SUPPLEMENTAL SPECIFICATION
SECTION 506 - STRUCTURAL STEEL

506.01 DESCRIPTION. This work shall consist of furnishing, erecting, and when specified, coating fabricated metal structures and structural components.

506.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Mortar, Type IV 707.03
Paint 708.01
General Requirements for Structural Steel 714.01
Structural Steel 714.02
High-Strength Low-Alloy Structural Steel 714.03
Carbon Steel Bolts and Nuts 714.04
High-Strength Bolts, Nuts, and Washers 714.05
Heat-Treated Structural Bolts 714.06
Anchor Bolts, Bearing Devices 714.08
Welded Stud Shear Connectors 714.10
Steel Tubing 714.11
Direct Tension Indicators 714.12
Tension Control Assemblies 714.13
Iron Castings 715.01
Bronze Castings 715.02
Preformed Fabric Bearing Pads 731.01
Bearing Pads 731.02

Unless otherwise specified in the Contract, all steel shall be high-strength low-alloy structural steel conforming to AASHTO M 270M/M 270, Grade 345W (Grade 50W). Galvanizing or metalizing shall be applied in accordance with Subsection 506.15. Coatings shall be applied in accordance with Section 513.

All materials shall conform to the prescribed AASHTO or ASTM specifications, and no substitutions will be allowed.

506.03 GENERAL FABRICATION REQUIREMENTS. Material furnished under this Section that is permanently incorporated into a Federal-Aid project shall be entirely manufactured and coated in the United States.

Except as modified below, fabrication shall be performed in accordance with the latest editions of the applicable AASHTO design code, ANSI/AASHTO/AWS D1.5 hereinafter designated as AWS D1.5, and interim specifications in effect on the date of the Contract. Unless otherwise indicated in the Contract, the applicable AASHTO design code shall be the latest edition of the AASHTO LRFD Bridge Design Specifications .

Prior to performing any work under this Section, the fabricator must have received approval for all Fabrication Drawings, welding procedures and any special Contract requirements and have notified the Structures Engineer at least seven days in advance of fabrication. The Contractor shall bear full responsibility and costs for all materials ordered, raw materials stockpiled, or for work performed prior to approval of the Fabrication Drawings or written authorization from the Structures Engineer.

All work shall be performed by the Fabricator indicated on the approved Fabrication Drawings unless otherwise authorized in writing by the Structures Engineer.

Structural steel furnished under this Section shall be fabricated in a plant having an AISC Major Steel Bridges (cbr) Certification and in a plant approved by the Agency prior to award of the Contract. Minor steel components including but not limited to downspouts, scuppers, and pedestrian hand railings may be fabricated in a fabrication plant that does not have an AISC Major Steel Bridges (cbr) Certification provided the fabrication plant is approved in writing by the Structures Engineer prior to the award of the Contract. All plants without certification shall have an organization, operation and equipment capable of producing a product equal to a certified plant.

The Fabricator shall demonstrate full capability for fabricating material(s) meeting the requirements of the Contract. Failure to meet Contract requirements will result in rejection of the material being fabricated and the termination of the ability to fabricate material for the State.

All plants must satisfy the following minimum requirements:

(a) Reference Materials. The plant shall have a library containing the latest editions of the following publications:

(1) AWS A5.0, A5.5, A5.17, A5.20, A5.23, C2.18, D1.1, D1.2, D1.3, D1.4, and D1.5.

(2) AASHTO *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, Parts I and II.

(3) AISC Quality Criteria and Inspection Standards, A Guide to the Shop Painting of Structural Steel, Manual of Steel Construction, and Structural Steel Detailing.

(4) Vermont *Standard Specifications for Construction*.

(5) AASHTO *Standard Specifications for Highway Bridges*.

(6) AASHTO LRFD Bridge Design Specifications.

(7) AASHTO LRFD Bridge Construction Specifications.

(8) AASHTO *Standard Specifications for Welding of Structural Steel Highway Bridges*.

(9) AREMA specifications, when applicable.

(10) American Society for Nondestructive Testing (ASNT) SNT-TC-1A.

(11) SSPC *Steel Structures Painting Manual*, Volumes 1 and 2.

(12) AASHTO/NSBA G1.1-1999.

In addition to the above, access to the latest editions of any applicable ASTM standards is required.

(b) Files. The Fabricator shall maintain an organized file containing:

(1) Records of material purchased.

(2) Inventory of material in stock.

(3) Certification records of all material and welding supplies.

(c) Personnel. Fabrication personnel shall meet the following minimum requirements:

The Fabricator's representative responsible for inspection, testing and quality matters shall be qualified and certified in accordance with the provisions of AWS QC 1, entitled *Standard for Qualification and Certification of Welding Inspectors*.

Welders shall be certified for each process and position of prequalified joints in the approved welding procedures, including tacking, in accordance with AWS D1.5 for all structural bridge items and ANSI/AWS D1.1, hereinafter designated as AWS D1.1, for items not covered in AWS D1.5.

(d) Material Fabrication Facilities.

(1) All fabrication shall be performed in an enclosed permanent structure, unless otherwise approved by the Structures Engineer.

To meet minimum requirements, a plant shall have the following:

a. Dry storage for manual electrodes and fluxes.

b. Ovens with proper temperature ranges for drying electrodes and fluxes.

c. Calibrated tools, gauges, tapes and instruments

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d. Suitable preheating equipment and means for measuring preheat.

e. DC and AC manual shielded metal arc welding equipment capable of at least 500 A output.

f. Mechanically guided burning equipment.

g. Machine shop facilities sufficient to perform the work specified.

h. Facilities and equipment for applying shop paint to perform the work specified.

i. Blast cleaning equipment suitable for preparing a surface meeting the requirements of Subsection 506.14 and the requirements of Section 513.

j. Suitable storage for materials and finished products.

(2) A plant engaged in fabrication of plate girders, rolled beams and other main member components requiring continuous welds over 600 mm (2 feet) in length shall also have the following equipment:

a. Automatic arc equipment.

b. Semiautomatic arc equipment.

c. Stud welding equipment capable of installing a 22 mm (7/8 inch) diameter stud, when applicable.

d. Equipment suitable for heat curving or heat cambering.

e. Hydraulic jacking equipment suitable for aligning and positioning structural components.

(3) Adequate office facilities and equipment for the Agency's Quality Assurance Inspector shall be separate from the Quality Control facilities and shall include the following:

a. A standard office desk with drawers, locks and keys.

b. Adjustable office chair.

c. Telephone.

d. Plan rack and file cabinet with lock and keys.

e. The following tools shall be available for the Inspector's use:

Weld gauges, micrometer, dry and wet film paint gauge, 3 m (10 foot) steel tape, 30 m (100 foot) steel tape, 2 m (6 foot) straightedge, temperature and marking crayons, ambient air thermometer, a level at least 600 mm (2 feet) long and a 600 mm (2 foot) carpenter's square.

The Engineer reserves the right to reject inadequate office facilities and require suitable alternatives.

(e) Testing Equipment. When code requirements necessitate nondestructive testing for quality control or quality assurance, the Fabricator shall have available the necessary nondestructive testing equipment for material or weld inspection (such as magnetic particle, radiograph, ultrasonic, or dye penetrant) or employ an outside inspection firm to fulfill the necessary nondestructive test requirements of the code. Nondestructive tests shall be performed in accordance with the applicable code in effect on the date of the Contract.

506.04 DRAWINGS AND PROCEDURES.

(a) General. As soon as practical after award of the Contract, the Fabricator shall prepare Fabrication Drawings in accordance with Section 105. Drawings, details and welding procedures must be submitted as a complete package for each structure sufficiently in advance of fabrication to allow for review, resubmittals and approval.

The Agency will review Fabrication Drawings, details and procedures for their compliance with the Contract. The Agency uses AASHTO/NSBA G1.1-1999, Section 4 as the basis for review of structural steel Fabrication Drawings. The Agency assumes no responsibility for dimensions and other information calculated by the Fabricator. The Fabricator is responsible for the fit of all components. If errors occur that cause problems during erection, the Contractor is responsible to make acceptable corrections.

The Agency is responsible for all principal dimensions and material properties contained in the Contract. The Fabricator and Contractor are responsible for bringing to the Agency's attention any errors or discrepancies they discover.

The Fabricator is responsible for dimensioning members and ordering material to compensate for weld shrinkage, distortion, elastic deformation, sweep, slope, machining, waste from cutting and other incidentals that are affected by the fabrication process.

(b) Details. Details not shown on the Plans that are necessary for completing the Fabrication Drawings shall be developed by the Fabricator.

The Fabrication Drawings shall provide a material list on each sheet for tabulating the number of pieces, piece marks, description, dimensions, type of material and mass (weight) of each piece. When the Contract item pay unit is on a per kilogram (pound) basis, the mass (weight) of each piece shall be extended and summarized for each sheet as specified in Subsection 506.24. Mass (weight) extensions (extended weights) shall be submitted to the Agency upon completion of fabrication.

All welds shown on the Fabrication Drawings shall identify, by symbol, the applicable procedure(s) and appropriate nondestructive testing requirements. A separate symbol must be used to identify each approved welding procedure. When more than one procedure is available, the Fabricator may identify several procedures for any given weld.

(c) Welding Procedures. Detailed welding procedures shall be prepared in accordance with the provisions of the applicable AWS/ANSI/AASHTO code revisions and submitted in accordance with the following:

(1) Welding procedures for each structure shall be a separate package of consecutively numbered sheets. Each sheet of the set shall identify the project name, number, structure and procedure qualification record.

(2) All procedures shall be prequalified. Procedure qualification test records shall be submitted along with each procedure. Heat input values during welding shall be shown for each procedure. The minimum heat input shall be 1.4 kJ/mm for material 10 to 19 mm (35 kilojoules per inch for material 3/8 to 3/4 inch) in thickness and 2.0 kJ/mm for material over 19 mm (50 kilojoules per inch for material over 3/4 inch) in thickness.

$$\text{Kilojoules per Millimeter} = \left(\frac{\text{Volts} \times \text{Amps} \times 0.06}{\text{Travel Speed in Millimeters per Minute}} \right) \quad \text{[Metric]}$$

$$\text{Kilojoules per Inch} = \left(\frac{\text{Volts} \times \text{Amps} \times 0.06}{\text{Travel Speed in Inches per Minute}} \right) \quad \text{[English]}$$

(3) Procedure specifications shall be presented in a format similar to Form E-1 of AWS D1.1, Appendix E, or Form E-2 of AWS D1.5, Appendix IV. Procedure qualification test records shall be presented in a format similar to Form E-2 of AWS D1.1, Appendix E, or Form E-1 of AWS D1.5, Appendix IV.

(4) Details of welded joints not prequalified under AWS D1.5, Section 2.6 shall be qualified.

(d) Revisions. Adjacent to or incorporated with the title box of each sheet shall be a revision record box including provision for: date of revision, symbol of revision number, revision made by, and description of each revision. As changes or revisions are made to previously approved sheets, the appropriate information shall be recorded, a revision number symbol placed adjacent to the appropriate detail and the sheet resubmitted for approval. It is the Fabricator's responsibility to transfer all "as noted" corrections to the originals.

Revisions of welding procedures shall also be resubmitted, as they occur**.**

506.05 QUALITY ACCEPTANCE. Quality Acceptance is inspection of fabrication by the Agency or the Agency's representative to verify compliance with these Specifications.

(a) Scope of Work. Inspection will include the examination of materials, processes, quality of work, reports and test results; the performance of tests specified; the evaluation of reports and tests; the approval, disapproval or rejection of materials, processes, quality of work, reports and test results; or other work specified or directed by the Engineer.

(b) Control of Work. The Inspector is a representative of the Engineer and will perform all the duties assigned and delegated to the Engineer in Section 105 as they pertain to the Contract with the exception of quantities of materials and payment thereof. The Inspector will witness, interpret and accept or reject all testing.

The Inspector will have the authority to reject any material or work that does not conform to the Contract requirements. Inspection of the work will conform to the requirements of the applicable AWS/ANSI/AASHTO codes and specifications referenced in the Contract.

(c) Tools and Equipment. Inspectors are expected to furnish their own personal safety equipment. They may make use of any tools the Fabricator is required to make available; however, the Fabricator is responsible for verifying that the equipment is properly calibrated and in working order.

506.06 QUALITY CONTROL.

(a) General. Quality Control is the inspection, testing and management of quality matters necessary for producing a product that conforms to the requirements of the Contract. The Fabricator is responsible for Quality Control.

The Fabricator is responsible for performing all nondestructive tests required by the Contract and any nondestructive tests necessary to determine the extent of metallurgical defects discovered in the base metal.

(b) Qualifications of Inspectors. The Fabricator's representative responsible for Quality Control shall be an AWS Certified Welding Inspector (CWI), qualified and certified in accordance with the provisions of AWS QC 1.

(c) Nondestructive Testing. The fabricator shall notify the Agency sufficiently in advance of any scheduled nondestructive testing so that all tests can be witnessed by an Agency Inspector. Nondestructive tests shall be performed in accordance with AWS D1.5.

Personnel performing and interpreting nondestructive tests (radiographic, magnetic particle, ultrasonic and dye penetrant) shall be NDT certified for Level II qualification in accordance with the American Society for Nondestructive Testing, Recommended Practice Number SNT-TC-1A.

(d) Ultrasonic Testing. Ultrasonic testing will not be permitted as a substitute for radiographic testing; however, ultrasonic testing may be used by the Fabricator to determine the extent of discontinuities, laminations and inclusions discovered in any weld or base metal.

506.07 MATERIAL IDENTIFICATION.

(a) Material Certifications. Certifications shall be prepared in accordance with Subsection 700.02. Prior to any fabrication or stockpile payment for material the Contractor shall furnish the Agency's Inspector one copy of all Type C Certification material test reports. Any material not properly identified or lacking acceptable test information shall not be incorporated in the work. If no Quality Acceptance Inspector is assigned or available when fabrication begins or at the time of the raw material stockpile payment, it is the Contractor's responsibility to ensure that Contract requirements are complied with.

Prior to shipment of any material, a copy of all Type C Certification material test reports and all applicable Type A Certifications, both pertaining to the items to be shipped, shall be sent to the Agency's Materials and Research Section. Acceptable certifications received by the Agency are a pre-requisite to payment for any fabricated material.

(b) Material Traceability. The origin of each piece of material to be incorporated in a product shall be clearly identified at all times during the fabrication of the product. If fabrication operations could obliterate the identity, the Fabricator may use a low-stress die stamp placed in an area not exposed on the finished structure. The die stamp character size shall be a minimum of 3 mm (1/8 inch) and a maximum of 6 mm (1/4 inch). Nonmetallic materials shall be identified to the satisfaction of the Engineer.

When requested, the Contractor shall furnish an affidavit certifying that throughout the fabrication operation identification of the steel has been maintained in accordance with this Specification.

When a steel stamp identification is used at a tension joint transition, the impression shall be placed on the thicker of the members.

506.08 BASE METAL REQUIREMENTS. When backing bars, extension bars and runoff plates are part of a welding process, the material used shall be of the same chemistry as the base metal.

Discontinuities, laminations, inclusions or other anomalies discovered in the base metal during the manufacturing process shall be individually evaluated. The Agency may require nondestructive testing to determine the extent of the defect. Repair procedures or replacement will be approved on an individual case basis.

Rolled beams shall be ordered from the mill without camber.

Primary stress carrying material (e.g., flanges, webs, splice plates and lateral connection plates) shall be ordered and prepared so that the direction of rolling is parallel to the stress in the member.

Members identified as "fracture critical" shall be subject to additional base metal requirements as specified in Subsection 506.11.

Members or components of members designated in the Contract as requiring Charpy V-Notch (CVN) testing, or members subject to tensile or compressive stress as specified in Subsection 714.01 shall be identified as a main member and shall therefore be subject to the requirements of main members.

506.09 PREPARATION OF BASE METAL. Material flame cuts by any thermal cutting process shall be made with an approved mechanically guided torch. The Fabricator shall use preheating, post heating or control of the cutting process to ensure that flame cut edges of main members of structural steel [e.g., AASHTO M 270M/M 270, Grade 345W (Grade 50W) or Grade 345 (Grade 50)] are not flame hardened. Flame cut edges that will not be included in a permanent weld shall have a Rockwell Hardness Value not greater than C30.

Pieces that are to be bent during fabrication shall be done so in accordance with AWS D1.5 and the applicable design code as defined in Subsection 506.03.

Cold bending of main members will not be permitted without written approval of the Agency. This approval may limit the radius of curvature and require nondestructive testing to verify that no internal distress or separation has occurred. Expenses incurred in performing any such nondestructive test examination shall be the responsibility of the Fabricator.

506.10 WELDING.

(a) General. All design details, quality of work, procedures and inspection of welding shall conform to the requirements of the AWS D1.5 Bridge Welding Code. For welding items other than those covered in AWS D1.5, one of the following publications shall be adhered to:

ANSI/AWS D1.1 Structural Welding Code - Steel
ANSI/AWS D1.2 Structural Welding Code - Aluminum
ANSI/AWS D1.3 Structural Welding Code - Sheet Steel
ANSI/AWS D1.4 Structural Welding Code - Reinforcing Steel

Welding will not be permitted without approved welding procedures and Fabrication Drawings meeting the requirements of Subsection 506.04.

Welding and inspection of shear connectors shall conform to the requirements of Section 508.

Stitch welds are not permitted; however, the skip and fill technique may be used when applicable to prevent distortion.

Prior to performing any corrective weld repairs, the Fabricator shall:

(1) Submit the proposed repair procedure to the Inspector in writing. Corrective procedures for radiographed butt welds may be included in the welding procedure.

(2) Receive written authorization from the Agency to proceed. Repair procedures detailed in an approved welding procedure may be authorized by the Agency's Inspector.

The Fabricator will be permitted a maximum of two repairs on any given welded joint. Should nondestructive test inspection indicate weld rejection after two repairs, the Agency may reject the entire weld and require its removal.

(b) Welding Processes. Shielded metal arc welding (SMAW) conforming to AWS D1.5, Section 1 shall be deemed prequalified. Submerged arc welding (SAW), flux core arc welding (FCAW), and gas metal arc welding (GMAW) shall be subject to qualification testing as described in AWS D1.5, Section 5 prior to approval. Other processes may be approved, on a project by project basis, provided procedure qualification results meet the specified acceptance criteria.

Submerged arc welding shall be used for all principal welds:

(1) The fully automatic process shall be used for attaching cover plates, flange to web welds and attaching connection or stiffener plates to girder webs.

(2) The semiautomatic process may be used when joint length, position or physical location restricts the use of the automatic process.

The manual shielded metal arc process shall be limited to attaching connection plates to rolled beams, welding bearing assemblies, repairs, tack welding, joints under 600 mm (24 inches) in length, minor attachments and other applications where the use of an automatic process is impractical.

When prior authorization has been granted, the gas metal arc welding (GMAW) and flux cored arc welding (FCAW) processes will be limited to indoor shop welding of bearing devices, scuppers, sign fixtures, light fixtures and low stressed members or components.

Gas metal arc welding short circuit arc (GMAW-S) will not be permitted.

Any gas shielded process subject to wind velocities in excess of 8.0 km/h (5 miles per hour) shall be protected by the use of a draft barrier(s).

(c) Shop Welding. The Fabricator shall maintain a file of the qualifications of all welders, welding operators and tackers qualified in accordance with AWS D1.5, Section 5. Requalification may be required in accordance with AWS D1.5, Section 6. AWS D1.1 shall be adhered to for welding of items not covered in AWS D1.5.

Groove welds shall be started and terminated with extension bars or runoff plates.

Fillet welds shall be performed in the flat or horizontal position unless restricted by member size or physical position.

(d) Field Welding. Welding performed in the field shall be done by welders or welding operators who have an AWS Certification designating them as qualified in the appropriate category for Structural Welding for the Agency.

The Agency's qualification requirements for field welding are contained in the *Manual for Field Welding*. This document may be obtained from the Agency's Construction Section. The Contractor shall have a copy for use any time field welding is anticipated.

The axis of any weld used to attach miscellaneous construction fixtures to main members as defined in Subsection 714.01 shall be in the same direction as the primary stress in the member and shall be approved in writing by the Engineer.

Welding performed in the field is subject to all of the requirements of Subsection 506.10. The shielded metal arc welding (SMAW) process is the only process approved for field welding.

Welding of miscellaneous construction fixtures such as form supports, screed supports and reinforcing steel chairs to any portion of the bridge structure will not be permitted without approved drawings and welding procedures. Any increase in material thickness made necessary by reduced allowable stresses resulting from such welding shall be at the Contractor's expense. Approval for any welding requiring an increase in material thickness must be obtained before the affected structural steel is fabricated.

Shear connectors shall be installed in accordance with Section 508.

(e) Process and Procedure Qualification.

(1) General. Welding processes and procedures requiring qualification shall be qualified in accordance with AWS D 1.5.

Welding and testing of samples shall be witnessed by an Agency Inspector or an authorized representative of a testing agency that is AWS certified in accordance with the provisions of AWS QC 1.

Process and procedure qualification record tests shall be reported in a format similar to those provided in AWS D15.

Procedure specifications shall be reported in a format similar to those provided in AWS D1.5.

(2) Acceptance Requirements. The basis for acceptance shall conform to the requirements of AWS D1.5. AWS D1.1 as modified by AASHTO, shall be used only for those items not covered in AWS D1.5.

506.11 FRACTURE CRITICAL MEMBERS. The Agency will identify in the Contract the members or member components that are categorized as "fracture critical."

Material for members or member components identified as "fracture critical" shall be furnished and fabricated in conformance with the requirements of AWS D1.5 for fracture critical components.

Welding performed on fracture critical members or components, and testing, shall be witnessed by an Agency representative. Qualification acceptance for any welding procedure shall be based on the results of mechanical tests and chemical analysis of deposited weld metal. Procedure requirements and basis of acceptance shall meet the requirements in AWS D1.5 for fracture critical components.

506.12 ASSEMBLY

(a) Camber. Beams and girders shall be fabricated to the camber indicated on the approved Fabrication Drawings.

(b) Curved Girders. Welded girders with radii less than 230 m (750 feet) shall be fabricated by cutting the flange plates to the required curvature. Each plate shall be flame cut simultaneously on both edges to reduce unbalanced shrinkage stresses. The flange plate lengths between shop splices shall not be less than 6 m (20 feet). Web plates shall be aligned to the center of the flange plates.

If the final curvature is not as specified after the flanges have been welded to the web, the girder shall be corrected by application of heat in accordance with an approved procedure.

(c) Heat Curving and Cambering. The final horizontal curvature and vertical camber shall be measured only after the member has cooled. The member shall be supported in a manner that will ensure accurate measurements for sweep and camber. The web shall be in a vertical position for measuring curvature and in a horizontal position for measuring camber.

Heating shall be performed in such a manner that the temperature of the steel does not exceed 610 °C (1125 °F). Artificial cooling will not be permitted until a member has cooled to 315 °C (600 °F). Under no conditions will water be permitted for cooling. Air may be used subject to the approval of the Inspector. Any member heated in excess of 650 °C (1200 °F) shall be rejected.

(d) Finish. All sharp corners and edges that are marred, cut or roughened in handling shall be rounded to a 1.6 mm (1/16 inch) radius by grinding.

(e) Connections and Bolting. The materials and fabrication procedure shall comply with the provisions of Subsection 506.19.

(f) Bearing Connections. Connections in bearing may require different tolerances of fit. Terms used to define the fit of connections are:

(1) Tight Fit (Welded Ends Only). Fifty percent of the projected bearing area shall be in contact within 0.5 mm (0.02 inch) with a permissible variation of 1.6 mm (1/16 inch) for the remaining 50 percent of projected area.

(2) Grind to Bear. Seventy-five percent of the projected area shall be in contact within 0.25 mm (0.01 inch) with a permissible variation of 0.8 mm (1/32 inch) for the remaining projected area.

(3) Mill to Bear. One hundred percent of the projected bearing area shall be in full contact.

(g) Intermediate Stiffeners. Where tight fit of intermediate stiffeners is specified, 50 percent of the projected bearing area shall be in contact within 0.5 mm (0.02 inch) with a permissible variation of 1.6 mm (1/16 inch) for the remaining 50 percent of the projected bearing area.

(h) Straightening Material. Straightening or repair of any member or component will be subject to written approval by the Agency. Procedures will be required describing in detail the distortion to be corrected and all procedures for heating, cooling, verifying final dimensions and nondestructive tests.

506.13 TOLERANCES. Rolled steel plates, shapes and bars shall be supplied to the permissible tolerances specified in AASHTO M 160M/M 160.

The camber and sweep of fabricated rolled members shall be subject to the same dimensional tolerances specified for welded members in AWS D1.5.

The metal bearing surface of any masonry bearing plate shall be flat, with a maximum permissible variation of 1 mm (0.04 inch) from a plane determined by any three of its corners.

There will be no permissible tolerance for over grinding. Welded butt joints shall be finished so that the final thickness of the joint is not less than the thickness of the thinner adjacent plate. Welded butt joints subjected to only compressive stresses shall be finished so the final thickness of the joint is not less than the ordered thickness of the thinner plate.

506.14 SURFACE PREPARATION. All materials shall be blast cleaned to the grade specified as defined by the pictorial surface preparation standard SSPC-VIS 1.

Further preparation shall conform to the following:

(a) Surfaces to Remain Uncoated. Surfaces may be blast cleaned either before or after fabrication.

The final surface appearance after fabrication shall be at least equivalent to preparation grade SSPC-SP10.

(b) Surfaces to be Galvanized or Metalized. Prior to galvanizing or metalizing, all corners and edges of steel plates, shapes, etc., shall be ground to a 1.6 mm (1/16 inch) radius.

(1) Galvanized. All material to be galvanized shall be cleaned to be at least equivalent to surface preparation grade SSPC-SP8.

(2) Metalized. All material to be metalized shall be cleaned in accordance with Subsection 506.15(b).

(c) Surfaces to be Painted. All material to be painted shall be cleaned in accordance with the applicable requirements of Section 513.

506.15 GALVANIZING OR METALIZING. Galvanizing or metalizing shall be performed in accordance with the following:

(a) Galvanizing. Surfaces to be galvanized shall be zinc coated in conformance with AASHTO M 111M/M 111 or, when applicable, AASHTO M 232M/M 232.

The Fabricator is responsible for straightening to specification tolerances any weldments that may have been distorted through stress relieving during the hot dipping process.

(b) Metalizing. Surfaces to be metalized shall be prepared and coated in accordance with AWS C 2.18, entitled "Guide for the Protection of Steel with Thermal Sprayed Coating of Aluminum and Zinc and Their Alloys and Composites", and the following:

(1) The coating shall be pure zinc (99.9 percent purity minimum).

(2) A minimum thickness of 150 μm (6 mils) shall be applied to all exterior surfaces. Internal surfaces (e.g., pot bearings) shall have a minimum coating of 50 μm (2 mils).

(3) All surfaces to be thermal sprayed shall be blast cleaned to white metal immediately prior to receiving surface protections. The final surface appearances shall be equivalent to preparation grade SSPC-SP5 as defined by SSPC-VIS 1. The first coating shall be applied within one hour of blast cleaning and the surface must be completely coated to the specified thickness within two hours of blasting.

(4) Exterior surfaces shall be sealed with an approved sealant conforming to the recommendations of the thermal spray supplier and approved by the Engineer. The minimum dry film thickness of the sealant shall be 50 μm (2 mils).

(5) Adherence of the metalized coating to the base metal shall be tested in accordance with AASHTO M 111M/M 111, Section 7.

506.16 MARKING, STORING AND SHIPPING.

(a) Marking. Each member shall be identified with an erection mark corresponding with the member identification mark on the approved Fabrication Drawings.

Identification marks may be painted on members that will receive field coats of paint.

Identification marks on unpainted steel shall be impressed into the member (with a low-stress stamp) in a non-stressed or low stressed area of the member. The Fabricator shall identify to the Contractor the procedure used for marking material.

(b) Storing. Material at the Fabricator's plant shall be stored above ground on platforms, skids or other suitable supports. It shall be kept clean, properly drained and protected from unwanted corrosion. Free circulation of air shall be provided around all surfaces.

Girders and beams shall be stored in the upright position, supported at their ends or points of bearing. Long members (e.g., columns and chords) shall be supported at sufficient points to prevent damage from deflection.

Special care shall be taken for unpainted steel to ensure that it has the opportunity to weather uniformly.

In addition to the requirements specified above, material or raw material stockpile storage shall be subject to any other storage criteria deemed necessary by the Engineer in accordance with Subsection 106.09.

(c) Shipping. Beams and girders shall be transported in the upright position. If the member's size or shape prohibits shipment in the upright position, the Fabricator shall submit a proposed method and details of shipment to the Agency for approval.

The Fabricator shall not ship any material, either to the project or to another manufacturer, without the Agency's approval. The Agency's Inspector will place a seal of approval on all material that has been accepted and will approve the loading, positioning and anchorage of all material being shipped.

506.17 FIELD HANDLING AND STORING. The Contractor is responsible for providing equipment that is adequate for safely lifting and placing, without damage, all material furnished. Permanent distortion caused by handling or storage will be cause for rejection.

The edges of nicks or bumps caused by handling shall be carefully ground to a 2 mm (1/16 inch) radius.

The storage requirements in Subsection 506.16 shall be applicable for all material stored in the field.

506.18 ERECTION.

(a) Methods and Equipment. Cranes, lifting devices, and other equipment for all structural steel erection shall be of adequate design and capacity to safely erect, align and secure all members and components in their final positions without damage. The Contractor is solely responsible for the methods and equipment employed for the erection of the structural steel. However, the Contractor shall lift and erect curved girders so that the web of the girder is maintained vertical within a 10 degree vertical tolerance.

The Contractor shall submit Construction Drawings in accordance with Section 105 for the methods and sequence of structural steel erection, the temporary bracing and the equipment to be used for the erection. The erection plan shall include the necessary computations to indicate the magnitude of stress in the segments during erection and to demonstrate that all of the erection equipment has adequate capacity for the work to be performed. The erection plan shall contain provisions for all stages of construction, including temporary stoppages.

The structural steel may be used for support of equipment prior to placement of the deck only with the written permission of the Engineer. The proposed use of structural steel for support of equipment shall be detailed in the erection plan.

Submittal of the erection plan is for documentation purposes only, and shall in no way be construed as approval of the proposed method of erection. Unless otherwise directed by the Engineer, the Contractor shall follow the erection plan as submitted.

(b) Bearings and Anchorages.

(1) Bearings shall be set level and in the exact position specified with full and uniform bearing. Pedestals detailed to be on a slope shall be set at the elevation and position specified.

(2) Metal bearing plates shall be placed on a 3 mm (1/8 inch) thick bearing pad conforming to Subsection 731.01 or 731.02. The bearing pad shall be the same size as the bearing plate with holes to accommodate the anchor bolts.

(3) Anchor bolts shall be positioned to the alignment and dimensions specified or approved in the Fabrication Drawings. When preset or cast-in anchorages are not specified, the Contractor shall drill holes and set the anchor bolts in a Type IV mortar.

If allowed in the Contract or ordered by the Engineer, a pre-approved adhesive may be used to set the anchor bolts into the concrete. If an adhesive is used, the manufacturer's installation requirements for the adhesive shall be followed during installation. The Engineer shall be provided a copy of the Material Data Safety Sheet (MSDS) and a copy of the manufacturer's installation requirements.

(4) Bearings shall initially be positioned to account for a mean temperature of 7 °C (45 °F) and for any bottom chord or flange elongation due to dead load deflection. As erection progresses, fixed bearings may be fully welded and expansion bearings tack welded to their respective members to prevent displacement. When full dead load has been applied to the structural system, any adjustments necessary shall be made to correct bearing position and inclination for a mean temperature of 7 °C (45 °F). Anchor bolts for sliding bearings shall be in the center of their slots and rockers or rollers set vertical.

Bearings shall be reset if they are out of position by more than the following tolerances:

Elastomeric Bearings:	Per Contract Plans.
Sliding Bearings:	6 mm (1/4 inch) from the correct position.
Rockersand Rollers:	Inclination of more than 3 degrees from the correct position.

If resetting the bearings requires jacking the superstructure, the Contractor shall meet all of the requirements of Section 502, including the submittal of Construction Drawings. The costs of resetting the bearings and meeting the requirements of Section 502 shall be incidental to the structural steel item(s) in the Contract.

(c) Assembly.

(1) Parts shall be accurately assembled as shown on the Contract Plans, Fabrication Drawings or erection drawings, following match marks when provided. Material shall be carefully handled so that no members or pieces will be bent, broken or damaged. Hammering that will injure or deform members will not be permitted. Bearing surfaces and contact surfaces shall be clean. Members shall be erected to the position specified and externally supported until all connections have been completed.

(2) Drift pins shall be used to align and center the connections of main and secondary members. Only light drifting will be permitted. Any member subjected to drifting that results in distortion of the member or elongation of the holes will be rejected. Cylindrical erection pins, the same size as the hole, shall be used at least in the extreme corners of all main member connections.

Main members have been match marked and shop reamed to fit a specified profile and should fit together easily.

Main members shall not be reamed larger than the hole size indicated on the approved Fabrication Drawings without written authorization from the Engineer.

Secondary members may be subjected to limited field reaming. Reaming or drilling to connect misaligned holes will not be permitted without the approval of the Engineer. Reaming of secondary members shall be approved by the Engineer on a case by case basis prior to the reaming. Reaming or drilling shall not cause elongation of any hole more than 1.6 mm (1/16 inch) for 75 percent of the holes in any subassembly and 3.2 mm (1/8 inch) for the remaining 25 percent of the subassembly (diaphragm, lateral bracing, etc.). Reaming that produces results in excess of these limits will be cause for rejection. Assembled parts requiring drilling or reaming shall be disassembled to remove any burrs or shavings.

Pins used for hinged connections and bearings shall be inserted with care and aligned so the members take full and even bearing. Nuts shall be adequately tightened and locked in position either by upsetting the threads or tack welding the nut to the bolt.

(3) The correction of minor misfits involving reaming (within specified limits) and cutting will be considered a legitimate part of the erection. However, errors in shop fabrication that prevent proper assembly shall be reported immediately to the Engineer. The Engineer shall approve any corrective action prior to it occurring.

506.19 BOLTING AND CONNECTIONS.

(a) General. Connections shall be made with high-strength bolts conforming to AASHTO M 164M (AASHTO M 164). Bolts and nuts shall be furnished by the same supplier. Bolts, nuts and washers shall be packaged and shipped so they are kept dry. When not in transit, bolts, nuts and washers shall be stored indoors under dry, ventilated conditions. All bolts and nuts shall be adequately and uniformly lubricated. Bolts and nuts not properly lubricated shall be cleaned and relubricated prior to installation in accordance with applicable specifications.

Bolt holes are specified as 2 mm (1/16 inch) larger in diameter than the bolt.

(b) Bolted Parts. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or other interposed compressible material. All joint contact surfaces and areas adjacent to bolt holes shall be free of scale, burrs, dirt and other foreign material that may prevent solid seating of the parts.

Prior to assembly, contact surfaces of galvanized stress-carrying members shall be lightly brushed or blasted to a dull gray appearance.

Faying surfaces of bolted connections shall be prepared and constructed in conformance with Section 513.

Splices and field connections of main members shall have all holes filled with high-strength bolts or cylindrical drift pins, with bolts fully tightened before external support systems are removed.

(c) Installation. Bolted connections shall be assembled with a hardened washer under the turned element. Hardened steel washers shall be used under both the head and the nut when bolts are used for the following connections:

(1) Oversized holes (fabricated as per Contract).

(2) Replacing existing bolts or rivets.

(3) Oversized and irregular hole conditions caused from field drilling or reaming.

(4) Connections between new steel and existing steel.

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

Bolts installed with the stem vertical shall have the heads up. Bolts installed with the stem horizontal shall have the head towards the weather unless clearance restrictions dictate otherwise.

Normally the nut will be the tightened element; however, if the position of bolt entering or wrench operation clearances prohibit this procedure the bolt may be the turned element.

Tightening of a bolt group shall progress systematically from the most rigid part of the joint to its free edges.

Previously tightened bolts shall be re-tightened until all bolts in the connection are tightened to the minimum required tension.

Recalibration of a wrench may be required any time there appears to be a significant change in the condition of bolt tightening.

All bolts in a connection shall first be brought to a “snug tight” condition. “Snug tight” is defined as initial tension sufficient to bring all the plies of the connection into firm contact while the drift pins remain in the connection. Snugging shall progress systematically, beginning at the most rigid part of the connection and progressing to the free edges until the connection is fully compacted.

All high-strength bolts shall be tightened to the specified tension as soon after installation as feasibly possible. Under no circumstances shall bolts be left untightened for more than five days after installation unless specific requirements to do so are indicated in the Contract or directed by the Engineer. Bolts left in place beyond five days without specific requirements in the Contract or as directed by the Engineer shall be removed and replaced with new bolts at the Contractor’s expense.

Bolts shall be tightened to develop a tension not less than 5 percent in excess of the minimum bolt tension specified in Table 506.19A by either the calibrated wrench, turn of the nut, torque, tension control assembly (“twist-off”), or direct tension indicator method. Bolts shall not be tightened to more than the maximum tension specified in Table 506.19A.

Bolts shall be tensioned by the Contractor in the presence of the Engineer using one of the following methods:

(1) Calibrated Wrench Method. A random sample of not less than three bolt and nut assemblies of each diameter, length, grade and type to be used in the work shall be checked a minimum of each working day in a device capable of indicating bolt tension.. The test shall be performed on each wrench to be used to determine the working torque for the wrench. Variations in the number or location of washers will require separate checks. Additional calibration of the wrenches being used shall be performed as directed by the Engineer.

All powered wrenches shall be adjusted to stall or cut-out at the specified tension. Power wrenches without cut-outs will not be permitted.

(2) Turn of the Nut Method. All bolts shall be tightened by the applicable amount of nut or head rotation specified in Table 506.19B. During the tightening operation, there shall be no rotation of the part not turned by the wrench.

A random sample of not less than three bolt and nut assemblies of each diameter, length, grade and type to be used in the work shall be checked each working day in a device capable of indicating bolt tension. The test shall demonstrate that the method of estimating the "snug tight" condition and controlling turns from "snug tight" to be used by the bolting crew(s) develops a tension of at least 5 percent in excess of the minimum bolt tension specified in Table 506.19A, and not more than the maximum tension specified in Table 506.19A. Separate checks will be required for each diameter fastener with hardened washers placed under the nut and/or bolt head as they will be used in the structure. Variations in the number or location of washers will require separate checks.

(3) Torque Method. Manual torque wrenches for installation shall be supplied by the Contractor, calibrated yearly, and each accompanied by a certificate indicating its date of calibration. A random sample of not less than three bolt and nut assemblies of each diameter, length, grade and type to be used in the work shall be checked a minimum of each working day in a device capable of indicating bolt tension. The test shall be performed on each wrench to be used to determine the working torque for the wrench. Additional calibration of the wrenches shall be performed as directed by the Engineer. Separate checks will be required for each diameter fastener with hardened washers placed under the nut and/or bolt head as they will be used in the structure. Variations in the number or location of washers will require separate checks.

This method may be used to "touch up" bolts previously tightened and that may have been loosened by the tightening process or as a means of bringing all bolts in any given connection to the specified tension.

(4) Tension Control Assembly Method. A tension control assembly consists of a tension control bolt with a spline end and a suitable nut and washer. This method shall be employed when installing "button" or "dome" headed high strength bolts.

All bolts shall be tightened by the application of torque to the nut and counter-torque to the spline end of the bolt using an approved spline drive installation tool. A random sample of not less than three tension control assemblies of each diameter, length, grade and type to be used in the work shall be checked a minimum of each working day in a device capable of indicating bolt tension. The test shall be performed to verify that the spline twist-off develops a tension of at least 5 percent in excess of the minimum bolt tension specified in Table 506.19A, and not more than the maximum tension specified in Table 506.19A . Additional verification of the tension control assemblies shall be performed as directed by the Engineer. Separate checks will be required for each diameter fastener with hardened washers placed under the nut and/or bolt head as they will be used in the structure. Variations in the number or location of washers will require separate checks.

(5) Direct Tension Indicator Method.

Direct tension indicators (DTIs) are compressible washers capable of indicating that a specified minimum bolt tension has been attained. DTIs installed with high strength bolts to indicate bolt tension shall be subjected to field verification testing prior to installation and the installation requirements specified below.

DTIs installed with high-strength bolts to indicate bolt tension shall be placed under the head of the bolt with the protrusions facing the head of the bolt, and the nut shall be turned, with a hardened washer underneath it, to tension the fastener. If for reasons of installation or inspection accessibility it is necessary to place the DTI under the turned element, the DTI shall be oriented so that the protrusions face outward from the work, and a hardened washer shall be placed between the DTI and the turned element.

The bolt, DTI, hardened washer and nut assembly used in the verification testing device and installed in the work shall be such that at least 3 and preferably not more than 5 threads are located in the grip. The grip is defined as the distance between the bearing face of the nut and the bolt head.

Bolts used in the verification test and installed in the work shall not be tightened to a "no-visible" gap condition such that all of the DTI protrusions are completely compressed. A visible gap must remain in at least one space after installation. It is permissible to have no entries and still have a visible gap. The tension in the bolt becomes indeterminate when no visible gap exists and may exceed the maximum tension of the fastener.

The Contractor shall supply 5 mil tapered feeler gages, a calibrated bolt tension-measuring device and equipment necessary to perform field verification testing and inspection of tensioned bolts. The feeler gages, fasteners and impact and manual wrenches shall be the same as that to be used in the work.

The Contractor shall obtain the services of a qualified technical advisor employed by the DTI manufacturer to make at least one site visit to assist the Contractor and to assure the proper installation and use of DTIs. This requirement may be waived by the Engineer if the Contractor can demonstrate to the Agency's satisfaction successful use of DTIs on previous projects for the Agency.

Verification testing shall be performed in a calibrated bolt tension measuring device, such as a Skidmore-Welhelm Calibrator, with a special flat insert (supplied by the Contractor) replacing the normal bolt head-holding insert. The special insert allows the DTI to be located on the flat front face of the tension measuring device for ease of observation and improved access for measuring the DTI gap during testing.

The verification testing shall demonstrate that the DTIs were properly manufactured. The fastener shall develop a tension of at least 5 percent in excess of the minimum bolt tension specified in Table 506.19A when the DTI has been compressed to allow entries for fewer than half the number of spaces, and the fastener shall not plastically deform when the DTI is compressed to the maximum allowable limit for the project.

Three verification tests are required to be performed on random samples of each combination of fastener rotational-capacity lot, DTI lot and DTI position (under the nut or bolt head) used on the project. All three tests must pass for the DTI and assembly combination to be approved. Testing shall be performed at the project site by the Contractor and witnessed by the Engineer.

When testing for the normal DTI position, the nut shall be turned with the bolt head against the DTI restrained from turning with another wrench. When testing with the DTI under the turned element, the turned element shall be placed on the flat front face of the tension measuring device and the unturned element will be in the rear held by another wrench.

a. Verification Test. The verification test shall be conducted in two stages as follows:

1. Stage 1. Tension the fastener to the Verification Tension load specified in Table 506.19C for the grade and size of fastener. If an impact wrench is used, tension to a load two-thirds below the required load and use a manual wrench to attain the required tension. Determine and record the number of entries of a 5 mil feeler gage in the spaces between the protrusions. When using coated (galvanized or epoxy coated) DTIs under the turned element, there shall be at least one entry of the feeler gage. The DTI lot will be rejected if the number of entries is less than the value in column 3 of Table 506.19C, or for coated DTIs used under the turned element, there are no entries.

2. Stage 2. Further tension the fastener beyond the verification load with a manual wrench until there are no entries for the 5 mil feeler gage but a visible gap exists in at least one space. Note and record the load in the bolt at this condition (the maximum allowable limit of DTI compression) and remove the fastener from the tension measuring device. The capability of the bolt to tolerate the maximum allowable limit of DTI compression is determined in two ways. The simplest is to hand turn the nut down the complete thread length of the bolt, excluding thread runout. If this is successful, then the bolt has not undergone significant plastic deformation and the assembly passes the verification test. Alternatively, if the nut cannot be turned down the complete thread length, the DTI lot will be rejected unless the load recorded is less than 95% of the average load measured in the rotational capacity test of the fastener lot as specified in the applicable AASHTO design code, in which case the assembly is deemed to have passed the test.

Bolts and DTIs used in verification tests shall be marked and shall not be reused in the work.

If the bolts are too short to be tested in the tension measuring device, Stage 1 of the Verification Test for the DTI shall be conducted on a longer bolt Stage 2 of the Verification Test shall be conducted for the short bolt with the short bolt in a convenient hole in the work. The fastener assembly shall be tensioned with a manual wrench until there are no entries for the 5 mil feeler gage but a visible gap exists in at least one space. The fastener shall then be disassembled. Subsequently, the nut must be run down, by hand, for the complete thread length of the bolt excluding thread runout. The DTI lot will be rejected if the nut cannot be assembled to this thread length. Three verification tests are required as specified above.

b. Installation. Installation of fasteners utilizing DTIs shall be conducted in two steps as follows:

1. Step 1. All of the bolts in a connection shall be installed to a snug tight condition. Snugging shall progress systematically beginning at the most rigid part of the connection and progressing to the free edges until the connection is fully compacted. At the snug tight condition all of the DTIs shall be inspected with the feeler gage to verify that they meet the number listed in column 3 of Table 506.19C. If the number of entries is less than the values specified in the Table, the fastener must be removed and another DTI installed, followed by re-snugging of the fastener. This is required because a fastener's tension may have relaxed during the snugging of adjacent fasteners. A compressed DTI does not rebound if the fastener tension is reduced. If a DTI which has fewer entries were left in place, it would give a false indication of bolt tension.

2. Step 2. The bolts in the connection shall then be further tensioned to the point that the number of entries for a 5 mil feeler gage meets the number listed in Column 5 of Table 506.19C. Tightening shall progress systematically beginning at the most rigid part of the connection and progressing to the free edges. Drift pins shall be removed during this process. Several cycles may be required. If the fastener is tightened so that no visible gap in any space remains, the bolt and DTI shall be removed and replaced by a new properly tightened fastener and DTI.

TABLE 506.19A (METRIC)
BOLT TENSION
AASHTO M 164M (ASTM A 325M) BOLTS

Nominal Bolt Diameter (mm)	Minimum Bolt Tension (kN)*	Maximum Bolt Tension (kN)**
M16	91.0	117.0
M20	142.0	182.7
M22	176.0	225.9
M24	205.0	263.7
M27	267.0	342.9
M30	326.0	419.4
M36	475.0	610.2

* Equal to 70 percent of specified maximum tensile strength of bolts.
** Equal to 90 percent of specified maximum tensile strength of bolts.

TABLE 506.19A (ENGLISH)
BOLT TENSION
AASHTO M 164 (ASTM A 325) BOLTS

Nominal Bolt Diameter (inches)	Minimum Bolt Tension (pounds)*	Maximum Bolt Tension (pounds)**
1/2	12,050	15,500
5/8	19,200	24,700
3/4	28,400	36,500
7/8	39,250	50,500
1	51,500	66,200
1 1/8	56,450	72,600
1 1/4	71,700	92,200
1 3/8	85,450	109,800
1 1/2	104,000	133,700

* Equal to 70 percent of specified maximum tensile strength of bolts.
** Equal to 90 percent of specified maximum tensile strength of bolts.

TABLE 506.19B
NUT ROTATION FROM SNUG TIGHT CONDITION
AASHTO M 164M (ASTM A 325M)
[AASHTO M 164 (ASTM A 325)] BOLTS

Bolt Length (as measured from underside of head to extreme end of point)	Disposition of Outer Faces of Bolted Parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (v:h) (bevel washer not used)	Both faces sloped not more than 1:20 (v:h) from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	(120 °) 1/3 turn	(180 °) 1/2 turn	(240 °) 2/3 turn
Over 4 diameters but not exceeding 8 diameters	(180 °) 1/2 turn	(240 °) 2/3 turn	(300 °) 5/6 turn
Over 8 diameters but not exceeding 12 diameters	(240 °) 2/3 turn	(300 °) 5/6 turn	(360 °) 1 turn

Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn (180 degrees) and less, the tolerance shall be ± 30 degrees; for bolts installed by 2/3 turn (240 degrees) and more, the tolerance shall be ± 45 degrees.

For bolt lengths exceeding 12 diameters, the required rotation must be determined by actual test in a suitable tension device simulating the actual conditions.

Table 506.19C (Metric) – AASHTO M 164 M(ASTM A 325M) Direct Tension Indicators

Bolt Size	Verification Tension[1] (kN)	Verification Required number of Entries[2,3]	Number of DTI Spaces between Protrusions	Installation Required Number of Entries[2,4]
M16	96	3-4	4	0-2
M20	149	3-5	5	0-2
M22	185	3-5	5	0-2
M24	215	3-5	5	0-2
M27	280	4-6	6	0-3
M30	342	4-7	7	0-3
M36	499	5-8	8	0-4

Table 506.19C (English) – AASHTO M 164 (ASTM A 325) Direct Tension Indicators				
Bolt Size (in.)	Verification Tension [1] (kips)	Verification Required number of Entries [2,3]	Number of DTI Spaces between Protrusions	Installation Required Number of Entries [2,4]
½	13	3-4	4	0-2
5/8	20	3-4	4	0-2
3/4	29	3-5	5	0-2
7/8	41	3-5	5	0-2
1	54	4-6	6	0-3
1-1/8	59	4-6	6	0-3
1-1/4	75	4-7	7	0-4
1-3/8	89	4-7	7	0-4
1-1/2	108	5-8	8	0-4

[1] Verification tension is 1.05 x the minimum tension in Table 506.19A.

[2] An entry occurs when a 5 mil tapered feeler gage fits into the space between DTI protrusions and touches the bolt shank.

[3] For coated DTIs under the turned element at least one entry is required.

[4] For coated DTIs under the turned element no entries are allowed.

(d) Acceptance of Bolt Tensioning.

The installation and tightening of bolted connections shall be observed to determine if the tightening procedure is working properly and the correct tension has been achieved. The Engineer will observe and verify the checking of impact wrenches used for the calibrated wrench method. The Engineer will also observe and verify the checking of manual torque wrenches used for the torque method.

The Contractor shall provide a tension measuring device, such as a Skidmore-Wilhelm Calibrator, that has been calibrated within the last year and is accompanied by a certificate verifying its date of calibration. The wrench shall be calibrated yearly and accompanied by a certificate indicating the date of calibration.

Before the installation of fasteners in the work, the Engineer shall check the marking, surface condition and storage of bolts, nuts and washers and the faying (contact) surfaces of joints for compliance with the Contract requirements.

With the exception of inspecting direct tension indicators and the tension control assemblies, the Engineer will inspect fasteners after installation by applying the inspecting wrench to a minimum of 10 percent of the bolts, but not less than two bolts, selected at random in each connection. The actual torque value of each inspected bolt will be determined as the head or nut is rotated 5 degrees in the tightening direction. This value shall be within the minimum and maximum job inspecting torque values as determined during the calibration of the inspection torque wrench using the bolt tension values specified in Table 506.19A.

The Engineer will determine the inspection torque at least once each day by tightening five bolts of the diameter, length and grade being used in the work in a device capable of indicating actual bolt tension. The job inspecting torque shall be taken as the average of three values thus determined after rejecting the high and low values. The inspecting wrench shall then be applied to the tightened bolts in the work and the torque necessary to turn the nut or head 5 degrees [approximately 25 mm at a 300 mm radius (1 inch at a 12 inch radius)] in the tightening direction shall be determined. Either the Engineer, or at the Engineer's option the Contractor in the presence of the Engineer,,shall use the inspection wrench.
Bolt tension for fasteners with DTIs shall be verified by the use of a manual inspection torque wrench (which indicates torque by means of a dial) or by using 5 mil tapered feeler gages provided and operated by the Contractor.

All bolts installed using DTIs shall be inspected after snug tightening and again after full tensioning, with 100% of the bolts inspected visually and 10% of the bolts in any connection (but not less than two) inspected by feeler gage. If the installation of inspected bolts is accepted, then the connection shall be accepted as properly tensioned. If any bolt in a connection does not pass inspection, then all (100%) of the bolts in that connection shall be inspected with the feeler gage. Any bolt which does not pass inspection as described herein shall be further tensioned if required, or if over tensioned, removed and replaced by a new properly tensioned bolt and DTI.

Bolts installed using tension control assemblies shall be visually inspected for consistent "twist-off" and thread stick out.

If any bolt in a connection is found to have a torque value below the minimum or above the maximum job inspecting torque, all bolts in that connection shall be inspected. All under-tightened bolts shall be tightened and reinspected. All over-tightened bolts shall be loosened and the bolt and nut removed for visual inspection of the bolt and nut threads. If there is visible thread damage or the nut does not spin freely on the bolt when turned by hand without the aid of a wrench, a new bolt and nut shall be installed. Undamaged fasteners may be reinstalled with the following exception: Galvanized bolts, AASHTO M 253M (AASHTO M253) bolts, tension control assemblies and direct tension indicators shall not be reused. This specification does not recognize standard torques determined from tables or from formulas which are assumed to relate torque to tension. Testing using such standard torques shall not be considered valid. Inspection torques must be determined directly from calibrations performed at the project site reflecting actual work conditions.

The procedure specified is intended for inspection of bolted connections and verification of pretension within 24 hours of tensioning the joint. If verification of bolt tension is required after a passage of a period of time and exposure of the completed joints, the procedures will provide an indication of bolt tension that is of questionable accuracy. Procedures appropriate to the specific situation should be used for verification of bolt tension. This might involve use of the inspection procedure, or might require the development and use of alternate procedures.

An additional required inspection step is to check the bolt thread stickout on the nut side after installation to the final specified gap to look for inconsistency of pattern. Any stickouts greater than the other bolts shall be investigated and discarded (e.g. if necking down of the bolt has occurred or the wrong length bolt was used). The end of the properly installed bolt shall be at least flush with the nut or stick out not more than three threads.

The Engineer shall be provided with safe access in accordance with Section 105 to conduct all inspection deemed necessary during and after the installation of the bolts. If the Engineer determines that the access provided is unsafe, work will be ordered to halt until such time the access is made safe. Any delays incurred by the unsafe access will not be cause for a monetary, material or delay claim.

506.20 THIS SUBSECTION RESERVED.

506.21 STRAIGHTENING BENT MATERIAL**.** Damaged, bent or misaligned structural steel may only be straightened or corrected by procedures approved by the Agency. The method of repair proposed by the Contractor shall be submitted as Construction Drawings for approval in accordance with Section 105. No corrective work shall be performed without Agency approval. Heating limitations and procedures shall conform to the requirements of Subsection 506.12.

Members or parts to be heat straightened must be free of stress from external forces other than those necessary and used in conjunction with the application of heat. Following straightening, the surface of the metal shall be free of any evidence of distortion or fracture. Required nondestructive tests shall be performed by NDT Level II or III personnel at the Contractor's expense.

506.22 FIELD CLEANING. When assembly of the fabricated structural components is complete, any rust, scale, dirt, grease or other foreign material shall be removed from the metal components.

If the components are new steel which is metalized or galvanized or which is to remain unpainted, the cost of such necessary cleaning will not be paid for directly, but will be considered incidental to the Section 506 items in the Contract.

506.23 UNCOATED STEEL. Care must be taken to keep chemicals and oils from contacting the exposed surfaces of unpainted steel during storage, erection and construction of the deck.

(a) Staining of Masonry. The Contractor shall protect all concrete and masonry from staining due to oxide formation on the steel.

(b) Cleaning of Steel. After all concrete has been placed, the outside surface of the fascia beams and bottom surface of their lower flanges shall be cleaned of all foreign material to a uniform appearance. The Engineer may require the exposed surfaces to be blast cleaned to preparation grade SSPC-SP10 defined by SSPC-VIS 1. The use of acids for cleaning is prohibited.

506.24 METHOD OF MEASUREMENT.

(a) Bids on a Kilogram (Pound) Basis. The quantity of Structural Steel, or other material being paid under this item, to be measured for payment will be the number of kilograms (pounds) used in the complete and accepted work. The mass (weight) of the material to be measured for payment under this item will be computed based on the approved Fabrication Drawings, as follows:

(1) Mass (weight) determined by the volume of material will be computed on the basis of the following densities:

Material	kg/m^3	$lbs./ft^3$
Aluminum, alloy	2800	173
Bronze, cast	8600	536
Copper, alloy	8600	536
Copper, sheet	8900	558
Iron, cast	7100	445
Iron, wrought	7800	487
Lead, sheet	11 300	707
Steel; rolled, cast, copper bearing, silicon, nickel and stainless	7850	490
Preformed fabric pads	1400	88

For any material not listed above, the material will be paid for by actual mass (weight) as measured on a certified scale.

(2) The mass (weight) of rolled structural shapes will be computed on the basis of their nominal mass per meter (weight per foot) as shown on the Plans or, if not shown on the Plans, by the masses (weights) shown in the current edition of the AISC Manual.

The mass (weight) of rolled shapes will be based on the overall net length shown on the approved Fabrication Drawings, with no allowance for milling, finishing or overrun, and with no deduction for cuts, clips, copes or open holes.

(3) The mass (weight) of plates will be based on the net finished dimensions shown on the approved Fabrication Drawings, with no allowance for milling, finishing, tolerance or overrun, and with no deductions for copes, clips and open holes. The masses (weights) of beveled plates or curved surface plates will be based on the finished maximum thickness shown on the approved Fabrication Drawings.

For gusset plates, scupper components, slotted plates and similar minor fixtures the net finished dimensions will be the minimum rectangular dimensions from which the parts are cut, except when it is practical to cut the parts in multiples from pieces of larger dimensions, in which case the mass (weight) will be based on the dimensions of the larger pieces, making necessary allowance for the material lost in cutting.

The net finished dimensions of flange plates will be the nominal width and the finished length measured along the centerline of the flange without deduction for width transitions, bevels or chamfers.

The net finished dimensions of the webs of all girders and of the webs of rigid frame legs will be the actual area of the web as detailed on the approved Fabrication Drawings.

(4) The mass (weight) of fabricated metal items such as U-bolts, welding studs and lugs will be based on the overall net dimensions of the finished product as shown on the approved Fabrication Drawings.

(5) All welding shall be considered as incidental work to the fabrication, and no measurement will be made for the mass (weight) of weld metal used.

(6) Measurement for castings will be by mass (weight) measured on scales.

(7) When it is specified that any part of the material is to be measured by actual mass (weight), finished work shall be weighed in the presence of the Inspector. In such case, the scales shall have been certified for accuracy within a one-year period.

(8) When the Contract includes bearings or bearing connections as part of this work, the mass (weight) of anchor bolts to be embedded in concrete will be based on the nominal dimensions shown on the approved Fabrication Drawings with no deduction for deformations but including the mass (weight) of nuts and washers. The mass (weight) of pins, pintels and rollers will be based on the overall finished dimensions shown on the approved Fabrication Drawings with no deductions for threads, open holes, pockets or allowance for excess diameter required for finishing.

(9) The mass (weight) of permanent shop and field bolts, nuts, direct tension indicators and washers incorporated into the structure and temporary erection bolts, nuts and washers shall be incidental to the Structural Steel item and no measurement will be made for mass (weight) of the bolts, nuts, direct tension indicators and washers.

(b) Bids on Lump Sum Basis. The quantity of Structural Steel, or other material being paid under this item, to be measured for payment will be the number of units for each structure complete and accepted as specified in the Contract.

506.25 BASIS OF PAYMENT. The accepted quantity of Structural Steel will be paid for at the Contract unit price per kilogram (pound) for the items specified in the Contract. Payment will be full compensation for furnishing, detailing, handling, transporting and placing the materials specified, including nondestructive testing of welds; for preparing the surface of new steel to be galvanized, metalized, or to remain unpainted; for necessary field cleaning; for sealer coating of metalized surfaces; for metalizing or galvanizing of surfaces unless otherwise paid for; for furnishing and implementing the erection plan, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment for Structural Steel on a lump sum basis will be full compensation for performing all work specified and for furnishing all labor, materials, tools, equipment, erection plan(s) and incidentals necessary to complete the work.

The costs of surface preparation of new steel to remain unpainted or to be galvanized or metalized will not be paid for directly, but will be considered incidental to the Section 506 items in the Contract.

Surface preparation of rehabilitated or reconditioned steel, whether it is to receive protective coating(s) or it is to remain uncoated; surface preparation of galvanized steel that is to receive additional protective coating(s); and surface preparation of new steel that is to receive protective coating(s), except for the sealer coating of metalized surfaces are not included in any Contract item in Section 506. The costs of this work will be paid under the appropriate Section 513 Contract items.

The Engineer may authorize progress payments in the following manner:

(a) A maximum of 75 percent of the estimated quantity may be paid when the steel has been delivered to the site.

(b) A maximum of 95 percent of the estimated quantity may be paid when the steel has been erected, falsework removed, extended weights have been received and checked, and painting of connections and "touch up" completed where required.

(c) After completion and acceptance of all work under this Section, 100 percent of the quantity will be paid.

All nondestructive testing and required quality control activities will be considered incidental to fabrication, and no separate payment will be made.

Payment will be made under:

Pay Item		Pay Unit
506.50	Structural Steel (Rolled Beam)	Kilogram (Pound)
506.55	Structural Steel (Plate Girder)	Kilogram (Pound)
506.56	Structural Steel (Truss)	Kilogram (Pound)
506.60	Structural Steel	Kilogram (Pound)
506.75	Structural Steel	Lump Sum