

SECTION 16447

STRUCTURAL BOLTING

PART 1 DESCRIPTION

- A. Furnish and install high-strength bolts for structural connections.

PART 2 MATERIALS

2.01 GENERAL

- A. Use the same supplier for bolts and nuts to ensure proper fit. Have the manufacturer or distributor perform rotational-capacity (R C) tests in accordance with Tex 452 A, as discussed in Section 16000, on all black or galvanized bolt, nut, and washer assemblies. Test each combination of bolt production lot, nut lot, and washer lot as an assembly and assign an R C lot number to each lot tested. Test 2 samples from each assigned R C lot.
- B. Furnish a manufacturer's certified test report (MCTR) or a distributor's certified test report (DCTR) for each R C lot supplied. Include in the MCTR or DCTR:
1. results of the R C tests,
 2. R C lot number,
 3. manufacturing location for assembly components,
 4. date and location of tests, and
 5. a statement that the materials represented by the test report conform to the specifications.

2.02 BOLTS

- A. Use bolts that meet the requirements of ASTM A 325 or A 490, except as modified in this Section. Provide bolts long enough for the installed bolt end to be flush with or outside the face of the nut.
- B. For weathering steel, use Type 3 bolts that meet ASTM A 325 or A 490. Use ASTM A 325 Type 1 for galvanized bolts.
- C. Provide bolts with UNC series threads for diameters less than or equal to 1 in. Provide bolts with 8UN series threads for diameters greater than 1 in.

2.03 NUTS

- A. Use nuts that meet the requirements of the applicable ASTM bolt specification (ASTM A 325 or A 490), and the applicable ASTM nut specification (ASTM A 563 or A 194), except that grade 2, C3, D, and D3 nuts must have a minimum Rockwell B hardness of 89.
- B. Provide nuts with UNC series threads for diameters less than or equal to 1 in. Provide nuts with 8UN series threads for diameters greater than 1 in.
- C. Ensure that galvanized nuts are lubricated with a lubricant containing a dye of a color that contrasts with the color of the galvanizing. If ASTM A 563 nuts will be galvanized, order them with supplemental requirement S2.

2.04 WASHERS

- A. Use washers that meet the requirements of ASTM F 436, and the applicable ASTM bolt specification (ASTM A 325 or A 490).

2.05 STORAGE

- A. Protect all bolts and nuts from dirt and moisture at the job site. Remove from protected storage only those bolts and nuts anticipated to be installed during a workday. Return unused fasteners to protected storage at the end of the day. Do not clean fasteners of lubricant present in the as-delivered condition. As directed, perform at the Contractor's expense a field R C test in accordance with Tex 452 A, as discussed in Section 16000, on any lot of fasteners that shows signs of rust, dirt, or loss of lubrication. If the fasteners fail the R C test, apply additional lubrication and rerun the R C test before installing bolts. Replace any fasteners that cannot be re-lubricated to pass the field R C test.

2.06 SAMPLING AND TESTING

- A. High-strength bolts, nuts, and washers may be sampled in accordance with Tex 719 I, as discussed in Section 16000. Perform field R C tests as directed in accordance with Tex 452 A, as discussed in Section 16000. Perform installation verification tests required in Section 16447, Part 4, 4.01, "Equipment Preparation."

2.07 FITUP BOLTS AND ERECTION PINS

- A. Provide fitup bolts of the same diameter as the connection bolts. Do not reuse galvanized bolts or ASTM A 490 bolts that have been used as fitup bolts. Provide a sufficient number of erection or drift pins, 1/32 in. larger than the bolt diameter.

2.08 PAINT MARKERS

- A. Provide white or yellow paint markers for marking bolts or nuts for wrench calibration, R C Tests, and bolt installation.

PART 3 EQUIPMENT

3.01 TESTING EQUIPMENT

- A. Provide a calibrated tension-measuring device (Skidmore-Wilhelm or equivalent), calibrated torque wrench, and other accessories necessary to perform the installation verification test and the R C test and to calibrate hydraulic torque wrenches.

3.02 WRENCHES

- A. Furnish either of the following types of wrenches.
 - 1. Air Driven Impact Wrenches
 - a. Furnish air-driven impact wrenches, air compressors, and related accessories of sufficient capacity to properly tension high-strength bolts. Impact wrenches should be of sufficient size and capacity to be able to tension fully a bolt in less than 15 seconds. Repair or replace any wrenches that are unable to apply full tension to a bolt within this time.
 - 2. Hydraulic Torque Wrenches
 - a. Furnish a calibrated hydraulic torque wrench, hydraulic pump, and related accessories capable of properly tensioning high-strength bolts. Calibrate the wrench to stall out or cut out completely when the bolt tension reaches 1.05 times the tension specified in Table 1. Calibrate the wrench by tensioning 3 bolts of each size in a calibrated tension-measuring device (Skidmore-Wilhelm or equivalent). When calibrating the wrench, mark each bolt and verify the rotation from snug-tight as specified in Section 16447, Part 4, 4.05, A, "Turn-of-the-Nut Method." Calibrate the wrench at least once each working day or as directed. Recalibrate the wrench for changes in bolt diameter; changes in bolt length greater than two bolt diameters; significant differences in the surface condition of the bolts, threads, nuts, or washers; or changes in the equipment or hose length.

PART 4 CONSTRUCTION

4.01 EQUIPMENT PREPARATION

A. Air-Driven Impact Wrench

1. Before beginning bolting, perform an installation verification test on 3 complete fastener assemblies of each combination of diameter, length, grade, and lot to be installed. Use the bolting crew that will perform the actual work for the test, and perform the test in the presence of the Owner's Representative. Follow the bolt-tensioning procedures in Section 16447, Part 4, 4.05, "Bolt Tensioning." Use a calibrated tension-measuring device (Skidmore-Wilhelm or equivalent) to verify and demonstrate that the method for estimating the snug-tight condition and controlling the turns from snug-tight develops a tension greater than 1.05 times the tension specified in Table 1. The snug-tight condition is defined as the tightness that exists when the plies of the joint are in firm contact.

B. Hydraulic Torque Wrench

1. Before beginning bolting, calibrate the wrench in accordance with Section 16447, Part 3, 3.02, A, 2, "Hydraulic Torque Wrenches." Use the bolting crew that will perform the actual work for the calibration and calibrate the wrench in the presence of the Owner's Representative. Follow the bolt-tensioning procedures in Section 16447, Part 4, 4.05, "Bolt Tensioning."

4.02 GENERAL

- A. Ensure that all material within the grip of the bolt is steel. Do not allow any compressible material such as gaskets or insulation within the grip. Ensure that the slope of parts in contact with the bolt head or nut does not exceed 1:20 with respect to a plane normal to the bolt axis. Prepare all joint surfaces, including those in contact with the bolt heads, nuts, or washers, so that the surfaces are free of dirt, loose rust, loose mill scale, burrs, and other matter that would prevent solid seating of the parts.
- B. Replace any bolts and nuts installed for shipping purposes unless the shop drawings indicate that the shop-installed bolts are to be fully tensioned in the shop. Do not tension bolts that have been installed snug-tight in the shop. Remove any bolts installed snug-tight in the shop and replace them with new bolts. Inspect and prepare the joint surfaces after removing shop-installed bolts that are not fully tensioned in the shop.
- C. Provide a hardened washer under either the nut or the bolt head, whichever is turned during tensioning. Install hardened washers under both the nut and bolt head of ASTM A 490 bolts when the outer plies being fastened have a yield strength less than 40 ksi.

- D. Tension all bolts to provide the minimum bolt tension values given in Table 1.
- E. Erect steel in conformance with Section 16441, “Steel Structures.” Do not tack-weld any parts to eliminate fitup bolts or to hold parts together while bolting.

Table 1
Bolt Tension

Nominal Bolt Size, in.	Minimum Tension (kips)	
	ASTM A 325 Bolts	ASTM A 490 Bolts
1/2	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

4.03 PREPARATION OF FAYING SURFACES

- A. If faying surfaces will be painted, ensure that the primer used is documented to have the required slip and creep characteristics to meet the specified mean slip coefficient as determined by “Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints” in the Research Council on Structural Connections’ *Specification for Structural Joints Using ASTM A325 or A490 Bolts*. If no mean slip coefficient or corresponding surface condition is specified, do not paint faying surfaces without approval.
- B. Perform blast-cleaning or painting of faying surfaces in accordance with Section 16446, “Cleaning and Painting Steel.” Provide an SSPC SP 10 blast-cleaning if surfaces to be in contact after final bolting will be left unpainted. Do not wire-brush uncoated faying surfaces. Roughen galvanized faying surfaces by hand wire-brushing. Ensure that the required finish exists at the time of bolting.

4.04 BOLT INSTALLATION

- A. Use the following procedure for bolt installation of a complete connection:
1. Fair-Up Holes
 - a. Use a minimum number of erection or drift pins, as directed, in the holes to “fair-up” all holes.

2. Install Bolts

- a. Install bolts in all remaining holes of the connection. Do not use excessive force, which results in damage to the threads, to install the bolts. If force is required to install the bolts, increase the number of erection or drift pins as necessary to align the holes. Do not ream the holes unless approved. If approved, ream the holes in accordance with Section 16441, Part 3, 3.11, D, "Misfits." Remove the erection or drift pins and install bolts in these holes. Bring the connection to a full snug-tight condition by snugging systematically from the most rigid part of the connection to the free edges. The snug-tight condition is defined as the tightness that exists when the plies of the joint are in firm, full contact. A snug-tight condition can usually be attained by a few impacts of an impact wrench or the full effort of a worker using an ordinary spud wrench as demonstrated in the installation verification test. As necessary, re-snug previously snugged bolts that may have relaxed as a result of the subsequent snugging of adjacent bolts to insure that all bolts are simultaneously snug-tight and the connection plates are in full contact.
- b. If snugging does not bring the plies of the joint into full contact, fully tighten a minimum number of bolts as directed until the plies are in full contact. Mark these bolts as fitup bolts. A non-galvanized ASTM A 325 bolt of the same diameter may be used as a fitup bolt in connections requiring the use of galvanized ASTM A 325 bolts or ASTM A 490 bolts. Re-snug all remaining bolts.

3. Tension Bolts

- a. Tension all bolts other than the fitup bolts in accordance with Section 16447, Part 4, 4.05, "Bolt Tensioning." Loosen all fitup bolts after tensioning all the other bolts in the connection. Ungalvanized ASTM A 325 bolts used as fitup bolts may be reused in a connection using this type of bolt. Replace all galvanized bolts and ASTM A 490 bolts used as fitup bolts. Tension these remaining untensioned bolts in accordance with Section 16447, Part 4, 4.05.

4. Bolt Reuse

- a. Do not reuse ASTM A 490 or galvanized ASTM A 325 bolts. Ungalvanized ASTM A 325 bolts may be reused one time if the threads have not been damaged. Retensioning previously tensioned bolts loosened by the tensioning of adjacent bolts is not considered to be reuse.

4.05 BOLT TENSIONING

- A. Install bolts and bring them to a snug-tight condition in the sequence described in Section 16447, Part 4, 4.04, "Bolt Installation." Use either the turn-of-the-nut method or the calibrated wrench method to tension high-strength bolts. For either method, ensure that the element not turned by the wrench (bolt head or nut) does not rotate.
1. Turn of the Nut Method
 - a. Match-mark the nuts and the protruding bolt ends after the bolts have been brought up to snug-tight condition and before final tensioning so that actual rotation can be determined. Tension all bolts in the connection to their final tension by the amount of rotation specified in Table 2. Start final tensioning at the center or most rigid part of the connection and progress toward the free edges.
 2. Calibrated Wrench Method
 - a. Use a calibrated hydraulic torque wrench to tension all bolts to 1.05 times the tension given in Table 1 after they have been brought to the snug-tight condition. Calibrate the wrench in accordance with Section 16447, Part 3, 3.02, A, 2, "Hydraulic Torque Wrenches." Start tensioning at the most rigid part of the connection and proceed to the free edges. Return the wrench to re-tension previously tensioned bolts that may have relaxed as a result of the subsequent tensioning of adjacent bolts. Place marks on the socket at one-third points so that the amount of rotation can be visually determined.

**Table 2
Nut Rotation from Snug-Tight Condition¹**

Bolt length (underside of head to end of bolt)	Disposition of Outer Face of Bolted Parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped less than 1:20 (beveled washer not used)	Both faces sloped less than 1:20 from bolt axis (beveled washer not used)
Up to and including 4 bolt diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 bolt diameters up to and including 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 bolt diameters up to and including 12 diameters ²	2/3 turn	5/6 turn	1 turn

1. Nut rotation is relative regardless of the element (nut or bolt) being turned. The tolerance is $\pm 30^\circ$ for bolts installed by 1/2 turn or less and 45° for bolts installed by 2/3 turn or more.

2. For bolt lengths greater than 12 diameters, determine the required rotation using the installation verification test in a simulated connection of solidly fitted steel.

PART 5 MEASUREMENT AND PAYMENT

- A. Installation and testing of bolts will not be paid for directly but will be subsidiary to the pertinent Sections requiring the use of high-strength bolts.
- B. When payment for the structure associated with the bolts is made under Section 16442, "Metal for Structures," bolts, nuts, and washers will be paid for in accordance with Section 16442.

END OF SECTION