# SECTION 615
# STEEL STRUCTURES

## 615.1-GENERAL:

**615.1.1-Description:** The 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 American Institute of Steel Construction (AISC) Quality Certification Program, category: "Major Steel Bridges", except fabricators of unspliced rolled beam bridges or parts for bridges such as cross frames or other miscellaneous components of larger bridges shall be certified in category: "Simple Steel Bridge Structures". The fabricators of fracture critical members shall be certified as category: "Major Steel Bridges" and, in addition, shall possess an "F" endorsement by AISC. Structural components such as expansion dams, drains, and scuppers may be fabricated in shops that are not AISC certified.

The fabricator (AISC certified or non certified) shall provide a quality control plan to the Engineer for approval. This plan shall contain information concerning the fabricator's internal control process. Information concerning the contents of the quality control plan can be found in the FHWA Region Three, Structural Committee for Economic Fabrication's Guidelines for the Development of a Quality Control Plan. The plan shall be approved by the Division prior to the start of fabrication.

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

Painting shall conform to the provisions of Section 688.

**615.1.2-Notice of Beginning of Work:** The Contractor shall give the Engineer ample notice of the beginning of work at the mill or at the fabrication 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.

**615.1.3-Inspection:** Structural steel shall be inspected in the fabrication shop. The Contractor shall furnish the Engineer with a copy of all mill orders and shop lists showing heat numbers to be used for each piece. Mill test reports that document each piece. Mill the chemical analysis and physical test results for each heat of steel to be used in the work shall also be furnished. Final approval of the material in the shop will not be given until the above data is approved.

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 minimum 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 shop where the material is stored or where work on the material is being performed.

**615.1.4-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 shop is intended as a means of facilitating the work and avoiding error, 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 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.

**615.2-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.

615.2.1

**615.2.2-Erection Drawings:** The Contractor shall submit drawings illustrating fully their proposed method of erection. The drawings shall show details of all falsework bents, bracings, 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. Design calculations, sealed by a West Virginia Registered Professional Engineer, shall be submitted

by the Contractor to the Engineer for approval which will demonstrate that allowable stresses for falsework and steel members being erected are not exceeded and that member capacities and final geometry shall be correct.

When the designated concrete deck overhang exceeds 2.5 feet (750 mm), the erection drawings submitted by the Contractor shall include complete details of the forming and bracing for the overhang and shall transmit the concrete dead load to an area of the girder which will prevent distortion of the web or distortion of the beam. All forming and bracing procedures are subject to approval of the Engineer.

**615.2.3-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 (¼ points minimum) in the cases of continuous beam and girders or rigid frames. The camber diagram shall shown calculated cambers to be used in preassembly of the structure in accordance with Section 615.5.3.

## 615.3-MATERIALS:

### 615.3.1-Structural Steel:

**615.3.1.1-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 as specified. If not so shown or specified, structural carbon steel shall be furnished. When copper bearing steel is specified, the steel shall contain not less than 0.2 percent copper.

All steel for use in main load-carrying member components subject to tensile stress, including splice plates, shall conform to Zone 2Charpy V-Notch Impact Test requirements of AASHTO M270.

Any additional materials required but not listed below shall comply with Division 700.

**615.3.1.2-Carbon Steel:** Unless otherwise specified, structural carbon steel for bolted or welded construction shall conform to 709.12.

**615.3.1.3-High-Strength Low-Alloy Structural Steel:** Shall conform to 709.8.

**615.3.2-High-Strength Fasteners:** Bolts, nuts, and washers shall conform to 709.24 and shall be either mechanically galvanized or coated with zinc rich primer. Hot-dip galvanizing may be used only when specified by the Contract documents.

**615.3.3-Welded Stud Shear Connectors:** When design requires the use of welded stud shear connectors, they shall meet the requirements of Section 7 of the ANSI/AASHTO/AWS D1.5, Bridge Welding Code.

**615.3.4-Steel Forgings and Steel Shafting:**

**615.3.4.1-Steel Forgings:** Shall conform to 709.13.1.

**615.3.4.2-Cold Finished Carbon Steel Shafting:** Shall conform to 709.13.2.

**615.3.5-Steel Castings:** Shall conform to 709.14.

**615.3.6-Iron Castings:** Shall conform to 709.10.

**615.3.7-Coating of Anchor Bolts, Nuts and Washers:** All anchor bolts, nuts and washers shall be hot dip galvanized in accordance with AASHTO M111 after fabrication.

**615.4-FABRICATION:**

**615.4.1-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 assembling 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. This may be done by writing the material grade on the piece or using the identification color code shown in Table 615.4.

| TABLE 615.4 IDENTIFICATION COLOR CODES | |
|---|---|
| Grade 50 | Green & Yellow |
| Grade 50W | Blue & Yellow |
| Grade 70W | Blue & Orange |
| Grade 100 | Red |
| Grade 100W | Red & Orange |

Other steels, except Grade 36 steel, not covered above, nor included in the AASHTO M160 Specification, shall have an individual colorcode which shall be established and kept on record for the Engineer.

Pieces of steel, other than Grade 36 steel, which prior to assembling into members, will be subject to fabricating operations, such as blast cleaning, galvanizing, heat forming, or painting which might remove or cover paint color

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

**615.4.2-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.

**615.4.3-Plates:**

**615.4.3.1-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.

**615.4.3.2-Plate Cut Edges:**

**615.4.3.2.1-Edge Planeing:** Sheared edges of plate more than ⅝ inch (16 mm) in thickness and carrying calculated stress shall be planed, milled, ground, or thermal cut to a depth of ¼ inch (6 mm).

**615.4.3.2.2-Thermal Cutting:** Shall conform to the requirements of the ANSI/AASHTO/AWS Bridge Welding Code D1.5.

**615.4.3.2.3-Visual Inspection and Repair of Plate Cut Edges:** Shall conform to the requirements of ANSI/AASHTO/AWS Bridge Welding code D1.5.

**615.4.3.3-Bent Plates:**

**615.4.3.3.1-General:** Unwelded, load-carrying, rolled-steel plates to be bent shall conform to the following:

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

Before bending, the corners of the plates shall be rounded to a radius of approximately 1/16 inch (2 mm) throughout the portion of the plate at which the bending is to occur.

**615.4.3.3.2-Cold Bending:** Cold bending shall be such that no cracking of the plate occurs. Minimum bend radii, measured to the concave face of the metal, are shown in table 615.4.3.3.2.

**Table 615.4.3.3.2-Minimum Bend Radii**

| Thickness in Inches (millimeters) (t) | Up to ½" (12 mm) | Over ½" to 1" (12 to 25 mm) | Over 1" to 1½" (25 to 38 mm) | Over 1½" to 2½" (38 to 64 mm) | Over 2½" to 4" (64 to 100 mm) |
|---|---|---|---|---|---|
| Bend radii for all grades of structural steel in this specification | 2t | 2½t | 3t | 3½t | 4t |

Allowance for springback of Grades 100 and 100W steels should be about three times that for Grade 36 steel. For break press forming, the lower die span should be at least 16 times the plate thickness. Multiple hits are advisable.

**615.4.3.3.3-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 shown in Table 615.4.7.

**615.4.4-Fit of Stiffeners:** 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 when shown on the plans or specified) on the flanges to which they transmit load or from which they receive load and shall meet the requirements of paragraph 3.5 of the ANS/AASHTO/AWS Bridge Welding Code D1.5. Intermediate stiffeners not intended to support concentrated loads, unless shown or specified otherwise, shall have a tight fit against both flanges. Diaphragm, crossframes or floorbeam connection plates shall be welded to both top and bottom flanges.

**615.4.5-Abutting Joints:** When specified by the contract plans, butting 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 ⅜ inch (10 mm).

**615.4.6-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 |

**615.4.7**

| | |
|---|---|
| Pins and pin holes | ANSI 125 |
| Sliding bearings | ANSI 125 |

**615.4.7-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 Grades 70W, 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 shown in Table 615.4.7.

| **Table 615.4.7-Maximum Heat Straightening And Hot Bending Temperature {ENGLISH}** | |
|---|---|
| Grade 70W > 6" from weld | 1,075° F |
| Grade 70W < 6" from weld | 900° F |
| Grade 100 or 100W > 6" from weld | 1,125° F |
| Grade 100 or 100W < 6" from weld | 950° F |

| **Table 615.4.7-Maximum Heat Straightening And Hot Bending Temperature (METRIC)** | |
|---|---|
| Grade 480W > 150 mm from weld | 580 °C |
| Grade 480W < 150 mm from weld | 480 °C |
| Grade 690 or 690W > 150 mm from weld | 610 °C |
| Grade 690 or 690W < 150 mm from weld | 590 °C |

In all other steels, the temperature of the heated area shall not exceed 1,200° F (650° c) as controlled by temperature indicating crayons, liquids, or bimetal thermometers.

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.

**615.4.8-Bolt Holes:**

**615.4.8.1-Holes for High-Strength Bolts and Unfinished Bolts:** (See

Section 615.5.5 for bolts included in designation "Unfinished Bolts").

**615.4.8.1.1-General:** All holes for bolts shall be either punched or drilled. Material forming parts of a member composed of not more than five thicknesses of metal may be punched 1/16 inch (2 mm) larger than the nominal diameter of the bolts whenever the thickness of the material is not greater than ¾ inch (20 mm) for structural carbon steel, ⅝ inch (16 mm) for high-strength steel or ½ inch (12 mm) for quenched and tempered alloy steel, unless subpunching and reaming are required under Section 615.4.8.5.

When there are more than five thicknesses or when any of the main material is thicker than ¾ inch (20 mm) for structural carbon steel, ⅝ inch (16 mm) for high-strength steel, or ½ inch (12 mm) for quenched and tempered alloy steel, all holes shall either be subdrilled and reamed or drilled full size.

When required, all holes shall be either subpunched or subdrilled (subdrilled if thickness limitation governs) 3/16 inch (5 mm) smaller and, after assembling reamed 1/16 inch (2 mm) larger or drilled full size to 1/16 inch (2 mm) larger than the nominal diameter of the bolts.

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

**615.4.8.1.2-Punched Holes:** The diameter of the die shall not exceed the diameter of the punch by more than 1/16 inch (2 mm). 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.

**615.4.8.1.3-Reamed or Drilled Holes:** Shall be cylindrical, perpendicular to the member, and shall comply with the requirements of Section 615.4.8.1.1 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. Parts shall not be held by welding.

**615.4.8.1.4-Accuracy of Holes:** Holes not more than 1/32 inch (1 mm) 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 slightly conical hole that naturally results from punching operations is considered acceptable. The width of slotted holes which are produced by thermal cutting or a combination of drilling or punching and thermal cutting shall be not more than 1/32 inch (1 mm) greater than the nominal width. The thermal cut surface shall be ground smooth.

**615.4.8.2-Accuracy of Hole Group:**

**615.4.8.2.1-Accuracy Before Reaming:** All holes punched full size,

subpunched, or subdrilled shall be so accurately punched so that after assembling (before any reaming is done) a cylindrical pin ⅛ inch (3 mm) smaller in diameter than the nominal size of the punched hole may be entered perpendicular to the face of the member, without drifting, in at least 75 percent of the contiguous holes in the same plane. If the requirement is not fulfilled, the improperly punched pieces will be rejected. If any hole will not pass a pin 3/16 inch (5 mm) smaller in diameter than the nominal size of the punched hole, this will be cause for rejection.

**615.4.8.2.2-Accuracy after Reaming:** When holes are reamed or drilled, 85 percent of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 1/32 inch (1 mm) between adjacent thickness of metal.

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

**615.4.8.3-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-size punched holes shall meet the requirements of Section 615.4.8.1.

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 Section 615.5.3.3.

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. Pieces shall not be held by welding.

**615.4.8.4-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 (5 mm) 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.

**615.4.8.5-Preparation of Field Connections:** Holes in all field connections and field splices of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched or subdrilled and subsequently reamed while assembled or drilled

full size to a steel template. 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. 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.

**615.4.9-Pins and Rollers:**

**615.4.9.1-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 (225 mm) in diameter shall be forged rollers and annealed. Pins and rollers 9 inches (225 mm) or less in diameter may be either forged and annealed or cold-finished carbon-steel shafting.

In pins larger than 9 inches (225 mm) in diameter, a hole not less than 2 inches in (50 mm) 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 damage by too rapid cooling, and before being annealed.

**615.4.9.2-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 (500 µm) for pins 5 inches (125 mm) or less in diameter, or by 1/32 inch (1 mm) 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 (1 mm). Boring of pin holes in built-up members shall be done after the member has been assembled.

**615.4.9.3-Threads for Bolts and Pins:** Threads for all bolts and pins for structural steel construction shall conform to the Unified Standard Series UNC ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 1⅜ inches (36 mm) or more shall be threaded six threads to the inch (25 mm).

**615.4.10-Eyebars:** Pin holes may be thermal cut at least 2 inches (50 mm) 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.

The eyebars shall be straight and free from twists and the pin holes shall be accurately located on the centerline of the bar. The inclination of any bar to the plane of the truss shall not 0.5 percent.

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

**615.4.11-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 defined in ASTM E44. 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 (38° C) at any one time.

Members of Grades 100/100W or Grade 70W (690/690W or Grade 480W) 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 100/100W and Grade 70W (690/690W and Grade 480W) steels shall not exceed 1,125° F and 1,075° F (610 °C and 580 °C), respectively.

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

**615.4.12-Curved Girders:**

**615.4.12.1-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 Sections providing the radii is not less than allowed by Article

10.15.2 of Division I of the AASHTO Standard Specifications for Highway Bridges.

**615.4.12.2-Heat Curving Rolled Beams and Welded Girders:**

**615.4.12.2.1-Materials:** Steels that are manufactured to a specified minimum yield point greater than 50,000 psi (345 Mpa) shall not be heat curved.

**615.4.12.2.2-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 simultaneously depending on flange widths and thicknesses; the strip shall be of sufficient width and temperature to obtain the required curvature. For 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 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 (300 m) 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 (300 m), the apex of the truncated triangle heating pattern applied to the outside flange surface shall extend past the web for a distance equal to one-eighth of the flange or 3 inches (75 mm), whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees, but the base of the triangle shall not exceed 10 inches (250 mm). 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 (32 mm) or greater, in which case, the two surfaces shall be heated concurrently. The maximum temperature shall be prescribed as follows.

**615.4.12.2.3-Temperature:** The heat-curving operation shall be conducted in such a manner that the temperature of the steel does not exceed 1,150° F (620° C) as measured by temperature indicating crayons or other suitable means. The girder shall not be artificially cooled until after naturally cooling to 600° F (315° C). The method of artificial cooling is subject to the approval of the Engineer.

**615.4.12.2.4-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 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 (50 mm) of the flanges at all times during the heating process to guard against a sudden sag due to plastic flange buckling.

**615.4.12.2.5-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 (37.5 mm) and the radius of the curvature is greater than 1,000 feet (30 meters). 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.

**615.4.12.2.6-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.

**615.4.12.2.7-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.

**615.4.13-Blank**

**615.4.14-Full Size Tests:** When full size 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 Section 615.7.2.

**615.4.15-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 (2.75 Mg) shall have the weights marked thereon. Structural members shall be loaded on trucks or railcars in such a manner that they may be transported and unloaded at their destination without being excessively stressed, deformed, or otherwise damaged.

High strength bolts, nuts, and washers shall be packaged as required by Section 709.24.9.1. Pins and small parts shall be shipped in boxes, crates, kegs, or barrels, but the gross weight of any package shall not exceed 300 pounds (136 kg). A list and description of the contained material shall be plainly marked on the outside of each shipping container.

**615.5-ASSEMBLY:**

**615.5.1-Bolting:** Surfaces of metal in contact shall be clean 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 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.

**615.5.2-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 ANSI/AASHTO/AWS Bridge Welding Code D1.5.

**615.5.3-Preassembly of Field Connections:**

**615.5.3.1-General:** Field connections of main members of trusses, arches, continuous beams, plate girders, bents, towers and rigid frames shall be preassembled prior to erection 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 and he 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 (45 meters), each assembly shall be not less than 150 feet (45 meters) 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.

**615.5.3.2-Bolted Connections:** For bolted connections, holes shall be prepared as outlined in Section 615.4.8. Where specified by the contract documents, 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.

**615.5.3.3-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, 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 bearing, special complex points, and similar considerations. Special points could be the portals of skewed trusses, for example. More than one check assembly may be required by the Engineer.

The check assemblies shall include the first sections of each major structural type to be fabricated and additional assemblies as required by the Engineer.

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 Division.

**615.5.3.4-Field Welded Connections:** For field welded connections the fit of members including the proper space between abutting surfaces shall be prepared and verified with the segment preassembled in accordance with Section 615.5.3.1.

**615.5.3.5-Assembly Verification:** Each assembly, including camber, alignment, accuracy of holes, and fit of milled or field welded joints, shall be approved by the Engineer before reaming or drilling is commenced or before an N/C drilled check assembly or field welded assembly is dismantled.

**615.5.4-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.

**615.5.5-Connections Using Unfinished, Turned or Ribbed Bolts:**

**615.5.5.1-General:** When unfinished bolts are specified, the bolts shall be unfinished, turned, or ribbed bolts, conforming to the requirements of Grade A Bolts of the Specification for Low-Carbon Steel Externally and Internally Threaded Standard Fasteners, 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 requirements of this Section do not pertain to the use of high-strength bolts. Bolted connections using high-strength bolts shall conform to Section 615.5.6.

**615.5.5.2-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 tight driving fit. Threads shall be entirely outside of the holes. A washer shall be provided under the nut.

**615.5.5.3-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 5/64 inch (2 mm) 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.

**615.5.6-Connections Using High-Strength Bolts:**

**615.5.6.1-General:** This specification covers the assembly of structural connections using high-strength bolts and nuts with hardened washers where initial tension in the bolt produces friction on the contact surfaces of the connected pieces sufficient in magnitude to resist shear.

**615.5.6.2-Bolted Parts:** Surfaces of bolted parts in contact with the bolt head and nut shall not have a slope of more than 1 to 20 with respect to a plane normal to the bolt axis. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material. Holes may be punched, subpunched, reamed or drilled and shall be of nominal diameter not more than 1/16 inch (2 mm) in excess of the nominal

bolt diameter.

When assembled, all joint surfaces, including those adjacent to the washers, shall be free of dirt, oil, loose scale, burrs, pits, and other defects that would prevent solid seating of the parts. All bolted surfaces shall be painted in accordance with Section 688, Painting Steel Structures.

**615.5.6.3 - Installation:** Fasteners shall be protected from dirt and moisture at the job site. Only the fasteners anticipated to be installed and tightened during a work shift shall be removed from protected storage. Fasteners not used shall be returned to protected storage at the end of the shift. Lot identification of all components shall be maintained at all times. Galvanized and zinc coated nuts shall be checked to verify that a visible lubricant is on the threads and nut faces. Fasteners shall not be cleaned of lubricant that is present in the delivered condition. Where galvanized fasteners must be tensioned by turning the bolt head, a visible lubricant that meets the requirements of AASHTO M 164, shall be applied to the washer that will be placed under the bolt head. The lubricant may be applied to the washer by the manufacturer prior to shipment, by the fabricator at the fabrication shop, or by the erector in the field. Fasteners which have accumulated rust, dirt or have been wet, shall be cleaned and relubricated, prior to installation. Bolt, nut and washer combinations as installed shall be from the same rotational-capacity lot.

A tension measuring device and torque wrench, suitable to the Engineer, shall be provided and maintained by the Contractor at all job sites where high-strength fasteners are being installed. The tension measuring device shall be used to confirm: (1) the suitability to satisfy the requirement of Table 615.5.6.3 A of the completed fastener assembly, including lubricant, to be used in the work, (2) rotational capacity testing requirements, and (3) that the bolting crew understands proper installation procedures. The tension measuring device and torque wrench shall be calibrated by an approved testing agency at least yearly. Documentation of calibration shall be provided to the Engineer.

Immediately prior to installation in the fabrication shop or on the project site, all high-strength fasteners shall be subjected to rotational-capacity testing by the fabricator or the contractor. Testing shall be in accordance with Section 709.24.5 and shall be conducted at a frequency of two assemblies per rotational-capacity lot number as identified on the shipping containers. Test results shall meet the requirements of Section 709.24.5. When fasteners have been cleaned and relubricated, the rotational-capacity testing, on the affected fasteners, shall be reconducted. The Engineer may request additional tests as necessary to provide assurance of product compliance.

Bolts shall be installed with a hardened washer under the nut or bolt head, whichever is the element turned in tightening. A flat washer may be used when the abutting surface adjacent to the bolt head or nut does not have a slope of more than 1 to 20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism.

The threaded end of bolts shall be placed on the inside, where practicable, to protect them from the weather.

All fasteners shall be tightened to give at least the required minimum bolt tension shown in Table 615.5.6.3 A on completion of the joint. Tightening shall be done by the TURN-OF-NUT METHOD.

**TABLE 615.5.6.3 A-FASTENER TENSION (ENGLISH)**

| Bolt Size (inches) | Required Minimum Fastener Tension (kips) |
|---|---|
| ½ | 12 |
| ⅝ | 19 |
| ¾ | 28 |
| ⅞ | 39 |
| 1 | 51 |
| 1⅛ | 56 |
| 1¼ | 71 |
| 1⅜ | 85 |
| 1½ | 103 |

| TABLE 615.5.6.3 A-FASTENER TENSION (METRIC) | |
|---|---|
| Bolt Size (mm) | Required Minimum Fastener Tension (kN) |
| M16 | 91 |
| M20 | 142 |
| M22 | 176 |
| M24 | 205 |
| M27 | 276 |
| M30 | 326 |
| M36 | 475 |

Impact wrenches shall be of adequate capacity and sufficiently supplied with air to perform the required tightening in approximately 10 seconds. Tightening may be done by turning the bolt while the nut is prevented from rotating when it is impractical to turn the nut.

A representative sample of not less than three bolt, nut and washer assemblies of each diameter, length, and grade to be used in the work shall be checked at the start of work, by the contractor, in a device capable of indicating bolt tension. The test shall demonstrate that the method for estimating snug tight condition, and controlling the turns from snug tight to be used by the bolting crew will develop a tension at least 5 percent greater than the tension required by Table 615.5.6.3 A. All additional fasteners (bolts, nuts, and washers) necessary for inspection and testing shall be provided by the Contractor as required by Section 105.5.

Bolts shall be installed in all holes of the connection and brought to "snug tight" condition. Snug tight is defined as that tightness which exists when the plies of the joint are in firm contact and a tension is induced in the bolts of approximately 40-50 percent of the required tension specified in Table 615.5.6.3 A.

Snug tightening shall progress systematically from the most rigid part of the connection to the free edge, and then the bolts of the connection shall be again retightened to snug tight in a similar systematic manner until all bolts are simultaneously snug tight and the connection is fully compacted. Following this initial operation, all bolts in the connection shall be tightened further by the applicable amount of rotation in Table 615.5.6.3 B. During the tightening operation, there shall be no rotation of the part not turned by the wrench. Tightening shall progress systematically from the most rigid part of the joint to its free edges.

**TABLE 615.5.6.3 B**
**NUT ROTATION FROM SNUG TIGHT CONDITION [a, b]**

| | DISPOSITION OF OUTER FACES OF BOLTED PARTS | | |
|---|---|---|---|
| Bolt Length in Diameters (measured from underside of head to end of bolt) | Both faces normal to bolt axis | One face normal to bolt axis other face sloped not more than 1:20 (bevel washers not used) | Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used) |
| Up to & including 4 | 1/3 turn | ½ turn | 2/3 turn |
| Over 4 but not exceeding 8 | ½ turn | 2/3 turn | 5/6 turn |
| Over 8 but not exceeding 12[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 ½ turn and less, the tolerance shall be plus or minus 30 degrees; for bolts installed by 2/3 turn and more, the tolerance shall be plus or minus 45 degrees.

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

c. No research or testing has been performed to establish the TURN-OF-NUT procedure for bolt lengths exceeding 12 diameters. Therefore, the required rotation must be determined by the Contractor by actual test in a suitable tension measuring device which simulates conditions of solidly fitted steel. Testing is subject to approval by the Engineer.

**615.5.6.4 - Inspection:** The Engineer will determine the following requirements are met in the work.

Before the installation of fasteners in the work, the Engineer will check the markings, lot identifications, surface condition and lubrication, storage of all bolts, nuts and washers and the faying surfaces of joints for compliance with requirements of Sections 615.3.2, 615.5.6.2, 615.5.6.3 and 709.24.9. The

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Engineer will observe calibration and testing procedures required in Section 615.5.6.3 to confirm the procedure is properly used and, when so used with the fastener assemblies supplied, the tensions specified in Table 615.5.6.3 A are provided. The Engineer will observe the installation of fasteners in the work to assure the procedure, as demonstrated in the initial testing to provide specified tension, is routinely properly applied. Bolts installed by the turn-of-nut method may reach tensions substantially above the values given in Table 615.5.6.3 A, but this shall not be cause for rejection.

**615.5.7-Welding:** Fabrication of welded members, welding, welder qualifications, prequalification of weld details and inspection of welds shall conform to the requirements of the ANSI/AASHTO/AWS Bridge Welding Code D1.5. Ultrasonic testing (UT) may be used for nondestructive testing of butt welded joints in lieu of radiographic testing (RT) at the Contractor's option.

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.

All of the above requirements apply equally to both shop and field welding operations.

**615.6-ERECTION:**

**615.6.1-General:** The Contractor shall provide all tools, machinery, and equipment necessary to erect the structure. The Contractor shall prepare and submit to the Engineer for approval, plans for falsework or for changes in the existing structure necessary for maintaining traffic. The falsework shall be properly designed and substantially constructed and maintained for the loads which will come upon it (see 615.2.2). Approval of the Contractor's plans shall not be considered as relieving the Contractor of any responsibility. In addition to the above, the Contractor's West Virginia Registered Professional Engineer shall certify to the Engineer that the falsework system has been assembled according to the approved falsework drawings, prior to placing loads on the falsework.

**615.6.2-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 damage from deflection. If the contract is for erection only, the Contractor shall check the material against the shipping lists and report promptly in writing any shortage or damaged discovered. The Contractor shall be responsible for the loss of any material while in their care, or for any damage caused to it after being received by the Contractor.

**615.6.3-Bearings and Anchorage's:** Masonry bearing plates shall not be

placed upon bridge-seat bearings which are improperly finished, deformed, or irregular. Bearing plates shall be set level in exact position and shall have a full and even bearing upon the masonry. Preformed fabric pads, of the thickness shown on the Plans, shall be placed between the bearings and the masonry. The preformed fabric pads or other material when specified, shall be included in the price bid for structural steel.

The Contractor shall drill the holes and set the anchor bolts, except where the bolts are built into the masonry. The bolts shall be set accurately and fixed with portland cement grout completely filling the holes. The location of anchor bolts in relation to the slotted holes in the expansion shoes shall correspond with the temperature at the time of erection. The nuts or anchor bolts at the expansion ends of spans shall be adjusted to permit the free movement of the span.

**615.6.4-Erection Procedure:**

**615.6.4.1-Conformance to Drawings:** The erection procedure shall conform to the erection drawings submitted in accordance with Section 615.2.2. Any modifications to or deviations from this erection procedure shall require revised drawings and verification of stresses and geometry by the Contractor's registered West Virginia Professional Engineer. The proposed revisions shall be approved by a West Virginia Registered Professional Engineer.

**615.6.4.2-Erection Stresses:** Any erection stresses that are induced in the structure as a result of the use of a method of erection or equipment which differs from that shown on the plans or specified, and which will remain in the finished structure as locked-in stresses shall be accounted for by the Contractor. The Contractor may provide additional material at their expense to keep both temporary and final stresses within the allowable limits used in design.

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.

**615.6.4.3-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.

**615.6.5-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 damage 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 all holes filled with high strength bolts before snug tightening begins. Snug tightening and final tightening shall be in accordance with Section 615.5.6.3.

Fitting-up bolts may be the same high-strength bolts used in the installation provided all requirements of Section 615.5.6 are strictly adhered to. 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 1/32 inch (1 mm) larger.

**615.6.6-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. Pin nuts shall be screwed up tight and the threads burred at the face of the nut with a pointed tool.

**615.6.7-Misfits:** The correction of minor misfits involving minor amounts of reaming 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. The Engineer's approval shall be obtained by the Contractor before any reaming of holes or other corrections are undertaken.

**615.6.8-Removal of Falsework and Cleaning Up of Site:** Upon completion of the erection and before final acceptance, the Contractor shall remove all falsework, excavated or useless materials, rubbish, and temporary buildings, shall restore, in an acceptable manner, all property which may have been damaged during the prosecution of the work, and shall leave the structure site and adjacent highway in a neat and presentable condition, satisfactory to the Engineer. All falsework or other obstructions placed in stream beds shall be removed by the Contractor.

**615.7-MEASUREMENT AND PAYMENT:**

**615.7.1-General:** Structural steel will be measured on a lump sum basis or on a pound (kilogram) basis, as required by the terms of the Contract, but it will be on a lump sum basis unless stipulated otherwise on the Plans.

Under contracts containing an item for structural steel, all metal parts, other than metal reinforcement for concrete, such as anchor bolts, nuts, shoes, rockers, rollers, bearing, and slab plate, pins and nuts, bolts embedded in concrete cradles and brackets, railing and railing posts, waterstops, preformed fabric or other type of bearing pads, and roadway drainage system when this material is connected to the metal work, will be paid for as structural steel unless otherwise noted, stipulated, or listed as separate pay items.

Steel grid flooring will be measured and paid for as structural steel only if noted on the Plans.

**615.7.2-Lump Sum Contracts:** In the case of a lump sum bid, it shall be the Contractor's responsibility to determine the weight on which he bases his bid, for the weight of structural steel shown on the Plans is approximate only. In the event of discrepancy between the Plan weight and the actual weight, no increase or decrease in the Contract lump sum price bid for the item will be made on account of such discrepancy.

**615.7.3-Pound Price Contracts:**

**615.7.3.1-General:** The payment in pound-price contracts will be based on the computed net weight of metal in the fabricated and erected structures, or on certified scale weights when so specified on the Plans. The weight of temporary erection bolts, drift pins, 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.

**615.7.3.2-Computed Weights Net:** The weight of the metal work to be paid for under the Contract for structural steel will be computed on the following basis:

| | UNIT WEIGHTS PER CUBIC FOOT | UNIT KG PER CUBIC METER |
|---|---|---|
| Aluminum cast or wrought | 173.0 | 2772 |
| Bronze, cast | 536.0 | 8586 |
| Copper-alloy | 536.0 | 8586 |
| Copper sheet | 558.0 | 8938 |
| Iron, cast | 445.0 | 7128 |
| Iron, malleable | 470.0 | 7529 |
| Iron, wrought | 487.0 | 7801 |
| Lead, sheet | 707.0 | 11 325 |
| Steel: rolled, cast, copper bearing, silicon, nickel and stainless | 490.0 | 7849 |
| Zinc | 450.0 | 7208 |

ii. The weights of rolled shapes will be computed on the basis of their nominal weights per foot (meter) as shown on the drawings or listed in the handbooks. The weights of plates will be computed on the basis of the nominal weight of the width and thickness as shown on the drawings, plus an estimated overrun computed as one-half of the "Permissible Variation in Thickness and Weight" as tabulated in

**615.7.3.2**

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iii. The weights of castings will be computed from the dimensions shown on the approved shop drawings, deducting for open holes. To this weight will be added five percent 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.

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

v. In computing pay weight on the basis of computed net weight, the following additional stipulations will apply:

The weight of all high-strength bolt heads, nuts, single washers and thread stick-throughs, both field and shop, will be included on the basis of Table 615.7.3.2.

**TABLE 615.7.3.2 (ENGLISH)**

| Nominal Diameter of High-Strength Bolt in Inches | WEIGHT PER 100 UNITS IN LB |
|---|---|
| | Bolt Head, Nut, One Washer and Stick-Through |
| ½ | 22 |
| ⅝ | 33 |
| ¾ | 55 |
| ⅞ | 84 |
| 1 | 120 |
| 1⅛ | 169 |
| 1¼ | 216 |

| TABLE 615.7.3.2 (METRIC) | |
|---|---|
| Nominal Diameter of High-Strength Bolt in Millimeters | Weight Per 100 Units in kg |
| | Bolt Head, Nut, One Washer and Stick-Through |
| M16 | 15.1 |
| M20 | 26.2 |
| M22 | 37.7 |
| M24 | 51.4 |
| M27 | 72.4 |
| M30 | 92.6 |

The weight of weld metal will be computed on the basis of the theoretical volume from dimensions of the welds.

**615.8-BASIS OF PAYMENT:**

The quantities, determined as provided above, will be paid for at the contract unit prices bid for the items listed below, which prices and payments shall be full compensation for furnishing all the material and doing all the work herein prescribed in a workmanlike and acceptable manner including all labor, tools, equipment, supplies, falsework, painting, and incidentals necessary to complete the work.

**615.9-PAY ITEMS:**

| ITEM | DESCRIPTION | UNIT |
|---|---|---|
| 615001-* | STEEL SUPERSTRUCTURE | LUMP SUM |
| 615002-* | PREFABRICATED STEEL BRIDGE SUPERSTRUCTURE | LUMP SUM |
| 615003-* | FABRICATED STRUCTURAL STEEL | LUMP SUM |
| 615004-* | FABRICATED STRUCTURAL STEEL | POUND (KILOGRAM) |

* Sequence number

**SECTION 616 – BLANK**