APPENDIX C

INSTALLATION PROCEDURES FOR HIGH-STRENGTH BOLTS

Introduction

The following protocol is for the sampling, installation and inspection of high-strength bolts used in connections undergoing full-scale testing. Methods are presented for three conditions:

- snug-tight only,
- pretensioned to the minimum required pretension, and
- pretensioned using standard approved shop and field practices.

Design, use and installation is governed by the American Institute of Steel Construction (AISC) Specification for Structural Steel Buildings, either ASD or LRFD, and the Research Council on Structural Connections (RCSC) Specification for Structural Joints Using ASTM A325 and A490 Bolts. Additional information for special applications may be drawn from the Structural Bolting Handbook, published by the Steel Structures Technology Center (SSTC)

Materials

Bolts, nuts and washers to be used for testing shall be purchased from domestic manufacturers with full manufacturer's certifications in accordance with the ASTM specifications. It is not necessary to repeat any physical testing of the fastener products to verify the manufacturer's test results. The manufacturer and lot numbers of the fasteners used shall be recorded. Preferably, fasteners shall be ordered in sufficient quantities so that the same lot may be used for each diameter, length and grade required. A common lot may be used for nuts and washers for a given diameter and grade.

Nuts shall be ASTM A563 grade DH or DH3, or ASTM A194 grade 2H. Alternatively, ASTM A563 nuts of grades C, C3 and D, or ASTM A194 grade 2, may be used provided the hardness as tested is at least 89 HRB or 180 Brinell. This is necessary to minimize the risk of nut thread stripping when performing testing in the bolt calibrator.

Although permitted for field use, the use of mechanically galvanized or hot dip galvanized fasteners is not recommended for laboratory testing. The overtapping of the nut threads increases the risk of thread stripping when overtightened.

Although permitted for field use, the use of twist-off bolts for laboratory testing is not recommended because of the difficulties in achieving exact control of specific levels of tension for various test purposes. Where twist-off bolts are used, confirmation or calibration of bolt tension through the use of load indicator washers shall be made.

All fasteners are to be stored by lot in closed containers, kept clean and dry. Black (uncoated fasteners) shall be oily to the touch. Do not relubricate any individual fasteners unless the entire lot is relubricated in the same manner. If relubricated, the fastener assembly must have the Pre-Installation Testing and Calibration testing, as described below, performed prior to use.

Joint Design and Tightening

Bolt lengths shall be selected so that the bolt end is at least flush with the outer face of the nut after installation.

Joints will preferably be configured so that the fastener assembly will be tightened by turning the nut rather than turning the bolt head. The bolt head must be held when turning the nut, and vice versa.

For testing purposes and torque measurement consistency, even though not required by RCSC for all cases, hardened steel ASTM F436 washers shall be used beneath the turned element.

For joint behavior that is dependent upon slip resistance (a slip-critical joint), the joint should be tensioned to the minimum required pretension. For joints in direct tension, the joints may be tightened to either the minimum required pretension, or pretensioned using standard approved shop and field practices, which will generally provide tensions higher than the minimum required pretension. For joints where bolt tension would not affect the behavior of the joint, the snug-tight only condition should be used.

Note: There is a proposed change in the RCSC Specification that would permit fasteners in direct tension joints to be installed only to the snug tight condition. Currently, they must be pre-tensioned. Verify the RCSC provisions with the Project Director for Topical Investigations prior to testing.

Pre-Installation Testing and Calibration

The following procedures are to establish benchmark values for certain tightening operations and to verify the suitability of the fastener assembly. The AASHTO/FHWA Rotational Capacity Test Procedure has been adapted for use in this section. For further details on the original AASHTO/FHWA test procedure, see SSTC pages 68-74.

Prior to installation in the test joint, five bolts, nuts and washers of the lots to be used in the test joint shall be subjected to pre-installation testing in a Skidmore-Wilhelm bolt tension calibrator or similar device. Each assembly shall be placed in the calibrator, oriented in the same manner so that the element turned (bolt head or nut) in the calibrator is also the element turned in the test joint. The washer used as a part of the assembly shall be placed directly below the turned element. Additional flat washers or plates shall be used to provide approximately two threads of stickout beyond the face of the nut prior to tightening. For long bolts, several washers in a stack may provide questionable calibration results, and therefore solid steel plates or stacks of flat plates are recommended for assemblies requiring more than one inch of stacked washers.

The assembly shall then be tightened by hand with a spud wrench or similar hand wrench. Do not exceed the required pretension. Upon completion of snugging, matchmark the end of the bolt, face of the nut, and face of the calibrator with a single straight line.

Tighten the assembly until the assembly reaches the required pretension as provided in AISC Table J3.7, as provided below.

Bolt Diameter (in.)	A325 Bolt	A490 Bolt
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

Bolt Diameter (in.)	A325 Bolt	A490 Bolt
1-3/8	85	121
1-1/2	103	148

Using a manual torque wrench with a dial-type torque indicator, measure the torque at this condition by applying the torque wrench in the tightening direction, placing the wrench into motion adequate to provide approximately 5° additional rotation. Record his torque value. The torque must not exceed the torque, measured in foot-pounds, per the following table. If the torque exceeds this amount, then the fastener assembly is considered poorly lubricated and should not be used until relubricated and retested.

Bolt Diameter (in.)	A325 Bolt	A490 Bolt
1/2	150	180
5/8	290	360
3/4	500	630
7/8	820	1030
1	1230	1540
1-1/8	1500	2160
1-1/4	2140	3060
1-3/8	2810	3990
1-1/2	3690	5320

Further turn the nut until the required turn for pretensioning is provided in accordance with RCSC Table 5, as provided below. Bolt length is measured from the underside of the bolt head to the end of the bolt. Record the bolt tension as measured in the bolt calibrator. Measure and record the torque at this tension using the same steps as in the previous paragraph.

Bolt Length	Rotation
up to and including 4 diameters	1/3 turn
over 4 but not exceeding 8 diameters	1/2 turn
over 8 but not exceeding 12 diameters	2/3 turn

Further tighten the assembly until a total of twice the number of turns required by RCSC Table 5 has been provided, as stated in the following table:

Bolt Length	Rotation
up to and including 4 diameters	2/3 turn
over 4 but not exceeding 8 diameters	1/3 turn
over 8 but not exceeding 12 diameters	1-1/3 turn

Record the bolt tension. The tension at his point should not be less than 15% higher than the

minimum required pretension, as provided per the table below.

Bolt Diameter (in.)	A325 Bolt	A490 Bolt
1/2	14	17
5/8	22	28
3/4	32	40
7/8	45	56
1	59	74
1-1/8	64	92
1-1/4	82	117
1-3/8	98	139
1-1/2	118	170

Remove the assembly from the Skidmore. Visually inspect the bolt threads and nut threads for any visual indications of stripping.

Should a specific combination of bolt lot, nut lot and washer lot be changed, the above Pre-Installation Testing Procedure shall be repeated for the new combination of lots.

Short Bolts

For bolts too short to fit into a Model M or Model L Skidmore-Wilhelm bolt calibration device, the use of the Model MS Skidmore-Wilhelm is recommended. Alternatively, the use of "calibrated" direct tension indicators (dti's) is permitted to verify minimum required bolt tension values. For calibration of dti's, see SSTC page 17. Calibrated dti's may not be used to establish or verify turn-of-nut procedures. Alternative methods must be used for turn-of-nut verification, or the dti installation procedure as described in SSTC page 30 or 31 may be used in lieu of turn-of-nut tightening.

Tightening a Joint to the Snug Tight Condition

The snug tight condition is defined as "the tightness achieved with the full effort of a worker with an ordinary spud wrench or a few hits of an impact wrench that brings the connected plies into firm contact." For the purposes of laboratory testing, the use of impact wrenches for snugging operations should be limited to parts over 1 inch in thickness or joints that have substantial gaps between the parts.

The joint must have the steel in contact immediately around each bolt hole. It is not necessary to have the steel in contact at outer edges of the joint, such as the edges of plates or the heels or toes of angles. For materials of 1-1/2 inches in thickness or more, it may not be possible to bring the joint into contact around the bolt holes when there is severe misalignment of parts. In this case, impact wrenches must be used for snugging the joint and the steel must be brought into solid contact where possible. For further discussion, see SSTC page 56.

Joints must be snugged in a systematic manner, starting from the most rigid part of the joint and proceeding toward the free edges, or from the part in contact toward the part of the joint not in contact.

Pretensioning a Joint to the Minimum Required Pretension

Bring the joint to the snug tight condition as described above. Using a manual torque wrench, apply the torque for the required minimum pretension as measured in the Pre-Installation Testing and Calibration procedure above. Joints should be pretensioned in a systematic manner, from the most rigid part of the joint to the free edges, and marked so that no assemblies are inadvertently missed.

Pretensioning Using Standard Approved Shop and Field Practices

Although other pretensioning methods (calibrated wrench, twist-off bolts, alternative design fasteners, and direct tension indicators) are approved for use under RCSC Specification, the turn-of-nut method is the method anticipated to be the most commonly used for heavy structural connections in building applications, and therefore has been selected for this protocol. Other methods may be used with the approval of the Project Director for Topical Investigations.

Bring the joint to the snug tight condition as described above. Matchmark the end of the bolt, the face of the nut, and the face of the steel using a straight line.

Using a manual torque wrench or impact wrench, apply the required rotation from RCSC Table 5 for the given bolt diameter and length. Verify that the required turns have been provided by visual inspection. Joints should be pretensioned in a systematic manner, from the most rigid part of the joint to the free edges, and marked so that no assemblies are inadvertently missed.

Upon completion of installation, use a manual torque wrench to measure the actual torque on one installed fastener per joint. Record this value. It is not expected that this torque will match the torque measured for a given rotation in the bolt calibration device, and is likely to be higher. Assuming a linear torque-tension relationship, the actual installed bolt tension may be estimated from the torque-tension relationship established in the Pre-Installation Testing performed above.

Strain-Gaging

If desired, some testing may be performed using strain-gaged bolts to determine bolt behavior during testing. Follow the gage manufacturer's written instructions on the set-up and use of such gages.

References

LRFD Specification for Structural Joints Using A325 or A490 Bolts, June 3, 1994, American Institute of Steel Construction, Inc., One East Wacker Drive, Suite 3100, Chicago, IL 60601-2001, 312-670-2400

Structural Bolting Handbook, May, 1996, Steel Structures Technology Center, Inc., 42400 W. Nine Mile Rd., Novi, MI 48375-4132, 248-344-2910