# Section 11
# STEEL STRUCTURES

## 11.1 GENERAL

### 11.1.1 Description

This work shall consist of furnishing, fabricating, and erecting steel structures and structural steel portions of other structures in accordance with these Specifications, the Special Provisions and the details shown on the plans.

The structural steel fabricating plant shall be certified under the AISC Quality Certification Program, Category I. The fabrication of fracture critical members shall be Category III.

Details of design which are permitted to be selected by the Contractor shall conform to Division I of these Specifications.

Painting shall conform to the provisions of Section 13, "Painting," of these Specifications.

Falsework used in the erection of structural steel shall conform to the provisions of Section 3, "Temporary Works," of these Specifications.

Structural components designated on the plans or in the special provisions as "fracture critical" shall conform to the provisions of Chapter 12 of the *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

Welding and weld qualification tests shall conform to the provisions of the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

### 11.1.2 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.

### 11.1.3 Inspection

Structural steel will be inspected at the fabrication site. The Contractor shall furnish to the Engineer a copy of all mill orders and certified mill test reports. Mill test reports shall show the chemical analysis and physical test results for each heat of steel used in the work.

With the approval of the Engineer, certificates of compliance shall be furnished in lieu of mill test reports for material that normally is not supplied with mill test reports, and for items such as fills, minor gusset plates and similar material when quantities are small and the material is taken from stock.

Certified mill test reports for steels with specified impact values shall include, in addition to other test results, the results of Charpy V-notch impact tests. When fine grain practice is specified, the test report shall confirm that the material was so produced. Copies of mill orders shall be furnished at the time orders are placed with the manufacturer. Certified mill test reports and Certificates of Compliance shall be furnished prior to the start of fabrication of material covered by these reports. The Certificate of Compliance shall be signed by the manufacturer and shall certify that the material is in conformance with the specifications to which it has been manufactured.

Material to be used shall be made available to the Engineer so that each piece can be examined. The Engineer shall have free access at all times to any portion of the fabrication site where the material is stored or where work on the material is being performed.

### 11.1.4 Inspector's Authority

The Inspector shall have the authority to reject materials or workmanship which do not fulfill the requirements of these Specifications. In cases of dispute, the Contractor may appeal to the Engineer, whose decision shall be final.

Inspection at the mill and shop is intended as a means of facilitating the work and avoiding errors, and it is expressly understood that it will not relieve the Contractor of any responsibility in regard to defective material or workmanship and the necessity for replacing the same.

The acceptance of any material or finished members by the Inspector shall not be a bar to their subsequent rejection, if found defective. Rejected materials and workmanship shall be replaced as soon as practical or corrected by the Contractor.

## 11.2 WORKING DRAWINGS

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.

Working drawings must be approved by the Engineer prior to performance of the work involved and such approval shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

### 11.2.1 Shop Drawings

The Contractor shall submit copies of the detailed shop drawings to the Engineer for approval. Working drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and corrections by the Contractor without delaying the work.

Working 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.

Where specific orientation of plates is required, the direction of rolling of plates shall be shown.

Working drawings shall specifically identify each piece that is to be made of steel which is to be other than AASHTO M 270 (ASTM A 709) Grade 36 steel.

### 11.2.2 Erection Drawings

The Contractor shall submit drawings illustrating fully his or her proposed method of erection. The drawings shall show details of all falsework bents, bracing, guys, dead-men, lifting devices, and attachments to the bridge members: sequence of erection, location of cranes and barges, crane capacities, location of lifting points on the bridge members, and weights of the members. The plan and drawings shall be complete in detail for all anticipated phases and conditions during erection. Calculations may be required to demonstrate that allowable stresses are not exceeded and that member capacities and final geometry will be correct.

### 11.2.3 Camber Diagram

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) in the cases of continuous beam and girders or rigid frames. The camber diagram shall show calculated cambers to be used in preassembly of the structure in accordance with Article 11.5.3.

## 11.3 MATERIALS

### 11.3.1 Structural Steel

#### 11.3.1.1 General

Steel shall be furnished according to the following specifications. The grade or grades of steel to be furnished shall be as shown on the plans or specified.

All steel for use in main load-carrying member components subject to tensile stresses shall conform to the applicable Charpy V-notch Impact Test requirements of AASHTO M 270 (ASTM A 709).

Welded girders made of ASTM A 709, Grade HPS70W steels shall be fabricated in accordance with the AASHTO *Guide Specifications for Highway Bridge Fabrication with HPS70W Steel,* which supplements the *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

#### 11.3.1.2 Carbon Steel

Unless otherwise specified, structural carbon steel for bolted or welded construction shall conform to: Structural Steel for Bridges, AASHTO M 270 (ASTM A 709) Grade 36.

#### 11.3.1.3 High-Strength Low-Alloy Structural Steel

High-strength low-alloy steel shall conform to:

Structural Steel for Bridges, AASHTO M 270 (ASTM A 709) Grades 50 or 50W.

#### 11.3.1.4 High-Strength Low-Alloy, Quenched and Tempered Structural Steel Plate

High-strength, low-alloy quenched and tempered steel plate shall conform to AASHTO M 270 (ASTM A 709) Grade 70W, or Grade HPS70W.

#### 11.3.1.5 High-Yield Strength, Quenched and Tempered Alloy Steel Plate

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

(a) Structural Steel for Bridges, AASHTO M 270 (ASTM A 709) Grades 100 or 100W.
(b) Quenched and tempered alloy steel structural shapes and seamless mechanical tubing, meeting all of the mechanical and chemical requirements of AASHTO M 270 (ASTM A 709) Grades 100 or 100W 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 AASHTO M 270 (ASTM A 709) Grades 100 and 100W steel.

#### 11.3.1.6 Eyebars

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

(a) Structural Steel for Bridges, AASHTO M 270 (ASTM A 709) Grade 36.
(b) Structural Steel for Bridges, AASHTO M 270 (ASTM A 709) Grades 50 and 50W.

#### 11.3.1.7 Structural Tubing

Structural tubing shall be either cold-formed welded or seamless tubing conforming to ASTM 500, Grade B or hot-formed welded or seamless tubing conforming to ASTM 501.

### 11.3.2 High-Strength Fasteners

#### 11.3.2.1 Material

High-strength bolts for structural steel joints shall conform to either AASHTO M 164 (ASTM A 325) or AASHTO M 253 (ASTM A 490). When high-strength bolts are used with unpainted weathering grades of steel, the bolts shall be Type 3.

The supplier shall provide a lot number appearing on the shipping package and a certification noting when and where all testing was done, including rotational capacity tests, and zinc thickness when galvanized bolts and nuts are used.

The maximum hardness for AASHTO M 164 (ASTM A 325) bolts 1 inch or less in diameter shall be 33 HRC.

Proof load tests (ASTM F 606 Method 1) are required for the bolts. Wedge tests of full-sized bolts are required in accordance with Section 8.3 of AASHTO M 164. Galvanized bolts shall be wedge tested after galvanizing. Proof load tests (AASHTO M 291) are required for the nuts. The proof load tests for nuts to be used with galvanized bolts shall be performed after galvanizing, overtapping, and lubricating.

Except as noted below, nuts for AASHTO M 164 (ASTM A 325) bolts shall conform to AASHTO M 291 (ASTM A 563) Grades DH, DH3, C, C3, and D. Nuts for AASHTO M 253 (ASTM A 490) bolts shall conform to the requirements of AASHTO M 291 (ASTM A 563) Grades DH and DH3.

- Nuts to be galvanized (hot-dip or mechanically galvanized) shall be heat treated Grade DH or DH3.
- Plain (ungalvanized) nuts shall have a minimum hardness of 89 HRB.
- Nuts to be used with AASHTO M 164 (ASTM A 325) Type 3 bolts shall be of Grade C3 or DH3. Nuts to be used with AASHTO M 253 (ASTM A 490) bolts shall be of Grade DH3.

All galvanized nuts shall be lubricated with a lubricant containing a visible dye. Black bolts must be oily to touch when delivered and installed.

Washers shall be hardened steel washers conforming to the requirements of AASHTO M 293 (ASTM F 436) and Article 11.5.6.4.3.

#### 11.3.2.2 Identifying Marks

AASHTO M 164 (ASTM A 325) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specification be identified by specific markings on the top of the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A 325," the manufacturer and the type, if Type 2 or 3. Nut markings must identify the grade, the manufacturer and if Type 3, the type. Markings on direct tension indicators must identify the manufacturer and Type "325." Other washer markings must identify the manufacturer and if Type 3, the type.

AASHTO M 253 (ASTM A 490) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specifications be identified by specific markings on the top of the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A 490," the manufacturer and the type, if Type 2 or 3. Nut markings must identify the grade, the manufacturer and if Type 3, the type. Markings on direct tension indicators must identify the manufacturer and Type "490." Other washer markings must identify the manufacturer and if Type 3, the type.

#### 11.3.2.3 Dimensions

Bolt and nut dimensions shall conform 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.

#### 11.3.2.4 Galvanized High-Strength Fasteners

When fasteners are galvanized, they shall be specified to be hot-dip galvanized in accordance with AASHTO M 232 (ASTM A 153) Class C or, mechanically galvanized in accordance with AASHTO M 298 (ASTM B 695) Class 50. Bolts to be galvanized shall be either AASHTO M 164 (ASTM A 325) Type 1 or Type 2 except that Type 2 bolts shall only be mechanically galvanized. Galvanized bolts shall be tension tested after galvanizing. Washers, nuts and bolts of any assembly shall be galvanized by the same process. The nuts should be overtapped to the minimum amount required for the fastener assembly, and shall be lubricated with a lubricant containing a visible dye so a visual check can be made for the lubricant at the time of field installation. AASHTO M 253 (ASTM A 490) bolts shall not be galvanized.

#### 11.3.2.5 Alternative Fasteners

Other fasteners or fastener assemblies, such as those conforming to the requirements of ASTM F 1852, 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-sized 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 Article 11.3.2.3, may be used, subject to the approval of the Engineer. Such alternate fasteners may differ in other dimensions from those of the specified bolts and nuts.

Subject to the approval of the Engineer, high-strength 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 high-strength steel lock-pin and collar fasteners shall meet the requirements of Article 11.3.2.3. Each fastener shall provide a solid shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than that of 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 tools, is cold swaged into the locking grooves forming 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 lockpin and collar fasteners, as approved by the Engineer.

#### 11.3.2.6 Load Indicator Devices

Load indicating devices may be used in conjunction with bolts, nuts, and washers specified in Article 11.3.2.1. Load indicating devices shall conform to the requirements of ASTM Specification for Compressible-Washer Type Direct Tension Indicators For Use with Structural Fasteners, ASTM F 959, except as provided in the following paragraph.

Subject to the approval of the Engineer, alternate design direct tension indicating devices may be used provided they satisfy the requirements of Article 11.5.6.4.6 or other requirements detailed in specifications provided by the manufacturer and subject to the approval of the Engineer.

### 11.3.3 Welded Stud Shear Connectors

#### 11.3.3.1 Materials

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.

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

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

*As determined by a 0.2% offset method.

#### 11.3.3.2 Test Methods

Tensile properties shall be determined in accordance with the applicable sections of ASTM A370, 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 7.2 of the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.* If fracture occurs outside of the middle half of the gage length, the test shall be repeated.

#### 11.3.3.3 Finish

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.

#### 11.3.3.4 Certification

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.

#### 11.3.3.5 Check Samples

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.

### 11.3.4 Steel Forgings and Steel Shafting

#### 11.3.4.1 Steel Forgings

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

#### 11.3.4.2 Cold Finished Carbon Steel Shafting

Cold finished carbon steel shafting shall conform to the specifications for Cold Finished Carbon Steel Bars Standard Quality, AASHTO M 169 (ASTM A 108). Grade 10160-10300, inclusive, shall be furnished unless otherwise specified.

### 11.3.5 Steel Castings

#### 11.3.5.1 Mild Steel Castings

Steel castings for use in highway bridge components shall conform to Standard Specifications for Steel Castings for Highway Bridges, AASHTO M 192 (ASTM A 486) or 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.

#### 11.3.5.2 Chromium Alloy-Steel Castings

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

### 11.3.6 Iron Castings

#### 11.3.6.1 Materials

(1) Gray Iron Castings—Gray iron castings shall conform to the Specification for Gray Iron Castings, AASHTO M 105 (ASTM A 48), Class No. 30 unless otherwise specified.
(2) Ductile Iron Castings—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.
(3) Malleable Castings—Malleable castings shall conform to the Specification for Malleable Iron Castings, ASTM A 47. Grade No. 35018 shall be furnished unless otherwise specified.

#### 11.3.6.2 Workmanship and Finish

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.

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

#### 11.3.6.3 Cleaning

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

### 11.3.7 Galvanizing

When galvanizing is shown on the plans or specified in the special provisions, ferrous metal products, other than fasteners and hardware items, shall be galvanized in accordance with the Specifications for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shape Plates, Bars, and Strip, AASHTO M 111 (ASTM A 123). Fasteners and hardware items shall be galvanized in accordance with the Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware, AASHTO M 232 (ASTM A 153) except as noted in Article 11.3.2.4 for high-strength fasteners.

## 11.4 FABRICATION

### 11.4.1 Identification of Steels During Fabrication

The Contractor's system of assembly-marking individual pieces, 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 original piece. The Contractor may furnish from stock, material that can be identified by heat number and mill test report.

During fabrication, up to the point of assembling members, each piece of steel, other than Grade 36 steel, shall show clearly and legibly its specification.

Any piece of steel, other than Grade 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 marking, shall be marked for grade by steel die stamping or by a substantial tag firmly attached. Steel die stamps shall be low stress-type.

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

### 11.4.2 Storage of Materials

Structural material, either plain or fabricated, shall be stored 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. See Article 11.5.6.4 for storage of high-strength fasteners.

### 11.4.3 Plates

#### 11.4.3.1 Direction of Rolling

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.

#### 11.4.3.2 Plate Cut Edges

*11.4.3.2.1 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.

*11.4.3.2.2 Oxygen Cutting*

Oxygen cutting of structural steel shall conform to the requirements of the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

*11.4.3.2.3 Visual Inspection and Repair of Plate Cut Edges*

Visual inspection and repair of plate cut edges shall be in accordance with the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

#### 11.4.3.3 Bent Plates

*11.4.3.3.1 General*

Cold bending of fracture critical steels and fracture critical members is prohibited. Perform cold bending of other steels or members in accordance with the *ANSI/AASHTO/AWS D1.5 Bridge Welding Code* and Table 11.4.3.3.2, and in a manner such that no cracking occurs.

*11.4.3.3.2 Cold Bending*

For bent plates, the bend radius and the radius of the male die should be as liberal as the finished part will permit. The width across the shoulders of the female die should be at least 8 times the plate thickness for Grade 36 steel. Higher strength steels require larger die openings. The surface of the dies in the area of radius should be smooth.

Where the concave face of a bent plate must fit tightly against another surface, the male die should be sufficiently thick and have the proper radius to ensure that the bent plate has the required concave surface.

Since cracks in cold bending commonly originate from the outside edges, shear burrs and gas cut edges should be removed by grinding. Sharp corners on edges and on punched or gas cut holes should be removed by chamfering or grinding to a radius.

Unless otherwise approved, the minimum bend radii for cold forming (at room temperature), measured to the concave face of the plate, are given in Table 11.4.3.3.2. If a smaller radius is required, heat may be needed to be a part of the bending procedure. Provide the heating procedure for review by the Engineer. For grades not included in Table 11.4.3.3.2, follow minimum bend radii recommendations of the plate producer.

If possible, orient bend lines perpendicular to the direction of final rolling of the plate. If the bend line is parallel to the direction of final rolling, multiply the suggested minimum radii in Table 11.4.3.3.2 by 1.5.

**TABLE 11.4.3.3.2 Minimum Cold-Bending Radii**

| Thickness Inches (t) | Up to 3/4 | Over 3/4 to 1, incl. | Over 1 to 2, incl. | Over 2 |
|---|---|---|---|---|
| ASTM A 709/ AASHTO M 270 Grades | | | | |
| 36 | 1.5t | 1.5t | 1.5t | 2.0t |
| 50 | 1.5t | 1.5t | 2.0t | 2.5t |
| 50W | 1.5t | 1.5t | 2.0t | 2.5t |
| HPS70W | 1.5t | 1.5t | 2.5t | 3.0t |
| 100 | 1.75t | 2.25t | 4.5t | 5.5t |
| 100W | 1.75t | 2.25t | 4.5t | 5.5t |

*11.4.3.3.3 Hot Bending*

If a radius shorter than the minimum specified for cold bending is essential, the plates shall be bent hot at a temperature not greater than 1,200°F, except for Grades 70W, 100 and 100W. If Grades 100 and 100W steel plates to be bent are heated to a temperature greater than 1,100°F, or Grade 70W plates to be bent are heated to a temperature greater than 1,050°F, they must be requenched and tempered in accordance with the producing mill's practice and tested to verify restoration of specified properties, as directed by the Engineer. Grade HPS70W steel to be bent shall not be heated to a temperature greater than 1,100°F. Requenching and tempering is not required for Grade HPS70W steel heated to this limit.

## 11.4.4 Fit of Stiffeners

End bearing stiffeners for 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. Intermediate stiffeners not intended to support concentrated loads, unless shown or specified otherwise, shall have a tight fit against the compression flange.

## 11.4.5 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.

## 11.4.6 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 |

## 11.4.7 Straightening Material

The straightening of plates, angles, other shapes, and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fracture or other injury to the metal. Distorted members shall be straightened by mechanical means or, if approved by the Engineer, by carefully planned procedures and supervised application of a limited amount of localized heat, except that heat straightening of AASHTO M 270 (ASTM A 709) Grades 70W, HPS70W, 100 and 100W steel members shall be done only under rigidly controlled procedures, each application subject to the approval of the Engineer. In no case shall the maximum temperature exceed values in the following table.

| | |
|---|---|
| Grade 70W | 1,050°F |
| Grade HPS70W | 1,100°F |
| Grade 100 or 100W | 1,100°F |

In all other steels, the temperature of the heated area shall not exceed 1,200°F as controlled by temperature indicating crayons, liquids, or bimetal thermometers. Heating in excess of the limits shown shall be cause for rejection, unless the Engineer allows testing to verify material integrity.

Parts to be heat straightened shall be substantially free of stress and from external forces, except stresses resulting from mechanical means used in conjunction with the application of heat.

Evidence of fracture following straightening of a bend or buckle will be cause for rejection of the damaged piece.

## 11.4.8 Bolt Holes

### 11.4.8.1 Holes for High-Strength Bolts and Unfinished Bolts*

*11.4.8.1.1 General*

All holes for bolts shall be either punched or drilled except as noted herein. Material forming parts of a member

*See Article 11.5.5 for bolts included in designation "Unfinished Bolts."

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 11.4.8.5.

When 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 and reamed or drilled full size. Also, when more than five thicknesses are joined, or as required by Article 11.4.8.5, material shall be subdrilled and reamed or drilled full size while in assembly.

When required, 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.

When shown on the plans, enlarged or slotted holes are allowed with high-strength bolts.

*11.4.8.1.2 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. The slightly conical hole that naturally results from punching operations is considered acceptable.

*11.4.8.1.3 Reamed or Drilled Holes*

Reamed or drilled holes shall be cylindrical, perpendicular to the member, and shall comply with the requirements of Article 11.4.8.1.1 as to size. Where practical, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Reaming and drilling shall be done with twist drills, twist reamers or rotobroach cutters. 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.

*11.4.8.1.4 Accuracy of Holes*

Holes not more than 1⁄32 inch larger in diameter than the true decimal equivalent of the nominal diameter that may result from a drill or reamer of the nominal diameter are considered acceptable. The width of slotted holes which are produced by flame cutting or a combination of drilling or punching and flame cutting shall generally be not more than 1⁄32 inch greater than the nominal width. The flame cut surface shall be ground smooth.

### 11.4.8.2 Accuracy of Hole Group

*11.4.8.2.1 Accuracy Before Reaming*

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% 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.

*11.4.8.2.2 Accuracy After Reaming*

When holes are reamed or drilled, 85% 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.

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

### 11.4.8.3 Numerically Controlled Drilled Field Connections

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. Full-sized punched holes shall meet the requirements of Article 11.4.8.1.

If N/C drilling or punching equipment is used, the Contractor, by means of check assemblies, will be required to demonstrate the accuracy of this drilling or punching procedure in accordance with the provisions of Article 11.5.3.3.

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.

### 11.4.8.4 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 when 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.

#### 11.4.8.5 Preparation of Field Connections

Holes in all field connections and field splices of main member of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched or subdrilled and subsequently reamed while assembled or drilled full size through a steel template while assembled. Holes for field splices of rolled beam stringers continuous over floor beams or cross frames may be drilled full size unassembled to a steel template. All holes for floor beams or cross frames may be drilled full size unassembled to a steel template, except that all holes for floor beam and stringer field end connections shall be subpunched and reamed while assembled or drilled full size to a steel template. 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.

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.

### 11.4.9 Pins and Rollers

#### 11.4.9.1 General

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 and annealed. Pins and rollers 9 inches or less in diameter may be either forged and annealed or cold-finished carbon-steel shafting.

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.

#### 11.4.9.2 Boring Pin Holes

Pin holes shall be bored true to the specified diameter, smooth and straight, at right angles with the axis of the member and parallel with each other unless otherwise required. The final surface shall be produced by a finishing cut.

The 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.

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 pin holes in built-up members shall be done after the member has been assembled.

#### 11.4.9.3 Threads for Bolts and Pins

Threads for all bolts and pins for structural steel construction shall conform to the United Standard Series UNC ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of $1\frac{3}{8}$ inches or more shall be threaded six threads to the inch.

### 11.4.10 Eyebars

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. Steel die stamps shall be low stress type. No welding is allowed on eyebars or to secure adjacent eyebars.

The eyebars shall be straight and free from twists and the pin holes shall be accurately located on the center line of the bar. The inclination of any bar to the plane of the truss shall not exceed $1/16$ inch to a foot.

The edges of eyebars that lie between the transverse center line 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.

### 11.4.11 Annealing and Stress Relieving

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 100°F at any one time.

Members of AASHTO M 270 (ASTM A 709) Grades 100/100W or Grade 70W steels shall not be annealed or normalized and shall be stress relieved only with the approval of the Engineer.

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 Grades HPS70W and 100/100W shall not exceed 1,100°F and for Grade 70W shall not exceed 1,050°F.

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 Section 4.4 of the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code,* when required by the plans, specifications, or special provisions governing the contract.

### 11.4.12 Curved Girders

#### 11.4.12.1 General

Flanges of curved, welded girders may be cut to the radii shown on the plans or curved by applying heat as specified in the succeeding articles providing the radii is not less than allowed by Article 10.15.2 of Division I.

#### 11.4.12.2 Heat Curving Rolled Beams and Welded Girders

*11.4.12.2.1 Materials*

Except for Grade HPS70W steel, steels that are manufactured to a specified minimum yield point greater than 50,000 psi shall not be heat curved.

*11.4.12.2.2 Type of Heating*

Beams and girders may be curved by either continuous or V-type heating as approved by the Engineer. For the continuous method, a strip or intermittent strips along the edge of the top and bottom flange shall be heated approximately simultaneously depending on flange widths and thicknesses; 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 wedge-shaped areas having their base along the flange edge and spaced at regular intervals along each flange; the spacing and temperature shall be as required to obtain the required curvature, and heating shall progress along the top and bottom flange at approximately the same rate.

For the V-type heating, the apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached. To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so that heat is not applied directly to the web. 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 width or 3 inches, whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30°, 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.

For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is only mandatory when the flange thickness is 1¼ inches or greater, in which case, the two surfaces shall be heated concurrently. The maximum temperature shall be prescribed as follows.

*11.4.12.2.3 Temperature*

The heat-curving operation shall be conducted in such a manner that the temperature of the steel does not exceed 1,200°F for Grades 36, 50 and 50W; 1,100°F for Grades HPS70W and 100/100W; and 1,050°F for Grade 70W as measured by temperature indicating crayons or other suitable means. The girder shall not be artificially cooled until after naturally cooling to 600°F. The method of artificial cooling is subject to the approval of the Engineer.

*11.4.12.2.4 Position for Heating*

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

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

*11.4.12.2.5 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 2½ 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.

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

*11.4.12.2.7 Measurement of Curvature and Camber*

Horizontal curvature and vertical camber shall be measured for final acceptance after 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.

## 11.4.13 Orthotropic-Deck Superstructures

### 11.4.13.1 General

Dimensional tolerance limits for orthotropic-deck bridge members shall be applied to each completed but unloaded member and shall be as specified in Article 3.5 of the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code* except as follows. The deviation from detailed flatness, straightness, or curvature at any point shall be the perpendicular distance from that point to a template edge which has the detailed straightness or curvature and which is in contact with the element at two other points. The term element as used herein refers to individual panels, stiffeners, flanges, or other pieces. The template edge may have any length not exceeding the greatest dimension of the element being examined and, for any panel, not exceeding 1.5 times the least dimension of the panel; it may be placed anywhere within the boundaries of the element. The deviation shall be measured between adjacent points of contact of the template edge with the element; the distance between these adjacent points of contact shall be used in the formulas to establish the tolerance limits for the segment being measured whenever this distance is less than the applicable dimension of the element specified for the formula.

### 11.4.13.2 Flatness of Panels

(a) The term "panel" as used in this article means a clear area of steel plate surface bounded by stiffeners, webs, flanges, or plate edges and not further subdivided by any such elements. The provisions of this article apply to all panels in the bridge; for plates stiffened on one side only such as orthotropic-deck plates or flanges of box girders, this includes the total clear width on the side without stiffeners as well as the panels between stiffeners on the side with stiffeners.

(b) The maximum deviation from detailed flatness or curvature of a panel shall not exceed the greater of:

$$\frac{3}{16} \text{ inch or } \frac{D}{144\sqrt{T}} \text{ inch}$$

where,

D = the least dimension in inches along the boundary of the panel

T = the minimum thickness in inches of the plate comprising the panel.

#### 11.4.13.3 Straightness of Longitudinal Stiffeners Subject to Calculated Compressive Stress, Including Orthotropic-Deck Ribs

The maximum deviation from detailed straightness or curvature in any direction perpendicular to its length of a longitudinal web stiffener or other stiffener subject to calculated compressive stress shall not exceed:

$$\frac{L}{480}$$

where L = the length of the stiffener or rib between cross members, webs, or flanges, in inches.

#### 11.4.13.4 Straightness of Transverse Web Stiffeners and Other Stiffeners not Subject to Calculated Compressive Stress

The maximum deviation from detailed straightness or curvature in any direction perpendicular to its length of a transverse web stiffener or other stiffener not subject to calculated compressive stress shall not exceed:

$$\frac{L}{240}$$

where L = the length of the stiffener between cross members, webs, or flanges, in inches.

### 11.4.14 Full-Sized Tests

When full-sized tests of fabricated structural members or eyebars are required by the contract, the Contractor shall provide suitable facilities, material, supervision, and labor necessary for making and recording the required tests. The members tested in accordance with the contract shall be paid for in accordance with Article 11.7.2.

### 11.4.15 Marking and Shipping

Each member shall be painted or marked with an erection mark for identification and an erection diagram showing these marks shall be furnished to the Engineer.

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.

Bolts, nuts and washers (where required) from each rotational-capacity lot shall be shipped in the same container. If there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. 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 materials shall be plainly marked on the outside of each shipping container.

## 11.5 ASSEMBLY

### 11.5.1 Bolting

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.

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.

### 11.5.2 Welded Connections

Surfaces and edges to be welded shall be smooth, uniform, clean and free of defects which would adversely affect the quality of the weld. Edge preparation shall be done in accordance with the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

### 11.5.3 Preassembly of Field Connections

#### 11.5.3.1 General

Field connections of main members of trusses, arches, continuous beams, plate girders, bents, towers and rigid frames shall be preassembled prior to erection as necessary to verify the geometry of the completed structure or unit and to verify or prepare field splices. Attaining accurate geometry is the responsibility of the Contractor who shall propose an appropriate method of preassembly for approval by the Engineer. The method and details of preassembly shall be consistent with the erection procedure shown on the erection plans and camber diagrams prepared by the Contractor and approved by the Engineer. As a minimum, the preassembly procedure shall consist of assembling three contiguous panels accurately adjusted for line and camber. Successive assemblies shall consist of at least one section or panel of the previous assembly (repositioned if necessary and adequately pinned to assure accurate alignment) plus two 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.

#### 11.5.3.2 Bolted Connections

For bolted connections holes shall be prepared as outlined in Article 11.4.8. Where applicable, major components shall be assembled with milled ends of compression members in full bearing and then shall have their subsized holes reamed to the specified size while the connections are assembled.

#### 11.5.3.3 Check Assembly—Numerically Controlled Drilling

When the contractor elects to use numerically controlled drilling, 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. Special points could be the portals of skewed trusses, for example.

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

Shop assemblies other than the check assemblies will not be required.

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 Department.

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.

#### 11.5.3.4 Field Welded Connections

For field welded connections the fit of members including the proper space between abutting flanges shall be prepared or verified with the segment preassembled in accordance with Article 11.5.3.1.

### 11.5.4 Match Marking

Connecting parts preassembled in the shop to assure proper fit in the field shall be match-marked, and a diagram showing such marks shall be furnished to the Engineer.

### 11.5.5 Connections Using Unfinished, Turned or Ribbed Bolts

#### 11.5.5.1 General

When unfinished bolts are specified, the bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A Bolts of Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength, ASTM A 307. 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. 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 11.5.6.

#### 11.5.5.2 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.

#### 11.5.5.3 Ribbed Bolts

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 $\frac{5}{64}$ inch greater than the nominal diameter specified for the bolts.

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.

## 11.5.6 Connections Using High-Strength Bolts

### 11.5.6.1 General

This article covers the assembly of structural joints using AASHTO M 164 (ASTM A 325) or AASHTO M 253 (ASTM A 490) high-strength bolts, or equivalent fasteners, installed so as to develop the minimum required bolt tension specified in Table 11.5A. The bolts are used in holes conforming to the requirements of Article 11.4.8.

### 11.5.6.2 Bolted Parts

All material within the grip of the bolt shall be steel, there shall be no compressible material such as gaskets or insulation within the grip. Bolted steel parts shall fit solidly together after the bolts are snugged, and may be coated or uncoated. The slope of the surfaces of parts in contact with the bolt head or nut shall not exceed 1:20 with respect to a plane normal to the bolt axis.

### 11.5.6.3 Surface Conditions

At the time of assembly, all joint surfaces, including surfaces adjacent to the bolt head and nut, shall be free of scale, except tight mill scale, and shall be free of dirt or other foreign material. Burrs that would prevent solid seating of the connected parts in the snug condition shall be removed.

**TABLE 11.5A Required Fastener Tension Minimum Bolt Tension in Pounds***

| Bolt Size Inches | AASHTO M 164 ASTM A 325 | AASHTO M 253 ASTM A 490 |
|---|---|---|
| 1/2 | 12,000 | 15,000 |
| 5/8 | 19,000 | 24,000 |
| 3/4 | 28,000 | 35,000 |
| 7/8 | 39,000 | 49,000 |
| 1 | 51,000 | 64,000 |
| 1-1/8 | 56,000 | 80,000 |
| 1-1/4 | 71,000 | 102,000 |
| 1-3/8 | 85,000 | 121,000 |
| 1-1/2 | 103,000 | 148,000 |

* The minimum bolt tension shall be taken as 70% of specified minimum tensile strength of bolts (as specified in ASTM Specifications for tests of full-size A 325 and A 490 bolts with UNC threads loaded in axial tension) rounded to the nearest kip.

Paint is permitted on the faying surface including slip critical joints when designed in accordance with Articles 10.32.3, or 10.56.1.3, Division I.

The faying surfaces of slip-critical connections shall meet the requirements of the following paragraphs, as applicable:

(1) In noncoated joints, paint, including any inadvertent overspray, shall be excluded from areas closer than one-bolt diameter, but not less than 1 inch, from the edge of any hole and all areas within the bolt pattern.

(2) Joints specified to have painted faying surfaces shall be blast cleaned and coated with a paint which has been qualified in accordance with requirements of Articles 10.32.3.2.3 or 10.57.3.3, Division I.

(3) Coated joints shall not be assembled before the coating has cured for the minimum time used in the qualifying test.

(4) Faying surfaces specified to be galvanized shall be hot-dip galvanized in accordance with AASHTO M 111 (ASTM A 123), and shall subsequently be roughened by means of hand wire brushing. Power wire brushing is not permitted.

### 11.5.6.4 Installation

#### *11.5.6.4.1 General*

Fastener components shall be assigned lot numbers (including rotational-capacity lot numbers) prior to shipping, and components shall be assembled when installed. Such components shall be protected from dirt and moisture at the job site. Remove from protective storage only the number of anticipated components to be installed during a work shift. Components not used shall be returned to protected storage at the end of the shift. Components shall not be cleaned of lubricant that is required to be present in as-delivered condition. Assemblies for slip-critical connections which accumulate rust or dirt resulting from job site conditions shall be cleaned, relubricated and tested for rotational-capacity prior to installation. All galvanized nuts shall be lubricated with a lubricant containing a visible dye. Plain bolts must be "oily" to touch when delivered and installed. Lubricant on exposed surfaces shall be removed prior to painting.

A bolt tension measuring device (a Skidmore-Wilhelm Calibrator or other acceptable bolt tension indicating device) shall be at all job sites where high-strength bolts are being installed and tensioned. The tension measuring device shall be used to perform the rotational-capacity test and to confirm (1) the suitability to satisfy the requirements of Table 11.5A of the complete fastener assembly, including lubrication if required to be used in the work, (2) calibration of the wrenches, if applicable, and (3) the understanding and proper use by the bolting crew of the installation method. To perform the calibrated wrench verification test for short grip bolts, direct tension indicators (DTI) with solid plates may be used in lieu of a tension measuring device. The DTI lot shall be first verified with a longer grip bolt in the Skidmore-Wilhelm Calibrator or an acceptable equivalent device. The frequency of confirmation testing, the number of tests to be performed, and the test procedure shall be as specified in Articles 11.5.6.4.4 through 11.5.6.4.7, as applicable. The accuracy of the tension measuring device shall be confirmed by an approved testing agency at least annually.

Bolts and nuts together with washers of size and quality specified, located as required below, shall be installed in properly aligned holes and tensioned and inspected by any of the installation methods described in Articles 11.5.6.4.4 through 11.5.6.4.7 to at least the minimum tension specified in Table 11.5A. Tensioning may be done by turning the bolt while the nut is prevented from rotating when it is impractical to turn the nut. Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to tension each bolt in approximately 10 seconds.

AASHTO M 253 (ASTM A 490) fasteners and galvanized AASHTO M 164 (ASTM A 325) fasteners shall not be reused. Other AASHTO M 164 (ASTM A 325) bolts may be reused if approved by the Engineer. Touching up or retensioning previously tensioned bolts which may have been loosened by the tensioning of adjacent bolts shall not be considered as reuse provided the tensioning continues from the initial position and does not require greater rotation, including the tolerance, than that required by Table 11.5B.

Bolts shall be installed in all holes of the connection and the connection brought to a snug condition. Snug is defined as having all plies of the connection in firm contact.

Snugging shall progress systematically from the most rigid part of the connection to the free edges. The snugging sequence shall be repeated until the full connection is in a snug condition.

**TABLE 11.5B Nut Rotation from the Snug-Tight Condition[a,b] Geometry of Outer Faces of Bolted Parts**

| 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 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[c] | 2/3 turn | 5/6 turn | 1 turn |

[a] Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30 degrees; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45 degrees.

[b] Applicable only to connections in which all material within grip of the bolt is steel.

[c] No research work has been performed by the Research Council 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.

#### *11.5.6.4.2 Rotational-Capacity Tests*

Rotational-capacity testing is required for all fastener assemblies. Galvanized assemblies shall be tested galvanized. Washers are required as part of the test even though they may not be required as part of the installation procedure. The following shall apply:

(a) Except as modified herein, the rotational-capacity test shall be performed in accordance with the requirements of AASHTO M 164 (ASTM A 325).

(b) Each combination of bolt production lot, nut lot and washer lot shall be tested as an assembly. Where washers are not required by the installation procedures, they need not be included in the lot identification.

(c) A rotational-capacity lot number shall have been assigned to each combination of lots tested.

(d) The minimum frequency of testing shall be two assemblies per rotational-capacity lot.

(e) For bolts that are long enough to fit in a Skidmore-Wilhelm Calibrator, the bolt, nut and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device.

(f) Bolts that are too short to be tested in a Skidmore-Wilhelm Calibrator may be tested in a steel joint. The tension requirement, in (g) below, need not apply. The maximum torque requirement, torque $< 0.25$ PD, shall be computed using a value of P equal to the turn test tension taken as 1.15 times the bolt tension in Table 11.5A.

(g) The tension reached at the below rotation (i.e., turn-test tension) shall be equal to or greater than 1.15 times the required fastener tension (i.e., installation tension) shown in Table 11.5A.

(h) The minimum rotation from an initial tension of 10% of the minimum required tension (snug condition) shall be two times the required number of turns indicated in Table 11.5B without stripping or failure.
(i) After the required installation tension listed above has been exceeded, one reading of tension and torque shall be taken and recorded. The torque value shall conform to the following:

$$\text{Torque} \leq 0.25\ PD$$

Where:

Torque = measured torque (foot-pounds)
P = measured bolt tension (pounds)
D = bolt diameter (feet).

*11.5.6.4.3 Requirement for Washers*

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

Hardened beveled washers for American Standard Beams and Channels shall be required and shall be square or rectangular, shall conform to the requirements of AASHTO M 293 (ASTM F 436), and shall taper in thickness.

Where necessary, washers may be clipped on one side to a point not closer than ⅞ of the bolt diameter from the center of the washer.

Hardened washers are not required for connections using AASHTO M 164 (ASTM A 325) and AASHTO M 253 (ASTM A 490) bolts except as follows:

- Hardened washers shall be used under the turned element when tensioning is to be performed by calibrated wrench method.
- Irrespective of the tensioning method, hardened washers shall be used under both the head and the nut when AASHTO M 253 (ASTM A 490) bolts are to be installed in material having a specified yield point less than 40 ksi. However, when DTIs are used they may replace a hardened washer provided a standard hole is used.
- Where AASHTO M 164 (ASTM A 325) bolts of any diameter or AASHTO M 253 (ASTM A 490) bolts equal to or less than 1 inch in diameter are to be installed in oversize or short-slotted holes in an outer ply, a hardened washer conforming to AASHTO M 293 (ASTM F 436) shall be used.
- When AASHTO M 253 (ASTM A 490) bolts over 1 inch in diameter are to be installed in an oversized or short-slotted hole in an outer ply, hardened washers conforming to AASHTO M 293 (ASTM F 436) except with 5/16 inch minimum thickness shall be used under both the head and the nut in lieu of standard thickness hardened washers. Multiple hardened washers with combined thickness equal to or greater than 5/16 inch do not satisfy this requirement.
- Where AASHTO M 164 (ASTM A 325) bolts of any diameter or AASHTO M 253 (ASTM A 490) bolts equal to or less than 1 inch in diameter are to be installed in a long slotted hole in an outer ply, a plate washer or continuous bar of at least 5/16 inch thickness with standard holes shall be provided. These washers or bars shall have a size sufficient to completely cover the slot after installation and shall be of structural grade material, but need not be hardened except as follows. When AASHTO M 253 (ASTM A 490) bolts over 1 inch in diameter are to be used in long slotted holes in external plies, a single hardened washer conforming to AASHTO M 293 (ASTM F 436) but with 5/16 inch minimum thickness shall be used in lieu of washers or bars of structural grade material. Multiple hardened washers with combined thickness equal to or greater than 5/16 inch do not satisfy this requirement.

Alternate design fasteners meeting the requirements of Article 11.3.2.6 with a geometry which provides a bearing circle on the head or nut with a diameter equal to or greater then the diameter of hardened washers meeting the requirements of AASHTO M 293 (ASTM F 436) satisfy the requirements for washers specified herein and may be used without washers.

*11.5.6.4.4 Turn-of-Nut Installation Method*

When the turn-of-nut installation method is used, hardened washers are not required except as may be specified in Article 11.5.6.4.3.

Verification testing using a representative sample of not less than three fastener assemblies of each diameter, length and grade to be used in the work shall be performed at the start of work in a device capable of indicating bolt tension. This verification test shall demonstrate that the method used to develop a snug condition and control the turns from snug by the bolting crew develops a tension not less than 5% greater than the tension required by Table 11.5A. Periodic retesting shall be performed when ordered by the Engineer.

After snugging, the applicable amount of rotation specified in Table 11.5B shall be achieved. During the tensioning operation there shall be no rotation of the part not turned by the wrench. Tensioning shall progress systematically from the most rigid part of the joint to its free edges.

*11.5.6.4.5 Calibrated Wrench Installation Method*

The calibrated wrench method may be used only when wrenches are calibrated on a daily basis and when a hardened washer is used under the turned element. Standard assumed to relate torque to tension shall not be acceptable.

When calibrated wrenches are used for installation, they shall be set to deliver a torque which has been calibrated to develop a tension not less than 5% in excess of the minimum tension specified in Table 11.5A. The installation procedures shall be calibrated by verification testing at least once each working day for each fastener assembly lot that is being installed that day in the work. This verification testing shall be accomplished in a tension measuring device capable of indicating actual bolt tension by testing three typical fastener assemblies from each lot. Bolts, nuts and washers under the turned element shall be sampled from production lots. Wrenches shall be recalibrated when significant difference is noted in the surface condition of the bolts, threads, nuts or washers. It shall be verified during actual installation in the assembled steel work that the wrench adjustment selected by the calibration does not produce a nut or bolt head rotation from a snug condition greater than that permitted in Table 11.5B. If manual torque wrenches are used, nuts shall be torqued in the tensioning direction when torque is measured.

When calibrated wrenches are used to install and tension bolts in a connection, bolts shall be installed with hardened washers under the turned element. Following snugging, the connection shall be tensioned using the calibrated wrench. Tensioning shall progress systematically from the most rigid part of the joint to its free edges. The wrench shall be returned to "touch up" previously tensioned bolts which may have been relaxed as a result of the subsequent tensioning of adjacent bolts until all bolts are tensioned to the prescribed amount.

*11.5.6.4.6 Alternative Design Bolts Installation Method*

When fasteners which incorporate a design feature intended to indirectly indicate that the applied torque develops the required tension or to automatically develop the tension required by Table 11.5A and which have been qualified under Article 11.3.2.5 are to be installed, verification testing using a representative sample of not less than three fastener assemblies of each diameter, length and grade to be used in the work shall be performed at the job site in a device capable of indicating bolt tension. The test assembly shall include flat-hardened washers, if required in the actual connection, arranged as in the actual connections to be tensioned. The verification test shall demonstrate that each bolt develops a tension not less than 5% greater than the tension required by Table 11.5A. Manufacturer's installation procedure shall be followed for installation of bolts in the calibration device and in all connections. Periodic retesting shall be performed when ordered by the Engineer.

When alternate design fasteners which are intended to control or indicate bolt tension of the fasteners are used, bolts shall be installed in all holes of the connection and initially snugged sufficiently to bring all plies of the joint into firm contact but without yielding or fracturing the control or indicator element of the fasteners. All fasteners shall then be further tensioned, progressing systematically from the most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tensioned bolts. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic partial tensioning prior to final yielding or fracturing of the control or indicator element of individual fasteners. If yielding or twist-off occurs prior to the final tensioning cycle, the fastener assembly shall be replaced with a new one.

*11.5.6.4.7 Direct Tension Indicator Installation Method*

When Direct Tension Indicators (DTIs) meeting the requirements of Article 11.3.2.6 are to be used with high-strength bolts to indicate bolt tension, they shall be subjected to the verification testing described below and installed in accordance with the method specified below. Unless otherwise approved by the engineer-of-record, the DTIs shall be installed under the head of the bolt and the nut turned to tension the bolt. The Manufacturer's recommendations shall be followed for the proper orientation of the DTI and additional washers, if any, required for the correct use of the DTI. Installation of a DTI under the turned element may be permitted if a washer separates the turned element from the DTI.

*11.5.6.4.7a Verification*

Verification testing shall be performed in a calibrated bolt tension measuring device. A special flat insert shall be used in place of the normal bolt head holding insert. Three verification tests are required for each combination of fastener assembly rotational-capacity lot, DTI lot, and DTI position relative to the turned element (bolt head or nut) to be used on the project. The fastener assembly shall be installed in the tension measuring device with the DTI located in the same position as in the work. The element not turned (bolt or nut) shall be restrained from rotation. The purpose of verification testing is to ensure that the fastener will be at or above the desired installation tension when the requisite number of spaces between the protrusions have a gap of 0.005 inches or less and that the bolt will not have excessive plastic deformation at the minimum gap allowed on the project.

The verification tests shall be conducted in two stages. The bolt nut and DTI assembly shall be installed in a manner so that at least three and preferably not more than five threads are located between the bearing face of the nut and the bolt head. The bolt shall be tensioned first to the load equal to that listed in Table 11.5C under Verification Tension for the grade and diameter of bolt. If an impact wrench is used, the tension developed using the impact wrench shall be no more than two-thirds the required tension. Subsequently a manual wrench shall be used to attain the required tension. The number of refusals of a 0.005 inch tapered feeler gauge in the spaces between the protrusions shall be recorded. The number of refusals for uncoated DTIs under the stationary or turned element, or coated DTIs under the stationary element, shall not exceed the number listed under Maximum Verification Refusals in Table 11.5C for the grade and diameter of bolt used. The maximum number of verification refusals for coated DTIs (galvanized, painted, or epoxy-coated), when used under the turned element shall be no more than the number of spaces on the DTI less one. The DTI lot is rejected if the number of refusals exceeds the values in the table or, for coated DTIs if the gauge is refused in all spaces.

After the number of refusals is recorded at the verification load, the bolt shall be further tensioned until the 0.005 inch feeler gauge is refused at all the spaces and a visible gap exists in at least one space. The load at this condition shall be recorded and the bolt removed from the tension measuring device. The nut shall be able to be rundown by hand for the complete thread length of the bolt excluding thread runout. If the nut cannot be rundown for this thread length, the DTI lot shall be rejected unless the load recorded is less than 95% of the average load measured in the rotational capacity test for the fastener lot as specified in Article 11.5.6.4.2g.

**TABLE 11.5C**

| Bolt Dia. (in.) | Verification Tension (kips) | | Maximum Verification Refusals | | DTI Spaces | | Minimum Installation Refusals | |
|---|---|---|---|---|---|---|---|---|
| | A325 | A490 | 325 | 490 | 325 | 490 | 325 | 490 |
| 1/2 | 13 | 16 | 1 | 2 | 4 | 5 | 2 | 3 |
| 5/8 | 20 | 25 | 1 | 2 | 4 | 5 | 2 | 3 |
| 3/4 | 29 | 37 | 2 | 2 | 5 | 6 | 3 | 3 |
| 7/8 | 41 | 51 | 2 | 2 | 5 | 6 | 3 | 3 |
| 1 | 54 | 67 | 2 | 3 | 6 | 7 | 3 | 4 |
| 1-1/8 | 59 | 84 | 2 | 3 | 6 | 7 | 3 | 4 |
| 1-1/4 | 75 | 107 | 3 | 3 | 7 | 8 | 4 | 4 |
| 1-3/8 | 89 | 127 | 3 | 3 | 7 | 8 | 4 | 4 |
| 1-1/2 | 108 | 155 | 3 | 4 | 8 | 9 | 4 | 5 |

Note: Maximum Verification Refusals are for uncoated DTIs used under stationary or turned element and for coated DTIs used under a stationary element. The maximum number of refusals for coated DTIs used under a turned element shall be no more than the number of spaces on the DTI less one.

Minimum Installation Refusals are for uncoated DTIs used under a stationary or turned element and for coated DTIs used under a stationary element. The gauge shall be refused in all spaces when coated DTIs are used under a turned element.

If the bolt is too short to be tested in the calibration device, the DTI lot shall be verified on a long bolt in a calibrator to determine the number of refusals at the Verification Tension listed in Table 11.5C. The number of refusals shall not exceed the values listed under Maximum Verification Refusals in Table 11.5C. Another DTI from the same lot shall then be verified with the short bolt in a convenient hole in the work. The bolt shall be tensioned until the 0.005 inch feeler gauge is refused in all spaces and a visible gap exists in at least one space. The bolt shall then be removed from the tension measuring device and the nut must be able to be rundown by hand for the complete thread length of the bolt excluding thread runout. The DTI lot shall be rejected if the nut cannot be rundown for this thread length.

*11.5.6.4.7b Installation*

Installation of fastener assemblies using DTIs shall be performed in two stages. The stationary element shall be held against rotation during each stage of the installation. The connection shall be first snugged with bolts installed in all the holes of the connection and tensioned sufficiently to bring all the plies of the connection into firm contact. The number of spaces in which 0.005 inch feeler gauge is refused in the DTI after snugging shall not exceed those listed under Maximum Verification Refusals in Table 11.5C. If the number exceeds the values in the table, the fastener assembly shall be removed and another DTI installed and snugged.

For uncoated DTIs under the stationary or turned element, or coated DTIs under the stationary element, the bolts shall be further tensioned until the number of refusals of the 0.005 inch feeler gauge is equal to or greater than the number listed under Minimum Installation Refusals in Table 11.5C. If the bolt is tensioned so that no visible gap in any space remains, the bolt and DTI shall be removed, and replaced by a new properly tensioned bolt and DTI.

The feeler gauge shall be refused in all spaces when coated DTIs (galvanized, painted, or epoxy-coated) are used under the turned element.

*11.5.6.4.8 Lock-Pin and Collar Fasteners*

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

*11.5.6.4.9 Inspection*

*11.5.6.4.9.1* The Engineer shall determine that the requirements of Articles 11.5.6.4.9.2 and 11.5.6.4.9.3, following, are met in the work.

*11.5.6.4.9.2* Before the installation of fasteners in the work, the Engineer shall check the marking, surface condition and storage of bolts, nuts, washers, and DTIs, if used, and the faying surfaces of joints for compliance with the requirements of Articles 11.3.2, 11.5.6.1, and 11.5.6.4.1.

The Engineer shall observe calibration and/or testing procedures required in Articles 11.5.6.4.4 through 11.5.6.4.7 as applicable, to confirm that the selected procedure is properly used and that, when so used with the fastener assemblies supplied, the tensions specified in Table 11.5A are developed.

The Engineer shall monitor the installation of fasteners in the work to assure that the selected installation method, as demonstrated in the initial testing to develop the specified tension, is routinely followed.

*11.5.6.4.9.3* Either the Engineer or the Contractor, in the presence of the Engineer at the Engineer's option, shall inspect the tensioned bolts using an inspection torque wrench, unless alternate fasteners or direct tension indicator devices are used, allowing verification by other methods. Inspection tests should be conducted in a timely manner prior to possible loss of lubrication or before corrosion influences torque.

Three fastener assembly lots in the same condition as those under inspection shall be placed individually in a device calibrated to measure bolt tension. This calibration operation shall be done at least once each inspection day. There shall be a washer under the turned element in tensioning each bolt if washers are used on the structure. If washers are not used on the structure, the material used in the tension measuring device which abuts the part turned shall be of the same specification as that used on the structure. In the calibrated device, each bolt shall be tensioned by any convenient means to the specified tension. The inspecting wrench shall then be applied to the tensioned bolt to determine the torque required to turn the nut or head 5° (approximately 1 inch at a 12-inch radius) in the tensioning direction. The average of the torque required for all three bolts shall be taken as the job-inspection torque.

Ten percent (at least two) of the tensioned bolts on the structure represented by the test bolts shall be selected at random in each connection. The job-inspection torque shall then be applied to each with the inspecting wrench turned in the tensioning direction. If this torque turns no bolt head or nut, the bolts in the connection will be considered to be properly tensioned. But if the torque turns one or more bolt heads or nuts, the job-inspection torque shall then be applied to all bolts in the connection. Any bolt whose head or nut turns at this stage shall be retensioned and reinspected. The Contractor may, however, retension all the bolts in the connection and resubmit it for inspection, so long as DTIs are not overtensioned or fastener assemblies are not damaged.

### 11.5.7 Welding

Welding, welder qualifications, prequalification of weld details and inspection of welds shall conform to the requirements of the current *ANSI/AASHTO/AWS D1.5 Bridge Welding Code.*

Brackets, clips, shipping devices, or other material not required by the plans or special provisions shall not be welded or tacked to any member unless shown on the shop drawings and approved by the Engineer.

## 11.6 ERECTION

### 11.6.1 General

The Contractor shall provide all tools, machinery, and equipment necessary to erect the structure.

Falsework and forms shall be in accordance with the requirements of Section 3, "Temporary Works."

### 11.6.2 Handling and Storing Materials

Material to be stored at the job site shall be placed on skids above the ground. It shall be kept clean and properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent injury from deflection. If the contract is for erection only, the Contractor shall check the material turned over to him or her against the shipping lists and report promptly in writing any shortage or injury discovered. The Contractor shall be responsible for the loss of any material while in his or her care, or for any damage caused to it after being received by the Contractor.

### 11.6.3 Bearings and Anchorages

Bridge bearings shall be furnished and installed in conformance with Section 18, "Bearing Devices," of these Specifications.

If the steel superstructure is to be placed on a substructure that was built under a separate contract, the Contractor shall verify that the masonry has been constructed in the right location and to the correct lines and elevations before ordering materials.

### 11.6.4 Erection Procedure

#### 11.6.4.1 Conformance to Drawings

The erection procedure shall conform to the erection drawings submitted in accordance with Article 11.2.2. Any modifications to or deviations from this erection procedure will require revised drawings and verification of stresses and geometry.

#### 11.6.4.2 Erection Stresses

Any erection stresses, induced in the structure as a result of using a method of erection which differs from the plans, shall be accounted for by the Contractor. The Contractor, at his own expense, shall prepare erection design calculations for such changed methods and submit them to the Engineer. The calculations shall indicate any change in stresses or change in behavior for the temporary and final structures. Additional material required to keep both the temporary and final stresses within the allowable limits used in design shall be provided at the Contractor's expense.

The Contractor will be responsible for providing temporary bracing or stiffening devices to accommodate handling stresses in individual members or segments of the structure during erection.

#### 11.6.4.3 Maintaining Alignment and Camber

During erection, the Contractor will be responsible for supporting segments of the structure in a manner that will produce the proper alignment and camber in the completed structure. Cross frames and diagonal bracing shall be installed as necessary during the erection process to provide stability and assure correct geometry. Temporary bracing, if necessary at any stage of erection, shall be provided by the Contractor.

### 11.6.5 Field Assembly

The parts shall be accurately assembled as shown on the plans or erection drawings, and any match-marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken, or otherwise damaged. Hammering which will injure or distort the members shall not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Splices and field connections shall have one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before installing and tightening the balance of high-strength bolts. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

Fitting-up bolts may be the same high-strength bolts used in the installation. If other fitting-up bolts are used they shall be of the same nominal diameter as the high-strength bolts, and cylindrical erection pins shall be $\frac{1}{32}$ inch larger.

### 11.6.6 Pin Connections

Pilot and driving nuts shall be used in driving pins. They shall be furnished by the Contractor without charge. Pins shall be so driven that the members will take full bearing on them. Pin nuts shall be screwed up tight and the threads burred at the face of the nut with a pointed tool.

### 11.6.7 Misfits

The correction of minor misfits involving minor amounts of reaming, cutting, grinding and chipping will be considered a legitimate part of the erection. However, any error in the shop fabrication or deformation resulting from handling and transporting will be cause for rejection.

The Contractor shall be responsible for all misfits, errors, and damage and shall make the necessary corrections and replacements.

## 11.7 MEASUREMENT AND PAYMENT

### 11.7.1 Method of Measurement

Pay quantities for each type of steel and iron will be measured by the pound computed from dimensions shown on the plans using the following rules and assumptions:

| Unit Weights, Pound per Cubic Foot | |
|---|---|
| Cast Iron | 445.0 |
| Malleable Iron | 470.0 |
| Wrought Iron | 487.0 |
| Steel-Rolled or Cast | 490.0 |

The weights of rolled shapes shall be computed on the basis of their nominal weights per foot as shown on the drawings, or listed in the handbooks.

The weights of plates shall be computed on the basis of the nominal weight for their width and thickness as shown on the drawings, plus an estimated overrun computed as one-half the "Permissible Variation in Thickness and Weight" as tabulated in Specification, "General Requirements for Delivery of Rolled Steel Plates, Shapes, Steel Piling, and Bars for Structural Use," AASHTO M 160 (ASTM A 6).

The weight of castings shall be computed from the dimensions shown on the approved shop drawings, deducting for open holes. To this weight shall be added 5% allowance for fillets and overrun. Scale weights may be substituted for computed weights in the case of castings or of small complex parts for which accurate computations of weight would be difficult.

The weight of temporary erection bolts, shop and field paint, boxes, crates, and other containers used for shipping, and materials used for supporting members during transportation and erection, will not be included.

The weight of any additional material required by Article 11.6.4.2 to accommodate erection stresses resulting from the Contractor's choice of erection methods will not be included.

In computing pay weight on the basis of computed net weight the following stipulations in addition to those in the foregoing paragraphs shall apply.

(a) The weight shall be computed on the basis of the net finished dimensions of the parts as shown on the approved shop drawings, deducting for copes, cuts, clips, and all open holes, except bolt holes.

(b) The weight of heads, nuts, single washers, and threaded stick-through of all high tensile strength bolts, both shop and field, shall be included on the basis of the following weights:

| Diameter of Bolt (in.) | Weight per 100 Bolts (lbs) |
|---|---|
| 1/2 | 19.7 |
| 5/8 | 31.7 |
| 3/4 | 52.4 |
| 7/8 | 80.4 |
| 1 | 116.7 |
| 1-1/8 | 165.1 |
| 1-1/4 | 212.0 |
| 1-3/8 | 280.0 |
| 1-1/2 | 340.0 |

(c) The weight of fillet welds shall be as follows:

| Size of Fillet Weld Inches | Weight—Pounds per Linear Foot |
|---|---|
| 3/16 | 0.08 |
| 1/4 | 0.14 |
| 5/16 | 0.22 |
| 3/8 | 0.30 |
| 1/2 | 0.55 |
| 5/8 | 0.80 |
| 3/4 | 1.10 |
| 7/8 | 1.50 |
| 1 | 2.00 |

(d) To determine the pay quantities of galvanized metal, the weight to be added to the calculated weight of base metal for the galvanizing will be determined from the weights of zinc coatings specified by AASHTO M 111 (ASTM A 123).

(e) No allowance will be made for the weight of paint.

### 11.7.2 Basis of Payment

The contract price for fabrication and erection of structural steel shall be considered to be full compensation for the cost of all labor, equipment, materials, transportation, and shop and field painting, if not otherwise provided for, necessary for the proper completion of the work in accordance with the contract. The contract price for fabrication without erection shall be considered to be full compensation for the cost of all labor, equipment, and materials necessary for the proper completion of the work, other than erection and field assembly, in accordance with the contract.

Under contracts containing an item for structural steel, all metal parts other than metal reinforcement for concrete, such as anchor bolts and nuts, shoes, rockers, rollers, bearing and slab plates, pins and nuts, expansion dams, roadway drains and scuppers, weld metal, bolts embedded in concrete, cradles and brackets, railing, and railing pots shall be paid for as structural steel unless otherwise stipulated.

Payment will be made on a pound-price or a lump-sum basis as required by the terms of the contract, but unless stipulated otherwise, it shall be on a pound-price basis.

For members comprising both carbon steel and other special steel or material, when separate unit prices are provided for same, the weight of each class of steel in each such member shall be separately computed, and paid for at the contract unit price therefore.

Full-size members which are tested in accordance with the specifications, when such tests are required by the contract, shall be paid for at the same rate as for comparable members for the structure. The cost of testing including equipment, labor and incidentals shall be included in the contract price for structural steel. Members which fail to meet the contract requirements, and members rejected as a result of tests, will not be paid for by the Department.