STANDARD SPECIFICATIONS
for
HIGHWAY BRIDGES

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®

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FABRICATION

ERECTION

Section 10

STEEL STRUCTURES

FABRICATION

10.1 TYPE OF FABRICATION

These specifications apply to bolted and welded construction.

10.2 QUALITY OF WORKMANSHIP

Workmanship and finish shall be equal to the best general practice in modern bridge shops.

10.3 MATERIALS

10.3.1 Structural Steel

10.3.1.1 General

Steel shall be furnished according to the following specifications. Unless otherwise specified, structural carbon steel shall be furnished.

10.3.1.2 Structural Steel

10.3.1.2.1 Carbon Steel

Unless otherwise specified, structural carbon steel for bolted or welded construction shall conform to: Structural Steel, AASHTO M183 (ASTM A36).

10.3.1.2.2 Eyebars

Steel for eyebars shall be of a weldable grade. These grades include structural steel conforming to:

(a) Structural Steel, AASHTO M 183 (ASTM A 36).
(b) High-Strength Low-Alloy Structural Steel with 50,000 psi, Minimum Yield Point to 4 inches thick, AASHTO M 222 (ASTM A 588 with Supplementary Requirement S1 of AASHTO M 222 mandatory).

10.3.1.3 High-Strength Low-Alloy Structural Steel

High-strength low-alloy structural steel shall conform to:

(a) High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, AASHTO M 223 (ASTM A 572).
(b) High-Strength Low-Alloy Structural Steel with 50,000 psi, minimum Yield Point to 4 inches thick, AASHTO M 222 (ASTM A 588).

10.3.1.4 High-Strength Low-Alloy Structural Steel for Welding

High-strength low-alloy structural steel for welding shall conform to:

(a) High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, Grade 50, AASHTO M 223 (ASTM A 572 with Supplementary Requirement S2 of AASHTO M 223 mandatory).
(b) High-Strength Low-Alloy Structural Steel with 50,000 psi, minimum Yield Point to 4 in. thick, AASHTO M 222 (ASTM A 588 with Supplementary Requirement S1 of AASHTO M 222 mandatory).

10.3.1.5 High-Strength Structural Steel for Bolted Construction

High-strength structural steel for bolted construction shall conform to:

(a) High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, AASHTO M 223 (ASTM A 572).
(b) High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 inches thick, AASHTO M 222 (ASTM A 588).

10.3.1.6 High-Yield-Strength, Quenched, and Tempered Alloy Steel Plate

High-yield-strength, quenched, and tempered alloy steel plate shall conform to:

(a) High-Yield-Strength, Quenched, and Tempered Alloy Steel Plate, suitable for welding, ASTM A 514.
(b) High-Strength Alloy Steel Plates, Quenched and Tempered for pressure vessels, ASTM A 517.

(c) Quenched and tempered alloy steel structural shapes and seamless mechanical tubing, meeting all of the mechanical and chemical requirements of A 514/A 517 steel, except that the specified maximum tensile strength may be 140,000 psi for structural shapes and 145,000 psi for seamless mechanical tubing, shall be considered as A 514/A 517 steel.

10.3.1.7 High-Strength Bolts

10.3.1.7.1 High-strength bolts for structural steel joints including suitable nuts and plain hardened washers shall conform to either AASHTO M 164 (ASTM A 325) or AASHTO M 253 (ASTM A 490). When M 164 type 3 bolts are specified, they along with suitable nuts and washers shall have an atmospheric corrosion resistance approximately two times that of carbon steel with copper.

10.3.1.7.2 Bolts and nuts manufactured to AASHTO M 164 (ASTM A 325) are identified by proper marking as specified on the top of the bolt heads and on one face of the nuts for three different types.

10.3.1.7.3 Bolts manufactured to AASHTO M 253 (ASTM A 490) are identified by marking on the top of the head with the symbol A 490 and the nuts shall be marked on one face with the legend "2H" or "DH".

10.3.1.7.4 Bolt and nut dimensions shall conform to the dimensions given in Table 10.3A and to the requirements for Heavy Hexagon Structural Bolts and for Heavy Semi-Finished Hexagon Nuts given in ANSI Standard B18.2.1 and B18.2.2 respectively.

TABLE 10.3A

	Bolt Dimensions in Inches Heavy Hexagon Structural Bolts			Nut Dimensions In Inches Heavy Semi-Finished Hexagon Nuts	
Nominal Bolt Size D	Width Across Flats, F	Height, H	Thread Length, T	Width Across Flats, W	Height, H
1/2	7/8	5/16	1	7/8	31/64
5/8	1-1/16	25/64	1-1/4	1-1/16	39/64
3/4	1-1/4	15/32	1-3/8	1-1/4	47/64
7/8	1-7/16	35/64	1-1/2	1-7/16	55/64
1	1-5/8	39/64	1-3/4	1-5/8	63/64
1-1/8	1-13/16	11/16	2	1-13/16	1-7/64
1-1/4	2	25/32	2	2	1-7/32
1-3/8	2-3/16	27/32	2-1/4	2-3/16	1-11/32
1-1/2	2-3/8	15/16	2-1/4	2-3/8	1-15/32

10.3.1.7 5 Circular washers shall be flat and smooth and their nominal dimensions shall conform to the dimensions given in Table 10.3B, except that for lock pin and collar fasteners, flat washers need not be used, unless slotted or oversized holes are specified.

10.3.1.7.6 Beveled washers for American Standard Beams and Channels or other sloping faces shall be required and shall be square or rectangular, shall taper in thickness, and shall conform to the dimensions given in Table 10.3B.

10.3.1.7.7 Where necessary, washers may be clipped on one side to a point not closer than 7/8 of the bolt diameter from the center of the washer.

10.3.1.7.8 Other fasteners or fastener assemblies which meet the materials, manufacturing, and chemical composition requirements of AASHTO M 164 (ASTM A 325) or AASHTO M 253 (ASTM A 490), and which meet the mechanical property requirements of the same specification in full-size tests, and which have body diameter and bearing areas under the head and nut, or their equivalent, not less than those provided by a bolt and nut of the same nominal dimensions prescribed in the previous paragraph, may be used. Such alternate fasteners may differ in other dimensions from those of the specified bolts and nuts. Their installation procedure may differ from those specified in Article 10.17.4 and their inspection may differ from that specified in Article 10.17.5. When a different installation procedure or inspection is used, it shall be detailed in a supplemental specification applying to the alternate fastener and that specification must be approved by the Engineer.

10.3.1.7.9 Subject to the approval of the Engineer, highstrength steel lock-pin and collar fasteners may be used as an alternate for high strength bolts as shown on the plans. The shank and head of the high-strength steel lock-pin and collar fasteners shall meet the requirements of the preceding paragraph. Each fastener shall provide a solid shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than the bolt specified, shall have a cold forged head on one end, of type and dimensions as approved by the Engineer, a shank length suitable for material thickness fastened, locking grooves, breakneck groove and pull grooves (all annular grooves) on the opposite end. Each fastener shall provide a steel locking collar of proper size for shank diameter used which, by means of suitable installation

TABLE 10.3B. Washer Dimensions[a]

Circular Washers					Square or Rectangular Beveled Washers for American Standard Beams and Channels		
Bolt Size, D	Nominal Outside Diameter[b]	Nominal Diameter of Hole	Thickness Min.	Thickness Max.	Minimum Side Dimensions	Mean Thickness	Slope Of Taper In Thickness
1/2	1-1/16	17/32	.097	.177	1-3/4	5/16	1:6
5/8	1-5/16	21/32	.122	.177	1-3/4	5/16	1:6
3/4	1-15/32	13/16	.122	.177	1-3/4	5/16	1:6
7/8	1-3/4	15/16	.136	.177	1-3/4	5/16	1:6
1	2	1-1/16	.136	.177	1-3/4	5/16	1:6
1-1/8	2-1/4	1-1/4	.136	.177	2-1/4	5/16	1:6
1-1/4	2-1/2	1-3/8	.136	.177	2-1/4	5/16	1:6
1-3/8	2-3/4	1-1/2	.136	.177	2-1/4	5/16	1:6
1-1/2	3	1-5/8	.136	.177	2-1/4	5/16	1:6
1-3/4	3-3/8	1-7/8	.178[c]	.28[c]	—	—	—
2	3-3/4	2-1/8	.178	.28	—	—	—
Over 2 to 4 Incl.	2D-1/2	D+1/8	.24[d]	.34[d]	—	—	—

[a] Dimensions in inches.
[b] May be exceeded by 1/4 inch.
[c] 3/16 inch nominal.
[d] 1/4 inch nominal.

tools, is cold swaged into the locking grooves forming a head for the grooved end of the fastener after the pull groove section has been removed. The steel locking collar shall be a standard product of an established manufacturer of lock-pin and collar fasteners, as approved by the Engineer.

10.3.1.8 Copper Bearing Steels

When copper bearing steel is specified, the steel shall contain not less than 0.2 percent of copper.

10.3.1.9 Welded Stud Shear Connectors

10.3.1.9.1 Shear connector studs shall conform to the requirements of Cold Finished-Carbon Steel Bars and Shafting, AASHTO M 169 (ASTM A 108), cold-drawn bars, grades 1015, 1018, or 1020, either semi- or fully-killed. If flux retaining caps are used, the steel for the caps shall be of a low carbon grade suitable for welding and shall comply with Cold-Rolled Carbon Steel Strip, ASTM A 109.

10.3.1.9.2 Tensile properties as determined by tests of bar stock after drawing or of finished studs shall conform to the following requirements:

Tensile Strength	(min.)	60,000
Yield Strength*	(min.)	50,000
Elongation	(min.)	20% in 2 inches
Reduction of area	(min.)	50%

*As determined by a 0.2% offset method.

10.3.1.9.3 Tensile properties shall be determined in accordance with the applicable sections of ASTM A 370, Mechanical Testing of Steel Products. Tensile tests of finished studs shall be made on studs welded to test plates using a test fixture similar to that shown in Figure 4.23.2 of AWS D1.1. If fracture occurs outside of the middle half of the gage length, the test shall be repeated.

10.3.1.9.4 Finished studs shall be of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other injurious defects. Finish shall be as produced by cold drawing, cold rolling, or machining.

10.3.1.9.5 The manufacturer shall certify that the studs as delivered are in accordance with the material requirements of this section. Certified copies of in-plant quality control test reports shall be furnished to the Engineer upon request.

10.3.1.9.6 The Engineer may select, at the Contractor's expense, studs of each type and size used under the contract, as necessary for checking the requirements of this section.

10.3.1.10 Unfilled Tubular Steel Piles

Unfilled Tubular Steel Piles shall conform to the requirements of Welded and Seamless Steel Pipe Piles

ASTM A 252, Grade 2, with chemical requirements meeting ASTM A 53, Grade B.

10.3.2 Steel Forgings and Steel Shafting

10.3.2.1 Steel Forgings

Steel forgings shall conform to the Specifications for Steel Forgings Carbon and Alloy for General Industrial Use, AASHTO M 102 (ASTM A 668), Classes C, D, F, or G.

10.3.2.2 Cold Finished Carbon Steel Shafting

Cold finished carbon steel shafting shall conform to the specifications for Cold Finished Carbon Steel Bars and Shafting, AASHTO M 169 (ASTM A 108). Grade 1016-1030, inclusive, shall be furnished unless otherwise specified.

10.3.3 Steel Castings

10.3.3.1 Steel Castings for Highway Bridges

Steel castings for use in highway bridge components shall conform to Standard Specification for Steel Castings for Highway Bridges, AASHTO M 192 (ASTM A 486) or Mild-to-Medium Strength Carbon-Steel Castings for General Applications AASHTO M 103 (ASTM A 27). The class 70 or grade 70-36 of steel, respectively, shall be used unless otherwise specified.

10.3.3.2 Chromium Alloy-Steel Castings

Chromium alloy-steel castings shall conform to the Specification for Corrosion-Resistant Iron-Chromium, Iron-Chromium-Nickel Alloy Castings for General Application, AASHTO M 163 (ASTM A 743). Grade CA 15 shall be furnished unless otherwise specified.

10.3.4 Iron Castings

10.3.4.1 General

Iron castings shall be gray iron castings conforming to the Specification for Gray Iron Castings, AASHTO M 105 (ASTM A 48), Class No. 30 unless otherwise specified.

10.3.4.2 Workmanship and Finish

10.3.4.2.1 Iron castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and value for the service intended.

10.3.4.2.2 Castings shall be boldly filleted at angles and the arrises shall be sharp and perfect.

10.3.4.3 Cleaning

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

10.3.5 Ductile Iron Castings

10.3.5.1 General

Ductile iron castings shall conform to the Specifications for Ductile Iron Castings, ASTM A 536, Grade 60-40-18 unless otherwise specified. In addition to the specified test coupons, test specimens from parts integral with the castings, such as risers, shall be tested for castings weighing more than 1,000 pounds to determine that the required quality is obtained in the castings in the finished condition.

10.3.5.2 Workmanship and Finish

10.3.5.2.1 Iron castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and value for the service intended.

10.3.5.2.2 Castings shall be boldly filleted at angles and the arrises shall be sharp and perfect.

10.3.5.3 Cleaning

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

10.3.6 Malleable Castings

10.3.6.1 General

Malleable castings shall conform to the Specification for Malleable Iron Castings, ASTM A 47. Grade No. 35018 shall be furnished unless otherwise specified.

10.3.6.2 Workmanship and Finish

10.3.6.2.1 Malleable castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and value for the service intended.

10.3.6.2.2 The castings shall be boldly filleted at angles and the arrises shall be sharp and perfect. The surfaces shall have a workmanlike finish.

10.3.6.3 Cleaning

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

10.3.7 Bronze Castings and Copper-Alloy Plates

10.3.7.1 Bronze Castings

Bronze castings shall conform to Standard Specifications for Bronze Castings for Bridges and Turntables, AASHTO M 107 (ASTM B 22) Alloys 913 or 911.

10.3.7.2 Copper-Alloy Plates

Copper-alloy plates shall conform to Standard Specifications for Rolled Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and other Structural Uses, AASHTO M 108 (ASTM B 100).

10.3.8 Sheet Lead

Sheet lead shall conform to the requirements for Common Desilverized Lead of the Specification for Pig Lead, ASTM B 29.

10.3.9 Sheet Zinc

Sheet zinc shall conform to the requirements for Type II of the Specifications for Rolled Zinc, ASTM B 69.

10.3.10 Galvanizing

When galvanizing is shown on the plans or specified in the special provisions, ferrous metal products shall be galvanized in accordance with the Specifications for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strip, AASHTO M 111 (ASTM A 123).

10.3.11 Canvas and Red Lead for Bedding Masonry Plates

These pads shall be formed on the bridge seat bearing area by swabbing the area with red lead paint, then placing upon it 3 layers of 12- to 14-ounce duck. Each layer shall be thoroughly swabbed on its top surface with red lead paint. The red lead paint shall conform to the specifications for paint for metals, Article 14.2.

10.3.12 Preformed Fabric Pads

The preformed fabric pads shall be composed of multiple layers of 8-ounce cotton duck impregnated and bound with high-quality natural rubber or of equivalent and equally suitable materials compressed into resilient pads of uniform thickness. The number of plies shall be such as to produce the specified thickness, after compression and vulcanizing. The finished pads shall withstand compression loads perpendicular to the plane of the laminations of not less than 10,000 pounds per square inch without detrimental reduction in thickness or extrusion.

10.4 STORAGE OF MATERIALS

Structural material, either plain or fabricated, shall be stored at the bridge shop above the ground on platforms, skids, or other supports. It shall be kept free from dirt, grease, and other foreign matter, and shall be protected as far as practicable from corrosion.

10.5 STRAIGHTENING MATERIAL AND CURVING ROLLED BEAMS AND WELDED GIRDERS

10.5.1 Straightening Material

Rolled material, before being laid off or worked, must be straight. If straightening is necessary, it shall be done by methods that will not injure the metal. Heat straightening of AASHTO M 244 (ASTM A 514) or ASTM A 517 steel shall be done only under rigidly controlled procedures, each application subject to the approval of the Engineer. In no case shall the maximum temperature of the steel exceed 1125F. Sharp kinks and bends shall be cause for rejection of the material.

10.5.2 Curving Rolled Beams and Welded Girders

10.5.2.1 Materials

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

10.5.2.2 Type of Heating

10.5.2.2.1 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 or wedgeshaped 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.

10.5.2.2.2 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.* When the radius of curvature is 1,000 feet or more, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend to the juncture of the flange and web. When the radius of curvature is less than 1,000 feet, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to one-eighth 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 with the approval of the Engineer.

10.5.2.2.3 For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is only mandatory when the flange thickness is 1 1/4 inches or greater, in which case, the two surfaces shall be heated concurrently. The maximum temperature shall be prescribed below.

10.5.2.3 Temperature

The heat-curving operation shall be conducted in such a manner that the temperature of the steel does not exceed 1150F as measured by temperature indicating crayons or other suitable means. The girder shall not be artificially cooled until after naturally cooling to 600F. The method of artificial cooling is subject to the approval of the Engineer.

*To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so that heat is not applied directly to the web.

10.5.2.4 Position for Heating

10.5.2.4.1 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.

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

10.5.2.5 Sequence of Operations

The girder shall be heat-curved in the fabrication shop before it is painted. The heat curving operation may be conducted either before or after all the required welding of transverse intermediate stiffeners is completed. However, unless provisions are made for girder shrinkage, connection plates and bearing stiffeners shall be located and attached after heat curving. If longitudinal stiffeners are required, they shall be heat-curved or oxygen-cut separately and then welded to the curved girder. When cover plates are to be attached to rolled beams, they may be attached before heat curving if the total thickness of one flange and cover plate is less than 2 1/2 inches and the radius of curvature is greater than 1,000 feet. For other rolled beams with cover plates, the beams must be heat-curved before the cover plates are attached; cover plates must be either heat curved or oxygen-cut separately and then welded to the curved beam.

10.5.2.6 Camber

Girders shall be cambered before heat curving. Camber for rolled beams may be obtained by heat-cambering methods approved by the Engineer. For plate girders, the web shall be cut to the prescribed camber with suitable allowance for shrinkage due to cutting, welding, and heat curving.* However, subject

*The heat-curving process may tend to change the vertical camber present before heating. This effect shall be most pronounced when the top and bottom flanges are of unequal widths on a given transverse cross section.

to the approval of the Engineer, moderate deviations from specified camber may be corrected by a carefully supervised application of heat.

10.5.2.7 Measurement of Curvature and Camber

Horizontal curvature and 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. 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; camber shall be checked by adequate means.

10.6 FINISH

Portions of the work exposed to view shall be finished neatly. Shearing, flame cutting, and chipping shall be done carefully and accurately.

10.7 BOLT HOLES

10.7.1 Holes for High-Strength Bolts and Unfinished Bolts**

10.7.1.1 All holes for bolts shall be either punched or drilled. Material forming parts of a member composed of not more than five thicknesses of metal may be punched 1/16 inch larger than the nominal diameter of the bolts whenever the thickness of the material is not greater than 3/4 inch for structural steel, 5/8 inch for high-strength steel or 1/2 inch for quenched and tempered alloy steel, unless subpunching and reaming are required under Article 10.10.

10.7.1.2 When there are more than five thicknesses or when any of the main material is thicker than 3/4 inch for structural steel, 5/8 inch for high-strength steel, or 1/2 inch for quenched and tempered alloy steel, all holes shall either be subdrilled or drilled full size.

10.7.1.3 When required under Article 10.10, all holes shall be either subpunched or subdrilled (subdrilled if thickness limitation governs) 3/16 inch smaller and, after assembling, reamed 1/16 inch larger or drilled full size to 1/16 inch larger than the nominal diameter of the bolts.

** See Article 10.16 for bolts included in designation "Unfinished Bolts."

10.7.1.4 When permitted by Division I, Article 10.32, enlarged or slotted holes are allowed with high-strength bolts.

10.7.2 Holes for Ribbed Bolts, Turned Bolts, or Other Approved Bearing Type Bolts

All holes for ribbed bolts, turned bolts, or other approved bearing-type bolts shall be subpunched or subdrilled 3/16 inch smaller than the nominal diameter of the bolt and reamed, assembled, or drilled to a steel template or, after assembling, drilled from the solid at the option of the Fabricator. In any case the finished holes shall provide a driving fit as specified on the plans or in the special provisions.

10.8 PUNCHED HOLES

The diameter of the die shall not exceed the diameter of the punch by more than 1/16 inch. If any holes must be enlarged to admit the bolts, such holes shall be reamed. Holes must be clean cut without torn or ragged edges. Poor matching of holes will be cause for rejection.

10.9 REAMED OR DRILLED HOLES

Reamed or drilled holes shall be cylindrical, perpendicular to the member, and shall comply with the requirements of Article 10.7 as to size. Where practicable, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Poor matching of holes will be cause for rejection. Reaming and drilling shall be done with twist drills. If required by the Engineer, assembled parts shall be taken apart for removal of burrs caused by drilling. Connecting parts requiring reamed or drilled holes shall be assembled and securely held while being reamed or drilled and shall be match marked before disassembling.

10.10 PREPARATION OF FIELD CONNECTIONS

10.10.1 Subpunching and Reaming of Field Connections

10.10.1.1 Unless otherwise specified in the special provisions or on the plans, holes in all field connections and field splices of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched (or subdrilled if subdrilling is required according to Article 10.7) and subsequently reamed while assembled onto a steel template, as required by Article 10.14. Holes for field splices of rolled beam stringers continuous over floor beams or crossframes may be drilled full size unassembled to a steel template. All holes for floor beam and stringer field end connections shall be subpunched and reamed to a steel template or reamed while assembled. Reaming or drilling full size of field connection holes through a steel template shall be done after the template has been located with utmost care as to position and angle and firmly bolted in place. Templates used for reaming matching members, or the opposite faces of a single member, shall be exact duplicates. Templates used for connections on like parts or members shall be so accurately located that the parts or members are duplicates and require no match-marking.

10.10.1.2 For any connection, in lieu of subpunching and reaming or subdrilling and reaming, the fabricator may, at his option, drill holes full size with all thicknesses or material assembled in proper position.

10.10.1.3 If additional subpunching and reaming is required, it shall be specified in the special provisions or on the plans.

10.10.2 Numerically-Controlled Drilled Field Connections

10.10.2.1 General

10.10.2.1.1 Alternately, for any connection or splice designated in Article 10.10.1, in lieu of subsized holes and reaming while assembled, or drilling holes full-size while assembled, the Contractor shall have the option to drill or punch bolt holes full-size in unassembled pieces and/or connections including templates for use with matching subsized and reamed holes by means of suitable numerically controlled (N/C) drilling or punching equipment subject to the specific provisions contained in this article. Full-size punched holes shall meet the requirements of Article 10.7.

10.10.2.1.2 If N/C drilling or punching equipment is used, the Engineer, unless otherwise stated in the special provisions or on the plans, may require the Contractor, by means of check assemblies, to demonstrate that this drilling or punching procedure consistently produces holes and connections meeting the requirements of Articles 10.12 and 10.14.

10.10.2.1.3 The Contractor shall submit to the Engineer for approval a detailed outline of the procedures that he proposes to follow in accomplishing the work from initial drilling or punching through check assembly, if required, to include the specific members of the structure that may be N/C drilled or punched, the sizes of the holes, the location of common index and other reference points, composition of check assemblies, and all other pertinent information.

10.10.2.2 Holes

Holes drilled or punched by N/C equipment shall be drilled or punched to appropriate size either through individual pieces, or drilled through any combination of pieces held tightly together.

10.11 ACCURACY OF PUNCHED AND DRILLED HOLES

All holes punched full size, subpunched, or subdrilled shall be so accurately punched that after assembling (before any reaming is done) a cylindrical pin 1/8 inch smaller in diameter than the nominal size of the punched hole may be entered perpendicular to the face of the member, without drifting, in at least 75 percent of the contiguous holes in the same plane. If the requirement is not fulfilled, the badly punched pieces will be rejected. If any hole will not pass a pin 3/16 inch smaller in diameter than the nominal size of the punched hole, this will be cause for rejection.

10.12 ACCURACY OF REAMED AND DRILLED HOLES

10.12.1 When holes are reamed or drilled, 85 percent of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 1/32 inch between adjacent thicknesses of metal.

10.12.2 All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centerlines of the connection as inscribed on the template. The centerlines shall be used in locating accurately the template from the milled or scribed ends of the members.

10.13 FITTING FOR BOLTING

10.13.1 Surfaces of metal in contact shall be cleaned before assembling. The parts of a member shall be assembled, well pinned, and firmly drawn together before drilling, reaming, or bolting is commenced. Assembled pieces shall be taken apart, if necessary, for the removal of burrs and shavings produced by the operation. The member shall be free from twists, bends, and other deformation.

10.13.2 The drifting done during assembling shall be only such as to bring the parts into position and not sufficient to enlarge the holes or distort the metal.

10.14 SHOP ASSEMBLING

10.14.1 The field connections of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be assembled in the shop with milled ends of compression members in full bearing, and then shall have their subsize holes reamed to specified size while the connections are assembled. Assembly shall be Full Truss or Girder Assembly unless Progressive Truss or Girder Assembly, Full Chord Assembly, Progressive Chord Assembly, or Special Complete Structure Assembly is specified in the special provisions or on the plans.

10.14.2 Check Assemblies with Numerically Controlled Drilled or Punched Field Connections and template drilled field connections of rolled beam stringers continuous over floorbeams or cross frames shall be in accordance with the provisions of Article 10.14.4.6.

10.14.3 Each assembly, including camber, alignment, accuracy of holes, and fit of milled joints, shall be approved by the Engineer before reaming is commenced or before an N/C drilled check assembly is dismantled.

10.14.4 A camber diagram shall be furnished to the Engineer by the Fabricator, showing the camber at each panel point in the cases of trusses or arch ribs, and at the location of field splices and fractions of span length (1/4 points minimum, 1/10 points maximum) in the cases of continuous beam and girders or rigid frames. When the shop assembly is Full Truss or Girder Assembly or Special Complete Structure Assembly, the camber diagram shall show the camber measured in assembly. When any of the other methods of shop assembly is used, the camber diagram shall show calculated camber.

10.14.4.1 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.

10.14.4.2 Progressive Truss or Girder Assembly

Progressive Girder Assembly shall consist of assembling initially for each arch rib, continuous beam line, or plate girder at least three contiguous shop sections. Progressive Truss Assembly shall consist of assembling initially for each truss, bent, tower face, or rigid frame, all members in at least three contiguous panels but not less than the number of panels associated with three contiguous chord lengths. Successive assemblies shall consist of not less than two sections or panels of the previous assembly (repositioned if necessary and adequately pinned to assure accurate alignment) plus one or more sections or panels added at the advancing end. In the case of structures longer than 150 feet, each assembly shall be not less than 150 feet long regardless of the length of individual continuous panels or sections. At the option of the fabricator, sequence of assembly may start from any location in the structure and proceed in one or both directions so long as the preceding requirements are satisfied.

Assemblies consisting of less than three shop sections or panels shall require approval of the Engineer.

10.14.4.3 Full Chord Assembly

10.14.4.3.1 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 their 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 the chord lines.

10.14.4.3.2 Field connection holes in web members shall be reamed to steel templates. At least one end of each web member shall be milled or shall be 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.

10.14.4.4 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.

10.14.4.5 Special Complete Structure Assembly

Special Complete Structure Assembly shall consist of assembling the entire structure, including the floor system. (This procedure is ordinarily needed only for complicated structures such as those having curved girders, or extreme skew in combination with severe grade or camber.)

10.14.4.6 Check Assemblies with Numerically Controlled Drilled Field Connections

10.14.4.6.1 A check assembly shall be required for each major structural type of each project, unless otherwise designated on the plans or in the special provisions, and shall consist of at least three contiguous shop sections or, in a truss, 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). Check assemblies should be based on the proposed order of erection, joints in bearings, special complex points, and similar considerations. Such special points could be the portals of skewed trusses, etc.

10.14.4.6.2 Use of either geometric angles (giving theoretically zero secondary stresses under dead-load conditions after erection) or cambered angles (giving theoretically zero secondary stresses under no-load conditions) should be designated on the plans or in the special provisions.

10.14.4.6.3 The check assemblies shall preferably be the first such sections of each major structural type to be fabricated.

10.14.4.6.4 No match-marking and no shop assemblies other than the check assemblies shall be required.

10.14.4.6.5 If the check assembly fails in some specific manner to demonstrate that the required accuracy is being obtained, further check assemblies may be required by the Engineer for which there shall be no additional cost to the contracting authority.

10.15 MATCH-MARKING

Connecting parts assembled in the shop for the purpose of reaming holes in field connections shall be match-marked, and a diagram showing such marks shall be furnished to the Engineer.

10.16 BOLTS AND BOLTED CONNECTIONS

The specifications of this article do not pertain to the use of high-strength bolts. Bolted connections fabricated with high-strength bolts shall conform to Article 10.17.

10.16.1 General

Bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A Bolts of Specification for Low-Carbon Steel Externally and Internally Threaded Standard Fasteners, ASTM A 307. Bolted connections shall be used only as indicated by the plans or special provisions. Bolts shall have single self-locking nuts or double nuts unless otherwise shown on the plans or in the special provisions. Beveled washers shall be used where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis.

10.16.2 Unfinished Bolts

Unfinished bolts shall be furnished unless other types are specified.

10.16.3 Turned Bolts

The surface of the body of turned bolts shall meet the ANSI roughness rating value of 125. Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of threads shall be equal to the body of the bolt or the nominal diameter of the bolt specified. Holes for turned bolts shall be carefully reamed with bolts furnished to provide for a light driving fit. Threads shall be entirely outside of the holes. A washer shall be provided under the nut.

10.16.4 RIBBED BOLTS

10.16.4.1 The body of ribbed bolts shall be of an approved form with continuous longitudinal ribs. The diameter of the body measured on a circle through the points of the ribs shall be 5/64 inch greater than the nominal diameter specified for the bolts.

10.16.4.2 Ribbed bolts shall be furnished with round heads conforming to ANSI B 18.5 unless otherwise specified. Nuts shall be hexagonal, either recessed or with a washer of suitable thickness. Ribbed bolts shall make a driving fit with the holes. The hardness of the ribs shall be such that the ribs do not mash down enough to permit the bolts to turn in the holes during tightening. If for any reason the bolt twists before drawing tight, the hole shall be carefully reamed and an oversized bolt used as a replacement.

10.17 CONNECTIONS USING HIGH STRENGTH BOLTS

10.17.1 General

This article covers the assembly of structural joints using AASHTO M164 (ASTM A 325) or AASHTO M 253 (ASTM A 490) high-strength bolts, or equivalent fasteners, tightened to a high tension. The bolts are used in holes conforming to the requirements of Articles 10.7, 10.8, and 10.9.

10.17.2 Bolts, Nuts, and Washers

Bolts, nuts, and washers shall conform to the requirements of Article 10.3.1.7.

10.17.3 Bolted Parts

10.17.3.1 The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material.

10.17.3.2 When assembled, all joint surfaces, including those adjacent to the bolt head, nuts, or washers, shall be free of scale, except tight mill scale, and shall also be free of burrs, dirt, and other foreign material that would prevent solid seating of the parts. Paint is permitted unconditionally in bearing-type connections.

10.17.3.3 In friction-type connections the Class, as defined below, indicating the condition of the contact surfaces shall be specified on the plans. Where no Class is specified all joint surfaces shall be free of scale, except tight mill scale and shall not have a vinyl wash.

(a) Classes A, B, and C (uncoated): Contact surfaces shall be free of oil, paint, lacquer, or other coatings.

(b) Class D (hot dip galvanized and roughened): Contact surfaces shall be lightly scored by wire brushing or blasting after galvanizing and prior to assembly. The wire brushing treatment shall be a light application of manual or power brushing that marks or scores the surface but removes relatively little of the zinc coating. The blasting treatment shall be a light "brush-off" treatment which will produce a dull gray appearance. However, neither treatment should be severe enough to produce any break or discontinuity in the zinc surface.

(c) Classes E and F (blast-cleaned, zinc rich paint): Contact surfaces shall be coated with organic or inorganic zinc rich paint as defined in the Steel Structures Painting Council System SSPC 12.00.

(d) Classes G and H (blast-cleaned, metallized zinc or aluminum): Contact surfaces shall be coated in accordance with AWS C2.2. Recommended Practice for Metallizing with Aluminum and Zinc for Protection of Iron and Steel, except that subsequent sealing treatments, described in Section IV therein, shall not be used.

(e) Class I (vinyl wash): Contact surfaces shall be coated in accordance with the provisions of the Steel Structures Painting Council Pretreatment Specifications SSPC PT3.

10.17.3.4 AASHTO M 164 (ASTM A 325) Type 2 and AASHTO M 253 (ASTM A 490) bolts shall not be galvanized nor shall they be used to connect galvanized material.

10.17.4 Installation

10.17.4.1 Bolt Tension

10.17.4.1.1 Each fastener shall be tightened to provide, when all fasteners in the joint are tight, at least the minimum bolt tension shown in Table 10.17A for the size of fastener used.

10.17.4.1.2 Threaded bolts shall be tightened by one of the methods described in Articles 10.17.4.3, 10.17.4.4, and 10.17.4.5. If required because of bolt entering and wrench operational clearances, tightening by the selected procedure may be done by turning the bolt while the nut is prevented from rotating. Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to perform the required tightening of each bolt in approximately 10 seconds.

10.17.4.1.3 AASHTO M 253 (ASTM A 490) and galvanized AASHTO M 164 (ASTM A 325) bolts shall not be reused. Other AASHTO M 164 (ASTM A 325) bolts may be reused, but not more than once, if approved by the Engineer. Retightening previously tightened bolts which may have been loosened by the tight-

TABLE 10.17A BOLT TENSION

Bolt Size (in.)	Minimum Bolt Tension[a] (lbs.) AASHTO M 164 (ASTM A 325) Bolts	AASHTO M 253 (ASTM A 490) Bolts
1/2	12,050	14,900
5/8	19,200	23,700
3/4	28,400	35,100
7/8	39,250	48,500
1	51,500	63,600
1-1/8	56,450	80,100
1-1/4	71,700	101,800
1-3/8	85,450	121,300
1-1/2	104,000	147,500

[a] Equal to 70 percent of specified minimum tensile strength of bolts.

ening of adjacent bolts shall not be considered as a reuse.

10.17.4.2 Washers

10.17.4.2.1 All fasteners shall have a hardened washer under the element (nut or bolt head) turned in tightening except that AASHTO M 164 (ASTM A 325) bolts installed by the turn of the nut method in holes which are not oversize or slotted may have the washer omitted. Hardened washers shall be used under both the head and nut, regardless of the element turned, in the case of AASHTO M 253 (ASTM A 490) bolts, if the material against which it bears has a specified yield strength less than 40 ksi.

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

10.17.4.3 Turn-of-Nut Tightening

When the turn-of-nut method is used to provide the bolt tension specified in Article 10.17.4.1, there shall first be enough bolts brought to a "snug tight" condition to ensure that the parts of the joint are brought into full contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 10.17B

TABLE 10.17B Nut Rotation[a] from Snug Tight Condition

Bolt Length measured from underside of head to extreme end of point	Disposition of Outer Faces of Bolted Parts: Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters[b]	2/3 turn	5/6 turn	1 turn

[a] Nut rotation is relative to bolt, regardless of the element (not or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30°; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45°.

[b] No research work has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation there shall be no rotation of the part not turned by the wrench.

10.17.4.4 Lock-Pin and Collar Fasteners

The installation of lock-pin and collar fasteners shall be by methods and procedures approved by the Engineer.

10.17.4.5 Tightening by Use of a Load Indicating Fastener System

Tightening by this means is permitted provided it can be demonstrated by an accurate direct measurement procedure that the bolt has been tightened in accordance with Table 10.17A. Tightening shall be by methods and procedures approved by the Engineer.

10.17.5 Inspection

10.17.5.1 The Engineer shall determine that the requirements of Articles 10.17.5.2 and 10.17.5.3, following, are met in the work.

10.17.5.2 The Engineer shall observe the installation and tightening of bolts to determine that the selected tightening procedure is properly used and shall determine that all bolts are tightened and in the case of direct tension indicator method that the correct indication of tension has been achieved. Bolts may reach tensions substantially above the value given in Table 10.17A, but this shall not be cause for rejection.

10.17.5.3 The following inspection shall be used unless a more extensive or different inspection procedure is specified.

(a) Either the Engineer or the Contractor in the presence of the Engineer, at the Engineer's option, shall use an inspection wrench which may be a torque wrench.

(b) Three bolts of the same grade, size,* and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension at least once each working day. There shall be a washer under the part turned in tightening each bolt if washers are so used on the structure. If no washer is used the material abutting the part turned shall be of the same specification as that used on the structure.

(c) Each bolt specified in paragraph b shall be tightened in the calibration device by any convenient means to an initial condition equal to 15 percent of the required tension and then the minimum tension specified for its size in Article 10.17.4.1. The inspecting wrench then shall be applied to the tightened bolt and the torque necessary to turn the nut or head 5 degrees (approximately 1 inch at 12-inch radius) in tightening direction shall be determined. The average torque measured in the tests of three bolts shall be taken as the job inspecting torque to be used in the manner specified in Paragraph (b).

(d) Bolts, represented by the sample prescribed in paragraph b, which have been tightened in the structure shall be inspected by applying, in the tightening direction, the inspecting wrench and its job inspecting torque to 10 percent of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt head is turned by this application of the job inspecting torque, the connection shall be accepted as properly tightened. If any nut or bolt head is turned by the application of the job inspecting torque, this torque shall be applied to all bolts in the connection, and all bolts whose nut or head is turned by the job inspecting torque shall be tightened and reinspected, or alternatively, the Fabricator or Erector, at his option, may retighten all of the bolts in the connection and then resubmit the connection for the specified inspection.

*Length may be any length representative of bolts used in the structure.

10.17.5.4 The procedures for inspecting and testing the lock-pin procedures and collar fasteners and their installation to assure that the required preload tension is provided shall be as approved by the Engineer.

10.18 PLATE CUT EDGES

10.18.1 Edge Planing

Sheared edges of plate more than 5/8 inch in thickness and carrying calculated stress shall be planed, milled, ground, or thermal cut to a depth of 1/4 inch.

10.18.2 Flame Cutting

Flame cutting of structural steel shall conform to the requirements of Article 3.22 of the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1981.

10.18.3 Visual Inspection and Repair of Plate Cut Edges

Visual inspection and repair of plate cut edges shall be in accordance with Article 3.2.3 of the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1981.

10.18.4 Re-entrant Corners

Re-entrant corners shall be filleted to a minimum radius of 3/4 inch before cutting.

10.19 WELDS

Welding of steel structures when authorized in accordance with the provisions of Division I, shall conform to the AWS Structural Welding Code AWS

D1.1-80, as modified by the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1981, and subsequent AASHTO Interim Specifications Bridges.

10.20 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 ANSI surface roughness requirements as defined in ANSI B46.1, Surface Roughness, Waviness and Lay, Part I:

Steel slabs .... ANSI 2,000
Heavy plates in contact in shoes to be welded .... ANSI 1,000
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

10.21 ABUTTING JOINTS

Abutting joints in compression members of trusses and columns shall be milled or saw-cut to give a square joint and uniform bearing. At other joints, not required to be faced, the opening shall not exceed 3/8 inch.

10.22 FABRICATION OF MEMBERS

10.22.1 Unless otherwise shown on the plans, steel plates for main members and splice plates for flanges and main tension members, not secondary members, shall be cut and fabricated so that the primary direction of rolling is parallel to the direction of the main tensile and/or compressive stresses.

10.22.2 Fabricated members shall be true to line and free from twists, bends, and open joints.

10.23 BENT PLATES

Unwelded, cold-bent, load-carrying, rolled-steel plates shall conform to the following:

10.23.1 They shall be so taken from the stock plates that the bend line will be at right angles to the direction of rolling, except that cold-bent ribs for orthotropic-deck bridges may be bent in the direction of rolling if permitted by the Engineer.

10.23.2 Bending

10.23.2.1 Bending shall be such that no cracking of the plate occurs. Minimum bend radii, measured to the concave face of the metal, are given in the following table:

THICKNESS IN INCHES

	Up to 1/2	Over 1/2 to 1	Over 1 to 1-1/2	Over 1-1/2 to 2-1/2	Over 2-1/2 to 4
All grades of structural steel in this specification	2t	2-1/2t	3t	3-1/2t	4t

10.23.2.2 Allowance for springback of AASHTO M 244 (ASTM A 514) and ASTM A 517 steels should be about 3 times that for structural carbon steel. For break press forming, the lower die span should be at least 16 times the plate thickness. Multiple hits are advisable.

10.23.2.3 If a shorter radius is essential, the plates shall be bent hot at a temperature not greater than 1200F, except for AASHTO M 244 (ASTM A 514) and ASTM A 517 steels. If AASHTO M 244 (ASTM A 514) or ASTM A 517 steel plates to be bent are heated to a temperature greater than 1125F, they must be requenched and tempered in accordance with the producing mill's practice. Hot bent plates shall conform to the requirements of 10.23.1 above.

10.23.3 Before bending, the corners of the plate shall be rounded to a radius of 1/16 inch throughout the portion of the plate at which the bending is to occur.

10.24 FIT OF STIFFENERS

End stiffeners of girders and stiffeners intended as supports for concentrated loads shall have full bearing (either milled, ground or, on weldable steel in compression areas of flanges, welded as shown on the plans or specified) on the flanges to which they transmit load or from which they receive load. Stiffeners not intended to support concentrated loads shall, unless shown or specified otherwise, fit sufficiently tight to exclude water after being painted.

10.25 EYEBARS

10.25.1 Pin holes may be flame cut at least 2 inches smaller in diameter than the finished pin diameter. All eyebars that are to be placed side by side in the structure shall be securely fastened together in the order that they will be placed on the pin and bored at both ends while so clamped. Eyebars shall be packed and match-marked for shipment and erection. All identifying marks shall be stamped with steel stencils on the edge of one head of each member after fabrication is completed so as to be visible when the bars are nested in place on the structure. The eyebars shall be straight and free from twists and the pin holes shall be accurately located on the centerline of the bar. The inclination of any bar to the plane of the truss shall not exceed 1/16 inch to a foot.

10.25.2 The edges of eyebars that lie between the transverse centerline of their pin holes shall be cut simultaneously with two mechanically operated torches abreast of each other, guided by a substantial template, in such a manner as to prevent distortion of the plates.

10.26 ANNEALING AND STRESS RELIEVING

10.26.1 Structural members which are indicated in the contract to be annealed or normalized shall have finished machining, boring, and straightening done subsequent to heat treatment. Normalizing and annealing (full annealing) shall be as specified in ASTM E 44. The temperatures shall be maintained uniformly throughout the furnace during the heating and cooling so that the temperature at no two points on the member will differ by more than 100F at any one time.

10.26.2 Members of AASHTO M 244 (ASTM A 514) or ASTM A 517 steels shall not be annealed or normalized and shall be stress relieved only with the approval of the Engineer.

10.26.3 A record of each furnace charge shall identify the pieces in the charge and show the temperatures and schedule actually used. Proper instruments, including recording pyrometers, shall be provided for determining at any time the temperatures of members in the furnace. The records of the treatment operation shall be available to and meet the approval of the Engineer. The holding temperature for stress relieving AASHTO M 244 (ASTM A 514) or ASTM A 517 steels shall not exceed 1125F.

10.26.4 Members, such as bridge shoes, pedestals, or other parts that are built up by welding sections of plate together shall be stress relieved in accordance with the procedure of paragraph 4.4 of AWS D1.1 when required by the plans, specifications, or special provisions governing the contract.

10.27 PINS AND ROLLERS

10.27.1 Pins and rollers shall be accurately turned to the dimensions shown on the drawings and shall be straight, smooth, and free from flaws. Pins and rollers more than 9 inches in diameter shall be forged rollers and annealed. Pins and rollers 9 inches or less in diameter may be either forged and annealed or cold-finished carbon-steel shafting.

10.27.2 In pins larger than 9 inches in diameter, a hole not less than 2 inches in diameter shall be bored full length along the axis after the forging has been allowed to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling, and before being annealed.

10.28 BORING PIN HOLES

10.28.1 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.

10.28.2 The distance outside to outside of end holes in tension members and inside to inside of end holes in compression members shall not vary from that specified more than 1/32 inch. Boring of holes in built-up members shall be done after the riveting is completed.

10.29 PIN CLEARANCES

The diameter of the pin hole shall not exceed that of the pin by more than 1/50 inch for pins 5 inches or less in diameter, or by 1/32 inch for larger pins.

10.30 THREADS FOR BOLTS AND PINS

Threads for all bolts and pins for structural steel construction shall conform to the Unified 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 1-3/8 inches or more shall be threaded 6 threads to the inch.

10.31 NOTICE OF BEGINNING OF WORK

The Contractor shall give the Engineer ample notice of the beginning of work at the mill or in the shop, so that inspection may be provided. The term "mill" means any rolling mill or foundry where material for the work is to be manufactured. No material shall be manufactured, or work done in the shop, before the Engineer has been so notified.

10.32 FACILITIES FOR INSPECTION

The Contractor shall furnish facilities for the inspection of material and workmanship in the mill and shop, and the Inspectors shall be allowed free access to the necessary parts of the works.

10.33 INSPECTOR'S AUTHORITY

Inspectors shall have the authority to reject any material or work that does not meet the requirements of these specifications. In case of dispute the Contractor may appeal to the Engineer, whose decision shall be final.

10.34 WORKING DRAWINGS AND IDENTIFICATION OF STEEL DURING FABRICATION

10.34.1 Working Drawings

10.34.1.1 The Contractor shall submit copies of the detailed shop drawings to the Engineer for approval. Any work done prior to the approval of these plans shall be at the Contractor's risk. When material must be ordered in advance, specific approval of such an action shall be obtained by the Contractor prior to placing the order. Shop drawings for steel structures shall give full detailed dimensions and sizes of component parts of the structure and details of all miscellaneous parts, such as pins, nuts, bolts, drains, etc.

10.34.1.2 The Contractor shall expressly understand that the Engineer's approval of the working drawings submitted by the Contractor covers the requirements for "strength and detail," and that the Engineer assumes no responsibility for errors in dimensions.

10.34.2 IDENTIFICATION OF STEELS DURING FABRICATION

10.34.2.1 Identification by Contractor

10.34.2.1.1 The Engineer shall be furnished with complete certified mill test reports showing chemical analysis and the physical tests for each heat of steel, for all members unless excepted by the Engineer. Each piece of steel to be fabricated shall be properly identified for the Engineer.

10.34.2.1.2 Shop drawings shall specifically identify each piece that is to be made of steel which is to be other than AASHTO M 183 (ASTM A 36) steel. Pieces made of different grades of steel shall not be given the same assembling or erecting mark, even though they are of identical dimensions and detail.

10.34.2.1.3 The Contractor's system of assembly-marking individual pieces, required to be made of steel other than AASHTO M 183 (ASTM A 36) steel, and the issuance of cutting instructions to the shop (generally by cross-referencing of the assembly-marks shown on the shop drawings with the corresponding item covered on the mill purchase order) shall be such as to maintain identity of the mill test report number.

10.34.2.1.4 The Contractor may furnish from stock, material that he can identify by heat number and mill test report.

10.34.2.1.5 Any excess material placed in stock for later use shall be marked with the mill test report number and shall be marked with its AASHTO M 160 (ASTM A 6) specification identification color code (see Table 10.34) if any, when separated from the full-size piece furnished by the supplier.

10.34.2.2 Identification of Steels During Fabrication

10.34.2.2.1 During fabrication, up to the point of assembling members, each piece of steel, other than AASHTO M 183 (ASTM A 36) steel, shall show clearly and legibly its specification identification color code shown in Table 10.34.

10.34.2.2.2 Individually marked pieces of steel which are used in furnished size, or are reduced from furnished size only by end or edge trim that does not disturb the heat number or color code or leave any usable piece, may be used without further color coding

TABLE 10.34 Identification Color Codes

AASHTO M 244 (ASTM A 514)	Red
ASTM A 517	Red and Blue
AASHTO M 223 (ASTM A 572)	Grade 50 Green and Yellow
AASHTO M 222 (ASTM A 588)	Blue and Yellow

Other steels, except AASHTO M 183 (ASTM A 36) steel, not covered above, nor included in the AASHTO M 160 (ASTM A 6) Specification, shall have an individual color code which shall be established and on record for the Engineer.

provided that the heat number or color code remains legible.

10.34.2.2.3 Pieces of steel, other than AASHTO M 183 (ASTM A 36) steel, which are to be cut to smaller size pieces shall, before cutting, be legibly marked with the AASHTO M 160 (ASTM A 36) specification identification color code.

10.34.2.2.4 Individual pieces of steel, other than AASHTO M 183 (ASTM A 36) steel, which are furnished in tagged lifts or bundles shall be marked with the AASHTO M 160 (ASTM A 6) specification identification color code immediately on being removed from the bundle or lift.

10.34.2.2.5 Pieces of steel, other than AASHTO M 183 (ASTM A 36) steel, which prior to assembling into members, will be subject to fabricating operations such as blast cleaning, galvanizing, heating for forming, or painting which might obliterate paint color code marking, shall be marked for grade by steel die stamping or by a substantial tag firmly attached.

10.34.2.2.6 The following identification color code shall be used to identify material required to meet the individual specifications given in Table 10.34.

10.34.2.3 Certification of Identification

Upon request, the Contractor shall furnish an affidavit certifying that throughout the fabrication operation he has maintained the identification of steel in accordance with this specification.

10.35 WEIGHING OF MEMBERS

In case it is specified that any part of the material is to be paid for by actual weight, finished work shall be weighed in the presence of the Inspector, if practicable. In such case, the Contractor shall supply satisfactory scales and shall perform all work involved in handling and weighing the various parts.

10.36 FULL SIZE TESTS

When full size tests of fabricated structural members or eyebars are required by the contract, the plans or specifications shall state the number and nature of the tests, the results to be attained, and the measurements of strength, deformation, or other performance that are to be made. The Contractor shall provide suitable facilities, material, supervision, and labor necessary for making and recording the tests. The members tested in accordance with the contract shall be paid for in accordance with Article 10.54. The cost of testing including equipment, handling, supervision, labor, and incidentals for making the tests shall be included in the contract price for the fabrication or fabrication and erection of structural steel, whichever is the applicable item in the contract, unless otherwise specified.

10.37 MARKING AND SHIPPING

10.37.1 Each member shall be painted or marked with an erection mark for identification and an erection diagram shall be furnished with erection marks shown thereon.

10.37.2 The Contractor shall furnish to the Engineer as many copies of material orders, shipping statements, and erection diagrams as the Engineer may direct. The weights of the individual members shall be shown on the statements. Members weighing more than 3 tons shall have the weights marked thereon. Structural members shall be loaded on trucks or cars in such a manner that they may be transported and unloaded at their destination without being excessively stressed, deformed, or otherwise damaged.

10.37.3 Bolts of one length and diameter and loose nuts or washers of each size shall be packed separately. Pins, small parts and packages of bolts, washers, and nuts shall be shipped in boxes, crates, kegs, or barrels, but the gross weight of any package shall not exceed 300 pounds. A list and description of the contained material shall be plainly marked on the outside of each shipping container.

10.38 PAINTING

Unless otherwise shown on the plans or specified, all iron and steel surfaces shall be cleaned and painted in accordance with Section 14 "PAINTING METAL STRUCTURES."

ERECTION