge tests of full-size bolts are required per section 8.3 of AASHTO M164. Galvanized bolts shall be wedge tested after galvanizing. Proof load tests per ASTM F606 are required for the nuts. The proof load tests for the nuts to be used with galvanized bolts shall be performed after galvanizing, overtapping, and lubricating.

# 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

1. **Notice of Fabrication.**
2. *Process Control and Quality Assurance.* Process Control (PC) of structural steel fabrication is the responsibility of the Contractor. The PC inspector is the duly designated person who acts for and on behalf of the fabricator on inspection, testing, and quality matters within the scope of the contract documents. PC inspection and testing shall be performed at least to the extent specified in the inspection clause of AWS D1.5, and additionally as necessary to ensure 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 on 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 per the provisions of the Contract documents. The QA inspector shall have the authority to verify the qualifications of PC inspectors and nondestructive testing (NDT) personnel to specified levels by written or performance tests or other means as determined necessary.

1. *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 14-day notice before 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.
2. *Notice of Shipment.* The Department's QA inspector shall be notified seven days in advance of shipment of structural steel to the jobsite. Notification shall include all part numbers included in the release. Before final QA inspection the contractor shall provide copies of the QC test reports, copies of the MTR’s for the material that is included in the release, and certificates of conformance (COC) per the contract documents.
3. **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. The detail drawing shall include a “T” designation for weld joints that are considered as tension.
4. **Shop Facilities for Fabrication.** Structural steel fabricators for all bridge structures as a minimum shall be certified under the AISC Quality Certification Program, per the category of the bridge being fabricated. The fabricator shall have successfully built at least two steel bridges of similar design within the last 5 years. The experience shall be submitted for acceptance to the Engineer before the bid process. If painting is required, the fabricator shall be certified to the AISC program for Complex Coatings Endorsement. Portions of work exposed to view shall be neatly finished. Lifting chains shall be provided with adequate softeners to prevent damage to the material while lifting and turning. If hooks are used for lifting, they shall have sufficient width of jaw and throat to prevent overstress and distortion from handling. Spreader beams, or multiple cranes, shall be provided for lifting plates and long members to prevent overstress and distortion. Welds and tack welds shall not be cracked from moving of members. Such occurrence shall require a written distortion control plan and complete inspection until the problem is corrected. The distortion control program and process control reports shall be forwarded to the QA inspector.

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

1. **Inspection.**
2. *Process Control Plan.* The contractor shall submit a written “Welding Process Control Plan” (WPCP) to the Engineer before the beginning of fabrication. The WPCP shall outline the quality control tasks to be performed by the fabricator to ensure that all work conforms to the Contract. The WPCP shall include the following items at a minimum:
* Name of the welding firm, welding quality control inspection firm, and Non-Destructive Testing (NDT) firm hired by the contractor as applicable. Name and qualifications of the welding Quality Control Manager and Quality Control Inspectors.
* Documentation of all qualifications for welders, welding operators and tack welders, including continuity records.
* Name and qualifications of NDT personnel including level of certifications and expiration date.
* WPSs and supporting PQRs
* Quality Control Procedures:
	+ - Methods and frequencies for performing all required visual inspection and NDT.
		- Methods of documentation for identification and tracking of welds including rejected lengths.
		- Procedures for identifying members distorted by welding and monitoring methods for straightening.
		- Calibration procedures for all NDT equipment.
		- Procedures for performing all NDT required.

The WPCP shall be subject to approval by the Engineer

1. *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 onsite monitoring of all inspection activities anytime welding or cutting operations are being performed.
2. *Supervision.* Adequate supervision and process control inspection of all welding shall be provided to ensure satisfactory, consistent, and uniform workmanship. Recurring weld defects shall be considered as evidence that proper control and supervision are not being provided. Welding and associated fabrication operations shall be suspended when, in the opinion of the QA inspector, there is a lack of proper process control. Operations shall not resume until the fabricator has made a significant change in procedure. Proposed changes shall be defined and submitted in writing and approved by the QA inspector before resuming fabrication. Changes shall both correct the problem and prevent reoccurrence.
3. *Edge Discontinuities.* All plates and shapes shall be inspected at the edges for the presence of laminar discontinuities and inclusions before welding or fitting to other pieces. The extent of all areas to be repaired shall be reported to the QA inspector.
4. *Welding Meters.* Verification of welding meters shall be performed no less than once every three months. A calibrated tong ammeter and voltmeter, external to the welding machine, shall be used. Records of these calibrations shall be available for review by the QA inspector.
5. *Reports.* The PC inspector shall submit the following reports to the QA inspector before acceptance: all nondestructive test reports, including tests of all repaired areas, the visual test report for all welds, dimensions, camber, and sweep measurements, welder qualification records, welding procedure specifications, procedure qualification records, welding machine settings, material traceability to each main member plate, and paint inspection reports. After each girder has been inspected by process control and has been accepted as conforming to the contract requirements, but before 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 before acceptance. Material subsequently found defective due to damage incurred in shipping and handling may be rejected even if previously accepted.

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

A 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.

1. **Nondestructive Testing.**
2. *Written Practice and Records*. The fabricator's Process Control Plan shall detail the nondestructive testing procedures, including the weld identification and location system. It shall also include the fabricator's Written Practice for the Administration of Personnel Qualification and Certification Program per The American Society for Nondestructive Testing SNT-TC509.18

1. 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 before acceptance of the assembly.

1. *Ultrasonic Inspection of Complete Penetration Groove Welds.*
	1. *Weld Stress Categories.* The following weldments shall be categorized as follows:
		1. *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.
		2. *Pier and End Diaphragms.* Pier and end diaphragms shall be considered as part of the web or flange to which they are welded.
		3. *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 before attaching to another member. Ultrasonic acceptance-rejection criteria shall be per 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 per the tension criteria of AWS D1.5.
		4. *Sequence.* All flange and web splices shall be welded and tested before fitting of the web to the flange.
	2. *Extent and Acceptance Criteria of Ultrasonic Testing.* Ultrasonic testing of complete penetration groove welds shall be performed by PC to the extent listed in Table 509-1. The percent inspection indicated for each category is the minimum percent of the total length of each weld that must be tested.

## Table 509-1

## UT ACCEPTANCE-REJECTION CRITERIA

##  COMPRESSIVE STRESS

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Tension-****Compression1** | **Weld Orientation2** | **Percent Inspection3** |
| FlangeFlangeFlangeFlange | TensionTensionCompressionCompression | TransverseLongitudinal TransverseLongitudinal | 100252510 |
| WebWebWebWeb | Tension**4**Tension**4**CompressionCompression | TransverseLongitudinal TransverseLongitudinal | 100252510 |
| Pier & End Diaphragms | Tension**4**Tension**4**CompressionCompression | TransverseLongitudinal TransverseLongitudinal | 100252510 |
| Notes:1. Tension areas shall be tested per the current edition of AWS DI.5. Compression areas shall be tested per the current edition 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»6the depth of the web from the tension flange.
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1. *Preparation of Test Material and Testing Procedures.* All groove welds shall be ground flush to a maximum surface roughness (ANSI B46.1) of 125 microinches and a medium range waviness such that no gap greater than 0.020 inch is present beneath a 2-inch-long straightedge placed anywhere on the test surface. The test surface shall be ground to bright metal and allow intimate coupling with the search unit. Failure to provide this condition shall result in repair or removal and re-welding of the joint, or alternative nondestructive testing methods, as determined by the QA inspector. The testing procedures established in the current edition of AWS D1.5 shall be amended as follows:
	1. *Splices.* All materials spliced shall be tested before attaching into the assembly.
	2. *Alternate Procedures.* Scanning of welds may be made using other methods, as approved by the Engineer, provided evaluation is made per clause 8, part C of AWS D1.5.
	3. *Butt Joints.* All butt joints shall be ground flush and shall include mandatory scanning using pattern “D” (Figure 8.7 of AWS D1.5) longitudinal to their axis.
	4. *Scanning Procedure.* AWS D1.5, UT Acceptance-Rejection Criteria – Compressive Stress, 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. 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 per 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. The Testing Angle and UT Acceptance-Rejection Criteria Tables 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 the search unit used to evaluate the flaw.
		5. Evaluation using reject may be used to evaluate flaws, only if calibration is per AWS D1.5, and the vertical linearity is within plus or minus 1 dB for a 60 dB range.

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.

1. *Through Thickness Tension Plate.* Ultrasonic testing of plates as identified in the plans as exhibiting tension in the through thickness direction shall be performed per ASTM A578. 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.
2. *Dye Penetrant Testing.* Dye penetrant testing per ASTM E165 may be substituted for magnetic particle testing with approval of the Engineer.
3. *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 per ASTM E709 and AWS D1.5, except as amended herein. Alternating current shall be used. The yoke spacing shall be between 2 and 4 inches. The minimum lifting power shall be 10 pounds. Red dry particles shall be used. The light intensity shall meet ASTM E709, Section 7.

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

Magnetic particle tests shall be performed at the following locations:

* 1. *Base metal.* All areas contacted by the carbon arc gouge electrode, the electrode cup, and the welding electrode. All three conditions are arc strikes.
	2. *Fillet Welds.* Each design weld size on main member to main member and secondary member to main member weldments. All stop-starts and weld termini. All linear indications shall further be evaluated with 10x or 30x magnification. Verification shall be resolved by excavation.
	3. *Groove welds.* All through thickness edges on transverse butt joint weldments in tension areas.
	4. *Repairs.* All repair welds to correct: defects in groove and fillet welds, plate cut edges, correction of fabrication errors in cutting, punching, drilling, or fitting, and members which are tacked or welded and subsequently cut apart and re-welded.
1. *Radiographic Testing.* When radiographic testing is specified, it shall be performed per 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 (-).
2. *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).*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.
	1. *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.
	2. *Hardness Testing*. Hardness testing shall be conducted as required by AWS D1.5. Oxygas cutting procedures used on tension flanges shall be qualified before 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 per ASTM E18. Each test area shall be contained within 6 square inches.

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

Production Process Control tests shall be performed by the Contractor. The number of tests shall be the next highest whole number calculated as follows: total number of tension flanges on the bridge divided by 10

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

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

1. **General Fabrication Requirements.**
2. *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 M160. Pieces of steel which, before 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.

If requested by the Engineer, the Contractor shall furnish an affidavit that certifies that the identification of steel has been maintained per this specification.

1. *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.
2. *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.
3. *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 carry 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 per subsection 509.18(f).
4. *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.
5. *Minimum Base Metal Temperature.* The minimum base metal temperature qualified to cut flanges and webs in tension, shall be established by hardness testing per subsection 509.18(f).
6. *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.
7. *Bent Plates.* Un-welded cold-bent steel plates shall conform to the following:
	1. Rolling Direction. The bend line shall be at right angles to the direction of rolling.
	2. Minimum Radii. Bending shall be such that no cracking of the plate occurs. Minimum bend radii, measured to the concave face of the metal, shall be 5t for all grades and thicknesses of steel conforming to AASHTO M270 (ASTM A709) unless approved by the Engineer.
	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.
8. *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.

$R=\frac{14bD}{\sqrt{F\_{y }}Ψt}$ , $R= \frac{7500b}{F\_{y }Ψ}$ 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 1/4 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.

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

1. Sequence of Operation*.* Members shall be heat curved before the completion of the following:
	1. Attachment of end bearing stiffeners.
	2. Attachment of lateral gusset plates.
	3. Attachment of longitudinal stiffeners.
	4. 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 before being welded to the curved girder. The girder shall be heat curved in the fabrication shop before it is painted. When cover plates are to be attached to rolled beams, they may be attached before heat curving if the total thickness of one flange and cover plate is less than 2 1/2 inches and the radius of curvature is greater than 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.
2. Camber. Cambering of welded plate girders, except for minor adjustments required after welding, shall be achieved by curved cutting of web plates before welding to flanges. Girders shall be cambered before heat curving. Heat cambering procedures shall be per subsection 509.19(i) and shall be approved by the Engineer before 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.

1. *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 1/32inch. 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.

1. *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 1/16inch 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 1/16inch larger than the nominal diameter of the fastener. For bolts 1 inch and larger, bolt holes shall be reamed to 1/8 inch larger than the bolt diameter. Subsized holes before reaming shall not be offset more than 1/16inch. 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 1/32inch 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.
2. *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 1/50inch for pins 5 inches or less in diameter, or 1/32inch for larger pins. Two pilot nuts and two driving nuts for each size pin shall be furnished unless otherwise specified.

1. **Welding.**
2. *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 cored arc welding (FCAW) will be permitted on secondary to main member attachments when performed in the flat or horizontal positions. Vertical or overhead welding positions using the FCAW process shall not be used unless approved by the Engineer of Record.

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 per 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.

1. *Base Metal Preparation.* The preparation of base metal shall be per 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.
2. *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 per AWS D1.5.
3. *Undercut.* Undercut in the stiffener, web or flange shall not exceed 0.01 inch in areas of tension as indicated on the plans when the axis of the undercut is normal to the longitudinal centerline of the girder, or normal to the centerline of bearings in the case of plate diaphragms. Undercut in compression areas shall not exceed 1/32 inch.
4. *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 per subsection 509.18(c).
5. *Gusset Plates.* Lateral gusset plates welded to girder flanges in tension shall be pre-heated to a minimum 250 °F. Maximum shall be specified in the approved WPS.
6. *Repairs.* All welding required to repair cracks, oxygen cut gouges, porosity, and undercut, shall conform to the following:
	1. General*.* Repairs made to correct undercut, craters, undersized welds, porosity, excessive roughness on oxygen cut gouges, and cracks shall not be performed without the knowledge of the PC inspector. Undercut may be prepared by contour grinding when approved by the Engineer. Areas repaired shall be recorded per AWS D 1.5, paragraph 6.5.8. Surfaces that are air carbon arc gouged shall be ground to bright metal before welding. Repair areas shall be preheated to a temperature of 200 to 300 °F before welding. Cracks removed before 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, unless approved by the Engineer.
	3. *Cut Edges.* Cavities resulting from the removal of cut edge discontinuities in plates shall be prepared before welding using a minimum ¼ inch radius and a minimum 40-degree angle. The base metal shall be ground to bright metal before welding.
	4. *Mislocated Holes.* Misfit holes shall not be repaired, unless approved by the Engineer. When holes are repaired per an approved welding procedure, the soundness shall be established by ultrasonic testing. In addition, the hardness, preheat, and post-weld heat shall be per AWS D1.5.
7. *Stud Welding.* Stud welding shall conform to AWS D1.5 as amended herein.

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

Stud attachments for fall protection systems or other temporary works are allowed on the top flange in locations where permanent shear studs will be attached. These attachments are allowed to be placed before formwork for the deck being installed.

* 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 on separate material 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.
1. *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.
2. *Gas Certification.* The Contractor shall furnish certification that the gas or gas mixture is suitable for the intended application per AWS D1.5 and the manufacturer's recommendations.
3. *Miscellaneous Attachments.* Attachments shall not be welded to main members, unless approved.
4. **Shop Assembly.**

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.

1. *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.
2. *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.
3. *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.
4. *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.
5. *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 per dimensional requirements before reaming or full-size drilling of holes.
6. *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.
7. *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.
8. *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.
9. *Abutting Joints.* Abutting joints in compression members and girder flanges, and in tension members when so specified on the plans, shall be faced and brought to uniform bearing. Where joints are not faced, the opening shall not exceed 1/4 inch.
10. *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.

1. **Shop Connections Using High-Strength Bolts.** Unless otherwise specified, all shop connections shall be made with high-strength bolts. All connections which remain in the permanent structure shall be made per subsection 509.28.
2. **Galvanizing.** Bolts, washers, and nuts used in the assembly and erection of galvanized railing and posts or where specified, shall be galvanized per AASHTO M232 Class C or shall be zinc coated per AASHTO M298. Structural steel shall be galvanized per AASHTO M111. 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, per ASTM A780, if applied to correct areas less than 1 square inch. Materials may only be stripped and regalvanized a single time.
3. **Shop Cleaning and Painting of Steel.** Graffiti shall be removed before painting, or in the case of ASTM A 709 Grade 50W steel, before shipping.
4. *Cleaning of Unpainted ASTM A 709 Grade 50W Steel.* The exterior surfaces of unpainted ASTM A 709 Grade 50W steel shall be cleaned with abrasive blasting to a minimum standard of Sa2 to remove mill scale and foreign material which would prohibit rusting to a uniform color. This cleaning shall occur after fabrication and before shipping. The use of paint, wax, crayon or similar materials for making steelwork during fabrication and erection shall not be permitted. Care shall be taken on site with both storage and handling of the girders such that the developing rust is not damaged.
5. *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.
6. *Paint Systems.* All structural steel shall be painted using a two-coat system with inorganic zinc-rich primer (shop coat) and high-build urethane topcoat as described in subsection 708.03. The shop coat shall have a dry film thickness of 3.0 mils. The topcoat shall have a thickness of 3.0 mils.
7. *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.
8. *Procedure.* Application of paint shall be per the manufacturer's recommendations.
9. *Surfaces in Contact with Concrete.* The areas that will come in contact with concrete shall not be painted.
10. *Field Weld Areas.* Areas of structural steel to be field welded shall not be painted before welding is completed.
11. *Erection Marks.* Erection marks for field identification of members shall be readily visible on shop painted surfaces.
12. *Faying Surfaces of Connections.* When splices are specified on the plans to be Class B slip critical, the contact surfaces of unpainted ASTM A709 Grade 50W steel shall be blast cleaned to a SSPC-SP6 commercial blast. When the inorganic zinc-rich primer is provided, the manufacturer shall qualify the paint by test per “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.
13. **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.

# CONSTRUCTION REQUIREMENTS

1. **Field Welding and Inspection.** Field welding will not be permitted unless shown on the plans or approved by the Engineer, except to attach studs. Before the start of any field welding, all required welding documentation including welder qualifications (WQTRs), WPSs, and PQRs shall be submitted to the Engineer for review and approval. All field welding will shall be completed by a qualified welder qualified per the given process and AWS D1.5 welding code requirements. All field welding and inspection shall be performed per this specification and AWS D1.5. All field welding shall be inspected by a CWI included in the Contractor’s Process Control Plan and shall be included in the cost of the work. Welding on metal deck forms shall be per AWS D1.3.
2. *Field Welding Process Control Plan*. The Contractor shall submit a written “Field Welding Process Control Plan” (FWPCP) to the Engineer prior to beginning field welding operations on permanent bridge structures. The FWPCP shall outline the quality control tasks to be performed by the contractor to ensure that all work conforms to the Contract. The FWPCP shall include the following items at a minimum:
	* Names, qualification documentation and continuity records of for all welders, welding operators and tack welders, who will be performing field welds.
	* Welding Procedure Specifications (WPS) and supporting Procedure Qualification Records (PQRs), if required, for welds to be performed.
	* Location and types of welds to be performed.
	* Number and type of welding equipment to be used and records of Welding Meter calibrations.
	* Method of electrode protection and storage.
	* Quality control procedures:
		1. Name of welding quality control inspection firm, and NDT firm hired by contractor who will be inspecting field welds.
		2. Names and qualifications of, Quality Control Inspector (QCI), CWI and NDT personnel including level of certification and expiration date.
		3. Frequency of visual and NDT inspection.
		4. Calibration documentation of all NDT equipment.
		5. Method for documenting that welding has been performed per contract requirements.

The FWPCP shall be submitted at least one week prior to the Pre-Erection Conference and be subject to approval by the Engineer.

Welding on driven pile shall be performed per requirements of section 502.

*Strengthening and repair of existing structures*. If welding is to be performed to existing components on structures built before 1970, metallurgical analysis will be provided by the Engineer. Contractor shall develop and submit to the engineer any WPS, PQR and WQTR documentation based on metallurgical analysis to ensure proper welding procedures are used. Engineer shall review and approve all welding documentation before contractor performing welding.

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 per AWS D1.5 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 0 F at the time of welding.

1. *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. The base metal where the stud is to be welded shall be ground to bright metal immediately before the weld being made. Manual welding will not be allowed except to make repairs. Stud welding shall be per subsection 509.20 (h).
2. *Repairing Stud Welds.* Stud welds may be repaired using a low-hydrogen SMAW process. Electrodes used to repair stud welds shall be kept in rod ovens per AWS D1.5. 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.
3. **Erection of Steel Structures.**

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

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

At least one week before the Pre-Erection Conference, the Contractor shall submit an Erection Plan to the Engineer. The Erection Plan will be reviewed by the Engineer and Staff Bridge concurrently and combined comments will be submitted in writing within one week. These comments shall be addressed in the final plan. The Final Erection Plan shall be signed and sealed by the Contractor’s Engineer and marked “Approved for Construction”. If falsework drawings are required, they shall conform to and be submitted per subsection 601.11.

The Contractor performing steel bridge erection shall be an AISC Certified Steel Erector (CSE) when field assembly is required. The erector shall have successfully completed erection of at least 2 bridge structures of the same category as the project within the last 5 years and have a minimum of 5 years of experience with the erection of bridges. The experience shall be submitted for acceptance to the Engineer. This requirement shall not apply to sign structures.

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

1. Temporary falsework support, struts, bracing, tie cables and other devices, material properties and specifications for temporary works, bolt torque requirements before releasing girders from the cranes (if required), connection details and attachments to other structure components or objects.
2. Procedure and sequence of operations, including a detailed schedule with completion times for work items that complies with the working hour limitations.
3. Minimum load chart lift capacity, outrigger size, and reactions for each crane.
4. Assumed loads and girder weights, lift points, lifting devices, spreaders, and angle of lifting cables.
5. Girder stresses at critical points along the girder length during progressive stages of erection shall be investigated to assure that the structural integrity and stability of the girders is maintained. Stresses at lift points induced as a result of lifting shall be investigated and adequate bracing provided as indicated by the analysis.
6. Locations of cranes, trucks delivering girders, and the location of cranes and outriggers relative to other structures, including retaining walls, wing walls and utilities.
7. Drawings, notes, catalog data showing the manufacturer’s recommendations or performance tests, and calculations clearly showing the above listed details, assumptions, and dimensions.
8. Contingency plans detailing what measures the Contractor will take in case of inclement weather (forecast or actual), equipment failure, delivery interruption, and slower than planned production.

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

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

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

When a bridge spans traffic of any kind, including those where vehicles, railroad, watercraft or pedestrians have access onto, under or adjacent to the bridge, the Contractor’s Engineer shall inspect and provide written approval that the erected girders are safe before opening the area beneath the girders to traffic. For this specification, traffic is defined as the vehicles, railroad, pedestrians, and watercraft moving along a route. The Contractor shall perform daily inspections of the erected girders and other permanent and temporary bridge elements until the deck concrete has attained the Field Compressive Strength. The Contractor’s Engineer shall provide an inspection form to the Engineer and the Contractor that lists the items the Contractor will document during the daily inspection of the erected girders. The inspection form shall include inspection items specific to each bridge being constructed. The Contractor shall provide the Engineer and the Contractor’s Engineer with written documentation of these inspections within 24 hours of each inspection.

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

1. *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.
2. *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.
3. *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.
4. *Falsework.* Falsework shall conform to subsection 601.11.
5. *Bearings.* Bearings and bearing seats shall conform to Section 512.
6. *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.
7. *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 evidence of fracture following the straightening procedures.
8. *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-P21035A. Spray can applications of zinc will not be allowed.
9. *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 on exterior surfaces. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled.

For fit up of girder field splices and field connections of main stress carrying members, erection pins shall be installed in all corner bolt holes on each side of splice, plus a minimum of 25 percent of the bolt holes, evenly distributed throughout the splice. The diameter of the erection pins shall be no less than the hole diameter minus 1/32 inch. At least 25 percent of the bolt holes shall be filled with high strength bolts. These bolts shall be fully tensioned before external support systems are removed and the connections completed by bolting, unless otherwise specified. The requirement for erection pins in the corner bolt holes does not apply to diaphragms and lateral bracing in straight girder spans, provided the member is adequately supported before removal of the external support. Members that are assembled before being erected shall have all bolts installed and fully tensioned. The structure shall not carry traffic or construction loads without approval of the Engineer.

1. *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.
2. *Misfits.* 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 shall be reported immediately to the Engineer. The Engineer's approval shall be obtained for methods of correction, such as reaming and the correction shall be made in the Engineer's presence.
3. *Cleaning of Connections.* When splices are designated Class B slip critical on the plans, the contact surfaces of splices shall be field inspected immediately before assembly. All foreign material shall be removed before fitting and bolting of the splices.
4. **Connections Using High-Strength Bolts.**
5. *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 completed and indicate the zinc thickness when galvanized bolts and nuts are used.
6. *Materials.* Washer type direct tension indicators shall conform to ASTM F959.

Bolts shall be F3125 Type 1 for connections which are painted. Bolts for unpainted ASTM A709 Grade 50W steel shall be ASTM F3125 Type 3. High strength bolt tensile strength requirements relative to bolt diameter shall be in conformance with ASTM F3125. Nuts shall be AASHTO M292 grade 2H or AASHTO M291 grade DH for plain or galvanized fasteners, except connections for unpainted ASTM A709 Grade 50W steel, in which case nuts shall be AASHTO M291 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. Galvanized or coated bolts of any Group or Grade, galvanized or coated spline end bolting assemblies of any Group or Grade, and F3125 [Grade A490] heavy hex bolts shall not be reused after tensioning.

Plain bolts shall be "oily" to the touch when installed. Weathered or rusty items shall be cleaned and relubricated per the manufacturer’s instructions before installation. Plain finish F3125 [Grade A325] heavy hex bolts may be reused (1) in snug-tightened joints without the Engineer’s approval and (2) in pretensioned joints and slip-critical joints with the Engineer’s approval.

1. *Contractor’s Process Control Plan.* The contractor performing erection shall submit a written ‘Bolting Process Control Plan’ (BPCP) to the Engineer before beginning of tensioning operations of bolting assemblies. The BPCP shall outline the quality control tasks to be performed by the contractor to ensure that all work conforms to the Contract. The BPCP shall include the following items at a minimum:
	* Name and qualifications of the tensioning Quality Control Manager and Quality Control Inspectors.
	* Sequence of structure assembly.
	* Procedures of collecting bolting assembly lot numbers as they will be tested and installed in the structure.
	* Quality control procedures:
		1. Method of tensioning
		2. Method and frequency of RC and PIV testing
		3. Method and frequency for performing required inspections to ensure required tension has been achieved in all bolting assemblies
		4. Method for documenting that tensioning has been performed per contract requirements
		5. Method for ensuring bolting hardware is protected from the elements.
		6. Calibration documentation for all tensioning and/or torque equipment.

The BPCP shall be submitted at least one week before the Pre-Erection Conference and be subject to approval by the Engineer.

1. *Tests Requirements before tensioning of fastening assemblies in structures.* Before commencing with any tensioning of fastening assemblies in a structure, all high strength fastener assemblies shall be subjected to a field rotational-capacity (RC) test per ASTM F3125 as well as a Pre-Installation Verification (PIV) test for the selected bolt installation method(s). All testing shall be performed in compliance with all of the following:
2. At the site of installation in the presence of the Engineer or designee.
3. BPCP shall be submitted and approved.
4. Before the placement of bolting assemblies of verified lots in the work.
5. On a sample of not fewer than three complete bolting assemblies for PIV and two complete bolting assemblies for RC, of each combination of diameter, length, grade and lot to be used in the work.
6. Using bolting assemblies that are representative of the condition of those that will be pretensioned in the work.
7. Using ASTM F436 washers positioned per RCSC Section 6.2.
8. Testing shall be performed daily, before installation, for the calibrated wrench method.
9. The accuracy of the BTMD shall be confirmed through calibration at least annually.
	1. *Rotational Capacity (RC) Test:*
		1. *Tension Procedure.* Fasteners shall be turned two times the required number of turns (from snug tight conditions) indicated in RCSC in a Calibrated Bolt Tension Measuring Device (BTMD), 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, per RCSC.
		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

* 1. *Pre-installation verification test (PIV)*

PIV testing shall be performed per RCSC. The bolting assembly shall be tested in a BTMD to verify that the pretensioning method to be used in the work develops a pretension that is equal or greater than that specified in table 509-2.

## Table 509-2

## MINIMUM BOLT PRETENSION

## FOR PRE-INSTALLATION VERIFICATION

|  |  |  |
| --- | --- | --- |
| **Nominal Bolt Size (in)** | **Group 120 [A325] (lb)** | **Group 150 [A490] (lb)** |
| 1/2 | 13,000 | 16,000 |
| 5/8 | 20,000 | 25,000 |
| 3/4 | 29,000 | 37,000 |
| 7/8 | 41,000 | 51,000 |
| 1 | 54,000 | 67,000 |
| 1 1/8 | 67,000 | 84,000 |
| 1 1/4 | 85,000 | 107,000 |
| 1 3/8 | 102,000 | 127,000 |
| 1 1/2 | 124,000 | 155,000 |

* 1. Snug Tight.Installation of all high strength bolts shall be per RCSC. The “snug tight” condition as defined in RCSC shall be accomplished for any method of tensioning.
1. Field Connections. Unless otherwise specified or approved, all field connections shall be made with ASTM F3125 Grade F2280 (Type 3) tension control bolts, or F3125 Grade A325 (Type 3) bolts using the Turn-of-Nut Method or Direct Tension Indicator method, per RCSC. Direct tension indicators shall be either washer type direct tension indicators or tension control bolts.
2. 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.
3. *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 before 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 snug-tightened 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.
4. *Impact Wrenches.* Impact wrenches, if used, shall be of adequate capacity to perform the required tightening of each bolt in approximately 10 seconds. https://www.aws.org/resources/blog
5. W*asher Location.* In addition to load indicating washers, each fastener shall have a hardened washer under the turning element.
6. *Beveled Washers.* Where the outer face of the bolted parts has a slope of more than 1:20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for lack of parallelism.
7. *Reusing Fasteners.* Reuse of fastening assemblies shall adhere to 509.28 (b)
8. *Locknuts and Lock Washers.* Subsections 509.28 (c), (e), and (f) shall not apply to bolts for which the plans specify lock washers or locknuts. Fasteners with lock washers or locknuts shall be snug tight only.
9. *Inspection.* The Contractor shall provide an acceptable platform from which the Engineer can inspect bolt tensioning operations and determine whether the work meets specification requirements. The following inspection and testing procedure shall be used for all high strength bolts used in structural connections unless a more extensive or different inspection is specified.
10. *Quality Assurance.* The Engineer will inspect a sufficient number of fasteners to ensure compliance with the RCSC Minimum Bolt Pretensioned and Slip-Critical Joints Table using a method commensurate with the type of fastener used. All loose fasteners shall be brought into compliance.

**Table 509-3**

**MINIMUM BOLT PRETENSION,**

**PRETENSIONED AND SLIP-CRITICAL JOINTS**

|  |  |  |
| --- | --- | --- |
| **Nominal Bolt Size (in)** | **Group 120 [A325] (lb)** | **Group 150 [A490] (lb)** |
| 1/2 | 12,000 | 15,000 |
| 5/8 | 19,000 | 24,000 |
| 3/4 | 28,000 | 35,000 |
| 7/8 | 39,000 | 49,000 |
| 1 | 51,000 | 64,000 |
| 1 1/8 | 64,000 | 80,000 |
| 1 1/4 | 81,000 | 102,000 |
| 1 3/8 | 97,000 | 121,000 |
| 1 1/2 | 118,000 | 148,000 |

1. **Field Cleaning and Painting of Steel.**
2. *Self-Weathering Steel.* Unpainted ASTM A709 Grade 50W steel shall be cleaned of foreign material after erection to ensure uniform weathering of the steel. It may be necessary to perform a final blast cleaning after deck construction at locations specified by the Engineer.
3. *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.
4. *Damaged Areas.* After the inspector has examined and approved the field connections and before application of topcoats, all uncoated areas and areas with damaged shop primer shall receive one coat of shop primer. The shop primer shall be thoroughly cured before application of the topcoat.
5. *Topcoat.* After retouching the shop coat and field cleaning has been satisfactorily completed, all steel work shall be painted with the required topcoat as specified in subsection 509.24. When the manufacturer of the topcoat is different than the manufacturer of the shop primer, the Contractor shall submit written documentation that the paints are compatible.
6. *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.
7. **Fracture Control Plan.** The Contractor shall submit a Fracture Control Plan (FCP). The 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 per this plan. The FCP shall be per AWS D1.5. Chemical and mechanical tests, as required by this plan, shall be the responsibility of the fabricator.
8. **Structure Number.** The location, letters, figures, and paint used for stenciling shall be per the plan details. Payment for structure number shall be included in the work.

# METHOD OF MEASUREMENT

(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

1. 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.
2. 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.
3. Allowance will not be made for the weight of shop paint in computing the pay weight of metal.
4. Allowance will not be made for the weight of the spelter coating in computing the pay weight of galvanized steel.
5. 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.
6. 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 509-3.

## Table 509-3

**NET BOLT WEIGHT**

**(head, nut, and stick-out)**

|  |  |
| --- | --- |
| **Nominal Bolt Size (In Inches)** | **Weight of 100 Bolts in Pounds** |
| 5/8- 11 UNC | 32 |
| 3/4 - 10 UNC | 53 |
| 7/8 - 9 UNC | 81 |
|  1 - 8 UNC | 117 |
| 1 1/8 - 7 UNC | 165 |
| 1 1/4 - 7 UNC | 212 |
| 1 3/8 - 6 UNC | 280 |

1. 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.
2. Allowance will not be made for weight of welds in computing the pay weight of structural steel.
3. 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.
4. 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.
5. 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, per subsection 104.02.
6. 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

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

Payment will be made under:

 **Pay Item Pay Unit**

|  |  |
| --- | --- |
| Structural Steel |  Pound |

 Structural Steel (Galvanized) Pound

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

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