SECTION 460
STRUCTURAL STEEL AND MISCELLANEOUS METALS

460-1 Description.

460-1.1 General: Prepare, fabricate, assemble, erect, and perform all nondestructive testing for structural steel or miscellaneous metal structures, or portions thereof in accordance with the Contract Documents.

Obtain Structural Steel and Miscellaneous Metals from a fabricator that is currently on the Department's Production Facility Listing. Fabricators seeking inclusion on the list shall meet the requirements of Section 105.

As used in this specification, the following terms shall apply:

Main or primary load-carrying member or component: This designation refers to the following;

1. Longitudinal or transverse rolled beams or fabricated girders (I or box, curved or straight)
2. All truss members not designated as cross frames
3. Cross frames, diaphragms and connection plates of horizontally curved beams or girders
4. Rib members of steel arches
5. Bracing members subjected to and specifically designed for traffic live load and/or other loads
6. Cross frames or diaphragms at pier and abutment supports of tub or box girders (trapezoidal members) and their connection plates
7. Attachments and components of the above such as splice, cover, cross frame and diaphragm connection and gusset plates, but not transverse and bearing stiffeners (unless acting as a cross frame or diaphragm)
8. Cables, moment release pins and links, and hangers
9. All steel substructure members except those designated as secondary in the Contract Documents
10. Other members as may be identified in the Contract Documents

Miscellaneous components - This designation refers to, but is not limited to, the following:

1. Ladders
2. Platforms
3. Bearings
4. Railings
5. End Wall Grates
6. Roadway Gratings
7. Metal Drainage Components
8. Steel Expansion Joint and Components

460-1.2 Fabrication Categories: As a prerequisite for being on the Department's Production Facility Listing, fabricators must currently be accredited in accordance with one of the programs in Table 460-1, by fabrication category/categories of the products that they are producing.

Fabricators are required to submit their proposed fabrication Quality Control (QC) Plan for review by the Department.

Table 460-1 Fabrication Categories	
Structure Type	Accepted Accreditation Program
Advanced Bridge: Tub or trapezoidal box girders, closed boxed girders, large or non-preassembled truss bridges, arches, cable supported bridges, moveable bridges, and bridges with curved radii tighter than defined for intermediate bridge.	AISC Advanced Bridge
Intermediate Bridge: A rolled beam bridge with field or shop slices, either straight or with a radius over 500 feet: a built-up I-shaped plate girder bridge with constant web depth (except for dapped ends), with or without splices, either straight or with a radius over 500 feet: a build-up I-shaped plate girder with variable web depth (e.g. haunched) either straight or with a radius over 1000 feet; a truss bridge with a length of 200 feet or less that is entirely or substantially preassembled at the certified facility and shipped in no more than three subassemblies.	AISC Intermediate Bridge
Simple Bridge: Unspliced rolled sections and pedestrian bridges	AISC Simple Bridge
Highway Metal Components, including Aluminum: Fence materials, guardrails, handrails, reinforcing steel (rebar), casing pipes, metal drainage items, stay-in-place forms, light poles, high mast poles, metal buildings, steel strain poles, bridge rail, stairs, walkways, grid decks, scuppers, expansion joints, bearings, ballast plates, complex expansion joints, high load multi-rotational bearings, bracing not designed for primary loads (diaphragms, cross frames, and lateral bracing), moveable bridge machinery and sign or signal structures erected partially or completely over the traveled roadway or mounted on bridges.	AISC Highway Metal Components ISO 9001 AWS CWF
NOTES: An AISC fracture critical (FC) endorsement is required for all FC work. Other accreditations programs may be submitted to the FDOT State Materials Office for review and consideration in addition to the programs listed in the table above.	

460-2 Materials.

Provide the materials specified in the Contract Documents in accordance with Sections 6, 105, ASTM A6, and AASHTO/AWS D1.5, Bridge Welding Code. Fabricate all unpainted steel elements using steels with weathering characteristics as defined in ASTM A709 for grades with a "W" suffix.

Structural components designated as "fracture critical" shall conform to the provisions of the AASHTO/AWS D1.5, Bridge Welding Code, Clause 12-AASHTO/AWS Fracture Critical Control Plan for Non-Redundant Members, in addition to the requirements of the Contract Documents.

Meet the additional following requirements:

Steel and Miscellaneous Metal Items .....Section 962
Material Testing and Certifications .....Section 962
Galvanizing.....Section 962
Structural Coatings.....Section 560
Structural Coating Materials.....Section 975

460-3 Pre-Assembly Requirements.

460-3.1 Shop Drawings: When shop drawings are required, submit such drawings in accordance with Section 5. For drawing presentation format, refer to the AASHTO/NSBA Steel Bridge Collaboration "Guidelines for Shop Detail Drawing Presentation".

460-3.2 Welding Procedures: Submit all shop and field welding procedures to the Engineer. Such procedures shall contain a notation that they have been reviewed by a Certified Welding Inspector, and shall be signed, dated and stamped accordingly.

460-3.3 Pre-Assembly Meeting: Prior to commencing work, a meeting shall be held between the Contractor and the Engineer. Representatives of the Fabricator, Suppliers or subcontractors may attend the meeting if requested by the Engineer or Contractor. During this meeting, the Engineer may review various aspects of the job, including but not limited to, any of the following:

1. Plant and Personnel Certification.
2. Organizational Structure of Contractor personnel.
3. Traceability of Materials to Pre-Qualified Fabricator.
4. Shop Drawing requirements, submittal, review and approval process.
5. Fabrication Procedures, especially shop assembly, welding and painting.
6. Sampling and Testing Procedures.
7. Project specific areas of concern for fabrication, inspection and testing.
8. Handling of Material Test Reports.
9. Work Schedule.
10. Lines of Communication.
11. Availability of Quality Control and Verification Inspectors during specific fabrication/erection operations.
12. Loading and Transporting.
13. Handling of non-conformance and repair issues.
14. Special Requirements.
15. Consistency between fabrication shop drawings and the Erection Plan, specifically between the fabrication shop blocking diagrams and available site locations for temporary support during erection.

460-3.4 Access to Fabrication Facilities: Provide the Engineer full access of facilities or sites where the product is being stored, fabricated, assembled, coated or erected.

Provide and maintain office facilities at the fabrication facility for the Department's inspectors that ensure a reasonable amount of privacy, are clean, properly illuminated, heated or air-conditioned as necessary and are relatively free of noise, dust and odors. Locate the office reasonably close to the work and provide access any time fabrication, assembly or erection operations are in progress. Provide a desk, chair, and a four-drawer locking file cabinet for the use by each inspector and the Engineer. Provide a telephone within the office with an outside line suitable for modem communication. Provide ready access to adequate

parking, fax and copy machines, and clean, contractor-maintained restrooms within a reasonable distance to the office.

The Engineer may observe any or all activities and perform nondestructive testing of materials, components and the fabricated product to the extent considered necessary to confirm the conformance with Contract Documents.

460-3.5 Notification Prior to Commencement of Assembly: Notify the Engineer at least one week prior to beginning assembly, when conducted in-state, and at least two weeks prior to beginning assembly, when conducted out-of-state.

460-4 Shop Workmanship and Assembly.

460-4.1 Handling, Transporting and Storage of Materials:

460-4.1.1 General: Handle, transport and store plates, shapes, assemblies, fastener components and other parts in a manner that protects them from damage and facilitates subsequent inspections in a safe manner.

Provide storage which will keep materials, assemblies, other components and parts clean, and free from dirt, grease, other foreign matter, unacceptable corrosion or coating deterioration, and any other adverse environmental conditions.

460-4.1.2 Bulk Materials: Ensure that all bulk materials, such as shear studs, are stored together in individual LOTs and that the outside of each container has a list and description of the contents. Maintain a separate list of the weights of all tools and erection materials.

460-4.1.3 Fastener Assemblies (Bolts, Nuts and Washers): Transport and store fastener assemblies in sealed, watertight containers. Label the side of each container with the supplier's name and LOT identification number, and marked to identify the contents and size of the fastener components. Ensure that all surfaces of the nuts are lubricated prior to their placement in watertight containers. Provide containers for components that are capable of protecting them from moisture and other harmful materials. Maintain containers in their sealed conditions until they are opened for use at their assembly locations.

Do not remove more fastener assemblies from the protected area than can be installed and tightened during a work shift. Leave the containers unopened until needed for assembly. At the end of the work shift, return unused fastener assemblies to the protected storage area for future use. Protect opened storage containers from contamination.

460-4.1.4 Coatings: Store coatings in accordance with Sections 962, and 975 and the manufacturer's recommendations. Notify the Engineer if the manufacturer's recommendations vary from that provided in the Contract Documents.

460-4.1.5 Anchor Rods and Nuts: Ship anchor rods and nuts as an assembly. Washers may be shipped separate from the assembly.

460-4.2 Material Traceability:

460-4.2.1 General: All materials arriving at the shop shall be properly identified in accordance the requirements of ASTM A6. Document all main load-carrying member material, high-strength fastener assemblies, and weld materials incorporated into the work through the entire fabrication process. Document this material traceability in a report type format that correlates heat numbers to their respective locations in the completed members. Submit diagrams and sketches as requested by the Engineer for clarity.

At the fabrication facility, maintain the records of the material testing and certification processes and component/part identification as part of the fabricator's permanent

project records for a period of not less than two years as measured from the last shipment of materials from the fabricator's facility. Submit all project-related records to the Engineer.

Mark the weight on members weighing more than three tons, in a visible location.

460-4.2.2 Match Marking of Members and Assemblies: Match mark all connecting members or parts that have been reamed or drilled while assembled. The fabricator shall submit a diagram showing all marks and clearly indicate the location of all the marks on the shop drawings.

Use painted marks, attached metal tags, other durable methods which do not degrade the finish of the piece, or low-stress type steel die stamps to identify and match mark pieces. If steel die stamps are used, they must be blunt nosed or interrupted dot dies, manufactured to produce impressions that are rounded at the bottom of the impression. Re-mark coated type markings as necessary to maintain continuity in traceability.

Mark splice plates and girders so that upon erection, the mark on the splice plate is located opposite a matching mark on the girder. Place the mark on web splice plates, midway down the long side of the plate, on either the right or left side, to correspond with the girder to which the splice plate will be temporarily attached for shipping to the erection site. Make a matching stamp on the girder web opposite the mark on the splice plate.

Place the mark on top or bottom flange splice plates, on the right or left end of the plate, corresponding to the girder to which the plate will be attached for shipment to the erection site. Place a corresponding mark on the girder flange opposite the mark in the splice plate.

As an alternate location for tub girder bottom flange splice plates, place the mark midway down the long side of the plate, on either the right or left side, to correspond with the girder to which the splice plate will be temporarily attached for shipping to the erection site. Make a matching mark on the girder flange opposite the mark on the splice plate.

Mark girders and beams on the left end, according to the orientation shown in the shop drawings, near the top flange. Mark diaphragms in the middle upper portion of the web. Mark cross-frames in the middle of the top or bottom horizontal member.

When heat numbers and other identification marking are applied by die stamping to fracture critical members, low stress dies shall be used.

Low-stress die stamp markings applied to fracture critical members shall be placed in locations or zones shown or described in the approved shop drawings. Low-stress or compression areas are preferred.

Ensure that during fabrication, the heat number is maintained on each primary load-carrying component by paint until the component is permanently joined into a piece marked member or assembly.

460-4.3 Workmanship:

460-4.3.1 Cutting, Shearing and Machining: Cutting (including burning and sawing), shearing, and machining shall be accomplished in accordance with the AASHTO/AWS 1.5, Bridge Welding Code and the following requirements:

Plane, mill, grind or thermally cut the sheared edges of main load-carrying member plate components greater than 5/8 inch thick to a depth of 1/4 inch.

Cut and fabricate steel plates so that the primary direction of rolling is parallel to the direction of the member or component main stress. For flanges and webs, the

direction of rolling is parallel to the flanges unless noted otherwise in the Contract Documents. Web splice plates may be rolled parallel to their length.

460-4.3.2 Bending:

460-4.3.2.1 Cold Bending: Fracture critical and non fracture critical plates and bars shall be cold bent, unless otherwise permitted according to the provisions of Section 460-4.3.2.2.

The minimum bend radii measured to the concave face of the plate, shall be taken as 5.0(t) for all grades and thicknesses of steel conforming to structural steel for bridges, AASHTO M270M/M 270 (ASTM A709/A709M), where 't' is the thickness of the plate in inches. For cross-frame or diaphragm connection plates up to 0.75 inches, the minimum bending radii may be taken as 1.5(t). For all other grades of steel the minimum bend radii recommendations from the plate fabricator shall be followed, but the radii shall not be less than the minimums specified herein.

Wherever possible, bend lines shall be oriented perpendicular to the direction of final rolling of the plate. If the bend lines are parallel to the direction of final rolling, the minimum bend radii shall be increased to 7.5(t).

460-4.3.2.2 Hot Bending: Fracture critical and non-fracture critical plates and bars may be bent hot subject to the approval of the Engineer. Heat-shrink methods as described in 460-4.3.4 are also permitted. If hot bending is to be employed, the heating and bending procedure shall be submitted for review and approval by the Engineer. The plates and bars shall be bent hot at a temperature above the blue brittle temperature of steel (700° F), not to exceed the temperature limits in Table 460-2. The minimum radii of the hot bend must satisfy the requirements of 460-4.3.2.1.

460-4.3.3 Straightening: Member components, such as plates, angles or shapes, are to be straightened before the parts are assembled. Perform straightening such that no cracking or other damage occurs in the part. If heat is to be used for straightening, follow the provisions of 460-4.3.4.

460-4.3.4 Heat Application:

460-4.3.4.1 General: At various points during the fabrication of structural steel, applications of heat may be necessary for hot-bending, cambering, curving or straightening. Use the temperature limits and guidelines given in this Section, unless alternate procedures have been approved by the Engineer. Routine straightening of material other than quenched and tempered material shall be done in accordance with the temperature limits and guidelines as specified herein, but do not require a submitted procedure.

Heat curving may be used in conjunction with a cut-curve procedure, in which a portion of the curvature is obtained by cutting the plates to all or part of the required radius, except as limited by 460-4.3.4.4.

460-4.3.4.2 Heating Process and Equipment:

460-4.3.4.2.1 Maximum Temperatures: The maximum allowable temperature to which the material can be heated is given in Table 460-2, Maximum Temperature Limits for Heat Applications.

Table 460-2
Maximum Temperature Limits for Heat Applications

ASTM A 709 Grade	Maximum Temperature, °F
36, 50, 50S, 50W & HPS 50W	1,200

Table 460-2 Maximum Temperature Limits for Heat Applications	
HPS 70W & HPS 100W	1,100

460-4.3.4.2.2 Timing of Heat Applications: Conduct heating operations prior to the application of coatings.

460-4.3.4.2.3 Allowable Preload Stresses: Preload compressive stresses will be permitted up to 0.5 times the minimum specified yield strength (Fy) of the material. This stress limit is applicable to all steels covered by this specification as listed in Table 460-2. If jacks are used, energize and lock off prior to the application of heat.

460-4.3.4.2.4 Heating Tips: Apply heat using orifice tips only. Select tip sizes proportional to the thickness of the heated material.

460-4.3.4.2.5 Torches: Manipulate the heating torches to guard against general and surface overheating. In addition, place heat reflective sheet material against the web before applying heat to the inside flange surface. When heating the inside flange surface, point the torches to prevent applying heat directly to the web.

460-4.3.4.2.6 Heating Patterns: Fundamental heating patterns (such as vee, line, edge, spot, and strip) may be used separately or in combination. Mark vee and strip heat patterns on the material surfaces prior to heating. When heating, bring the steel within the planned pattern to the specified heating temperature as rapidly as possible without overheating the steel. Apply heat in accordance with the approved procedure.

460-4.3.4.2.7 Thin Wide Plates: Prevent buckling of thin wide plates by not applying excessive heat.

460-4.3.4.2.8 Verification of Temperatures: Use temperature-sensitive crayons, pyrometers, or infrared non-contact thermometers for verifying temperatures during heating operations. When heating patterns are used, make regular verifications of the temperatures throughout the pattern. Remove the heating flame from the material before taking measurements.

460-4.3.4.2.9 Cooling: Prior to the use of any artificial cooling, allow steel to cool below 600°F. Use only dry compressed air. Do not quench with water or a water and air mixture.

460-4.3.4.2.10 Reheating: Reheat only after the material has cooled below 250°F.

460-4.3.4.2.11 Over Heating: The Engineer may reject the product, if any portion of the material is exposed to heating higher than the allowable temperature.

460-4.3.4.3 Heat-Curving of Bridge Members (Weak Axis Shaping):

460-4.3.4.3.1 General: Rolled beams and girders may be heat-curved at the job site, provided that the heating is performed in accordance with the Engineer's approval.

460-4.3.4.3.2 Sequence of Operations: Heat curve members prior to the attachment of longitudinal stiffeners.

460-4.3.4.3.3 Web Position: When the radius is less than 1,000 feet, heat curve members with the web in the horizontal position or preloaded to induce stress prior to heating. Otherwise, members may be heat-curved with the web in either the vertical or horizontal position.

460-4.3.4.3.4 Subsequent Heats: If multiple locations are to be heated, do not reheat the same location until after at least three heats at other locations.

460-4.3.4.3.5 Locating Heating Patterns: Space the heating patterns along the full length of each flange to produce a circular (not parabolic) curvature. Adjust the heating patterns to produce the necessary curvature. Compensate for differences in flange thickness and width as necessary. Use enough heating patterns in each piece to eliminate chording effects.

460-4.3.4.4 Minimum Radius for Heat-Curving: Heat-curving of beams and girders is allowed when the horizontal radius of curvature measured to the centerline of the member web is greater than both values calculated by Equations 4.1 and 4.2 below, and greater than 150 feet at any and all cross sections throughout the length of the member. Do not heat curve steels with a minimum specified yield strength greater than 50 ksi, other than ASTM A709, Grade HPS 70W.

$$R = \frac{14bD}{\sqrt{F_y \psi t}} \text{ in.} \qquad \text{(Equation 4.1)}$$

$$R = \frac{7500b}{F_y \psi} \text{ in.} \qquad \text{(Equation 4.2)}$$

where:

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

In addition to the above requirements, do not heat curve if the radius is less than 1,000 feet when the flange thickness exceeds 3 inches or the flange width exceeds 30 inches.

460-4.3.4.5 Heat-Cambering (Strong Axis Shaping):

460-4.3.4.5.1 General: Procedures for cambering of built-up plate girders shall be submitted as a part of the Producer Quality Control (QC) Plan. In the procedures, address any proposed preloading and heat application and control. Minor heat adjustments in camber at the finishing stage of the girder do not require approval if the patterns and temperatures are followed in accordance with the approved procedures.

Do not utilize heat-cambering as the primary source of vertical camber in horizontally curved main load-carrying members; cut the web plate to the required position. Only use heat-cambering on horizontally curved main members to adjust cut cambering with the approval of the Engineer.

460-4.3.4.5.2 Web Position: Support members to be heat-cambered with the web vertical. Space supports to take maximum advantage of dead load in the member prior to the application of heat.

460-4.3.4.5.3 Subsequent Heats: If multiple locations are to be heated, do not reheat the same location until after at least three heats at other locations.

460-4.3.4.5.4 Rolled Beams: Rolled beams may be heat-cambered to provide the required curvature at the producing mill. Attach all detail material, such as connection plates, bearing stiffeners and gusset plates, after the beam has been heat-cambered.

460-4.3.4.6 Heat-Straightening Damaged Structural Steel:

460-4.3.4.6.1 General: Submit procedures for heat-straightening for the Engineer's review prior to beginning the work. Describe in detail the distortion to be corrected and all details for preloading, heating, cooling, verifying final dimensions, and nondestructive testing.

460-4.3.4.6.2 Cracking: As a minimum, visually examine all heat-straightened areas. Notify the Engineer when suspected areas of cracking are found. Examine these areas by one or more of the following methods, as directed by the Engineer:

1. Visual examination;
2. Liquid penetrant examination
3. Magnetic particle examination
4. Ultrasonic examination
5. Radiographic examination

460-4.3.4.6.3 Restraining Forces: Restraining forces (usually jacks) shall be set to restrain the steel during heating, but allow free contraction during cooling. In addition, apply the restraining forces in a direction tending to restore the member and limit the magnitude so that the material is not overstressed during heating.

460-4.3.4.6.4 Heating: Heat the steel in a single pass following the specified pattern and allow it to cool to below 250°F prior to reheating. Select heating patterns and sequences appropriate for the type of damage and shape of the cross section. Simultaneous vee heats may be used provided the clear spacing between vees is greater than the width of the plate element.

460-4.3.4.6.5 Subsequent Repair: Heat cambered members damaged after cambering may be repaired. However, do not repair previously heat-straightened members in the same region of damage without the approval of the Engineer.

460-4.3.4.7 Heat Treatment:

460-4.3.4.7.1 General: When any special form of heat treatment is required, it will be described in the Contract Documents. Perform heat treatments prior to any boring, machining or straightening operations.

460-4.3.4.7.2 Stress Relief: Where required, perform thermal stress relief in accordance with the procedure outlined in the AASHTO/AWS D1.5, Bridge Welding Code. Provide welding materials consistent with the stress relieving process utilized.

460-4.3.4.7.3 Normalizing and Annealing: Where required by the Contract Documents, perform normalizing and annealing as defined in ASTM A941. Maintain temperatures uniformly throughout the furnace during heating and cooling so that the temperatures at any points on the member do not differ by more than 130°F.

460-4.3.4.8 Contact and Bearing Surfaces: Provide surface finishes of bearings, base plates, and other contact surfaces in accordance with the ANSI surface roughness requirements as defined in ANSI B46.1, Surface Roughness, Waviness and Lay, Part I, given in Table 460-5, ANSI Surface Roughness Requirements.

Table 460-5 ANSI Surface Roughness Requirements	
Steel slabs	ANSI 2000 micro-inch
Heavy plates in contact with shoes to be welded	ANSI 1000 micro-inch
Milled ends to compression members, milled or ground ends of stiffeners or rockers	ANSI 500 micro-inch
Bridge rollers and rockers	ANSI 250 micro-inch
Sliding bearings	ANSI 125 micro-inch
Pins and pin holes	ANSI 125 micro-inch

460-4.3.4.9 Cleaning and Coating (Including Galvanizing):

460-4.3.4.9.1 General: Clean and coat the work in accordance with 460-2 and/or 460-7.2 and Sections 560, and 562.

460-4.3.4.9.2 Removal of Lubricants: Remove lubricants from the exposed surfaces of installed fastener assemblies and other surfaces in accordance with the approved Producer QC Plan or the paint manufacturer's recommendations prior to painting. Demonstrate the procedures to the Engineer prior to preparations for painting. Bring to the Engineer's attention any manufacturer's processes or procedures that conflict with those specified in the Contract Documents.

460-4.3.5 Bolt Holes:

460-4.3.5.1 General: Unless shown otherwise in the Contract Documents, the bolt hole geometry is to be as shown in Table 460-3, Bolt Hole Geometry.

Table 460-3 Bolt Hole Geometry				
Bolt Diameter (d), inch	Standard (Diameter, inch)	Oversize (Diameter, inch)	Short-Slotted (Width, inch by Length, inch)	Long-Slotted (Width, inch by Length, inch)
1/2	9/16	5/8	9/16 x 11/16	9/16 x 1 1/4
5/8	11/16	13/16	11/16 x 7/8	11/16 x 1 9/16
3/4	13/16	15/16	13/16 x 1	13/16 x 1 7/8
7/8	15/16	1 1/16	15/16 x 1 1/8	15/16 x 2 3/16
1	1 1/16	1 1/4	1 1/16 x 1 5/16	1 1/16 x 2 1/2
> 1 1/8	d + 1/16	D + 5/16	(d + 1/16) x (d + 3/8)	(d + 1/16) x (2.5 x d)
Note: Except as shown elsewhere in the Contract Documents, bolt holes in the connections of primary members are to be standard size.				

460-4.3.5.2 Holes, Tolerances and Quality: Make bolt (and anchor rod) holes using any method suitable to the Fabricator and as specified below; except holes for high strength fasteners in main or primary load-carrying members which are not to be punched full size, but may be thermally cut in accordance with 460-4.3.5.4 and ground smooth with the approval of the Engineer.

The misalignment of holes in a bolt group relative to the same holes in the component or components it is joined to in a connection, shall not exceed 1/32 inch for 85% of the bolt holes in that group. Bolt holes are to be normal to the work and have no tears,

cracks, fins, dirt, loose rust, burrs or other anomalies, and the surface is to be flat within a slope of 1/20. Bolt holes are to be round within plus or minus 1/32 inch and within plus or minus 1/32 inch of the specified size. For subsize holes, a pin 1/8 inch smaller than the subsize holes must be able to pass through all assembled plies in at least 75% of the locations prior to reaming. Holes inclined more than 3 degrees to a surface in any direction must have a hardened beveled washer provided at that face. Unless specified elsewhere in the Contract Documents, it is not required to coat the inside of the bolt holes.

460-4.3.5.3 Slotted Holes: Slots may be made by a single punch, or by joining two adjacent drilled or punched holes when punching is permitted. When joining holes, thermal cutting is to follow the common tangent to the two holes, and this cut is to be ground. Do not make slotted holes more than 1/32 inch in width nor 1/16 inch greater in length than specified. Grind smooth any flame cut portions of the slot to ANSI 1000 micro-inches.

460-4.3.5.4 Holes in Plates Not Subjected to Tensile Stress: Large diameter holes in heavy plates not subjected to tensile stress (such as bearing plates) and slotted holes in materials not subject to tensile stress may be thermally cut, followed by appropriate grinding to smooth the periphery. Stop the practice if gouges or other defects occur, or if directed by the Engineer. These holes are to meet the following criteria:

Do not thermally cut holes in ASTM A709, GradeHPS 100W steel. Provide hole centerlines aligned within plus or minus 1/16 inch of theoretical. The inside (cut) faces of the hole are to be perpendicular to the plane of the plate. Eighty-five percent of the (open) hole diameter is not to exceed that specified in the Contract Documents, plus or minus 1/16 inch. Local notches, gouges or the maximum diameter shall not exceed that specified in the Contract Documents plus or minus 3/32 inch.

460-4.3.5.5 Punching: Material forming parts of a member composed of five thicknesses or less of metal may be punched full-size. When more than five thicknesses of material are joined, material shall be subdrilled or subpunched and then reamed full-size, or drilled full-size while in assembly. Subpunched or subdrilled holes, when required, must be at least 3/16 inches smaller than the finished hole size.

Holes in cross frames, lateral bracing components, and the corresponding holes in connection plates between girders and cross frames or lateral components may be punched full size. Holes in longitudinal main load-carrying members, transverse floorbeams, and any components designated as fracture critical (FCMs) shall not be punched full-size.

460-4.3.5.6 Edge Distance: Provide minimum as-fabricated distance from the center of a bolt hole to an edge as given in Table 460-4, Edge Distances.

Table 460-4
Edge Distances

Fastener Size, Inch	Sheared Edge, Inch	Rolled Edges of Plates or Shapes or Gas Cut Edges Inch
5/8	1 1/8	7/8
3/4	1 1/4	1
7/8	1 1/2	1 1/8
1	1 3/4	1 1/4

460-4.3.5.7 Bolted Splice Gaps: Unless shown elsewhere in the Contract Documents, the tolerance for bolted splice gaps (open distance face-of-web/flange to face-of-web/flange) shall be from zero (no gap between faces) to a maximum of 1/8 inch greater than the gap shown on the Contract Plans. If no gap is shown in the Contract Plans, assume that a nominal gap of 3/8 inch is required. In addition, meet the edge distance requirements, provided above.

460-4.3.5.8 Maximum Edge Distance: Unless otherwise specified in the Contract Documents, the maximum fabricated distance from any edge to the center of the hole shall be 8 times the thickness of the thinnest outside plate, not to exceed 5 inches with no additional tolerance allowed.

460-4.3.5.9 Spacing of Bolt Holes: Space bolt holes within plus or minus 3/16 inch of that shown in the Contract Documents.

460-4.3.5.10 Holding of Plies: When drilling or reaming is accomplished through multiple plies of material, do not hold the materials together by welds not specified in the Contract Drawings.

460-4.4 Member Geometry:

460-4.4.1 General:

460-4.4.1.1 Tolerances: Provide dimensional tolerances as follows:

1. Rolled shapes, plates, bars, wide flange sections and miscellaneous steel in accordance with ASTM A6;
2. Fabricate girders in accordance with the AASHTO/AWS D1.5, Bridge Welding Code and as described below;
3. For built-up members not specifically covered by AASHTO/AWS D1.5, apply AASHTO/AWS D1.5, Bridge Welding Code, except as noted below or as directed by the Engineer.

460-4.4.1.2 Camber and Sweep: Tolerances for camber and sweep of continuous and simply supported girders of any shape shall be as described in the AASHTO/AWS D1.5, Bridge Welding Code. The camber and sweep tolerances for steel pier caps shall be the same as those specified for girders. Measure sweep for horizontally curved members from the theoretical centerline for comparison to the aforementioned requirements.

460-4.4.1.3 Alternate Sections: Rolled sections or fabricated sections of equal or slightly greater dimensions than the section specified may be proposed for the Engineer's approval. Changes that reduce fatigue resistance or significantly affect splice design or deflection will require complete design calculations.

460-4.4.1.4 Web Flatness: Maximum deviation from flatness for webs of curved and/or cambered sections shall be the same as for straight built-up girders. Measure curved girder web flatness using a straightedge oriented perpendicular to the flanges ("vertical", flange to flange).

460-4.4.1.5 Girder Length: If measuring girder length with a device that is free of thermal effects, appropriately adjust the measurements to the reference temperature shown in the Contract Documents. Measure the length of horizontally curved girders along the arc.

460-4.4.2 Specialty Structures:

460-4.4.2.1 Box Members as Bent Caps:

460-4.4.2.1.1 Tolerances: Unless otherwise shown in the Contract Documents, submit tolerances for bearing planes and box twist to the Engineer for review and

approval. Prior to submitting these tolerance values for approval, coordinate between the Erector and the Fabricator.

460-4.4.2.1.2 Bearings: Unless otherwise specified in the Contract Documents, each bearing is to be true to a tolerance of 1/32 inch across its entire width in either direction.

460-4.4.2.1.3 Beam Trueness: Unless otherwise specified in the Contract Documents, the plane of beam supports on the box girder (the bearing area specifically attached to the box girder) is to be true to the box girder bearing within 1/16 inch in the short direction and true to the vertical axis of the nesting girders (those girders attached to or resting on the box girder) within 1/16 inch.

460-4.4.2.2 Trapezoidal Bridge Members: As a minimum, trapezoidal bridge members (tub or box girders) shall meet AASHTO/AWS D1.5, Bridge Welding Code dimensional tolerances. Camber may be verified with the girder in its upright position, supported to avoid dead load deflections.

460-4.4.2.3 Pinholes: Unless shown elsewhere in the Contract Documents, bore pinholes:

1. True to the specified diameter;
2. Smooth to ANSI 3 (125 micro-inches);
3. At right angles with the axis of the member;
4. Parallel with each other; and
5. With a diameter of the pinhole not exceeding that of the pin by more than 0.015 inch for pins 5 inches or less in diameter, or 1/32 inch for larger pins.

460-4.4.2.4 Truss Chord Joints: Abutting joints in truss chords not specified to be mill-to-bear shall have openings of 1/4 inch, plus or minus 1/8 inch.

Abutting joints in truss chords specified to be mill-to-bear shall be faced and brought into bearing. When assembled, provide 85% or more of the abutting surfaces in full contact. Allowable visible gaps shall not exceed 1/64 inch.

460-4.4.2.5 Horizontally Curved Beams and Skewed Steel Girders: Account for torsion induced deflections for horizontally curved beams and skewed steel girders. Unless otherwise defined in the Contract Documents, a horizontally curved beam or girder is a longitudinal or transverse bridge component with a radius less than 10,000 feet anywhere along its continuous length.

460-4.5 Shop Assembly:

460-4.5.1 General: Ensure the fit of all connections and the geometry of all components. Unless specified elsewhere in the Contract Documents, check the fit of all longitudinal girder/beam lines in accordance with 460-4.5.1.1. Perform this prior to transporting the pieces in question to the site for erection.

460-4.5.1.1 Progressive Girder or Truss Assembly: Assemble the structure for a minimum of three spans, panels, field sections, segments or longitudinal chords of the structure. Successive assemblies shall consist of at least one longitudinal segment of the previous assembly, repositioned as necessary for accurate alignment, plus two or more longitudinal segments added at the advancing end. For entire structures less than 150 feet in length or less than three segments, assemble the entire longitudinal line. Meet the requirements of 460-4.5.1.4 when utilizing computer-numerically-controlled drilling equipment.

When a transverse structural steel member or members is required for the continuation of the uninterrupted girder or beam line, truss, arch rib, bent tower face or

rigid frame, and is designated elsewhere in the Contract Documents to be shop assembled, the Fabricator may include this member or component in a separate subassembly and not the three segment longitudinal assembly (discussed above). If combined in a different subassembly, include the longitudinal member(s) or component(s), as designated elsewhere in the Contract Documents to be shop assembled, that frame directly into the transverse structural member. Do not include the transverse member(s) in the longitudinal assembly unless directed so elsewhere in the Contract Documents or by the Engineer. Account for end rotations and deflections as necessary, and submit the procedure to the Engineer for review.

460-4.5.1.2 Progressive Chord Assembly: When specified elsewhere in the Contract Documents, assemble the truss chords for a minimum of three panels or longitudinal segments of the structure. Successive assemblies shall consist of at least one longitudinal segment of the previous assembly, repositioned as necessary for accurate alignment, plus two or more longitudinal segments added at the advancing end. For entire structures less than 150 feet in length or less than three segments, assemble the entire longitudinal line. Meet the requirements of 460-4.5.1.4 when using computer-numerically-controlled drilling equipment.

Account for transverse members indicted elsewhere in the Contract Documents to be included in the shop assembly as in 460-4.5.1.1.

When assembled in accordance with this subsection, the holes of the connections will be so located that they will be drilled to the final geometric angles. This will require that the truss members, when erected under the no load (or practically no load or stress) condition, must be bent and forced to fit the end conditions. This condition will introduce an initial reverse secondary stress that will theoretically wane when the structure assumes the loading for which it is cambered. Submit the procedure to the Engineer for review.

460-4.5.1.3 Special Complete Structure Assembly: When specified elsewhere in the Contract Documents, this type of shop assembly will include assembling the entire structure including the diaphragms, cross frames, integral steel substructure and floor components. Miscellaneous components are not included unless directed elsewhere in the Contract Documents. Establish procedures for each structure or structure type including consideration of incremental erection, temporary field support locations, stage construction and final tightening of field connections. Submit the procedures for review by the Engineer.

460-4.5.1.4 Computer-Numerically-Controlled (CNC) Drilling Associated with Progressive Girder, Truss or Chord Assembly: If the Fabricator chooses to drill the holes in all plies of all connections of the continuous main girder or beam line, truss, arch rib, bent, tower face or rigid frame and any intersecting (transverse) members utilizing computer-controlled-numerical drilling procedures, piece-wise assembly of the entire continuous girder or beam line, truss, arch rib, bent, tower face or rigid frame is not required if the following requirements are met:

Prior to transporting to the site, perform a check fit of the first three spans, panels, field sections, segments or longitudinal chords; or entire first bent, tower face or rigid frame of the structure to ensure the accuracy of the CNC procedures and equipment.

As selected by and at the discretion of the Engineer and prior to transporting to the site, perform another check fit of a different assembly of three spans, panels, field sections, segments or longitudinal chords; or another entire bent, tower face or rigid frame of the structure to ensure that the accuracy of the CNC procedures and equipment is maintained. If either of the above fails to meet the Contract requirements, assemble the entire girder or beam line, truss, arch rib, bent, tower face or rigid frame as originally prescribed in 460-4.5.1.1 or 460-

4.5.1.2 as prescribed elsewhere in the Contract Documents. Account for transverse members indicated elsewhere in the Contract Documents to be included in the shop assembly as in 460-4.5.1.1.

460-4.6 Evaluation of Work: The Engineer will evaluate and accept materials and work conforming to the Contract Documents. These evaluations may take place prior to or following delivery of the materials to the site of the structure. Materials or work that fails to meet Contract requirements will be rejected.

The Engineer may, at his sole discretion, permit further inspections and testing of materials or work that fail to meet Contract requirements for acceptance. The cost of such inspections and tests shall be borne by the Contractor.

Bring to the attention of the Engineer, all nonconforming work and or materials that cannot be brought into conformance with the Contract Documents using pre-established procedures as outlined in the Department approved Producer QC Plan. Submit the following information to the Engineer:

A cover letter prepared on the Contractor's letterhead and addressed to the Engineer briefly describing the nonconforming work and the proposed credit to the Contract proportionate to the nonconformance. For each fabricating facility and for each project within that fabrication facility, submittals must be numbered consecutively beginning with the number 1, at the start of each project. Erectors will start with one for each individual project.

A completed Department Nonconforming Structural Steel and Miscellaneous Metal Component Data Sheet prepared by the Contractor and countersigned by the Engineer's designated representative to indicate agreement between the Contractor and the Department regarding the nonconformance, not any solution, resolution or credit. If the Contractor and the Engineer's designated representative are not in agreement regarding the nonconformance, the Engineer's designated representative will either reject the submittal indicating the reason(s) for the rejection or modify the submittal and forward to the Engineer. In the event of modification, the Contractor will initial the submittal before being forwarded to the Engineer, thereby indicating the Contractor's concurrence with the modification.

A list of supporting information such as sketches, documentation, calculations, pictures, etc., must be included in the appropriate space on the Nonconforming Component Data Sheet. Supporting information regarding Contract Document noncompliance in the form of separate documents is only necessary when space on the Department Nonconforming Structural Steel and Miscellaneous Metal Component Data Sheet is inadequate for the required data. All of the supporting information required for the form must be prepared by, or under the supervision of, the Specialty Engineer who will sign and seal the supporting information.

If requested by the Engineer, submit a structural and durability evaluation of the proposed repair and/or remediation. This evaluation must be conducted under the supervision of a Specialty Engineer and the submittal is to bear the Specialty Engineer's signature and seal.

460-4.7 Member or Component Certification: Coordinate with the Engineer to schedule final inspection of the completed work within two weeks prior to shipment or erection to verify that all Contract Document requirements have been met. After verification that all Contract Document requirements have been met and all necessary repairs have been satisfactorily completed, the Quality Control Manager shall certify, by initials and/or signature, such materials, components or members. The record shall include certification for:

1.Items being shipped or stored prior to final assembly. Affix a certification in the form of a stamp or tag in accordance with 460-4.2 and as indicated in the Producer Q C Plan, and with a copy of the certification placed in the Contractor's permanent project records,

2. Work being placed into its final position. Document in the Contractor's permanent project records.

Submit a summary certification at the least once a month or with each payment request that includes the following or similar wording. "The undersigned, being a responsible official of (insert Contractor identification) certifies that the materials, components or members listed herein have been produced under strict quality control and meet the requirements of the Contract Documents" Include a positive identification in the certification such that the applicable materials, components and/or members can be uniquely identified utilizing just the summary certification document. The Quality Control Manager shall sign this summary certification.

460-5 Bolted Connections.

460-5.1 General: Use bolts as follows:

1. Use galvanized ASTM A325 Type 1 bolts in all field installed bolted structural steel connections for painted steel.

2. Use either black or galvanized ASTM A325 Type 1 bolts in all shop installed bolted structural steel connections that will be shop painted.

3. Use black ASTM A325 Type 3 bolts in all bolted structural steel connections for weathering steel that is to remain unpainted.

4. Use the bolts as specified for connected assemblies or parts that are designated as miscellaneous components where the fastener type is specified elsewhere in the Contract Documents.

Tighten ASTM A325 bolts in accordance with the procedures specified below for turn-of-nut or direct-tension-indicator (DTI) tightening.

Lubricate and maintain consistency in lubrication of fastener assembly during Rotational Capacity (RC) testing and installation. Assemblies that exhibit a loss of lubrication, as determined by the Engineer, may be re-lubricated and retested prior to installation.

Use ASTM A490 bolts only with the approval of the Engineer. Submit procedures in accordance with ASTM A490 for the handling, lubrication, installation, tightening and testing of such bolts. Do not install ASTM A490 bolts without prior approval of the procedures by the Engineer.

When the Engineer approves ASTM A307 bolts for use in miscellaneous components, tighten them such that the plies of the joint are in firm contact. Use three to five impacts of an impact wrench or the full effort of a person using an ordinary spud wrench to obtain a snug connection.

Fasten aluminum, other materials or assemblies of dissimilar materials in accordance with the Contract Documents.

Install ordinary rough or machine bolts and nuts in accordance with the Contract Documents.

460-5.2 Testing:

460-5.2.1 Rotational Capacity (RC) Tests: At the location of and prior to installation of permanent high-strength fasteners in main or primary load-carrying member connections, perform RC tests in accordance with FM 5-581 (for long bolts) or FM 5-582 (for short bolts) to ensure that the fasteners are capable of developing the specified strength and that the fasteners are properly lubricated. As a minimum, test two assemblies per LOT designation.

The bolt, nut and washer shall come from the same LOT and be packed in the same container (or group of containers assigned the same LOT), except in special cases where nuts and washers have only one production LOT number for each size.

Short bolts may also be tested using FM 5-583 with DTIs calibrated with long bolts installed in a Tension Measuring Device.

Washers are required for RC tests even though they may not be required for jobsite installation. Where washers are not required for jobsite installation, LOT identification is not required. The washer coating shall be the same as that for the bolt and nut.

If any of the required tests fails, the entire LOT will be rejected.

460-5.2.2 Verification of Direct Tension Indicator (DTI) Device Performance: On a daily basis (when DTI devices are being installed) and at the location of installation, perform DTI Verification tests in accordance with FM 5-583. Perform this test on a minimum of two high-strength fastener assemblies from each fastener assembly LOT and position of the DTI prior to production installation. If either assembly fails, test additional fastener assembly LOT/DTI combinations as requested by the Engineer to verify that the Requirements of the Contract Documents have been satisfied. These two tests are in addition to the RC tests required in 460-5.2.1. If, after additional testing, the DTI fails to meet the requirements of FM 5-583, the LOT will be rejected by the Engineer.

460-5.3 Reuse and Retightening: Do not reuse ASTM A490 bolts or galvanized ASTM A325 bolts. Black ASTM A325 bolts with free spinning nuts may be reused one time with the Engineer's approval. Previously tightened bolts that may have been loosened by the tightening of adjacent bolts can be further tightened from the original position. Ensure proper lubrication prior to retightening. Discard and replace fractured or damaged bolts.

460-5.4 Assembly of Bolted Connections:

460-5.4.1 General: Verify that the faying surfaces are in accordance with the Contract Documents, are free of dirt or other foreign materials, and that the geometry of the bolt holes and the connection meets the requirements of 460-4.3.4.9.

Install fastener assembly components of the same LOT and of the size and quality specified in the Contract Documents. Provide final bolts, cylindrical erection pins or other fit-up bolts as indicated in the Erection Plan.

When it is impractical to turn the nut, tighten the fastener by turning the bolt while preventing the nut from rotating. During this tightening operation, do not allow the rotation of the part of the fastener assembly not turned by the wrench.

460-5.4.2 Preparation of Faying Surfaces: Provide coated and non-coated faying surfaces in accordance with the Contract Documents. Faying surfaces specified as blast-cleaned must satisfy SSPC SP-10 'Near-White Blast Cleaning.'

When painting of the slip-critical faying surface of bolted connections is required, use only the prime coat. Prepare and coat the faying surfaces prior to installation of the fasteners. Provide certification of the slip critical classification required in the Contract Documents.

Submit certification to the Engineer that galvanized faying surfaces meet or exceed a Class C slip critical classification, unless a different classification is required elsewhere in the Contract Documents. Mechanically roughen galvanized faying surfaces in accordance with the galvanizer's recommendations.

460-5.4.3 Reaming: Do not over size bolt holes by reaming (or any other method) without the approval of the Engineer.

460-5.4.4 Drifting: Do not over size, stretch or otherwise damage bolt holes by improper and excessive drifting.

460-5.4.5 Splice Plate Filler Material: Unless otherwise specified in the Contract Documents, provide filler material edges within 1/8 inch of the adjacent splice material edge. Where required for proper alignment at a bolted flange splice, additional filler material may be added provided that the total thickness of filler plates is less than 1/4 inch.

460-5.4.6 Installation of Fastener Assemblies: Unless shown otherwise in the Erection Plan, install the bolts of the connection by progressing systematically from the most rigid part of the connection to the free edges. Install bolts in all holes of the connection and bring them to a "snug tight" condition. Following the sequence indicated in the Erection Plan, further tighten all the bolts in the connection.

For ASTM A325 bolts, obtain the required bolt tension as shown in Table 460-6, Minimum Required Fastener Tension in accordance with the turn-of-nut method specified in 460-5.4.8, or when DTIs are used, the DTI tightening method specified in 460-5.4.9.

For connections (such as large main load-carrying members or truss joints) in which previously tightened high strength bolts become loose and require retightening upon the tensioning of others, install into a minimum of ten percent of the holes fully tensioned bolts prior to final tensioning of the permanent bolts. Distribute these first bolts randomly throughout the connection. If directed by the Engineer, remove the initial bolts and install permanent bolts at each location, otherwise retighten in accordance with 460-5.3.

Table 460-6
Minimum Required Fastener Tension

Bolt Size, inch	Tension ASTM A 325 bolts, kips
5/8	19
3/4	28
7/8	39
1	51
1 1/8	56
1 1/4	71
1 3/8	85
1 1/2	103

460-5.4.7 Bolt Tension: Provide a Skidmore-Wilhelm Calibrator, or other equivalent bolt tension measuring device, wherever final connections are being made. Confirm the accuracy of the tension measuring device by having it calibrated by an approved testing agency once a year.

460-5.4.8 Turn-of-Nut Tightening: For each work shift, perform tests utilizing a representative sample of five fastener assemblies, from each LOT to be installed that shift. Perform the tests using the tension measuring device, following the same procedure to be used for actual installation of the fastener assemblies, to a snug-tight tension and corresponding torque, which, when the additional turns required in Table 460-7, Nut Rotation from the Snug-Tight Condition are added, will result in at least 1.05 times the minimum required fastener installation tension as shown in Table 460-6. Place a washer under the part turned in the

tightening of the bolt. Consider the job inspection snug-tight torque as the average of three test values determined after rejecting the high and low-test values.

For fastener assemblies too short to fit in the tension measuring device, modify the determination of the job inspection snug-tight torque in accordance with FM 5-582.

460-5.4.8.1 Snug-Tight Condition: In the turn-of-nut method, first bring all the fastener assemblies of the connection to a "snug-tight" condition to ensure that all parts of the connection are in firm contact with each other. For the purposes of this specification, "firm contact" shall mean the condition that exists on a faying surface when the plies are solidly seated against each other, but not necessarily in continuous contact. Regard snug-tight as the tightness required to produce the bolt tension, which following the final applied rotation, produces at least 1.05 times the minimum required bolt tension in accordance with Table 460-6, Minimum Required Fastener Tension. In the presence of the Engineer, and on a daily basis, determine the job inspection snug-tight torque as specified herein.

460-5.4.8.2 Final Tightening: After verification of the snug-tight condition in accordance with 460-5.4.11 by the Engineer, tighten all fastener assemblies in the joint by applying the applicable amount of nut rotation specified in Table 460-7, Nut Rotation from the Snug-Tight Condition. Once snug-tight, bring all fasteners to the required tension within the same work shift.

Table 460-7
Nut Rotation from the Snug-Tight Condition

Bolt Length Measured from Underside of Head to End of Bolt	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis and Other Face Sloped Not More than 20:1.Bevel Washer not Used.	Both Faces Sloped Not More than 20:1 from Normal to Bolt Axis. Bevel Washers not Used.
Up to and Including Four (4) Diameters	1/3 turn	1/2 turn	2/3 turn
Over Four (4) Diameters but not Exceeding Eight (8) Diameters	1/2 turn	2/3 turn	5/6 turn
Over Eight (8) Diameters but Not Exceeding Twelve (12) Diameters	2/3 turn	5/6 turn	1 turn

Notes:
1. Nut rotation is relative to the bolt, regardless of the element being turned.
2. Tolerance for bolts installed by 1/2 turn or less is ± 30 degrees. For bolts installed by 2/3 turn or more, the tolerance is ± 45 degrees.
3. Nut rotations given are only applicable to connections in which all material within the grip of the bolt is steel.
4. For bolt lengths exceeding 12 diameters, establish the required rotation by performing actual tests in a suitable tension device simulating the actual conditions. Submit procedures to the Engineer for review.

460-5.4.9 Direct-Tension-Indicator (DTI) Tightening: After complying with the requirements of 460-5.2.2, install and tighten DTI devices following the procedures described in the DTI Verification Test. Do not permit the DTI to turn during installation and tightening. Provide washers in accordance with 460-5.4.10.

460-5.4.9.1 Snug-Tight Condition: Install the bolts as specified through Step 3 (Snug-Tight Condition) of the DTI Verification test. If the 0.005 inch feeler gage is

refused in more gaps than shown in the table in Step 3.5 of the test, or the DTI device becomes loose and can be spun by hand, remove the bolt and DTI device, discarding the DTI device. Provide a new DTI device and reinstall the assembly and bring to the snug-tight condition.

460-5.4.9.2 Final Tightening: After verification by the Engineer that the snug-tight condition for all bolts has been met, tighten all fastener assemblies in the joint such that the number of spaces in which the 0.005 inch thickness gauge is refused is equal to or greater than the number shown in Table 460-8, DTI Device Tightening Criteria. Once snug-tight, bring all fasteners to the required tension within the same work shift.

Table 460-8
DTI Device Tightening Criteria

Number of Spaces in DTI	4	5	6	7	8	9
Minimum Spaces in which Gage is Refused	2	3	3	4	4	5

Do not tighten the assembly beyond the smallest gap permitted in Step 3.5 of FM 5-583. Remove and replace bolts, discarding the DTI, which have a DTI with a smaller gap or no gap.

460-5.4.10 Washers:

460-5.4.10.1 General: Provide ASTM F436 hardened steel washers as follows:

1. For connections (and all associated testing) using ASTM A490 bolts, use a hardened washer under each element.
2. For connections using ASTM A325 bolts, use hardened washers under the turned element.
3. Use hardened steel washers as part of the Rotational Capacity tests.
4. Where the outer face of the bolted parts has a slope of greater than 20:1 with respect to a plane normal to the bolt axis, use a hardened, beveled washer to compensate for the lack of parallelism.
5. Where bolts are to be installed in a oversized or slotted hole in an outer ply, provide a single washer satisfying ASTM F436, or continuous bar satisfying ASTM A709: for ASTM A325 bolts, provide a thickness of at least 5/16 inch; and for ASTM A490 bolts, provide a thickness of 3/8 inch. Provide these washers or bars to completely cover the slot after installation. Provide a finish consistent with the bolt specified.
6. In non-Direct-Tension-Indicator (DTI) applications, clip washers on one side to a point not closer than 7/8 of the bolt diameter from the center of the washer, if necessary.

460-5.4.10.2 Use of Washers with Direct-Tension-Indicators (DTIs) Devices: When DTIs are used; use ASTM F436 hardened washers as follows:

1. When the nut is turned and the DTI is located under the bolt head, a hardened washer is to be located under the nut.
2. When the nut is turned and the DTI is located under the nut, a hardened washer is to be located between the nut and the DTI.
3. When the bolt head is turned and the DTI is located under the nut, a hardened washer is to be located under the bolt head.

4. When the bolt head is turned and the DTI is located under the bolt head, a hardened washer is to be located between the bolt head and the DTI.

460-5.4.11 Inspection:

460-5.4.11.1 Turn-of-Nut Tightening:

1. Once the snug-tight condition is achieved for all of the fastener assemblies of the connection, within 24 hours of snugging the first bolt in the connection and in the presence of the Engineer, verify for a minimum of three (3) bolts [two (2) for two bolt connections] or 10% of the fastener assemblies, that the job inspection snug-tight torque has been attained. These fasteners are to have a snug-tight torque equal to or exceeding that specified in 460-5.4.8. Perform this check using the same torque wrench used in 460-5.4.8. For bolts tested in accordance with FM 5-583 or when multiple torque wrenches are required, provide a calibrated torque wrench or wrenches.

2. If the tested fasteners do not obtain the job inspection snug-tight torque, test all remaining untested fastener assemblies using the torque wrench in the connection in question. Following testing of all assemblies, bring to snug-tight all assemblies and retest as stated above. Re-snug and retest as necessary using the calibrated torque wrench until the minimum testing stated above is performed favorably.

3. Following confirmation of the snug-tight condition as performed by the Contractor, and in the presence of the Engineer, match mark the fastener assemblies on the end of the bolt thread and on the nut, and then tighten the nut the amount of rotation specified in Table 460-7, Nut Rotation from the Snug-Tight Condition. The Engineer will accept the connection as fully tightened when all of the following conditions are met:

a. the rotation specified in Table 460-7 has been achieved,

b. there are no loose assemblies in the connection,

c. all plies of the connection are in firm contact,

d. there are no indications that excessive stretching or yielding has occurred in the fastener assembly,

e. bolt stick-through is consistent per LOT.

460-5.4.11.2 Direct-Tension-Indicator (DTI) Tightening: Prior to bringing the connection to a snug-tight condition, verify in the presence of the Engineer that the 'dimples' of the DTI are not deformed or damaged. Bring the connection to a snug-tight condition and tighten in accordance with the requirements of 460-5.4.9. The Engineer will accept the connection as fully tightened when all of the following conditions are met:

1. The requirements of 460-5.4.9 have been achieved,

2. There are no loose assemblies in the connection,

3. All plies of the connection are in firm contact,

4. There are no indications that excessive stretching or yielding has occurred in the fastener assembly,

5. Bolt stick-through is consistent per LOT.

460-6 Welding.

460-6.1 General: Perform all shop and field welding in accordance with the applicable AWS Welding Code. This requirement includes the use of qualified welders, qualified weld procedures, and qualified inspection personnel.

460-6.2 Welding on Non-Dynamically Loaded Elements: Perform welding on miscellaneous components and other statically (non-dynamically, non-cyclically, etc.) loaded

structural elements in accordance with the AWS D1.1, Structural Welding Code, or the AASHTO/AWS D1.5, Bridge Welding Code.

460-6.3 Electroslag Welding: Perform NGI-ESW welding in accordance with the AASHTO/AWS D1.5, Bridge Welding Code.

460-6.4 Welding of Hollow Structural Steel Sections (Pipes and Tubes): Except as noted in the Contract Documents, perform all shop and field welding of Hollow Structural Shapes in accordance with the AWS D1.1, Structural Welding Code as amended herein.

460-6.4.1 Highway Sign Structures, Luminaires and Traffic Signals: For structural steel sign structures, lighting poles, and traffic signal poles, comply with AWS D1.1 Structural Welding Code. as well as the additional requirements of AASHTO Standard Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals, Section 5.15, Welded Connections.

460-6.4.2 Tubular Bridge or Sign Structures: Comply with the requirements of the AWS D1.1 Structural Welding Code as amended by the following:

Unless otherwise shown in the Plans, perform ultrasonic testing (UT) or radiographic testing (RT) on full penetration groove welds at the following frequency (use the AWS D1.1 Tubular Connections Class R Criteria for UT and Cyclically Loaded Criteria for RT.

One hundred percent of each joint subject to tension or reversal of stress.

Twenty-five percent of each joint subject to only compression or shear. If discontinuities are found in the joint, the remainder of the joint shall be tested.

Perform Magnetic Particle Testing at the following frequencies:

A minimum of 25% of all fillet or partial penetration groove welds in main members (Use the AWS D1.1 Tubular Connections Criteria). If discontinuities are found, the remainder of the welds on the members shall be tested.

460-6.5 Field Welding: Field weld only with the approval of the Engineer.

460-6.6 Tack Welds: Do not weld or tack any fill plates, brackets, clips, shipping devices, or other materials not required by the Contract Documents or allowed by the AASHTO/AWS D1.5 Bridge Welding Code.

460-7 Erection.

460-7.1 Pre-erection Requirements:

460-7.1.1 Erection Quality Control (QC) Plan: Submit an Erection QC Plan for review and approval of the Engineer.

460-7.1.2 Submittals: Meet the requirements of Sections 5 and 103 for any required submittals. Provide submittals to the Engineer for review by the Department in accordance with Section 5 and the Contract Documents.

460-7.1.3 Erection Plan: Submit, for the Engineer's review, an Erection Plan locating all primary members, lifting equipment and temporary supports or braces, and bolting pattern tightening procedures not considered routine. Ensure that the plan includes the Specialty Engineer's signature and stamp. Include supporting calculations indicating that the design unit stresses indicated in the Contract Documents have not been exceeded. Submit this plan or plans to the Engineer three weeks before erecting the piece or pieces.

Include the following information in the Erection Plan:

1. A plan of the work area showing all substructure units and foundations; surface roads and railroads; all streams, creeks and rivers; all overhead utilities; and

any underground utilities that could possibly impact, or be adversely affected by, erection operations as determined by the Specialty Engineer.

2. The erection sequence for all primary load-carrying members and all primary load-carrying member bracing. Note any and all permanent or temporary support and/or bracing locations, including crane-holding positions.

3. The center of gravity locations, pick weight and delivery orientation for all primary load-carrying members.

4. Identify any bolting requirements not considered routine.

5. Locate all pick crane work points.

6. Identify all temporary works and staging areas such as barges, mats and temporary excavation support.

7. Include capacity charts on the drawings for each crane configuration and boom extension utilized.

8. Details of all temporary bracing, falsework, towers and shoring.

9. Submit any procedures requested by the Engineer and not contained in the Erection Plan.

460-7.2 Special Requirements for Uncoated Weathering Steel:

460-7.2.1 General: Do not use marking materials (grease sticks, crayons) that leave behind a residual film that may affect the weathering process of the steel. Store the girders as required for non-weathering steels.

460-7.2.2 Steel Preparations: Prior to erection, perform the following as appropriate:

Blast clean the exposed fascia of the exterior girders (both I and box) to meet SSPC-SP10 criteria; blast clean the remaining exposed surfaces of steel trapezoidal girders, not required to be prepared otherwise, to meet SSPC-SP6 criteria; for steel I-girders, if a non-uniform mill scale finish has developed, as determined by the Engineer, blast clean all remaining exposed surfaces, not required to be prepared otherwise, to SSPC-SP6 criteria; coat the inside of box members including, but not limited to, all bracing members, cross frames and diaphragms in accordance with Section 560. Coat the exterior face of box girder end diaphragms and all interior surfaces of box girders extending beyond the end diaphragm with an inorganic zinc coating system in accordance with Section 560.

460-7.2.3 Concrete Substructure Preparations:

460-7.2.3.1 Substructure Areas Not Receiving Class 5 Finish: Prior to erection of the girders, cover all exposed substructure concrete surfaces to protect them against staining from the weathering steel components. Leave the covering in place until after placement of the concrete deck. As directed by the Engineer, clean all visible stains on concrete in areas not receiving a Class 5 Finish by sandblasting and follow-on cleaning using a stain remover or commercial cleaner after completion of the structure in accordance with Section 400.

460-7.2.3.2 Substructure Areas Receiving a Class 5 Finish: If the Class 5 Finish is to be applied prior to the placement of the concrete deck, cover all finish concrete surfaces after application and curing of the Class 5 Finish to protect them from staining from the weathering steel components. Leave the covering in place until after placement of the concrete deck. Upon removal of the covering, reapply the Class 5 Finish to cover any stains which may be present.

If the Class 5 Finish is to be applied after placement of the concrete deck, no substructure covering will be required.

460-7.2.4 Structure and Site Clean Up: Upon the completion of construction, remove all oil, dirt, grease or other foreign material, including excessive or uneven mill scale from the steel. Remove lubricants from the exposed surfaces of installed fastener assemblies and other surfaces in accordance with the manufacturer's recommendations. Follow procedures specified in Section 560 as appropriate. Final surface finish is to be an even mill scale as approved by the Engineer.

460-7.3 Coordination with Substructure: Prior to the erection of primary load-carrying members, conduct a survey to document the vertical, longitudinal and transverse position of all substructure units and anchor rod locations. Appropriately account for ambient temperature in the survey.

Should a discrepancy be identified with the Contract Documents, submit the necessary details to the Engineer for resolution.

460-7.4 Placing Anchor Rods: Locate and place anchor rods within the tolerance shown in the Contract Documents or within 1/4 inch of the theoretical location shown. If anchor rods cannot be located to the specified tolerance, place only with the approval of the Engineer. Unless shown otherwise in the Contract Documents, provide galvanized anchor rods, nuts and washers as follows:

1. Set the anchor rods in preformed holes vertical to the plane of the bridge seat.
2. Provide 4 inch diameter holes.
3. Provide non-shrink grout/mortar of a strength greater than or equal to that of the substructure concrete strength, or as shown elsewhere in the Contract Documents.
4. Install the rods in accordance with the grout/mortar manufacturer's recommendations.
5. Clean the threads of the anchor rods as necessary without damaging the coating.

460-7.5 Preparation of Bearing Areas and Setting of Bearings: Prior to placing superstructure bearing units (including but not limited to neoprene pads and masonry plates), prepare the top of concrete pad (bearing area) in accordance with Section 400. If a discrepancy is identified, report it to the Engineer for resolution.

For expansion bearings with slotted holes for anchor rods, which allow movement of the superstructure with respect to the substructure, vary the location of the slotted plate in relation to the anchor rods, in accordance with the prevailing temperature at the time of setting.

For fixed bearings at multiple adjacent piers, if necessary, horizontally jack the substructure units to correctly set the centerline of bearing. Adequately account for temperature.

Unless specified elsewhere in the Contract Documents, locate the theoretical centerline of bearings to within 1/16 inch transverse to longitudinal girder lines; and in the direction parallel to the longitudinal girder line locate the theoretical centerline of bearing within 1/4 inch of the theoretical centerline of bearing.

After setting the bearings and installing anchor rod nuts, washers and any other associated hardware specified in the Contract Documents, clean the protruding/exposed surfaces of the assembly of all deleterious material. Finish-coat metal parts in accordance with 460-4.3.4.11.

460-7.6 Tightening of Anchor Bolt/Rod Nuts:

460-7.6.1 Fixed and Expansion Pot Bearing: Tighten anchor bolts or rod nuts to a 'snug tight' condition such that the different mating surfaces (such as the top of concrete, neoprene and steel) are in firm contact. The nut or bolt is to be tight enough to develop friction

between surfaces to prevent sliding, but not over-tightened that bulging or damage occurs in any of the mating materials.

460-7.6.2 Fixed and Expansion Bearings with Elastomeric Bearing Pads: Draw down the lower nut such that a total gap of 1/2 inch exists between the nut and bearing plate. Tighten a second nut of the same specification to a snug tight condition against the lower nut maintaining the required gap.

460-7.7 Bolted Connections: For splice connections of primary members, as well as connections of diaphragms or crossframes, fill at least 50% of the holes prior to crane release. The 50% may be either erection bolts in a snug tight condition or full size erection pins, but at least half (25% of all holes) shall be bolts, and sufficient pins shall be used near outside corners of splice plates and at member ends near splice plate edges to ensure alignment. Filled holes should be uniformly distributed between the web and flange connections for primary members such that approximately 50% of the web connections are filled and approximately 50% of the flange connections are filled. For diaphragms or cross-frames, the filled holes should be uniformly distributed between all the bolt groups connecting the diaphragm or crossframe to the primary member. The 50% requirement may be waived if a reduced percentage is calculated as sufficient and shown on the approved Erection Plan. Primary member splice connections that are made up on the ground (prior to erection) shall be 100 percent complete prior to any lifting operation. Fully tighten all bolts prior to installation of deck forming for each unit.

460-7.8 Final Position of Girder Webs: Unless shown elsewhere in the Contract Documents, detail the girders and cross frames as directed by the Engineer. The final condition is to be defined as with the deck and parapets cast, but without any future wearing surface. A web will be considered plumb if it is within a tolerance horizontally between the top and bottom of the web of 3/32 inch per foot of web depth compared against the theoretical position as required in the Contract Documents. Measure the out-of-plumb perpendicular to the face of the web. Erect trapezoidal girders to the geometry shown in the Contract Documents to the same 3/32 inch per foot of web depth tolerance.

460-7.9 Inspection and Final Acceptance:

460-7.9.1 General: Perform Quality Control inspections of all phases of the work. The inspection frequency and depth shall be sufficient to ensure that all materials and workmanship incorporated into the work meet the requirements of the Contract Documents and that the processes are controlled to ensure that the final finished product(s) conform to the physical characteristics and dimensions required by the Contract Documents. The Quality Control Manager shall be responsible for all inspection operations. An adequate number of Quality Control Inspectors shall be available to ensure review of all materials and fabrication processes are preformed in accordance with the Producer QC Plan. Weekly meetings shall be held with the Engineer to review inspection findings. The review of this information is to identify any refinements and/or improvements in the process being utilized in the work. The frequency of the meetings may be altered by the Engineer.

460-7.9.2 Inspection/Final Acceptance: Ensure the final alignment, profile and fastening of the erected steel is in accordance with the Contract Documents.

460-8 Method of Measurement.

460-8.1 General: The quantities to be paid for will be the items covered by this Section, following acceptance by the Engineer. Partial payments may be made for fabricated components yet to be assembled into larger components, members and assemblies as allowed for elsewhere in the Contract Documents.

460-8.2 Deductions and Allowances: No deductions from the computed weight of rolled or fabricated structural steel or miscellaneous components will be made for sheared edges, punchings, holes, milling, plaining or other items of waste associated with the finished components or parts.

460-8.3 Weights of Structural Steel and Miscellaneous Materials: The weights of structural steel will be taken as nominal weights as reported in the AASHTO LRFD Bridge Construction Specifications and ASTM Specifications, in that order of precedence, using the dimensions shown in the Contract Documents.

460-8.4 Structural Steel: The quantity of structural steel and miscellaneous metals becoming part of the completed structure and accepted by the Engineer will be paid for at the quantity shown in the Contract Documents, or as modified by the Engineer, measured in pounds, or by the Contract lump sum price for Structural Steel.

460-8.5 High-Strength Fastener Assemblies: The weight of high-strength fastener assemblies (including nuts and washers) installed by the Contractor and accepted by the Engineer will be computed on the basis of an average length in accordance with Table 460-9:

Table 460-9
Weights of High-Strength Fastener Assemblies

Diameter of High-Strength Fasteners, inch	3/4 inch	7/8 inch	1 inch	1 1/8 inch	1 1/4 inch
Weight per 100, pounds	52	100	135	182	238

The weight of high-strength fastener assemblies will be included in the determination of the weight of the completed structure in determining the quantity paid when payment is not by Lump Sum. The Engineer will determine values for sizes of high-strength fastener assemblies not shown.

460-8.6 Welding and Welds; Fasteners Not Designated as High-Strength; Anchor Rods, Nuts, Bolts and Associated Washers; Transporting; Handling; and Erection: Welding and welds; fastener assemblies not designated as high-strength; anchor rods, nuts, bolts and associated washers; transporting; handling; and erection are considered incidental to the work and will not be paid for separately.

460-8.7 Shims and Fill Plates: The quantity of shims and fill plates will be included in the determination of the weight of the completed structure in determining the quantity paid when payment is not by Lump Sum.

460-8.8 Coatings: The preparation, application, clean-up and the consumables used in the coatings process are considered incidental to the work and will not be paid for separately.

460-8.9 Weathering Steel Preparation, Handling and/or Clean-up: The preparation, handling, and/or clean-up of weathering steel or the “rust" marks on other items (concrete units, etc.) caused by the development of the patina are considered incidental to the work and will not be paid for separately.

460-8.10 Shear Connectors: Shear connectors are considered incidental to the work and will not be paid for separately.

460-8.11 Span Jacking (Fixed Bridge): Jacking of substructure units of adjacent fixed piers required to set bearing in accordance with the Contract Documents is considered incidental to the work and will not be paid for separately.

460-9 Basis of Payment.

460-9.1 General: Prices and payments will be for full compensation for all work specified in this Section completed and accepted, including but not limited to testing, bolting, welding, cleaning and coating, temporary works and erection. No separate payment will be made for falsework or other erection expense.

460-9.2 Payment Items: Payment will be made under:

Item No. 460- 1-	Structural Steel - Rehab - per pound.
Item No. 460- 2-	Structural Steel - New/Widening - lump sum.
Item No. 460- 6-	Ladders & Platforms - lump sum.
Item No. 460- 13-	Structural Steel Rehab - Sandwich Plate System - per square yard.
Item No. 515- 4-	Aluminum Bullet Railings - per linear foot.
Item No. 460- 71-	Metal Traffic Railing - per foot.
Item No. 460- 81-	Rivet or High-Strength Bolt Replacement - each.
Item No. 460- 95-	Structural Steel Repair - per pound.
Item No. 460- 98-	Pipe Hanger - each.
Item No. 460-112-	Anchor Bolt Replacement - each.