Section 2408. Steel Structures

2408.01 DESCRIPTION.

A. Fabrication and erection of:

1. All types of bridge structures for which the main members spanning the various supports are composed of steel.

2. Other structures or parts of structures where the design or intended use of steel is based on physical or chemical properties of the steel.

B. The quality of work and finish is to be equal to the best practice in modern bridge shops. Perform shearing and chipping neatly and accurately. Neatly finish all portions of the work exposed to view.

2408.02 MATERIALS REQUIREMENTS, IDENTIFICATION, AND FABRICATION.

Unless elsewhere modified in the contract documents, all fabrication to which this section applies shall be done in the states, territories, and possessions of the United States and in other locations within the geographic limits of North America and in steel fabrication shops and plants that are approved prior to the letting according to Materials I.M. 557. All main member fabrication, except bearing devices, must be fabricated by plants certified as Category III, Major Steel Bridges, under the provisions of AISC's Quality Certification Program.

A. Base Materials.
Use materials meeting the requirements of Division 41 for the following:

1. Rolled Plates, Shapes, and Eyebars.
Apply Section 4152.

2. Forgings and Castings.
Apply Section 4153.

3. Bronze Metal (rolled or cast).
Apply Article 4190.03.

4. Bolts, Nuts, and Washers.
Apply Article 4153.06.

5. Bearing Pads.
Apply Article 4195.02.

6. Galvanizing.
Apply Article 4100.07.

B. Identification of Steel during Fabrication.

1. Main members of steel structures are defined to include the following. The contract documents may also designate other members as main members.

- Rolled sections or flange and web plates in main beams and girders,
- Floor beams,
- Stringers,
- Abutment diaphragms,
- Cross frames carrying direct live loads,
- Lateral bracing and cross frames in horizontally curved bridges,
- Cover plates, splice plates, and gusset plates,
- Bearing stiffeners and bearing devices, and
- Stiffeners connecting live load carrying members to main beam or girder webs.

2. Before steel, as received, is cut for fabrication, provide the Engineer two copies of certified mill test reports showing chemical and physical test results for the steel involved.

3. For all steels, use a record keeping system for individual pieces, and issue cutting instructions to the shop that will maintain identity of the mill test report number. Generally, this record keeping system consists of cross referencing assembly marks shown on the shop drawings with the corresponding item, covered on the mill purchase order. Provide the inspector with a copy of the cutting instructions.

4. The Contractor may furnish material from stock which can be identified by heat number and mill test report.

5. Identify main members and component parts thereof by heat number, unless the Engineer allows exception. Ensure each piece of steel (other than ASTM A 709/A 709M Grade 36 (Grade 250) steel) clearly and legibly shows its proper color code. Maintain these identifications until the steel is cleaned for painting.

6. Provided the heat number or color code remains legible, individually marked pieces of steel may be used without further color coding if they are used in furnished size or reduced from furnished size only by end or edge trim that does not disturb the heat number or color code or leave any usable piece.

7. Before cutting, legibly mark pieces of steel (other than ASTM A 709/A 709M Grade 36 (Grade 250) steel) which are to be cut to smaller size pieces with the proper color code.

8. Upon being removed from the bundle or lift, immediately mark with the proper color code individual pieces of steel (other than ASTM A 709/A 709M Grade 36 (Grade 250) steel) which are furnished in tagged lifts or bundles.

9. Mark for grade by steel die stamping, or by a firmly attached substantial tag, pieces of steel (other than ASTM A 709/A 709M Grade 36 (Grade 250) steel) which, prior to assembling into members, will be subject to

fabricating operations, for example blast cleaning, galvanizing, heating for forming, or painting, that might obliterate paint color code marking.

10. During fabrication, up to the point of assembling members, ensure each piece of steel (other than ASTM A 709/A 709M Grade 36 (Grade 250) steel) clearly and legibly shows its specification identification color code as shown in Table 2408.02-1:

Table 2408.02-1: Specification Identification Color Code

Section	Steel Grade	Color Code
ASTM A709/A 709M	100 (690)	Red
ASTM A 709/A 709M	100W (690W)	Red and Orange
ASTM A 709/A 709M	50 (345)	Green and Yellow
ASTM A 709/A 709M	50W (345W)	Blue and Yellow

11. Ensure other steels not covered above and not included in ASTM A 6/A 6M have an individual color code established and on record for the Engineer.

12. Provide an affidavit in the form of a cutting list, listing heat numbers and grade of steel, and a statement certifying that throughout the fabrication operation the identification of steel has been maintained according to this specification.

C. Fasteners.

1. Where indicated in the contract documents, "rough bolted connections" may be used. In these connections, bolts may be hex-head bolts meeting the requirements of ASTM A 307. Ribbed bolts may be used when specified in the contract documents. Under the nut of each ASTM A 307 hex-head bolt, fit one ANSI B18.21.1 helical spring lock washer, except for:

- Expansion joint bolts that are to be removed after the expansion joint is installed, or
- Anchor bolts through slotted holes where a cut washer is provided.

2. When rough bolts or ribbed bolts are to be used, furnish 5% more than the number of bolts of each size and length shown in the contract documents. When turned bolts or high strength bolts are to be used, furnish 2% more than the number of bolts and corresponding washers and nuts shown in the contract documents.

D. Pins and Rollers.

1. Turn pins and rollers to the specified dimensions. Ensure they are smooth, straight, and free from flaws.

2. Forge and anneal pins and rollers more than 9 inches (225 mm) in diameter.

3. For pins larger than 9 inches (225 mm) in diameter, longitudinally bore a 2 inch (50 mm) hole through the center after the forging has cooled below the critical range and before the forging is annealed. Reject pins showing a defective interior condition.

E. Bars and Plates.

1. Unless otherwise noted on the plans, and as excepted below, roll edges of all main stress carrying members composed of plates and all steel material designated on plans as "bar" or "UM plate". They may be thermal cut, provided that with thermal cut plates a smooth surface is secured by the use of a mechanical guide the Engineer approves according to Article 2408.03, B. Web splice plates and bearing stiffeners 5/8 inch (16 mm) or less in thickness may be made of sheared plates.

2. Unless otherwise noted in the contract documents, secondary stress members may be made of sheared plates. If sheared plates are used, dull their exposed sharp corners by grinding.

3. Cut plates so the direction of stress in main members is in the direction of rolling, except web splice plates.

4. For main stress carrying members, use members defined in Article 2408.02, B as main members.

F. Bent Plates.
Use unwelded, cold bent, load carrying, rolled steel plates complying with the following:

1. They are taken from the stock plates so the bend line is at right angles to the direction of rolling.

2. They are bent in such a manner that no cracking of the plate occurs. Minimum bend radii, measured to the concave face of the metal, are shown in Table 2408.02-2 for all grades of structural steel in this specification.

Table 2408.02-2: Minimum Bend Radii

Thickness in Inches (millimeters)					
	Up to 1/2 (12)	Over ½ to 1 (12 to 25)	Over 1 to 1 1/2 (25 to 40)	Over 1 1/2 to 2 1/2 (40 to 60)	Over 2 1/2 to 4 (60 to 100)
Minimum Bend Radii for Metal Thickness (t)	2t	2.5t	3t	3.5t	4t
NOTE: Low alloy steel in thickness over 2 1/2 inch (12 mm) may require hot bending for small radii.					

a. Allowance for springback of ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel should be about three times that for structural carbon steel. For brake press forming, the lower die span should be at least 16 times the plate thickness. Multiple hits are advised.

b. If a shorter radius is essential, hot bend plates at a temperature no greater than 1200°F (650°C), except for ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel. If ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel plates are bent at temperatures greater than 1125°F (610°C), they must be requenched and tempered in accordance with the producing mill's practice. For hot bent plates, conform to Article 2408.02, F, 1.

3. Before they are bent, round the plate corners to a radius of 1/16 inch (1.6 mm) throughout that portion of the plate at which the bending is to occur.

G. Sheared Edge Finish.

Plane, to a depth of 1/4 inch (6 mm), sheared edges of plates more than 5/8 inch (16 mm) in thickness and carrying calculated stress. Grind, if necessary, to secure a finish equivalent to an ANSI 1000 (25 µm) surface roughness. Fillet re-entrant corners to a minimum radius of 1 inch (25 mm) before cutting.

H. Thermal Cutting.

Apply Article 2408.03, B. Thermal cut main stress carrying members only when the steel in the area of the cut is above 40°F (4°C) and in a dry surface condition.

I. Stress Relief Heat Treatment.

1. For structural members which are indicated in the contract documents to be stress relieved, perform finish machining, boring, and straightening subsequent to heat treatment. Perform stress relief heat treatment according to Section 4.4 AASHTO/AWS D1.5M/D1.5-02.

2. Do not anneal or normalize members made of ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel. Stress relieve only with the Engineer’s approval.

3. For each furnace charge, maintain a record that identifies pieces in the charge and shows the temperatures and schedule actually used. Provide instruments, such as recording pyrometers, for determining the temperature of members in the furnace at any time. Submit the treatment operation records to the Engineer for approval.

4. Unless stated otherwise in the contract documents, stress relieve all members, such as bridge shoes, pedestals, rockers, or other parts, which are built up by welding sections of plate together.

J. Plate Girders.

Fabricate welded plate girders according to the following requirements:

1. Web Plates.

a. Cut edges of a girder web true and straight or to camber and other detailed curvatures with the accuracy necessary to serve a correct fit up to the flange plate.

b. Weld web plates completely in shop separately before assembly with the flange plates as shown in the contract documents.

2. Web Stiffeners.

a. Bearing Stiffeners.

1) Ensure end stiffeners of girders and stiffeners intended as supports for concentrated loads have full bearing on the flanges to which they transmit load or from which they receive load.

2) Mill or grind these surfaces, or on weldable steel in compression areas of flanges, weld as shown in the contract documents.

b. Intermediate Stiffeners.

Ensure intermediate stiffeners (not intended to support concentrated loads) fit sufficiently tight to be in close contact with the flanges, unless shown or specified otherwise.

c. Stiffener Welding.

1) Start the fillet welds connecting the stiffener or connection plate to the web at the end of the stiffener that is adjacent to the tension flange.

2) Progress toward the compression flange.

3) Before welding, ensure no gap exists between the web and the intermediate stiffeners, bearing stiffener, or connection plates in excess of 3/32 inch (2.4 mm).

3. Flange Plates.

a. Fabricate flange plates using universal mill plates or thermal cut plates which are cut according to Article 2408.02, H.

b. Weld flange plates for welded girders completely in shop separately before assembly with the web plate as shown in the contract documents.

4. Tack Welding.

Submit tack welding and fit up procedures to the Engineer for review and approval.

K. Camber of Rolled Beam and Plate Girder Spans.

1. When specified in the contract documents, camber the rolled beams and plate girders constituting the main supporting members of a span. Unless specified otherwise in the contract documents, camber to a uniform, approximately circular curve for the entire length of the beam or between designated points. Compound or reverse curves may be required on special designs as shown on the plans.

2. Camber of beam spans may be produced either in the rolling mill or in the fabricating shop. Camber of beam spans may also be induced or corrected by local heating. In all cases, ensure beams conform to the specified shape within tolerance limits. Ensure beams are free from kinks, buckles, or other local imperfections. Improper heating or cooling which might affect grain structure, strength, or ductility of the metal are causes for rejection.

3. Rolled beams may be cambered by heating in the following manner:

- **a.** Complete welding of cover plates before commencing final heating operations.
- **b.** Support the beam near its ends in such a manner that the side to be made concave faces upward.
- **c.** Apply heat with an oxyacetylene, butane, natural gas, or other approved gas flame to areas so selected that distortion other than the required camber will not occur. Apply heat by playing the flame over the section to be heated until the metal attains a temperature of 1000°F to 1200°F (540°C to 650°C). Use temperature indicating crayons, liquids, or bimetal thermometers to control the temperature. Notify the Engineer before any heating is done.

4. Use wedge or triangular shaped heated areas with an included angle between 20 and 45 degrees. Locate the vertex of the angle approximately 1 inch (25 mm) above the point on the web midway between flanges. Slowly play the flame from the torch (or torches) over the area to be heated. Commence at the vertex of the angle and finish at the widest part of the heated wedge, which extends across the width of the flange on the side to be made concave. Manipulate the torch (or torches) so that the total area of the heated zone is rapidly brought to the proper temperature at the same time as nearly as practical.

5. Uniformly space the heated sections at short intervals to produce uniform curvature. Heat no fewer than three sections. Heating of additional sections may be required in the case of unusually long or heavily cambered beams. Air cool the metal slowly and away from wind or drafts. Do not use water to cool the metal. Do not heat any area more than once.

6. Camber plate girders by cutting the web plate to the proper curvature to produce a camber within the allowable tolerance. When cutting the web plate, include an allowance to compensate for the effect of the heat of welding operations to be performed on the girder during fabrication.

7. Do not induce or correct camber in plate girders by local heating without the Engineer's prior approval. Do not heat ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steels.

L. Bolt Holes.

1. General.

a. Drill or punch all bolt holes. Do not punch holes in metal thicker than 3/4 inch (19 mm) for carbon steel and 5/8 inch (16 mm) for alloy steel. Instead, subdrill and ream holes, or drill holes to full size. Subpunch and ream, subdrill and ream, or drill full size holes in main stress carrying members. Punch or drill full size holes for members (other than main stress carrying members) made of metal no thicker than 3/4 inch (19 mm) for carbon steel and 5/8 inch (16 mm) for alloy steel.

b. When reaming is required, subpunch or subdrill all holes. Subdrilling will be required if thickness limitations govern. Subpunch or subdrill holes 3/16 inch (5 mm) smaller than the nominal diameter of the bolts. After assembling, either ream holes to 1/16 inch (2 mm) larger or drill holes full size to 1/16 inch (2 mm) larger than the nominal diameter of the bolts.

c. In steel templates, place hardened steel bushings in holes accurately dimensioned from the centerline of the connections as inscribed on the template. Use the centerline to accurately locate the template from the milled or scribed ends of the members.

2. Punched Holes.

Limit the diameter of the die to at the most 1/16 inch (2 mm) more than the diameter of the punch. If any holes must be enlarged to admit the bolts, do so by reaming. Holes shall be clean cut without torn or ragged edges. The slightly conical hole that naturally results from punching operations is considered acceptable with the Engineer's approval.

3. Reamed or Drilled Holes.

Ream or drill holes cylindrical and perpendicular to the member. Where practical, use mechanical means to direct reamers. Perform reaming and drilling using twist drills, twist reamers or rotobroach cutters. Assemble connecting parts that require reamed or drilled holes and then securely hold while reaming or drilling. Match-mark parts before disassembling.

4. Accuracy of Holes.

Holes fabricated using a drill or reamer of the nominal diameter and not more than 1/32 inch (1 mm) larger in diameter than the true decimal equivalent of the nominal diameter are considered acceptable. Limit the width of slotted holes, produced by flame cutting or a combination of drilling or punching and flame cutting, to no more than 1/32 inch (1 mm) greater than the nominal width. Grind the flame cut surface smooth.

5. Accuracy Before Reaming.

Subpunch or subdrill all holes accurately enough that after assembling (before any reaming is done) a cylindrical pin 1/8 inch (3 mm) smaller in

diameter than the nominal size of the 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 subpunched or subdrilled pieces will be rejected. Any hole that does not allow a pin 3/16 inch (5 mm) smaller in diameter than the nominal size of the subpunched or subdrilled hole to pass will be rejected.

6. Accuracy After Reaming or Drilling.
Ensure that at least 85% of reamed or drilled holes in a contiguous group show no offset greater than 1/32 inch (1 mm) between adjacent thicknesses of metal.

7. Misplaced Holes.
Misplaced holes may be a basis for rejection. Repair only with the Engineer's approval.

8. Removal of Burrs.
Remove burrs on outside or faying surfaces. If the Engineer requires, disassemble assembled parts to remove burrs.

M. Boring Pin Holes.
Unless otherwise required, bore pin holes to be: 1) true to detailed dimensions; 2) smooth; and 3) straight at right angles with the axis of the member and parallel with each other. Finish cut according to Article 2408.03, E.

N. Reaming Subpunched Field Connections.

1. When subpunched and reamed holes are required for field connections, fully assemble main members of the structure and firmly bolt together.

2. Adjust main members to line and fit before reaming holes in connecting joints.

3. Before parts are disassembled for shipping and handling, match-mark respective pieces with a low stress riser steel stamp so that they can be reassembled in the same position when the structure is erected in the field. Steel stamping on the edges of plates will not be permitted.

4. In lieu of subpunching and reaming holes, the fabricator may drill holes full size, while members are assembled, by any of the following procedures:

- By laying out the location of the holes on the outside plate with center punch marks and drilling full size, or
- By subpunching holes in the outside plate and enlarging subpunched holes by drilling full size, and drilling full size through the remaining plates, or
- By predrilling splice plates or plates full size and using these as a template to drill full size through the remaining plates.

5. Ensure the accuracy of drilled holes is as specified in Article 2408.02, L, 4.

6. Do not interchange reamed parts. Ream connecting joints (such as floor beam and stringer connections not assembled as provided above) to a metal template.

O. Pilot and Driving Nuts.

On pin connected spans, furnish pilot and driving nuts for each size pin, unless provided otherwise in the contract documents.

P. Mill and Shop Inspection.

1. **General.**
   - **a.** Provide the Engineer ample notice of the beginning of work at the mill and shop so inspection may be provided. Mill inspection of rolling will not be required unless the Engineer requests. If inspection of rolling is not requested, provide the Engineer complete test reports of mill inspections, showing chemical and physical tests for each heat of all structural steel sections as specified in Articles 2408.02, A and 4152.02.
   - **b.** Notify the Engineer before fabricating material.

2. **Inspector's Authority.**
   - **a.** The inspector has the authority to reject material or work which does not fulfill the requirements of these specifications. In cases of dispute, appeal to the Engineer, whose decision is final.
   - **b.** 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 from any responsibility in regard to imperfect material or quality of work and the necessity for replacing the same.

3. **Facilities for Inspection.**
   Furnish facilities for inspection of material and workmanship in the mill and shop. Allow inspectors free access to necessary parts of the premises.

4. **Mill Orders and Shipping Statements.**
   Provide the Engineer with as many copies of mill orders and shipping statements (showing the weights (mass) of individual members) as may be requested.

5. **Rejection.**
   Approval of any material or finished members will not be a bar to their subsequent rejection, if found defective. Promptly replace, or make good, rejected material and work.

Q. Shop Painting.

This portion describes surface preparation and shop painting of weathering and non-weathering structural steel and incidental parts, as well as the requirements for water washing of weathering structural steel. The work

includes the following items: preparation of all surfaces to be painted, application of paint, protection, drying of paint coatings, and repairing and repainting of coating damaged in the shop or after erection, or both.

1. Surface Preparation.

a. General.

1) Provide a near white metal blast cleaning to steel surfaces to be painted according to SSPC-SP10. First clean bearing assemblies of any surface contamination using suitable solvents according to SSPC-SP1, and then provide a near white metal blast cleaning according to SSPC-SP10. The standard used for acceptance of the surface preparation will be SSPC-VIS 1, Visual Standard for Abrasive Blast Cleaned Steel.

2) Do not blast clean machined surfaces designated in the contract documents to have a surface roughness of ANSI 125 (3.125 µm) or less. Masking or other protection is required if these parts are subjected to the blast cleaning process.

3) Use a clean, dry abrasive free from organic contamination. After blasting, thoroughly clean the surface to be painted with dry, oil free, compressed air to remove all blast residue.

4) Achieve a sharp, angular blast profile of a minimum 1 mil (25 µm) and maximum 3 mils (75 µm) on all surfaces, including thermal cut edges. When shot is used for blasting, use a blast media containing at least 10% steel grit.

b. Non-weathering Structural Steel Applications.

1) Remove oily or greasy residues with solvent according to SSPC-SP1, Solvent Cleaning, before the top coat is applied.

2) Ensure surfaces to be top coated comply with the specifications and are dry.

c. Weathering Structural Steel Applications.

1) For weathering structural steel applications, provide a Commercial Blast according to specification SSPC-SP6 to surfaces not requiring painting.

2) After blasting, apply at least three uniform applications of water mist (at 24 hour intervals between applications) to all unpainted areas of outside surfaces of the fascia girders to ensure uniform weathering. Apply each application on dry surfaces. Perform the water mist application within 48 hours after the painted surfaces have been properly cured. Ensure all water mist applications are witnessed by a representative of the Contracting Authority.

2. Painting.

a. General.

1) Perform shop painting only in a facility approved by AISC, SSPC, or the Engineer. Allow only painters who are trained and certified by an independent outside agency for the type of work performed to apply the paint.

2) Prior to painting, ensure all surfaces are free of all moisture, dirt, oxidation products, oil, and other detrimental material, and is of a suitable temperature according to the manufacturer's

recommendations. Follow the paint manufacturer's application recommendations regarding mixing, thinning, application, pot life, steel temperature, and weather conditions. Apply paint so the painted areas have a smooth, uniform, adhering coat that is free of over-spray, dry spray, mud cracking, runs, sags, cracks, holidays, or other defects.

3) Do not paint machined surfaces with small clearances between moving components, such as full circle pins and pin holes, partial circle pins and pin recesses in castings, and similar surfaces. Instead, shop coat these surfaces with an application of waterproof multipurpose grease complying with National Lubricating Grease Institute No. 3, or other approved protective coating. Thoroughly clean machined surfaces before applying grease. Apply protective coating as soon as practical after component parts have been machined, welded if required, and blasted.

4) Before erection, wipe machined surfaces clean and apply a second shop coat of the same grease used above.

b. Non-weathering Structural Steel Applications.

1) General.

a) Use prime coat and topcoat paints manufactured by the same company. Protect painted surfaces to prevent soiling during painting and through the tack-free stage. Take care not to damage the paint system during handling, delivery, storage, and erection of the structural steel. Repair prime coat damage attributable to shop activities according to the paint manufacturer's recommendations before shipment to the field. Repair topcoat damage according to the manufacturer's recommendations.

b) Shop apply a prime coat to structural steel surfaces, including faying surfaces of high strength bolt connections. Also shop apply a prime coat to all bearing assemblies, except galvanized masonry plates and galvanized swedged bolts unless specified otherwise in the plans.

2) Shear Studs.

a) When shear studs are welded to the top of the top flange of a beam or girder after the paint system is applied, grind the paint off in the areas of the weld to facilitate welding.

b) After welding, repair paint damage on the underside of the top flange. Touch-up on the top side of the top flange is not required (this will be covered with PCC).

3) Prime Coat.

a) Apply a coat of zinc silicate paint to all surfaces as soon as possible after blasting and before formation of any surface rust, and no later than 16 hours after blasting the surface. Approved paints are shown in Materials I.M. 482.02, Appendix A. Use a target average dry film thickness of 4 mils (100 µm) with no spot measurement below 3 mils (75 µm) or above 6 mils (150 µm).

b) Perform repairs or build-up of the paint film as soon as possible, and no later than 24 hours from the initial application.

c) Completely reblast and repaint steel members with coating areas measuring less than 3 mils (75 µm) that have not been corrected within 24 hours.

d) Correct, to the Engineer's satisfaction, all defects in application such as runs, sags, mud cracking, over-spray, and dry spray.

e) Excessive coating thickness is as equally undesirable as unacceptably thin coating thickness, and both will be sufficient cause for rejection. Excessive thickness will be evaluated on a case-by-case basis in consultation with the coating manufacturer.

f) Inorganic zinc silicate paint film will be considered cured and ready for shipment after achieving a resistance rating of 4 as verified by 50 Methyl Ethyl Ketone (MEK) rubs as per ASTM D 4752. Moisture misting and plastic tenting may be required during cold application temperatures and low relative humidity conditions to aid in prime coat curing.

4) Top Coat.

a) When designated by the contract documents, shop apply a topcoat of waterborne acrylic paint to all primed surfaces. Paint galvanized fasteners according to Article 2408.02, Q, 2, b, 5, after bolting. It is recommended that application be initiated with a mist coat applied prior to full coat application. To avoid moisture condensation, keep the top coat under a roof, protected from dirt, dust, and moisture, in an area where the temperature is maintained above 40°F (5°C) for a minimum 24 hours after painting is completed.

b) Shield concrete at all junction points of concrete and steel so that application of paint on steel is complete without overspray on the concrete.

c) Approved paints are listed in Materials I.M. 482.05, Appendix A. Ensure the dry film thickness of the top coat is a minimum of 2 mils (50 µm). Unless otherwise specified in the contract documents, use a topcoat color that is Iowa standard foliage green Federal Color Standard Number 14223.

5) Field Repair and Painting.

a) After erection, repair and repaint paint damage due to transportation, handling, or construction activities. Use an approved zinc rich epoxy paint listed in Materials I.M. 482.02, Appendix C, for repairing primer, priming un-galvanized fasteners, and any coating damage to galvanized fasteners.

b) Ensure areas to be repaired and repainted are clean, dry, and free from grease, oil, corrosion products, and other detrimental materials. Do not apply paint to surfaces unless they are free from moisture or frost. Follow the paint manufacturer's recommendations for repair.

c) When designated by the contract documents, include a field applied waterborne acrylic topcoat.

6) Cleaning of Paint Surfaces.
Upon completion of concrete placement, clean exposed structural steel surfaces to remove all concrete and laitance before the concrete sets up.

c. Weathering Structural Steel Applications.

1) Apply a coat of zinc silicate paint to all surfaces as soon as possible after blasting and before formation of any surface rust, and no later than 16 hours after blasting the surface. Approved paints are shown in Materials I.M. 482.02, Appendix A and Appendix C. Ensure the minimum average dry film thickness is 4 mils (100 µm) with no spot measurement below 3 mils (75 µm) or above 6 mils (150 µm). Perform any repairs or build up to the applied prime coat as soon as possible and no later than 24 hours from the initial application.

2) Apply a top coat of waterborne acrylic paint from the approved lists shown in Materials I.M.s 482.05, Appendix A; or 482.07, Appendix A, to the primed surfaces after the primer has cured to a resistance rating of 4 as verified by 50 MEK rubs as per ASTM D 4752 for inorganic zinc rich primers. Use a top coat color matching Federal Color Standard Number 20045. Ensure the top coat covers all the primed surfaces, except faying surfaces of bolted joints, with a uniform film of paint. Apply the top coat in the shop unless otherwise permitted in writing by the Engineer.

3) Paint the following areas:

- **a)** All the weathering steel for a distance of 1.5 times the girder depth on each side of the expansion joints.
- **b)** All the bearing assemblies except galvanized masonry plates and galvanized swedged bolts unless specified otherwise in the plans.
- **c)** Embedded girder ends over the entire embedment length plus an additional distance of 1.0 foot (300 mm). Seal the crevice between the embedded steel and concrete by caulking with a neutral cure and non-sag silicone. Two products meeting these criteria are Dow 888 or CSL 342 joint seal.
- **d)** Prepare exterior surfaces of all galvanized components indicated in the plans to be painted and all galvanized floor drains according to the written recommendations of the paint manufacturer. Paint with the same type of waterborne acrylic paint used for top coat as noted in this specification.

4) After erection of the bridge, prepare all fasteners in the painted areas using suitable hand tools, mechanical tools, or blasting equipment. Prime with a zinc rich epoxy paint from the approved list shown in Materials I.M. 482.02, Appendix C. Clean the primed surfaces and apply a top coat of waterborne acrylic paint from the approved list shown in Materials I.M. 482.05, Appendix A. Use a top coat color matching Federal Color Standard Number 20045.

5) After completing construction, prepare and repaint defects or damage to the paint system.

6) Ensure all steel surfaces are free of contaminants, including dirt or concrete.

R. Marking and Shipping.

1. Ship pins, small parts, and small packages of bolts, washers, and nuts in boxes, crates, kegs, or barrels. Do not allow the gross weight (mass) of any package to exceed 300 pounds (135 kg). Plainly mark a list and description of the contained material on the outside of the shipping container.

2. Pack bolts of one length and diameter and loose nuts or washers of each size separately. Also pack items from different manufacturers or from different lots separately.

S. Shop Storage of Material.
Store structural material, whether plain or fabricated, above ground upon platforms, skids, or other supports. Keep it free from dirt, grease, and other foreign material.

2408.03 CONSTRUCTION.
Place the steel superstructure on a substructure constructed as provided in Section 2405. Apply the requirements of Sections 2403, 2404, 2410, 2411, 2412, 2413, and 2508 to the various types of construction.

A. Working Drawings, Shop Drawings, Changes, and Substitutions.
Submit detailed shop drawings according to Article 1105.03. Welding procedures will be considered an integral part of shop drawings and will be reviewed for each contract.

1. All material ordered or work done prior to review of the shop drawings is at the Contractor's risk. Ensure shop drawings for steel structures give detailed dimensions and sizes of component parts of the structure and details of all miscellaneous parts, such as pins, nuts, bolts, drains, etc.

2. Ensure shop drawings identify each piece that is to be made of steel required to be other than ASTM A 709/A 709M Grade 36 (Grade 250) steel. Ensure pieces made of different grades of steel are not given the same assembling or erecting mark, even though they are of identical dimensions and detail.

3. Sections other than those shown on shop drawings reviewed by the Engineer may be used under the following provisions:
- **a.** The substitute section is equal in strength and stiffness to the section originally shown.
- **b.** The substitution is approved by the Engineer.
- **c.** The substitution is made at no additional cost to the Contracting Authority.

4. Ensure shop drawings for steel structures show accumulated dimensions for each line of beams or girders in laydown. Ensure the accumulated dimensions are shown at the locations of the following

details: bearings, welded or bolted splices, stiffeners, gusset plates, and drain connecting holes.

B. Welding.

1. Comply with ANSI/AWS D1.1 Structural Welding Code procedures and requirements for the following items, except comply with AASHTO/AWS D1.5M/D1.5-02 as modified below for filler metal and welder qualification requirements.

- **a.** Bridge Components and Miscellaneous Items. This includes bearing assemblies, sole plates, expansion joint devices, pile and appurtenances, drainage system components, guardrail connections, metal railing, chain link enclosures and wire fence components, conduit systems, and tread plates.
- **b.** Traffic Signal Components.
- **c.** Sign Support Components.
- **d.** Lighting Structure Components.
- **e.** Pre-Engineered Pedestrian Bridges.

2. Comply with AASHTO/AWS D1.5M/D1.5-02, as modified by this specification, for welding and fabricating steel structures.

3. Each of the modifications in this article is referenced by the appropriate paragraph number in AASHTO/AWS D1.5M/D1.5-02, to which it is a modification.

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for
Modifications to ANSI/AASHTO/AWS D1.5 95 Bridge Welding Code

SECTION 1. General Provisions

1.3 Welding Processes

ADD the following Paragraphs after the existing 1.3.1:

1.3.1.1 Welding of main members and welding of attachments thereto shall be performed using only shielded metal arc, flux cored arc, submerged arc, and/or stud welding processes. Unless otherwise approved by the Engineer, all welding of butt splices and flange to web welds and stiffeners to web welds shall be done using the submerged arc process. Shielded metal arc welding may be used for repairs to butt splices and flange to web welds.

1.3.1.2 The WPS shall be initialed by the welder and posted at the welder's workstation at all times during welding operations.

REPLACE Paragraph 1.3.2 with the following:

Electroslag (ESW) and electrogas (EGW) welding are specifically disapproved for use.

SECTION 3. Workmanship

3.2 Preparation of Base Metal

ADD the following paragraph before the existing first Paragraph 3.2.2:

For main members, thermal cutting is limited to oxygen cutting except that plasma arc cutting of web and stiffeners may be used when approved by the Engineer.

DELETE the last sentence of Paragraph 3.2.7 which reads "Excess Camber may be corrected by heating without the engineer's approval."

3.5 Dimensional Tolerances

REPLACE all of the text and tables of Paragraph 3.5.1.3 with the following:

Camber of main members of continuous or simple span bridges with lines composed of rolled beams, beams and girders, or girders, shall be fabricated so that when the members are assembled in laydown with bearing points accurately positioned as shown on the erection diagram, points on any member shall not vary in the offset position from that indicated in the erection diagram by more than ± 1/2 inch (13 mm).

The erection diagram on the shop drawings shall show camber offsets at bearing points and splice points, and at midpoints of individually cambered beams or girders.

REPLACE Paragraph 3.5.1.4 with the following:

Permissible variation in specified sweep for horizontally curved welded beams or girders is

$$\frac{\pm\ 1/8 \text{ in. x No. of ft. of total length}}{10} \quad (\pm\ 1 \text{ mm/m of the total length})$$

provided the member has sufficient lateral flexibility to permit the attachment of diaphragms, cross-frames, lateral bracing, etc., without damaging the structural member or its attachments.

REPLACE Paragraph 3.5.1.14 with the following:

Mechanically connected joints and splices of main members with surfaces intended to be parallel planes shall be nearly parallel after connection, and the surfaces to be in contact shall have an offset no greater than 1/16 inch (1.6 mm) after all filler plates have been added, if any. The accuracy of the angle of connecting stiffeners, angles, or plates shall be ± 0.5 degrees, when measured at the hole locations.

3.7 Repairs

REPLACE Paragraph 3.7.4 with the following:

Prior approval of the Engineer shall be obtained for repairs to base metal, repair of major or delayed cracks, or for a revised design to compensate for deficiencies.

ADD the following paragraph before the existing Paragraph 3.7.7:

The approval of the Engineer is required for all corrections of mislocated holes.

ADD the following Paragraph after the existing 3.7.7:

3.7.8 The maximum number of repairs to unacceptable defects in a butt splice shall be three, i.e., the times a butt splice may be opened, welded closed, and resubmitted for NDT inspection, unless otherwise approved by the Engineer.

SECTION 5. Qualifications

Part A. General Requirements

5.2 Qualification Responsibility

REPLACE Paragraph 5.2 with the following:

To qualify welding procedures, the Contractor shall produce test weldments, perform nondestructive testing and machine specimens for mechanical testing in accordance with this code. The Contracting Authority will witness the production of test weldments and conduct mechanical tests.

Part B. Welder, Welding Operator, and Tack Welder Qualification

5.21 General Requirements

REPLACE Paragraph 5.21.4 with the following**:**

Shop welder's, welding operator's, or tack welders qualification herein specified shall be considered as remaining in effect from the end of the month in which the tests were taken, for a period of 1 year. The

qualification for the above may be extended annually, based on a letter from the fabricator/Contractor certifying that they have been engaged in the process(es) for which they qualified without interruption of more than 6 months during the preceding twelve months, or by requalification. The field welder's qualification herein specified will be considered as remaining in effect from the end of the month in which the test was taken, for a period of 1 year. For field welders who have successfully passed their qualification tests without failure for 3 consecutive years, requalification will only be required every 2 years. Requalification may be required at any time there is a specific reason to question a welder's ability to make sound welds.

5.21.6 Responsibility

REPLACE Paragraph 5.21.6.1 with the following:

To qualify welders, welding operators, and tackers, the Contractor shall furnish test weldments, and perform nondestructive testing in accordance with this code. The Contracting Authority shall witness the production of test weldments and conduct mechanical tests. The Contractor may, at no additional cost to the Contracting Authority, engage an outside firm or agency to witness production of test weldments and conduct mechanical tests. The acceptance of work performed by an outside firm or agency is the prerogative of the Contracting Authority.

5.23 Qualification Tests Required

ADD Subparagraph 5.23.1 (5) after the existing 5.23.1 (4):
Plate weld tests may also be accepted for qualification of welding pipe piling of any diameter.

REPLACE Paragraph 5.23.3 with the following:

Tack Welder Qualification. A tack welder shall be qualified by fillet-weld-break specimen made using the same criteria as listed for plate-fillet welder qualification in Table 5.6. The tack welder shall make a 1/4 inch (6 mm) maximum size tack weld approximately 2 inches (50 mm) long on the fillet-weld-break specimen, as shown in Fig. 5.28.

SECTION 6. Inspection

Part A. General Requirements

6.7 Nondestructive Testing

REPLACE Subparagraph 6.7.1.2(1) with the following:

100% of each joint subject to tension or reversals of stress, except that on vertical butt weld splices in beam or girder webs, only 1/3 of the web depth beginning at the point, or points, or maximum tension need be

tested. If unacceptable discontinuities are found in the first 1/3, the remainder of the weld shall be tested.

REPLACE Subparagraph 6.7.1.2(2) with the following:

50% of each joint subject to compression or shear in each main member including longitudinal butt weld splices in beam or girder webs. If unacceptable discontinuities are found in the first 50% of joint, the entire length shall be tested.

Part B. Radiographic Testing of Groove Welds in Butt Joints

6.10 Radiographic Procedure

ADD the following Paragraph after existing 6.10.5.3:

6.10.5.4 Where areas being radiographed are adjacent to the edge of the plate, edge block shall be used.

6.12 Examination, Report, and Disposition of Radiographs

REPLACE Paragraph 6.12.3 with the following:

Two sets of radiographs shall be taken for welds subject to radiographic testing, including any that show unacceptable quality prior to repair. One radiograph of each test shall, upon completion of Q.C. and Q. A. interpretation, be forwarded to the Office of Materials, Ames, Iowa. The second set of radiographs shall be retained by the Contractor as part of on-site inspection records. Upon completion of the project, this second set will become the property of the Contractor.

C. Shop Assembly.
Assemble the various parts of the structure in the shop as follows:

1. If zinc silicate primer is to be used, clean and shop paint surfaces which will be in contact before assembly according to the contract documents. If zinc silicate primer is not to be used, carefully clean to be free from loose mill scale, dirt, or other foreign material, surfaces which will be in contact. Do not paint before assembly.

2. After assembly, paint and protect all surfaces, except those against which plastic concrete will be placed, as provided in Article 2408.03, X, and the contract documents.

3. Ensure members are free from objectionable twists, bends, or other deformations.

4. Bring members to be welded into correct alignment and hold in position by bolts, clamps, wedges, guylines, struts, tack welds, or other suitable devices, until welding is completed. Use jigs and fixtures where practical. Allow for warpage and shrinkage.

D. Drifting of Bolt Holes.
Allow drifting during assembling only to the extent of bringing the parts into position, but not sufficient to enlarge the holes or distort the metal.

E. Facing Bearing Surfaces.

1. Mill ends of columns and pedestals to true surfaces and correct bevels. Plane warped or deformed base and cap plates to fit accurately.

2. Attach connection angles for base and cap plates to columns before ends are faced. Perform milling only after the member has been fully assembled.

3. Mill bearing surfaces of warped or deformed base and cap plates that are not to be placed in contact with concrete after the plates are attached to the column. Ensure surfaces of base plates that are to be placed in contact with concrete are free from warps and other deformations.

4. All bearing surfaces of castings are to be machined flat. Ensure that:
- Sole plates of beams, girders, and trusses have full contact with the flanges, and the bearing surface is smooth and true and is truly perpendicular to the web of the member.
- Curved sole plates make full line bearing with masonry plates, which line (unless shown otherwise in the contract documents) is at right angles to the axis of the beam, girder, or truss, and with the web of the member.
- Bottom surfaces of masonry plates are free from warps and projections.

5. For bearing material in contact with other material, except as otherwise indicated, apply the following tolerances for flatness:
   - 1/32 inch in 12 inches (1 mm in 400 mm), and
   - 1/16 inch (2 mm) tolerance overall.

6. The degree of surface finish required will be indicated in the contract documents. Ensure the surface finish of bearing and base plates and other bearing surfaces that are to come into contact with each other or with concrete meet the surface roughness requirements as defined in ANSI B46.1, Surface Roughness, Waviness and Lay, Part 1. Unless indicated otherwise on the plans, finish the following parts to the degree indicated in Table 2408.03-1:

Table 2408.03-1: Surface Finish

Steel slabs including masonry plates and cast shoes in contact with concrete	ANSI 2,000 (50 µm)
Heavy plates in contact in shoes to be welded	ANSI 1000 (25 µm)
Milled ends of compression members, stiffeners, and fillers	ANSI 500 (12.5 µm)
Bridge rollers, rockers, and top surfaces of masonry plates in contact with rollers and rockers	ANSI 250 (6.25 µm)
Pins and pinholes	ANSI 125 (3.125 µm)
Slide bearings	ANSI 125 (3.125 µm)

7. Ensure surfaces of bronze bearing plates intended for sliding bearings are smooth and free from surface projections.

8. In machining sliding bearing surfaces, set the cut of the tool to be in the direction of movement. In machining nonsliding bearing surfaces, set the cut of the tool to be either parallel or normal to the direction of movement.

F. Abutting Joints.

1. **Ends of Compression Members.**
   Accurately face abutting ends of compression members after the members are assembled, to secure an even bearing when assembled in the structure.

2. **Ends of Tension Members.**
   Neatly shear or cut ends of tension members at splices with openings not exceeding 1/4 inch (6 mm).

3. **Splices of Continuous Beams and Girders.**
   Neatly shear or cut ends of beams and girders to be spliced with a minimum opening of 1/8 inch (3 mm) and a maximum opening not exceeding 1/4 inch (6 mm) for rolled beam spans and 1/2 inch (13 mm) for plate girder spans. This dimension shall be detailed on the shop drawings.

G. End Connection Angles.

Ensure end connection angles of floor beams and stringers are flush with each other and accurately set to position and length of member. In general, do not machine end connection angles unless indicated in the contract documents. However, faulty assembling may be cause for requiring them to be milled. In this case, do not reduce their thickness by more than 1/16 inch (2 mm). Do not reduce their bolt bearing value below the design requirements.

H. Pin Clearance.

Ensure the diameter of the pin hole does not exceed that of the pin by more than 1/50 inch (0.5 mm) for pins 5 inches (125 mm) or less in diameter, or 1/32 inch (0.8 mm) for larger pins.

I. Finished Members.

Ensure pieces forming one built up member are straight and close fitting. Ensure finished members are true to detailed dimensions and free from twists, bends, open joints, or other defects resulting from faulty fabrication or defective work.

J. Shop Erection.

1. Completely assemble the main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames for inspection in the shop when complete assembly is feasible. In lieu of complete assembly, at the option of the Contractor, progressive truss or girder assembly will be permissible, as follows:

a. Initially for each truss, arch rib, bent, tower face, or rigid frame:

- Assemble at least three contiguous shop sections, or
- In the case of structures longer than 150 feet (45 m), assemble all members in at least three contiguous panels, but no less than the number of panels associated with three contiguous chord lengths (i.e., length between field splices) and no less than 150 feet (45 m).

b. In order that the assembled portion of the structure is never less than specified above, include a sufficient number of sections or chord lengths in each laydown so the assembled portion will remain long enough when the rearward section or chord is removed after inspection of the laydown. At the Contractor's option, the portion of the structure which is retained may be disassembled and reassembled in a new location for the new laydown.

c. Initially for each continuous beam or plate girder line, assemble at least three contiguous shop sections. In the case of structures larger than 150 feet (45 m), assemble no less than 150 feet (45 m) of structure. Accomplish each succeeding laydown in such a manner that at least one contiguous section is retained from the previous laydown, and no less than 150 feet (45 m) of structure is assembled (except that the last laydown in a line may be less than 150 feet (45 m) long). At the Contractor's option, the portion of the structure which is retained may be disassembled and reassembled in a new location for the new laydown.

2. As shop sections are progressively assembled and removed, place each retained section in the new laydown with the same relative orientation to the erection base line as it was found to have in the previous laydown.

3. As shop sections are progressively assembled and removed, scribe suitable marks on the sections remaining so that accurate center to center of bearing dimensions and overall length can be achieved.

K. Field Handling and Storage.

1. Load, transport, unload, and pile structural members so the metal will be kept clean and free from damage by rough handling. Pad shipping supports, lifting devices, and deck form support points to minimize paint damage.

2. Store material in a manner to prevent deterioration by rust or loss of minor parts. Do not pile material to rest upon the ground or in water; instead, place material on suitable skids or platforms. Place girders and beams upright and shore. Ensure skids beneath long members, such as columns or chords, are close enough to prevent damaging the members by deflection.

L. Falsework.

1. Provide detailed plans for falsework or centering, according to Article 1105.03. In no case is the Contractor relieved of responsibility for results obtained by use of these plans or safety of workers on the project. Have the Engineer review and check the adequacy of falsework before erecting the structure which the falsework is to carry.

2. Design falsework for supporting steel during erection to carry, without appreciable settlement or deformation, the full load coming upon it. Use either full length pile bents or framed bents supported by piles or spread footings.

3. Determine bearing values of piles according to Article 2501.03, H, and set them to be at least equal to the loads imposed upon them during construction.

4. To determine the number and size of spread footings or mudsills to be used, use the load to be supported and the bearing value of the soil on which they rest, giving due consideration to soils softening during high water, frozen ground thawing, etc. Do not use mudsills on soils or in situations where scour may occur.

5. Use 1500 pounds per square foot (70 kPa) as a safe bearing value for sand, gravel, firm clay, and other similar confined materials in beds thicker than the falsework footing width.

6. If necessary to extend falsework above the elevation to which piles are driven, cut off at least the majority of all piles in any bent at the same

elevation and cap. Construct a framed bent to the required height. Cap each falsework bent transversely at the proper elevation with material of adequate size securely fastened to each pile or post in the bent. Securely brace all bents longitudinally and transversely with diagonal bracing.

M. Preparation of Bearing Area.

1. Ensure column bases, truss and girder pedestals, and shoes have a full uniform bearing upon the concrete of the substructure.

2. Correct bridge seats of piers or abutments which are improperly finished, deformed, or irregular within the bearing area of masonry plates before the plates are placed.

3. Bed the pedestals and shoes for truss and girder spans, as well as columns for steel viaducts, on the bearing area so as to have full and even bearing. Unless otherwise required, use a bedding consisting of a single layer of 1/8 inch (3 mm) sheet lead meeting requirements in Article 4195.01.

N. Handling Members.

1. Handle component parts of a structure using methods and appliances that does not produce damage to the member by twisting, bending, or otherwise deforming the metal.

2. Do not place any member that is slightly bent or twisted into its place until its defects are corrected.

3. Members that have been seriously damaged in handling may be rejected.

O. Straightening Bent Material.

1. When the Engineer permits straightening of plates, angles, other shapes, and built up members, straighten using methods that will not produce fracture or other injury. Straighten distorted members using mechanical means.

2. If the Engineer approves, distorted members may be straightened by the carefully planned and supervised application of a limited amount of localized heat, except perform heat straightening of ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel members only under rigidly controlled procedures, with each application requiring the Engineer's approval. In no case allow the maximum temperature of ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel to exceed 1125°F (610°C), or allow the temperature to exceed 950°F (510°C) at the weld metal or within 6 inches (150 mm) of the weld metal. Do not apply heat directly on weld metal. In all other steels, do not allow the temperature of the heated area to exceed 1200°F (610°C) (a dull

red) as controlled by use of temperature indicating crayons, liquids, or bimetal thermometers.

P. Straightening Material and Placing Members.

1. Rolled material shall be straight when it is laid out for work. If straightening is necessary, do so by means which will not damage the metal.

2. Sharp kinks or bends is sufficient cause for rejection of the material.

3. Perform heat correction only when the Engineer approves. Heat straightening of ASTM A 709/A 709M Grade 100/100W (Grade 690/690W) steel will not be permitted.

4. Unless otherwise shown in the contract documents or ordered by the Engineer, place members which deviate from a straight line by an amount within the tolerance specified in ASTM A 6/A 6M in the structure in such a manner that the stress to be imposed will tend to straighten the member.

5. Heat straighten parts to be substantially free of stress and external forces, except stresses resulting from mechanical means used in conjunction with the application of heat.

6. Inspect metal surface following straightening of a bend or buckle for evidence of fracture. Repair or replace members showing fracture.

Q. Assembling Steel.

1. Accurately assemble parts as shown in the contract documents. Follow a match-marking system.

2. Handle material so that parts will not be bent, broken, or otherwise damaged. Do not hammer in a manner which will damage or distort the members.

3. Clean bearing surfaces and surfaces to be in permanent contact before the members are assembled.

4. Ensure important connections in trusses, girders, floor systems, and so forth have at least 25% of the holes on each side of the connection filled with drift pins, and another 25% of the holes on each side of the connection filled with temporary fitting up bolts drawn up snugly before the temporary support is removed. If the ultimate connection is to be made with high strength bolts, these bolts may be used as fitting up bolts. At milled connections of compression chords of truss spans, except the hip connection, the number of drift pins may be reduced to no less than 10% of the number of holes.

R. Alignment.

1. Before placing permanent bolts in field connections, adjust the structure to correct grade and alignment. For truss spans, block up the elevation of each panel point (ends of floor beams) on the falsework to the correct camber as shown in the contract documents and shop drawings. Leave this blocking in place until all tension chord splices are fully bolted and all other truss connections are pinned and bolted.

2. Support splice joints of continuous beams and girders using adequate falsework or other approved means as directed by the Engineer. Adjust as closely as possible to the required position before bolting is started.

S. Bolting.

Make main connections with high strength bolts, nuts, and washers meeting the requirements of Article 4153.06. All other fasteners will be considered non-high strength fasteners and may be used only where shown on the plans.

1. Length of Bolts.

a. Ensure the length of high strength bolts so that, when properly installed in a snug tight condition, the end of the bolt is flush with or outside the face of the nut.

b. Ensure the length of non-high strength bolts so that when tightened there is no less than 1/4 inch (6 mm) of bolt protruding from the nut.

c. Ensure the length of turned bolts so that when the nut is fully threaded there is no more than:

- 1/8 inch (3 mm) of thread within the thickness of metal to be gripped, and
- 1/4 inch (6 mm) of thread protruding from the nut.

d. Furnish ribbed bolts in a variety of diameters and lengths that:

- When installed will result in a drive tight fit, and
- When tightened will fill the nut and protrude no more than 3/16 inch (5 mm).

2. Bolt Holes.

Ensure holes for non-high strength and high strength bolts permit free entry of the bolt without driving. Carefully ream holes for ribbed bolts to provide for a driving fit. Ream holes for ribbed bolts to be cylindrical and to permit entry of the bolts at right angles to the faying surfaces.

3. Storage of High Strength Fasteners.

Protect bolts, nuts, and washers from the elements.

4. Fastener Acceptance Testing.

a. Prior to steel erection and in the presence of the Engineer, test two representative fastener assemblies from each rotational-capacity test lot as described in Materials I.M. 453.06B. A fastener assembly consists of a bolt, nut, and washer from the same rotational-capacity lot as furnished by the supplier.

b. The Engineer may order additional rotational-capacity tests if there is reason to suspect any change in fastener condition or level of lubrication.

c. Failure of rotational-capacity tests will be cause for rejection of that fastener lot.

5. Installing High Strength Fasteners.

Assemble, tension, and inspect high strength fasteners as described below. In special cases other methods may be used with prior approval of the Engineer.

a. Assembly.

1) Ensure that:

- Surfaces of bolted parts adjacent to the bolt head and nuts are parallel.
- Bolted parts fit solidly together when assembled, without containing gaskets or any other flexible material.
- Holes are no more than 1/16 inch (2 mm) in diameter greater than the nominal bolt diameter.

2) For slotted holes, the dimensions will be shown on the plans or shop drawings.

3) For painted applications, clean and prime the faying surfaces with zinc silicate paint. For unpainted applications, blast clean faying surfaces to:

- Remove mill scale, and
- Be free from paint, lacquer, dirt, oil, burrs, pits, or other defects which would prevent the solid seating of parts or would interfere with the development of friction between parts.

4) Ensure the fastener assembly installed in the field is made up of bolts, nuts, and washers from the same rotational-capacity lot number. Assemble fasteners with one hardened washer under the turned element (either bolt head or nut). When galvanized fasteners are specified:

- Furnish nuts that are pre-lubricated with a dyed lubricant according to ASTM A 563, or
- Field lubricate fastener threads with beeswax or other approved wax-based lubricant.

5) Use high strength weathering fasteners for weathering structural steel. Use galvanized high strength fasteners for non-weathering structural steel, with or without a specified field top coat.

6) Properly tighten each fastener to at least the minimum bolt tension shown in Table 2408.03-2:

Table 2408.03-2: Minimum Bolt Tension

Bolt Dia. inches (mm)	Min. Bolt Tension, lbf.[(a)] (kN[(a)])	Bolt Dia. inches (mm)	Min. Bolt Tension, lbf.[(a)] (kN[(a)])
1/2 (12.7) 5/8 (15.9) 3/4 (19.0) 7/8 (22.2) 1 (25.4)	12,050 (53.6) 19,200 (85.4) 28,400 (126.3) 39,250 (174.6) 51,500 (229.1)	1 1/8 (28.6) 1 1/4 (31.8) 1 3/8 (34.9) 1 1/2 (38.1)	56,450 (251.1) 71,700 (318.9) 85,450 (380.1) 104,000 (462.6)
[(a)] Equal to the proof load (length measurement method) given in ASTM A 325.			

7) Tighten high strength bolts using the turn-of-nut method.

8) Ensure impact wrenches (if used) are of adequate capacity and sufficiently supplied with air to develop the minimum tension of each bolt in approximately 10 seconds.

b. Turn-of-Nut Method.

1) Use the turn-of-nut method to provide the minimum bolt tension specified above.

2) Install bolts in all holes of the connection and bring to a "snug tight" condition. Consider bolts to be "snug tight" when tensioned to approximately 20% of the minimum bolt tension listed above and faying surfaces are in full contact. If full contact of faying surfaces is not achieved after all bolts have been tensioned to 20% of minimum tension, submit a corrective procedure to the Engineer for approval.

3) Systematically progress with snug tightening starting at the center of the connection and working out to the free edges. Check the fasteners of the connection in a similar systematic manner. Retighten as necessary until all fasteners are simultaneously in a "snug tight" condition and the faying surfaces are in full and continuous contact.

4) When all fasteners in the connection are "snug tight", match-mark the face of the connecting part, the nut, and the bolt point using paint, crayon, or other approved means to provide a reference for determining the relative rotation of the parts during final tightening.

5) Following this operation, tighten all fasteners in the connection further by the applicable amount of rotation specified in Table 2408.03-3. Systematically progress with tightening starting at the center of the joint and working out to the free edges. During this operation, do not rotate the part without using the wrench.

Table 2408.03-3: Nut Rotation from "Snug Tight" Conditions[(a)] (Disposition of Outer Faces of Bolted Connections)

Bolt Length (Under side of head to end of bolt)	Both faces normal to bolt axis	One face normal to bolt axis and other slope not more than 1:20 (beveled washer not used)	Both faces sloped not more than 1:20 from normal to the bolt axis (beveled washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters[(b)]	2/3 turn	5/6 turn	1 turn

[(a)] Nut rotation is relative to the bolt, regardless of the element (nut or bolt) being turned. For bolts installed using 1/2 turn and less, use a tolerance of ± 30 degrees. For bolts installed using 2/3 turn and more, use a tolerance of ± 45 degrees.

[(b)] For bolt lengths exceeding 12 diameters, the required rotation must be determined by actual field tests in a suitable tension measuring device which simulates conditions of solidly fitted steel.

c. Inspection.

1) Check bolted connections, after tightening, in the presence of the Engineer for proper installation, applicable rotation, and general joint condition. The inspection of fasteners, with a torque wrench, at connections of steel diaphragms to concrete beams will not be required.

2) Furnish and use an inspecting wrench which is calibrated and capable of measuring torque.

3) To calibrate the inspecting wrench:

a) Select a representative sample of no less than three bolts and nuts of each diameter, length, grade, and turned element, to be tensioned that day.

b) Check the samples prior to inspection in a device capable of indicating bolt tension. Turn the same element during testing that will be turned during actual work.

c) Use the inspecting wrench to tension the bolt and determine the torque necessary to achieve a bolt tension 5% greater than the specified minimum bolt tension.

d) Use the average of the three torque values for the job inspecting torque value(s).

4) Establish the job inspecting torque value(s) at least once prior to each day's inspection. Have an approved testing agency calibrate the tension measuring device at least every 6 months.

5) Inspect installed and tightened fasteners, represented by the above tests, for acceptance by attempting to tighten the fastener using the inspection torque wrench and the predetermined inspection torque value(s). Acceptance will be based on the random checking of at least 10% of the fasteners in each connection. A minimum of two fasteners per connection will be checked. The connection will be accepted as properly tightened if:

- The faying surfaces are in full and continuous contact, and
- No bolt or nut is turned at a torque value less than or equal to the inspection torque value(s).

6) If any bolt or nut is turned at torque values below the inspection torque value(s), check all fasteners in that connection. Tighten and reinspect all bolts or nuts which turn below inspection torque values.

7) Bolts tightened by the turn-of-nut method may reach tensions substantially above the values specified, but this is not cause for rejection.

d. Reuse of Bolts.

1) Do not reuse high strength bolts and nuts. Do not incorporate construction bolts or fit-up bolts into the final connection.

2) Tensioning of fasteners up to a snug-tight condition as described in Article 2408.03, S, 5, will not be considered as reuse.

3) Retightening (touching up) previously tightened bolts which may have been loosened by the tightening of adjacent bolts will not be considered as reuse.

T. Swinging the Span.

After permanent bolting of truss spans has been inspected and accepted, remove the centering and swing the span free on its permanent supports. Fully bolt all main connections before the span is swung, except permanently bolt milled compression chord connections after the span is swung.

U. Adjustment of Pin Nuts.

Adjust nuts on pins to the amount specified in the contract documents. Locate pins in the holes so the members take full and even bearing.

V. Setting Anchor Bolts.

1. Refer to Article 2405.03, H, for setting anchor bolts for bridge bearings.

2. Set anchor bolts, other than those for bridge bearings, in concrete with a polymer grout, according to Article 2405.03, H, or with a mechanical grip system. When the mechanical grip system is used:

- Ensure the diameter of the hole is suitable for the device used,

- Hold the anchor firmly in place using an expanding metal device approved by the Engineer, and
- Fill the annular space with cement grout or other material approved by the Engineer.

W. Setting Rocker Bearings.

1. Adjust rocker bearings at expansion ends of spans to provide for:
- Movement due to temperature,
- Elongation of bottom chord, and
- Probable substructure movement.

2. Assume a mean temperature of 50°F (10°C) when determining temperature movements.

X. Field Painting.
Field paint steel structures or parts of structures as required in the contract documents.

2408.04 METHOD OF MEASUREMENT.
The Engineer will compute the quantity of various items of structural concrete, steel reinforcement, structural steel, and incidental metal parts involved in construction of steel structures as follows:

A. Structural Concrete.
Article 2403.04 applies.

B. Steel Reinforcement.
Article 2404.04 applies.

C. Structural Steel and Incidental Metal Parts.

1. Structural Steel.
a. The weight (mass) of structural steel measured for payment includes the weight (mass) of:
- rolled shapes and plates, as fabricated, and
- incidental parts, such as castings, bearing plates, expansion devices, bolts, and incidental metal parts necessary for completion of the structure.

b. Unless the contract contains a separate item for metal railings, material for such railings is included with structural steel. Incidental materials, such as bronze, wrought iron, lead, castings, and so forth will be classed as structural steel unless covered by a separate item in the contract.

c. Reinforcement for concrete is not included in this item.

2. Weight (Mass).
a. The weight (mass) of structural steel as defined above, for which payment will be made, is the weight (mass) in pounds (kilograms) computed by the Engineer as shown in the contract documents. In the case of a substitution, by the Contractor, of a heavier section

than that shown, the weight (mass) of the section shown in the contract documents is the measured quantity.

b. The weight (mass) of structural steel, computed by the Engineer and shown in the contract documents, is presumed to be correct and provides the basis of payment. If the Contractor presents evidence that the weight (mass) computed by the Engineer is in error by more than 0.50%, the weight (mass) will be recomputed.

3. Variation in Weight (Mass).

If the weight (mass) of any member is less than 97.5% of the computed weight (mass), such member may be rejected.

4. Computed Weight (Mass).

a. The Engineer will compute the weight (mass) of structural steel on the basis of the following assumptions:

1) Steel: 490 pounds per cubic foot (7850 kg/m^3)

2) Cast Iron: 450 pounds per cubic foot (7210 kg/m^3)

b. The weight (mass) of rolled shapes and plates is computed on the basis of their nominal weights (mass) and dimensions as shown in the contract documents, deducting for copes and cuts.

c. The weight (mass) of welds is to be included in the computed weight (mass), assuming the weights (mass) of fillet welds to be used as in Table 2408.04-1:

Table 2408.04-1: Weight (Mass) of Welds

Size of Weld in. (mm)	Wt. per Linear Ft., lb. (Mass per Meter), (kg)	Size of Weld in. (mm)	Wt. Per Linear Ft., lb. (Mass per Meter), (kg)
1/4 (6)	0.16 (0.21)	1/2 (13)	0.64 (0.99)
5/16(8)	0.25 (0.38)	5/8 (16)	1.00 (1.51)
3/8 (10)	0.36 (0.59)	3/4 (19)	1.44 (2.13)

d. The weight (mass) of heads, nuts, single washers, and threaded stick through all high strength shop bolts is to be included in the computed weight (mass) on the basis of the weights (mass) shown in Table 2408.04-2:

Table 2408.04-2: Weight (Mass) of Bolts

Dia. Of Bolt in. (mm)	Wt. per 100 Bolts, lb. (Mass per 100 Bolts), (kg)	Dia. Of Bolt in. (mm)	Wt. Per 100 Bolts, lb. (Mass per 100 Bolts), (kg)
12 (12.7)	19.7 (8.9)	1 1/8 (28.6)	165.1 (74.9)
5/8 (15.9)	31.7 (14.4)	1 1/4 (31.8)	212.0 (96.2)
3/4 (19.0)	52.4 (23.8)	1 3/8 (34.9)	280.0 (127.0)
7/8 (22.2)	80.4 (36.5)	1 1/2 (38.1)	340.2 (154.3)
1 (25.4)	116.7 (52.9)		

e. The computed weight (mass) includes the total weight (mass) of field bolts as specified in Article 2408.02, C, and the total weight (mass) of shims required to be furnished for incorporation into the structure.

f. The weight (mass) of castings will be computed from the dimensions shown in the contract documents with an addition of 5% for fillets and overrun.

D. Surface Preparation and Painting Structural Steel.
Surface preparation and painting structural steel will not be measured.

2408.05 BASIS OF PAYMENT.

Payment for various items of Structural Concrete, Steel Reinforcement, Structural Steel, and Incidental Metal Parts will be as follows:

A. Structural Concrete.
Article 2403.05 applies.

B. Steel Reinforcement.
Article 2404.05 applies.

C. Structural Steel and Incidental Parts.

1. Contract unit price per pound (kilogram) or lump sum for metal railing and structural steel.

2. Payment is full compensation for:

- Furnishing all materials.
- Preparation, including fabrication, nondestructive testing and inspection required by the contract documents, transportation, and erection.
- Furnishing all labor.
- Equipment.
- Incidentals to complete the structure including the surface preparation and painting of the completed structure.
- Repair and cleaning of the paint at the shop and after erection.

D. Surface Preparation and Painting Structural Steel.
Incidental to the structure.