SECTION 410 STEEL STRUCTURES

410.1 DESCRIPTION

This work consists of furnishing, fabricating and erecting the steel and miscellaneous metals required for structures.

410.2 MATERIALS

Materials shall conform to the following sections:

Steel: Section 970.

Portland Cement: Section 750.

Paint: Section 411.

410.3 CONSTRUCTION REQUIREMENTS

The structural steel fabicating plant shall be certified under the AISC Quality Certification Program, Catagory I. Fabricators of steel bridge girders, trusses, arches and main supporting members shall be certified Category III Fabricators in the AISC Quality Certification Program. Structural steel shall be fabricated, erected, welded, and painted in accordance with these specifications.

A. **Notice of Beginning of Work:** The Contractor shall require the fabricator to give the Engineer 30 days notice prior to beginning work at the mill or in the shop, so inspection may be provided. The term "mill" means any rolling mill or foundry where material for the work is to be manufactured. Material shall not be manufactured or work done in the shop prior to notification.

B. **Facilities for Inspection:** Facilities for the inspection of material and workmanship in the mill and shop shall be furnished. The inspector shall be allowed free access to the work.

C. **Rejections:** The acceptance of any material or finished members by the inspector shall not preclude the subsequent rejection if found defective by the Engineer. Rejected material and workmanship shall be replaced or repaired.

D. **Identification of Steel:** The Contractor shall require the fabricator to demonstrate, by a written procedure and by actual practice, a method of material application and traceability, visible at least through the "fit up" operation, of the main stress carrying elements of a shipping piece. The traceability method shall be capable of verifying proper material application as it relates to:

-Material Specification designation.

-Heat Number if required.
-Material test reports for special requirements where required.

E. Shop Plans: Shop plans will be required for all structural steel and miscellaneous metal parts for structures. Shop plans for steel structures and structural steel components shall give full detailed dimensions and sizes of component parts of the structures and details of all miscellaneous parts such as pins, nuts, bolts, drains, etc. Where specific orientation of plates is required, the direction of rolling of plates shall be shown. Shop plans shall identify the material type and grade for each piece of structural steel. Unless otherwise specified on the plans, the fabricator shall initially submit two copies of the shop plans to the Office of Bridge Design for review. Shop plans shall be submitted a minimum of 15 days prior to start of fabrication. One reviewed copy will be sent back to the fabricator who will then make the necessary changes and then send six final copies to the Office of Bridge Design for approval and distribution.

F. Shop Assembling:

1. Cleaning Surfaces: Surfaces of metal in contact shall be cleaned before assembling.

2. Bolted Connections: Each bolted field connection of main members of continuous plate girders or beam spans shall be subpunched or subdrilled and subsequently reamed while the girder or beam sections are shop assembled. At the fabricators option, each bolted field connection of main members of continuous plate girders or beam span may be simultaneously drilled through the girder and splice plate, to full size holes while the girder or beam sections are shop assembled.

a. Assembly: Only the girder or beam sections involved in the reaming of a particular connection must be assembled at any one time. The sections involved, including all splice plates and filler plates, shall be assembled and firmly drawn together with bolts before reaming.

b. Disassembly: After disassembly, all burrs and shavings produced by the reaming operation shall be removed.

G. Welding Inspection: Shop and field welding and welding inspection of structural steel and steel railing shall be done in accordance with the the latest edition of the ANSI/AASHTO/AWS D1.5-xx Bridge Welding Code.

Electroslag or Electrogas welding processes shall not be used.

H. Welder Qualification: Welders, Welding Operators, and Tack Welders (hereafter the term Welder shall refer to all three) shall be qualified in accordance with the latest edition of the ANSI/AASHTO/AWS D1.5-xx Bridge Welding Code (hereafter referred to as the Code). Welders, except Tack Welders, shall be qualified for an unlimited thickness groove weld in test Position 3G (vertical). If the project requires overhead welding, qualification in Position 4G (overhead) will also be required. Tack Welders shall be qualified in accordance with the Code. Welder qualification shall be performed under the supervision of an AWS

Certified Welding Inspector (CWI) qualified and certified in accordance with the provisions of AWS QC1.

Inspectors performing nondestructive inspection, other than visual inspection, shall be qualified in accordance with the American Society for Nondestructive Testing (ASNT) "Recommended Practice No. SNTC-TC-1A, Level II." Test results shall be recorded on the "Welder and Welding Operator Qualification Record," Form E-4 (Appendix III of the Code), signed by the inspector and submitted to the Bridge Construction Engineer (BCE). If approved, the BCE will issue a Welder Certification Card to the Welder.

Welding will not be allowed without a valid Welder Certification Card. The BCE will accept Form E-4's for review on which the test date is not more than one year old. If the test date is more than one year but not more than two years old, the BCE will also require evidence of continued employment as a Welder or Welding Operator. If the test date is more than two years old, retesting will be required. Welder certification cards will remain valid indefinitely unless the Welder is not engaged in the processes of welding, for which he is qualified, for a period exceeding six months. If there is some reason to question the Welder's ability the Engineer may revoke the Welder Certification Card unless a satisfactory retest is accomplished.

I. Transportation, Handling, Storage and Erection: Structural steel shall be loaded, transported, unloaded, and stored without damaging the material. Material shall be stored on skids above the ground, so the materials can be kept clean and drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids properly spaced to prevent deflection. High strength bolts shall be stored so they will be kept free from rust or foreign material.

Girders shall not be placed until seven days after the supporting concrete, including grout used to construct bearing pads, has been placed or until the concrete or grout has attained a compressive strength of 2000 psi (14 MPa). Forming operations for the deck shall not begin until all of the girders in a continuous unit have been erected and adjusted and required erection elevations taken.

1. **Falsework:** The falsework shall conform to the requirements of Section 423.

2. **Bearings and Anchorages:** Bridge bearings shall be set level, in exact position, and must have full and even bearing on the concrete.

   Elastomeric bearing pads shall set directly on the concrete.

   Cast iron, steel or rolled steel bearings shall be bedded on the concrete with a single thickness sheet of preformed fabric bearing pad.

   Anchor bolts may be set in the concrete or the concrete blocked out and the bolts set later. When holes are blocked out, they shall be approximately four inches in diameter to allow for horizontal adjustment of the bolts.

Location of anchors and setting of rockers or rollers shall take into account any variation from the mean temperature at time of setting and anticipated lengthening of bottom chord or bottom flange due to dead load after setting. At mean temperature or the temperature indicated on the contract and under dead load, the rockers and rollers shall set vertical and the anchor bolts at expansion bearings shall be centered in their slots. Full and free movement of the superstructure at the movable bearings must not be restricted by improper setting or adjustment of bearings or anchor bolts and nuts.

Bridge bearings shall not be placed on masonry bearing areas which are irregular or improperly formed.

Grout used to set anchor bolts and construct bearing pads shall conform to the requirements of Section 460.3.R

3. **Straightening Bent Material and Cambering:** The straightening of plates, angles, other shapes and built-up members shall be done by methods that will not produce fracture or other injury. Distorted members shall be straightened by mechanical means or by the carefully planned and supervised application of a limited amount of localized heat. Heat straightening of ASTM A514/A517 steel members shall be done only under rigidly controlled procedures. The maximum temperature of the ASTM A514/A517 steel shall not exceed 1125EF (605EC), nor shall the temperature exceed 950E F (510EC) within six inches of weld metal. Heat shall not be applied directly on weld metal. In all other steels, the temperature of the heated area shall not exceed 1150E F (620EC). Temperature shall be controlled by indicating-crayons, liquids or bimetal thermometers.

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

   Following the straightening of a bend or buckle, the surface of the metal shall be inspected for evidence of fracture.

   Correction of errors in camber in welded beams and girders of ASTM A514/A517 material shall be done only under rigidly controlled procedures.

4. **Assembling Steel:** The parts shall be accurately assembled and match-marks shall be followed. The material shall be handled so parts will not be bent, broken or damaged. Hammering which injures or distorts the members shall not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking to give the trusses proper camber. The blocking shall be left in place until the tension chord splices are fully bolted and all other truss connections pinned and bolted. Permanent bolts in splices of butt joints of compressions members and permanent bolts in railings shall not be tightened until the span has been swung.

Splices and field connections shall be faired up with a sufficient number of fit-up-bolts or erection pins to maintain dimensions and plumbness of the structure and allow free entry of the bolts used in the final connection. Girder erection data given on the contract shall be utilized to establish proper girder profile, prior to final tightening to the bolts in the splices. Drifting during assembly to bring the parts into position shall not enlarge holes or distort the metal.

5. High-Strength Bolts:

a. All bolts, nuts, and washers shall have the manufacturers markings on them. The supplier shall provide the symbol and address of each bolt, nut, and washer manufacturer.

b. The supplier's certification shall provide a corresponding lot number which appears on the shipping package and on the certification. The certificate shall provide all test results and shall indicate when and where all testing was done, including the rotational capacity tests and the zinc coating thickness.

c. High-strength bolts shall be new ASTM A325 Type I bolts unless ASTM A490 bolts are specified on the plans.

d. Bolts, nuts, and washers shall conform to ASTM A325 and shall be mechanically galvanized.

e. High-strength bolts require tightening using direct tension indicators.

1) Direct tension indicators shall be mechanically galvanized in accordance with Class 50 of ASTM B695.

2) The average load indicator gap shall be reduced to 0.005 inch (0.125 mm) while tightening. The appropriate 0.0005 inch (0.0125 mm) feeler gauge shall be supplied.

f. The maximum hardness for AASHTO M164 (A325) bolts shall be 33Rc. The maximum tensile strength shall be 150 ksi (1030 MPa) for bolts 1 inch (25 mm)or less in diameter and 120 ksi (825 MPa) for larger bolts.

g. Nuts for mechanically galvanized fasteners shall be overtapped to the minimum amount required for the fastener assembly.

h. Mechanically galvanized nuts shall be lubricated with a lubricant containing a visible dye. Fasteners shall be protected from accumulating dirt prior to installation. Weathered, rusted, or soiled fasteners shall be cleaned and relubricated prior to installation.

i. High strength fasteners shall be subjected to a rotational-capacity test (AASHTO M164, Section 8.5) and shall meet the following:

1) Go through two times the required number of turns (from snug tight conditions) indicated in Table 1, nut rotations from snug tight conditions in a Skidmore-Wilhelm Calibrator, or equivalent tension measuring device, without stripping or failure.

2) During this test, the maximum recorded tension shall be equal to or greater than 1.15 times the Required Fastener Tension, Table 2.

3) The measured torque to produce the Required Fastener Tension shall not exceed the value obtained by the following equation:

(English)	**(Metric)**
Torque = 0.0208 PD	Torque = 0.00235 PD
Torque = Measured Torque (Foot-Pounds)	Torque = Measured Torque (N•m)
P = Measured Bolt Tension (Pounds)	P = Measured Bolt Tension (N)
D= Nominal Bolt Diameter (Inches)	D = Nominal Bolt Diameter (m)

j. The supplier and contractor shall maintain the identification and integrity of fasteners supplied under either the "Production Lot" or "Shipping Lot" method. All certificates, test reports and shipping containers shall be identified with the appropriate lot identification number. The Contractor shall indicate, at the preconstruction meeting, how he plans to maintain the integrity of the lots thru installation.

k. The test data referred to in 12.1 of ASTM A563 and 13.2 and 13.3 of A194 shall be furnished.

l. Proof load tests on bolts (ASTM F606 Method 1) are required. Wedge testing of full size bolts is required in accordance with Section 8.3 of AASHTO M164. Galvanized bolts shall be wedge tested after galvanizing. Proof load tests (AASHTO M291) are required for the nuts and shall be performed after galvanizing, overtapping, and lubricating.

m. A Skidmore-Wilhelm Calibrator, or other acceptable bolt tension indicating device, will be furnished by the Department at each job site during bolt installation.

TABLE 1 Nut Rotation from Snug Tight Conditions[1-2]

	Disposition of Outer Faces of Bolted Parts		
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[3]	2/3 turn	5/6 turn	1 turn

[1]Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by ½ turnand less, the tolerance should be +/- 30º ; for bolts installed by 2/3 turn and more, the tolerance should be +/- 45º.
[2]Applicable only to connections in which all material within the grip of the bolt is steel.
[3]No research has been performed by the Council to establish the turn-of-nut procedure for bolt lengths exceeding 12 diameters. Therefore the required rotation must be determined by actual test in a suitable tension measuring device which simulates conditions of solidly fitted steel.

TABLE 2 Required Fastener Tension
(English)

	Minimum Tension [a] in 1000's of Pounds (kips)	
Nominal Bolt Size, Inches	AASHTO M164 (ASTM A325) Bolts	AASHTO M253 (ASTM A490) Bolts
½	12	15
5/8	19	24
3/4	28	35
7/8	39	49
1	51	64
1-1/8	56	80
1-1/4	71	102
1-3/8	85	121
1-1/2	103	148

[a]Equal to 70 percent of specified minimum tensile strengths of bolts (as specified in ASTM Specifications for tests of full size A325 and A490 bolts with UNC threads loaded in axial tension) rounded to the nearest kip.

Table 2 Required Fastener Tension
(Metric)

Nominal Bolt Size, mm & pitch	Minimum Tension [a] in kN. AASHTO M164 (ASTM A325M) Bolts (kN)	AASHTO M253 (ASTM A490M) Bolts (kN)
M16x2	90	115
M20x2½	140	180
M22x2½	175	220
M24x3	205	255
M27x3	265	335
M30x3½	325	410
M36x4	475	595

[a]Equal to 70 percent of specified minimum tensile strengths of bolts (as specified in ASTM Specifications for tests of full size A325 and A490 bolts loaded in axial tension) rounded to the nearest 5 kN.

6. **Connections Using High Strength Bolts:** Girder splices and other structural joints utilizing high strength bolts in friction-type connections shall use the direct tension indicator fastening system.

a. Direct tension indicators (DTI) shall conform to the requirements of ASTM F959.

The direct tension indicators shall be capable of providing the required bolt tension when the measured gap between the direct tension indicator and the surface against which the protrusions bear is reduced to that specified. The direct tension indicator shall be specifically marked to identify the type of bolt for which it is to be used. A different marking shall be used for ASTM A325 bolts than for ASTM A490 bolts. Direct tension indicators shall be new and unused.

Bolt lengths shall be determined as shown in Table 1.

TABLE 3
(English)
BOLT LENGTH

Bolt Size In Inches	Add to Grip* to Determine Bolt Length in Inches

5/8	7/8
3/4	1
7/8	1 1/8
1	1 1/4

* Grip is thickness of material to be connected, exclusive of washers. For each flat washer, add 3/16 inch to the grip. For each bevel washer, add 5/16 inch to the grip. For each direct tension indicator, add 1/8 inch to the grip.

NOTE: Irregular lengths shall be adjusted to the next longer 1/4 inch increment.

TABLE 3
(Metric)
BOLT LENGTH

Bolt Size	Add to Grip* to Determine Bolt Length in mm
M16	20
M20	24
M22	26
M24	28

* Grip is thickness of material to be connected, exclusive of washers. For each flat washer, add 3.1 mm for M16 and M20, add 3.4 mm for M24 mm and larger to the grip. For each bevel washer, add 7.5 mm to the grip. For each direct tension indicator, add 3 mm to the grip.

NOTE: Irregular lengths shall be adjusted to the next longer 5 mm increment.

b. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or other interposed compressible material.

When assembled, all joint surfaces, including those adjacent to the bolt heads, nuts or washers shall be free of scale, burrs, dirt, other foreign material and defects that would prevent solid seating of parts. Tight mill scale does not apply.

In girder splices and other friction-type connections, all contact surfaces shall be free of oil, paint, lacquer, and other coatings.

c. All fasteners shall have a hardened washer under the element turned in tightening. For installations utilizing ASTM A490 bolts where the steel work comprising the grip has a specified yield strength less than 40 ksi (275 MPa), special requirements for hardened washers will be

noted on the contract.

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

In the normal installation, the direct tension indicator shall be placed on the bolt with the protrusions bearing against the underside of the bolt head. For this type installation, the nut is the turned element and the hardened washer will be placed between the steel work and the nut.

If required, due to bolt entering and wrench operation clearances, it will be permissible to use the bolt head as the turned element. In this type installation, a hardened washer shall be placed under the bolt head and the direct tension indicator placed on the bolt with its protrusions bearing against the hardened washer.

In those installations, where inspection of the bolt head is too difficult, it will be permissible to place the direct tension indicator at the nut end. The direct tension indicator shall be placed on the bolt with protrusions facing toward the nut. A hardened washer is then placed on the bolt against the protrusions and the nut is installed. With this type installation, the nut is the turned element. Direct tension indicator protrusions shall bear against a hardened surface.

The surface contacting the protrusions of a direct tension indicator shall not turn during the tightening operation. For those type installations where the direct tension indicator is used adjacent to a hardened round washer, some slight movement of the hardened round washer is acceptable.

On bolt installations where beveled washers are used, or galvanized bolts are specified, or slotted or oversize holes are used, special requirements for hardened round washers and direct tension indicators must be observed, as provided in the contract.

d. All bolts in a joint shall be tightened to reduce the gap between the washer face of the bolt head and the face of the direct tension indicator. If the direct tension indicator is installed nearest to the turned element, between the face of the direct tension indicator and the hardened round washer, the average gap shall conform to that specified in 410.3.I.5.e.

When the average gap is equal to or less than that specified in 410.3.I.5.e. the bolt tensions indicated in Table 2 shall be assumed satisfied, unless the Engineer determines additional verification is

required.

A sufficient number of bolts shall first be placed in the joint and "snugged" to insure that all faying surfaces are in firm contact, prior to tightening. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary wrench. Bolts shall be placed in any remaining holes and snugged tight as erection bolts or pins are removed. All bolts in the joint shall then be tightened progressing systematically from the center most rigid part of the joint to its free edges. When tightening, the element not turned shall be held with a hand wrench to prevent rotation.

The gap between the bolt head and the face of the direct tension indicator is reduced while tensioning, due to the bolt clamping force which flattens the washer protrusions. When tightening, complete closure of the gap around the circumference should be avoided, to prevent over tightening theBolt. The gap may not be uniform around the circumference of the direct tension indicator as the wrench may pull the bolt off center in the hole, resulting in non-uniform compression of the protrusions. When non-uniform gap exists, the average gap criteria is satisfied if the gap measured at several points around the circumference shows 50 percent of the measurements to be equal to or less than the value specified in 410.3.I.5.e. If there is no gap at only one point on the circumference, the bolt is properly tightened and no further tightening shall be attempted.

Impact wrenches shall be of adequate capacity to perform the required tightening of each bolt in approximately 10 seconds.

The Contractor shall check the gap on a sufficient number of bolts to assure that the completed joint meets the requirements of this specification. A metal feeler gauge capable of probing between adjacent protrusions of the direct tension indicator shall be supplied by the Contractor. The Contractor shall supply the Engineer with an identical gauge for inspection.

After all bolts in a joint have been tightened, the Contractor shall return to the first bolts tightened to assure that they have not loosened. Lost tension may be restored by tightening so that the gap is slightly less than originally measured.

e. In order to determine acceptability of direct tension indicators prior to their actual installation, the Engineer shall witness the Contractor perform the following test:

1) At least three bolts, nuts, hardened round washers, and direct

tension indicators shall be selected from each lot of stockpiled materials intended for job use and shall be placed individually in a calibration device capable of indicating bolt tension. They shall be installed in the same manner and tightened with the same equipment intended for job use. If the bolt tension is equal to or greater than that specified in Table 2 when the gap is equal to or more than that specified in 410.3.I.5.e, the direct tension indicators shall be acceptable for use. The Engineer may order this test performed at additional times during the course of the job as warranted. The calibration device will be furnished by the Department. All costs associated with conducting these tests will be at the Contractor's expense.

2) The Engineer shall have full opportunity to witness installation of bolted connections and shall periodically observe the installation and tightening operation to ensure that proper procedures are being adhered to.

3) Upon completion of a bolted joint, the Engineer shall determine that all bolts have been tightened. A minimum of 20 percent, but not less than four bolts in each joint, shall be inspected with a metal feeler gauge. If all gaps checked are within the allowable distance described, the joint shall be accepted as properly tightened. If gaps checked are in excess of that specified, the Contractor shall reinspect and retighten each bolt in the joint, as required, and resubmit the joint for inspection.

4) The metal feeler gauge shall be used as a "no go" inspection tool by inserting the tapered nose of the gauge into the openings between protrusions. If the gauge does not enter, but a gap is evident, the installation is acceptable.

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

8. **Misfits:** The correction of minor misfits involving harmless amounts of reaming, cutting, and chipping will be considered a legitimate part of the erection. Any error in the shop fabrication or deformation resulting from handling and transportation which prevents the proper assembling and fitting of parts by the moderate use of drift pins or by a moderate amount of reaming and slight chipping or cutting, shall be reported immediately to the Engineer. The Engineer's approval of the method of correction shall be obtained. The

correction shall be made in the Engineer's presence. The Contractor shall be responsible for all misfits, errors, and injuries and shall make the necessary corrections and replacements.

J. **Painting Structures:** Painting structures shall be in accordance with Section 411. New structural steel shall have both the prime and finish coats of paint applied in the shop prior to shipment unless otherwise specified in the plans.

410.4 METHOD OF MEASUREMENT

Field measurement of structural steel will not be required. Adjustment in the contract price will not be made if the weight furnished is more or less than the estimated weight.

The weights of rolled shapes, slabs and plates will be computed on the basis of their nominal weights and dimensions. The weight will be computed on the following basis:

Unit weights of material in pounds per cubic foot (kilograms per cubic meter):

Cast Iron..... 445.0 (7128.0)
Copper Sheet..... 558.0 (8938.0)
Lead Sheet..... 707.0 (11,325.0)
Steel: cast, copper bearing, silicone,
nickel or stainless..... 490.0 (7849.0)
Wrought Iron..... 487.0 (7801.0)
Zinc..... 450.0 (7208.0)
Bronze or Copper-Alloy Bearing Plates..... 490.0 (7849.0)

The quantities of the various other pay items which constitute the completed and accepted structure will be measured for payment according to the plans and specifications.

410.5 BASIS OF PAYMENT

Structural steel will be paid for at the lump sum contract price. Payment will be full compensation for furnishing, fabricating, delivery, erecting ready for use, for the required non-destructive weld testing by radiographing, magnetic particle, ultrasonic inspection, or other specified alternate test procedures. Payment shall also include painting of the structural steel, unless a separate bridge painting bid item is included in the contract.

If changes in the work, which vary the weight of steel to be furnished, are ordered the payment will be adjusted as follows:

The value per pound (kilogram) of the increase or decrease in the weight of structural steel involved in the change shall be determined by dividing the contract lump sum amount by the estimate of weight shown on the plans. The adjusted contract payment will be the contract amount plus or minus the value of the steel involved in the change.

The accepted quantities will be paid for at contract unit price.