ITEM 447

STRUCTURAL BOLTING

447.1. Description. This Item shall govern for furnishing and installing of high strength fasteners used in structural connections as shown on the plans and in accordance with this Item.


(1) General. Bolts and nuts shall be furnished by the same supplier to ensure proper fit.

Rotational-capacity tests shall be performed on all black or galvanized bolt, nut and washer assemblies by the manufacturer or distributor prior to shipping. Each combination of bolt production lot, nut lot and washer lot shall be tested as an assembly and a rotational-capacity lot number assigned to each combination of the lots tested. The manufacturer or distributor shall furnish, to the Engineer, a manufacturer's certified test report (MCTR) or a distributor's certified test report (DCTR) for each rotational-capacity lot furnished. The MCTR or DCTR shall include the results of all tests; location of where bolt assembly components were manufactured; the date and location of the tests; results of the R-C tests and a statement that the materials represented by the test report conform to the specifications.

(2) Bolts. Bolts from M16 to M36 inclusive shall conform to the requirements of ASTM A 325 or A 490 except as provided herein.

Bolts shall conform to the requirements for heavy hexagon structural bolts as specified in ANSI B18.2.1. The length of the bolt shall be such that the point of the bolt will be flush with or outside the face of the nut when completely installed.

Unless otherwise specified, bolts shall conform to the dimensions for heavy hex structural bolts specified in ANSI B 18.2.3.7M.

Threads shall be the metric coarse thread series as specified in ANSI B1.13M, and shall have class 6g tolerances.

Bolts for painted structures shall be Type 1, 2, or 3 in accordance with ASTM A 325 or A 490. When weathering steel is specified, bolts shall be Type 3.

Galvanized bolts shall be either ASTM A 325 Type 1 or Type 2. Galvanizing shall be in accordance with ASTM A 325 except that the maximum Rockwell hardness of these bolts shall be limited to 33 Rc.

(3) Nuts. Nuts shall conform to the requirements of ASTM A 325 or A 490 except as provided herein.

Unless otherwise specified, threads in nuts shall be the metric coarse thread series as specified in ANSI B1.13M, and shall have grade 6H tolerances.

Nuts for painted structures shall be grades 2, C, D, or C3 with a minimum Rockwell hardness of 89HRB (Brinell hardness 180HB) or heat treated grades 2H, DH, or DH3. Weathering steel nuts shall be grade C3 or DH3. Nuts to be galvanized shall be heat treated grade 2H, DH, or DH3.
Nuts that are to be galvanized shall be tapped oversize the minimum amount required for proper assembly. The amount of overtap in the nut shall be such that the nut will assemble freely on the bolt in the coated condition and shall meet the mechanical requirements of ASTM A 563 and the rotational-capacity test.

Galvanized nuts shall be lubricated with a lubricant containing a dye of any color that contrasts with the color of the galvanizing.

(4) Washers. Circular, beveled and clipped washers shall conform to the requirements of ASTM F 436.

(5) Alternate Fasteners. When shown on the plans or approved by the Engineer, high-strength steel lock-pin and collar fasteners may be used as an alternate for high-strength bolts. The shank and head of the high-strength steel lock-pin and collar fasteners shall meet the chemical composition and mechanical property requirements of ASTM A 325 or A 490. The fasteners shall provide a solid shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than the bolt specified; shall have a cold forged head on one end, of the type and dimensions as approved by the Engineer; and shall have a shank length suitable for the material thickness fastened, locking grooves, breakneck groove and pull groove (annular grooves) on the opposite end. Each fastener shall provide a steel locking collar of proper size for the shank diameter used which, by means of suitable installation tools, is cold swaged into the locking grooves forming a head for the grooved end of the fastener after the pull groove section has been removed. The steel locking collar shall be a standard product of an established manufacturer of lock-pin and collar fasteners. Flat washers will not be required when lock-pin and collar fasteners are used unless slotted or oversized holes are specified.

447.3. Sampling and Testing. Sampling of high-strength bolts, nuts and washers will be in accordance with Test Method Tex-719-I.

Testing of high strength bolts, nuts and washers shall be in accordance with the applicable ASTM specification. Wherever final bolting is performed, Rotational Capacity tests shall be performed by the Contractor and witnessed by the Engineer in accordance with Test Method Tex-452-A.

447.4. Identification and Dimensions. ASTM A 325 and A 490 for bolts and the specification referenced therein for nuts require that bolts and nuts be identified by specific markings on the top of the bolt head and on one (1) face of the nut.

Bolts manufactured in accordance with ASTM A 325 or A 490 shall have head markings identifying the strength grade by the symbol "A325" or "A490", the manufacturer and the type, if Type 2 or 3. Nut markings shall identify the strength grade, the manufacturer and the type, if Type 3.

Washers for use when weathering steel is specified shall be marked on one (1) face near the outer edge with the numeral "3", or other distinguishing marks indicating that the washer is of a weathering type.

447.5. Construction Methods.

(1) General. All material within the grip of the bolt shall be steel. There shall be no compressible material such as gaskets or insulation within the grip.
The slope of the surfaces of parts in contact with the bolt head or nut shall not exceed 1:20 with respect to a plane normal to the bolt axis.

All joint surfaces, including those adjacent to the bolt heads, nuts or washers, shall be free of dirt, loose rust, loose scale, burrs and other matter that will prevent solid seating of the parts.

Unless otherwise shown on the plans, faying surfaces of all nongalvanized joints, including splice plates, shall be given a Class "A" Blast Cleaning, in accordance with Item 446, "Cleaning, Paint, and Painting", prior to final bolting in the shop or field. Faying surfaces shall be free of loose rust prior to final bolting in the shop or field. Loose rust shall be removed by blast cleaning.

Galvanized faying surfaces shall be roughened by hand wire brushing.

When shown on the plans, faying surfaces shall be blast cleaned and coated with a paint that provides the specified mean slip coefficient as determined by the "Test Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints" as adopted by the Research Council on Structural Connections. Coated joints shall not be assembled before the coatings have cured for the minimum time used in the qualifying test.

Bolts and nuts shall be protected from dirt and moisture at the job site. Only as many fasteners as are anticipated to be installed and tightened during a work day shall be taken from protected storage. Fasteners not used shall be returned to protected storage at the end of the day. Fasteners that show signs of rust or dirt shall be cleaned and relubricated prior to installation. Any additional lubrication required must be applied prior to installing bolts in the holes.

Bolts shall be installed with a hardened washer under either the nut or bolt head, whichever is turned during tightening. When the outer plies being fastened have a yield strength of less than 275 megapascal, a hardened washer shall be installed under both the head and nut when A 490 bolts are used.

All fasteners shall be tightened to provide the minimum bolt tension values shown in Table 1.

The following procedures shall apply for bolt installation of a complete connection, regardless of the method of tightening:

(a) A minimum number of the holes, as determined by the Engineer, at a bolted connection shall be filled with erection pins to "fair-up" all holes.

(b) Install and tighten in a well distributed pattern a minimum of 25 percent of the final number of bolts, following a pattern of progression from the center or most rigid part of the joint toward the free edges, making sure that all plies of the connection are properly fitted and in contact. The tightness of fit-up bolts need not be inspected; however, overtightening of fit-up bolts shall not be permitted. Mark these bolts as fit-up bolts.

(c) Install and tighten all remaining bolts by the required amount. Remove the erection pins and fill the remaining holes with bolts. Loosen all A 325 bolts used for fit-up, and replace all A 490 bolts used for fit-up. Tighten these bolts by the required amount.

(d) The bolting crew shall mark finished work with an identifying symbol and the Inspector
will mark accepted work.

A 490 bolts and galvanized A 325 bolts shall not be reused. Other A 325 bolts may be reused one time, if approved by the Engineer. Retightening previously tightened bolts which may have been loosened by the tightening of adjacent bolts will not be considered as reuse.

(2) Tightening Methods. Unless otherwise shown on the plans, tightening shall be by one or more of the following methods.

(a) Turn-of-Nut Tightening. A representative sample of not less than three bolt and nut assemblies of each diameter, length and grade to be used in the work shall be checked at the start of work in a device capable of indicating bolt tension (Skidmore-Wilhelm Bolt Calibrator or equal). The test shall demonstrate that the method for estimating the "snug tight" condition and controlling the turns from snug tight develops a tension not less than five (5) percent greater than the tension specified in Table 1.

Bolts shall be installed in the sequence described in subsection (1) and brought to a "snug tight" condition. "Snug tight" is defined as the tightness that exists when the plies of the joint are in firm contact. This may be attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Snug tightening shall progress systematically from the most rigid part of the connection toward the free edges. Then the bolts of the connection shall be retightened in a similar systematic manner until all bolts are simultaneously snug tight and the connection is fully compacted. Nuts and the protruding bolt ends shall be match marked before final tightening, to allow the inspector visual means of determining actual rotation. Match marks shall be made by the bolting crew with a spot of paint after the bolts have been brought up to snug tight. Following this initial operation, all bolts in the connection shall be tightened further by the applicable amount of rotation specified in Table 2. Tightening shall progress systematically from the most rigid part of the joint to its free edges. During the tightening operation there shall be no rotation of the element not turned by the wrench.
**TABLE 1**

**Fastener Tension**

<table>
<thead>
<tr>
<th>Nominal Bolt Size, Millimeters</th>
<th>Minimum Tension* in Kilonewtons</th>
<th>A 325 Bolts</th>
<th>A 490 Bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>M16</td>
<td>91</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>M20</td>
<td>142</td>
<td>179</td>
<td></td>
</tr>
<tr>
<td>M22</td>
<td>176</td>
<td>221</td>
<td></td>
</tr>
<tr>
<td>M24</td>
<td>205</td>
<td>257</td>
<td></td>
</tr>
<tr>
<td>M27</td>
<td>267</td>
<td>334</td>
<td></td>
</tr>
<tr>
<td>M30</td>
<td>326</td>
<td>408</td>
<td></td>
</tr>
<tr>
<td>M36</td>
<td>475</td>
<td>595</td>
<td></td>
</tr>
</tbody>
</table>

*Equal to 70 percent of specified minimum tensile strengths of bolts rounded to nearest kilonewton.

**TABLE 2**

**Nut Rotation from Snug Tight Condition *,**

<table>
<thead>
<tr>
<th>Disposition of Outer Face of Bolted Parts</th>
<th>Bolt length (Under side of head to end of bolt)</th>
<th>Both faces normal to bolt axis</th>
<th>One face normal to bolt axis and other face sloped not more than 1:20 (beveled washer not used)</th>
<th>Both faces sloped not more than 1:20 from normal to the bolt axis (beveled washer not used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to and including 4 diameters</td>
<td>1/3 turn</td>
<td>1/2 turn</td>
<td>2/3 turn</td>
<td></td>
</tr>
<tr>
<td>Over 4 diameters but not exceeding 8 dia.</td>
<td>1/2 turn</td>
<td>2/3 turn</td>
<td>5/6 turn</td>
<td></td>
</tr>
<tr>
<td>Over 8 diameters but not exceeding 12 dia.***</td>
<td>2/3 turn</td>
<td>5/6 turn</td>
<td>1 turn</td>
<td></td>
</tr>
</tbody>
</table>

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

** Alternate Fastener Installation. When fasteners which incorporate a design feature intended to indirectly indicate the bolt tension or automatically provide the bolt tension specified in Table 1 are to be installed, a representative sample of not less than three (3) fasteners of each diameter, length and grade shall be checked at the start of work in a device capable of indicating bolt tension (Skidmore-Wilhelm Bolt Calibrator or equal). The test assembly shall include flat hardened washers, if required in the actual
connection, arranged as in the actual connections to be tensioned. The calibration test shall demonstrate that each fastener develops a tension not less than five (5) percent greater than the tension specified in Table 1. The Manufacturer's installation procedure shall be followed for installation of fasteners in the calibration device and in all connections.

When alternate design fasteners are used, they shall be installed by a procedure submitted by the Contractor and approved by the Engineer. The procedure shall incorporate the concept of erection pins and fit-up bolts as described in subsection (1). If these fasteners are used as fit-up bolts and the control or indicator element is twisted off during the fit-up stage, then the bolt must be replaced prior to final acceptance of the work. All fasteners shall then be further tightened, progressing systematically from the most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tightened fasteners. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic partial tightening prior to final twist-off of the control or indicator element of individual fasteners.

(c) Lock-Pin and Collar Fastener Installation. The installation of lock-pin and collar fasteners shall be by methods and procedures submitted by the Contractor and approved by the Engineer. This method shall incorporate the concept of erection pins and fit-up bolts as described in subsection (1).

447.6. Measurement and Payment. No direct compensation will be made for the installation of bolts or fasteners. Payment will be subsidiary to the pertinent items requiring the use of high-strength bolts.

Measurement and payment for the bolts, nuts and washers required for structural steel connections will be in accordance with Item 442, "Metal for Structures".