This month's SteelWise features answers to general questions on bolting in structural steel framing systems.

steelwise

# THE NUTS AND BOLTS OF NUTS AND BOLTS

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**AISC IS UPDATING** the Frequently Asked Questions section of its website (**www.aisc.org**). As these updates are created, selected sections will be published as SteelWise articles. This month's installment covers bolting questions.

## 6. Bolting

The AISC *Specification for Structural Steel Buildings* and the RCSC *Specification for Structural Joints Using High-Strength Bolts* cover requirements for the use of bolts in structural steel connections. The FAQs in this section include a discussion of portions of these provisions and subsequent recommendations. Some of the discussion is taken from *Bolt Bulletins* published by RCSC.

### 6.1. Economical Suggestions

**6.1.1. Why should bolt diameters be limited to a 1-in. maximum when possible?**

The industry standard ¾-in., ⅞-in. and 1-in. bolt diameters provide adequate design strength for the vast majority of connections in steel structures. Accordingly, commonly available bolt installation equipment has been designed with a capacity to fully tension 1-in. diameter ASTM A490 bolts when required; larger bolts will usually require special equipment and/or effort. Additionally, bolt diameters larger than 1 in. may require larger clearances, edge distances, and spacings than are standard. Therefore, bolt diameters larger than 1 in. should be avoided, when possible, to help prevent potential bolt tensioning difficulties.

**6.1.2. Why should mixed use of ASTM A325 and A490 bolt grades be limited to different diameters?**

If ASTM A325 and A490 bolts of the same nominal diameter are mixed on a project, there exists the possibility that the A325 bolts might be installed where the A490 bolts were required. Therefore, when ASTM A325 and A490 bolts are used on the same project, quality assurance is simplified if different diameters are used for different grades.

### 6.2. Ordering Bolts

**6.2.1. What quality requirements must high-strength bolts, nuts and washers meet?**

The manufacturing quality requirements for high-strength bolts, nuts and washers are covered in the following specifications: for high-strength bolts, ASTM A325/A325M and ASTM A490/A490M; for nuts, ASTM A563/A563M or ASTM A194/A194M; for washers, ASTM F436/F436M; for direct tension indicators, ASTM F959/F959M; and for tension control bolt/nut/washer assemblies, ASTM F1852 and ASTM 2280. These fasteners should be specified and accepted based upon the criteria established therein.

**6.2.2. What information must be included in the purchase order for high-strength bolts?**

From RCSC Educational Bulletin No. 3 (see **www.boltcouncil.org**), the purchase order for high-strength bolts must include the ASTM grade (A325 or A490), the type (1 or 3), a copy of the project specification for the manufacturer or vendor, and the "Ordering Information" as required by the appropriate ASTM *Specification*. Additionally, the purchase order should require the following:

1. That the vendor provide certification that the bolts, nuts, and washers furnished conform to all requirements of the referenced ASTM specification.
2. That certified manufacturer's mill test reports be supplied that clearly show the applicable ASTM mechanical and chemical requirements together with the actual test results for the lot of supplied fasteners.
3. That the bolt heads and the nuts of the supplied fasteners be marked with the manufacturer's identification mark and the ASTM grade and type as specified in ASTM specifications.
4. For projects requiring slip-critical connections, that the lubricated bolt, nut and washer be pre-assembled to ensure proper fit of the bolt and nut and that the lot be tested for strength prior to shipment to the purchaser to meet the requirements of the 2004 RCSC *Specification* Table 4.

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**6.2.3. When must high-strength bolts be ordered as a bolt/nut assembly from a single manufacturer?**

As indicated in the RCSC *Specification* Commentary, there are two cases in which bolts and nuts must be treated as a manufactured matched assembly: when bolts are galvanized (Commentary Section 2.3.3) and when "tension-control" bolts are specified (Commentary Sections 2.2 and 8.2.3). In the former case, because nut-thread over-tapping to accommodate the added thickness of galvanizing may reduce the nut stripping strength, ASTM A325 requires that the galvanized assembly be lubricated and tested by the manufacturer to ensure adequate rotational capacity. In the latter case, some of the negative aspects of this torque-controlled installation method are minimized through good quality control in the matched assembly.

**6.2.4. Is it acceptable to substitute ASTM Grade BC, A354 Grade BD or A449 bolts for ASTM A325 or A490 bolts?**

In general, this is not an acceptable substitution. While ASTM A449 seems to offer the same strength as ASTM A325, the use of A449 material is restricted in the *Specification* Section J3.1 to bolt diameters larger than 1½ in. or lengths exceeding 12 diameters. This is because these bolts are not produced to the same inspection and quality assurance requirements as ASTM A325 bolts. If the bolts must be pre-tensioned, the bolt geometry including the thread pitch, thread length, head and nut(s) shall be equal to or (if larger in diameter) proportional to that required by the RCSC *Specification*. Installation shall comply with all applicable requirements of the RCSC *Specification* with modifications as required for the increased diameter and/or length to provide the design pretension.

In other words, pre-installation verification is only required when the bolts are to be pre-tensioned.

**6.2.5. Is it acceptable to substitute SAE J429 grades 5 and 8 bolts for ASTM A325 and A490 bolts, respectively?**

No. The strength properties of SAE J429 grade 5 bolts and ASTM A325 bolts are identical; likewise, SAE J429 grade 8 bolts are the strength equivalent of ASTM A490 bolts. These material specifications differ, however, in that ASTM A325 and A490 specify thread length and head size, whereas SAE J429 does not. Additionally, quality assurance and inspection requirements for ASTM A325 and A490 bolts are more stringent.

**6.2.6. What is an ASTM A325T bolt?**

The "T" in the designation ASTM A325T invokes supplement S1 in ASTM A325, which allows for full-length threading (ASTM A325T). This provision may be specified for ASTM A325 bolts of length less than or equal to four times the bolt diameter only; there is no similar provision in ASTM A490. The fully threaded bolt allows the fabricator the option to use a single-length fastener in the majority of bolting applications, if desired. Note that if ASTM A325T bolts are specified, it is impossible to exclude the threads from the shear plane and the design must be based upon the "threads included" strength values. Fully threaded A325 bolts are marked on the head of the bolt with "A325T" instead of "A325", so that they can be identified even after installation

## 6.3. Verification Testing

**6.3.1. What constitutes evidence of material conformity for high-strength bolts, washers, and nuts?**

RCSC recommends that purchase orders require the following as evidence of conformity:

1. That the vendor provides certification that the bolts, nuts and washers furnished conform to all requirements of the referenced ASTM specification.
2. That the certified manufacturer's mill test reports supplied that clearly show the applicable ASTM mechanical and chemical requirements together with the actual test results for the supplied fasteners.
3. That the bolt heads and the nuts of the supplied fasteners must be marked with the manufacturer's identification mark, the strength grade and type as specified by ASTM specifications.
4. That, for projects requiring slip-critical connections, the lubricated bolt, nut and washer be preassembled to assure proper fit of the bolt and nut and the assembly tested for strength to meet 1.05 times the requirements of Table 8.1 of the *Specification for Structural Joint Using ASTM A325 or A490 Bolts* prior to shipment to the purchaser.

**6.3.2. When must the purchaser test high-strength bolts and why must they be tested if the manufacturer has already done so?**

Section 7 of the RCSC *Specification* requires pre-installation verification "only as indicated in Section 8.2." In other words ,pre-installation verification is only required when the bolts are to be pre-tensioned. ASTM Specifications are adequate and appropriate for the strength and quality of the separate components, but may not be representative of the factors and conditions that determine performance of the fastener assembly during installation and service as it is used in construction. For one example, the bolt itself is tested for strength by the manufacturer by screwing the bolt into a standard testing fixture and subjecting it to pure tension. However, in usual applications, bolt tension is induced by torque on the nut and the bolt is subject to combined tension and torque, which may cause the bolt to fail at a load less than its strength in pure tension. RCSC states that pre-installation verification is necessary to:

1. Confirm the suitability of the complete fastener assembly, including lubrication, for pre-tensioned installation.
2. Confirm the procedure and proper use by the bolting crew of the pre-tensioning method to be used.

## 6.4. Handling and Storage

**6.4.1. Should bolts and nuts be cleaned of all grease, wax or other lubricant prior to installation?**

No. Bolts are intentionally lubricated to facilitate installation. Accordingly, it is stated in the RCSC *Specification* Section 2.2 that "Fastener components shall not be cleaned or modified from the as-delivered condition." Note, however, that provision is also made in the Commentary of this section for fasteners that accumulate rust or dirt resulting from job site conditions, which, if used, "…can be cleaned and lubricated by the fabricator or erector." The Commentary also states that ASTM F1852 and F2280 twist offs are suitable only if the manufacturer lubricates them.

**6.4.2. What storage requirements apply to high-strength bolts, nuts and washers?**

All fastener components must be stored in a manner that affords complete protection from moisture, heat, and dirt contamination. These precautions are necessary to avoid corrosion, loss of lubricant effectiveness, and dirt contamination that will both alter the required installation torque and increase the corresponding scatter of installed tension.

Each day, upon removal from storage, each bucket of fasteners should be visually inspected for corrosion, lubricant condition, and dirt contamination; any fastener found to be corroded, lacking lubrication, or dirty is unacceptable for installation, but may be cleaned, re-lubricated with an approved lubricant, and re-tested (see Section 7 of the RCSC *Specification*). Though pre-installation verification is only required to be performed on fasteners to be pre-tensioned, it can also be used to establish the adequacy of fasteners. Such fastener assemblies that cannot be demonstrated to have an installed tension that is 5 percent greater than the specified minimum tension required in the RCSC *Specification* Table 8.1 should be deemed unacceptable for use.

Guidance from the manufacturer or supplier should be sought in determining approved lubricants used to re-lubricate fasteners.

Only the number of fasteners that are required for work to be done that day should be removed from storage. At the end of the workday, all fasteners that are not installed should be returned to storage.

## 6.5. Bolt Installation

**6.5.1. What can be done to prevent the nut from loosening?**

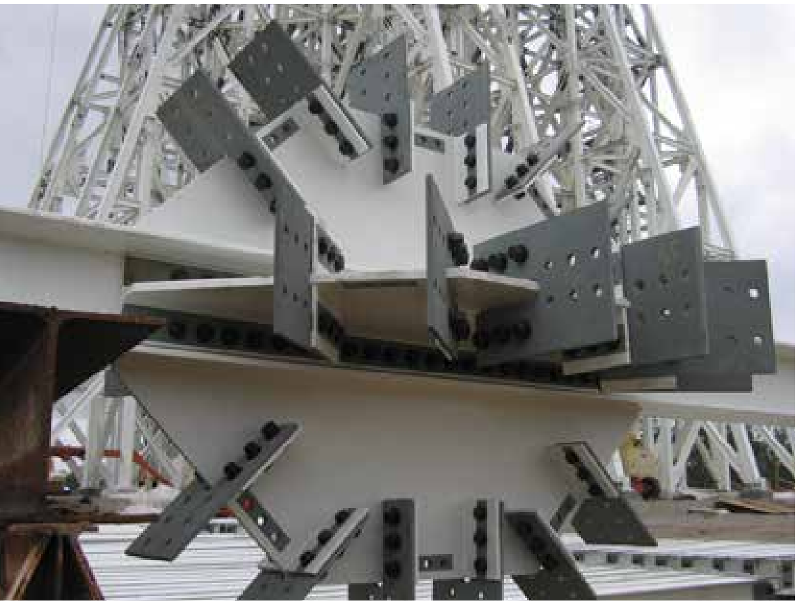
In general, when properly installed, the high-strength bolt-nut assembly will not loosen. When snug-tight bolts are used, the loading will be such that loosening of a nut will not occur. When fully tensioned bolts are required, as for slip-critical connections subjected to vibratory or fatigue loading, the installed tension and the attendant friction on the threads will prevent the nut from loosening.

In some other cases, such as nuts on anchor rods (for which full-tensioning is generally inappropriate), further consideration may be required. In such cases, an additional jamb-nut or second nut may be provided. Alternatively, the threads can be spiked or marred or the nut can be tack-welded to the base metal to prevent it from turning. Note that the latter two solutions are permanent actions. There also exist proprietary nut devices with locking features to prevent the nut from backing off.

**6.5.2. What is the definition of snug-tight bolt installation and when is it allowed?**

The RCSC *Specification* defines a snug-tightened joint as a joint in which the bolts have been installed in accordance with Section 8.1. Note that no specific level of installed tension is required to achieve this condition, which is commonly attained after a few impacts of an impact wrench or the full effort of an ironworker with an ordinary spud wrench. The plies should be in firm contact, a condition that means the plies are solidly seated against each other, but not necessarily in continuous contact. There is no upper limit to the pretension that can be present in a snug-tightened joint. Twist-off-type tension-control bolts can be used in snug-tightened joints, even if the splined ends are severed during installation.

It is a simple analogy to say that a snug-tight bolt is installed in much the same manner as the lug nut on the wheel of a car; each nut is turned to refusal and the pattern is cycled and repeated so that all fasteners are snug. Essentially, snug-tight bolts utilize the higher shear/bearing strength of high-strength bolts with installation procedures similar to those used for ASTM A307 common bolts, which are never fully tensioned (see 6.6.2).



**6.5.3. When must bolts be fully tensioned?**

Snug-tight high-strength bolts are permitted for all bearing joints except when fully tensioned (bearing or slip-critical) bolts are required per the AISC *Specification* Section J1.10 and the 2004 RCSC *Specification* Section 4.2. For example, high-strength bolts must be fully tensioned for:

1. Slip-critical connections (see 6.5.4 ). RCSC-2004, Sections 4.3.
2. Connections where the bolts are subject to direct tension loading.
3. Column splice connections in tier structures that are 200 ft or more in height, 100 to 200 ft in height if the least horizontal dimension is less than 40% of the height, or less than 100 ft in height if the least horizontal dimension is less than 25% of the height.
4. In structures over 125 ft in height, connections of beams and girders to columns and of any other beams and girders upon which the bracing of columns is dependent.
5. In structures carrying cranes with a capacity of over five tons, roof-truss splices and connections of trusses to columns, columns splices, column bracing, knee braces, and crane supports.
6. Connections for supports of running machinery or of other live loads that produce impact or stress reversal.
7. Other connections stipulated as fully tensioned on the design plans.

**6.5.4. When should bolted connections be specified as slip-critical?**

Slip in bolted connections is not a structural concern for the majority of connections in steel building structures. The RCSC *Specification* Commentary Section 4.1 states that "The maximum amount of slip that can occur in a joint is, theoretically, equal to twice the hole clearance. In practical terms, it is observed in laboratory and field experience to be much less; usually about one-half the hole clearance. Acceptable inaccuracies in the location of holes within a pattern of bolts usually cause one or more bolts to be in bearing in the initial, unloaded condition. Furthermore, even with perfectly positioned holes, the usual method of erection causes the weight of the connected elements to put some of the bolts into direct bearing at the time the member is supported on loose bolts and the lifting crane is unhooked. Additional loading in the same direction would not cause additional joint slip of any significance."

In some cases, slip resistance is required. The AISC and RCSC specifications list cases where connections must be designated by the structural engineer of record as slip-critical:

1. Joints that are subject to fatigue load with reversal of the loading direction
2. Joints that utilize oversized holes
3. Joints that utilize slotted holes, except those with applied load approximately normal (within 80° to 100°) to the direction of the long dimension of the slot
4. Joints in which slip at the faying surfaces would be detrimental to the performance of the structure
5. The extended portion of bolted, partial-length cover plates, as required in AISC Specification Section F13.3
6. Bolted connections with undeveloped fills, as required in Section 573 J5.2.(d)

One special case also exists. A nominal amount of slip resistance is required at the end connections of bolted built-up compression members so that the individual component will act as a unit in column buckling. As specified in the 2005 AISC *Specification* Section E6.2, "The end connection shall be welded or pre-tensioned bolted with Class A or B faying surface."

**6.5.5. When a bolt is installed in the vertical position must the head of the bolt point upward?**

No. There is no requirement governing the entering direction of the bolt. Some people feel that bolts should be installed with the head up, so that a loosened bolt will not fall from the hole. However, a falling nut is nearly as dangerous as a falling bolt and a bolt without a nut should not be relied on to carry load.

**6.5.6 Must nuts be installed such that the markings are visible after installation?**

Neither the AISC nor the RCSC *Specification* governs the orientation of the nut. It is unlikely that nuts would be systematically installed with the markings to the inside, so it is likely that at least some of the markings will be visible during inspection. Manufacturers have the option of making the nuts with either a double chamfer or with one washer face, but for both configurations either orientation is allowed during installation.

## 6.6. Methods for Fully Tensioned Installation

**6.6.1. What torque is required to fully tension a high-strength bolt?**

Torque is an invalid measure for fully tensioned installation, unless it is calibrated. In 1951, the first RCSC *Specification* incorporated a table of standard torque values for the installation of fully tensioned high-strength bolts. However, depending upon the condition of the threads, it was demonstrated that the resulting installed tension varied by as much as plus or minus 40 percent. It is now known that clean, well lubricated threads result in tensions that are higher than required (and probably a few broken bolts), whereas, rusted, dirty, or poorly lubricated

threads result in tensions that are below the minimum required. Therefore, recognition of these standard torque values has long been withdrawn. Accepted procedures for fully tensioning high-strength bolts can be found in the RCSC *Specification* Section 8.2 (see also 6.6.3.). If torque is to be used as in the calibrated wrench method as described in the RCSC *Specification* Section 8.2.2, it must be calibrated on a daily basis for the lot, diameter, and condition of bolts being installed.

**6.6.2. Can an ASTM A307 bolt be fully tensioned?**

No, ASTM A307 is the bolting strength equivalent of the ASTM A36 steel specification. As such, it is a mild steel material that is suitable only for use in snug-tight bearing connections. Note that ASTM A307 bolts are seldom used in structural connections today, except perhaps for the end connections of purlins and girts, incidental sub-framing, and as anchor rods.

**6.6.3. What are the accepted procedures for fully tensioning (pre-tensioning) high-strength bolts?**

Provisions in the RCSC *Specification* Section 8.2 include four methods for the pre-tensioning of high-strength bolts. The use of these procedures is governed by the provisions listed below: turn-of-nut pre-tensioning, calibrated wrench pre-tensioning, twist-off-type tension-control bolt pre-tensioning, and direct tension indicator pre-tensioning. RCSC also allows the use of alternative-design fasteners and alternative washer-type indicating devices. When used properly, each method can produce properly tensioned high-strength bolts.

Regardless of the method used, pre-installation verification must be performed, the snug-tight condition must be achieved prior to pre-tensioning, washers must be positioned as required in Section 6.2, and installation should commence at the tightest part of the joint and progress toward the free edges. Several cycles may be needed to achieve a snug tight condition.

**6.6.4. How should the turn-of-nut pre-tensioning be used?**

The RCSC *Specification* covers the turn-of-nut method in Section 8.2.1.

**6.6.5. How should the calibrated wrench pre-tensioning be used?**

The RCSC *Specification* covers the calibrated wrench method in Section 8.2.2. Hardened washers must be used under the element to be turned in tightening.

**6.6.6. How should twist-off-type tension-control (TC) bolt pre-tensioning method be used?**

The 2004 RCSC *Specification* covers the use of twist-off-type tension-control (TC) pre-tensioning in Section 8.2.3.

It should be noted that the sheared-off splined end of an individual bolt indicates only that, at the time the splined end was broken, enough torque had been applied to the bolt to fracture the break-neck. Proper tension is assured for all bolts in a connection only if the bolts have been systematically snug-tightened and subsequently fully tensioned as specified.

Note that specific and proper lubrication of "tension-control" or twist-off bolts is essential to the reliable installation of these fasteners.

**6.6.7. How should the direct-tension-indicator pre-tensioning be used?**

Direct-tension-indicator pre-tensioning is covered in Section 8.2.4 of the RCSC *Specification*.

Strict adherence to the manufacturer's installation instructions is required with direct-tension indicators (DTI).

**6.6.8. What is the upper limit on the installed tension of high-strength bolts?**

As stated in RCSC *Specification* Sections 9.2.1 through 9.2.4, installed tensions in excess of those given in RCSC *Specification* Table 8.1 shall not be cause for rejection. Accordingly, there is no specified upper limit on the installed tension of high-strength bolts. This supports the long-standing rule of thumb that as long as the bolt is not broken during installation, the bolt is adequate for service.

This general rule applies because the bolt is subjected to combined stress (tension and torque) during installation. Once installed, however, the torque is relaxed and the bolt is essentially subject only to a tensile stress that is always less than the combined stress. Thus, even if the bolt were on the verge of failure during installation, it would be subject to a less demanding state of stress (simple pretension) during service.

**6.6.9. A bolt has broken during installation. Is this cause for significant concern?**

A bolt may break during installation for several reasons.

When trying to snug-tighten joints involving very thick plies the force required to deform the plates and achieve firm contact may be high enough to rupture the bolt. In fact, repeated attempts to further compact a joint that each result in broken bolts may actually signal that firm contact has been achieved and that the pre-tensioning process can proceed.

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The occasional breaking of a bolt should not be cause for concern, though the cause should be sought so that the issues that led to the problem can be resolved.

## 6.7. Faying Surfaces

**6.7.1. When is paint permitted on the faying surfaces of bolted connections?**

In snug-tight and fully tensioned bearing connections, paint is unconditionally permitted on the faying surfaces. In slip-critical connections, however, if paint is present, it must be a qualified paint. A qualified paint is one that has been tested in accordance with the RCSC *Specification* Appendix A and offers a defined slip-coefficient. Other paints that do not offer a defined slip-coefficient are not permitted in areas closer than one bolt diameter but not less than 1 in. from the edge of any hole and in all areas within the bolt pattern of slip-critical connections, even when due to inadvertent over-spray.

**6.7.2. Both the AISC and RCSC Specifications require that paint on the faying surfaces of slip-critical connections be qualified (providing a minimum slip coefficient) or that such surfaces remain unpainted. Does this requirement apply to the surfaces under the bolt head and nut?**

No. In a slip-critical connection, the faying surfaces are those that resist relative movement (or slip) of the plies. This occurs on the contact surfaces between the plies, not those surfaces under the bolt head or nut.

**6.7.3. What is the difference between the surface preparation requirements for Class A and B surfaces in slip-critical connections?**

With uncoated faying surfaces, clean mill scale provides a Class A slip resistance, μ=0.30, whereas blast cleaning is required to obtain the higher Class B slip coefficient, μ=0.50. With painted faying surfaces, the slip resistance is determined by the tested performance of the paint system as meeting Class A, B, or some other intermediate slip coefficient and the steel to be painted must be blast-cleaned in all cases. Roughened (see 6.7.4) hot-dip galvanized surfaces also provide a Class A slip coefficient, μ=0.30.

**6.7.4. As required in the RCSC *Specification* Section 3.2.2(c), galvanized surfaces in slip-critical connections must be roughened by means of hand wire brushing. What treatment constitutes roughening?**

The *Guide to Design Criteria for Bolted and Riveted Joints* (published by RCSC) indicates that the galvanized surface must be visibly altered without disrupting the continuity of the galvanizing. This is usually accomplished by wire brushing as indicated in the RCSC *Specification* Section 3.2.2, such treatment must be controlled to achieve the necessary roughening or scoring. Power wire-brushing is generally not acceptable because it tends to polish the surface rather than roughen it. Note that an acceptable result can be achieved with a variable-speed power tool with a stiff wire brush when used at a speed that is comparable to that for hand wire brushing.

High-strength bolts that have not been previously subjected to significant pretension are suitable for reuse.

## 6.8. Inspection

**6.8.1. What should the inspector observe when bolts are installed?**

AISC *Specification* Section N5.6 governs inspection of high-strength bolting.

**6.8.2. How is a dispute over installed bolt tension in slip-critical connections resolved?**

When disputes arise, an arbitration procedure utilizing a calibrated torque wrench is covered in the RCSC *Specification* Section 10, "Arbitration." As discussed in 6.6.1, published standard torque values are not acceptable for use in lieu of actual calibrated torque values.

## 6.9. Bolt Tension Calibration

**6.9.1. The RCSC *Specification* discusses a "calibration device capable of indicating bolt tension." What is an example of such a bolt tension calibration device?**

One such device is the Skidmore-Wilhelm Bolt Tension Calibrator, manufactured by the Skidmore-Wilhelm Manufacturing Company (**www.skidmore-wilhelm.com**). When a sample bolt is installed in the "Skidmore," the tension is measured on a dial gauge. Thus, the appropriate torque for use in the calibrated wrench installation method may be determined, or the proper tension resulting from the turn-of-nut, alternative design bolt, or direct tension indicator methods may be verified. It is not intended that the use of other similar devices be excluded by this discussion.

**6.9.2. When short bolts will not fit in the bolt tension calibration device how can they be tested?**

Because devices such as the Skidmore have a minimum bolt length, testing of shorter bolts can be accomplished in any convenient steel plate by the use of a washer-type direct tension indicator (DTI). A similar DTI must first be tested using a longer bolt in the bolt tension calibration device to verify that they are neither under nor over strength. Alternatively, a calibrated torque may be determined using a bolt tension calibration device and a longer bolt with a hardened washer under the turned element. This torque may then be used for testing shorter bolts with a hardened washer under the turned element in a steel plate, provided lubrication and condition of threads for the long and short bolts are similar.

## 6.10. Washer Requirements

**6.10.1. When are beveled washers required?**

To assure proper bolt performance, it is required in the RCSC *Specification* Section 6.1.1 that the surfaces against which the head and nut bear have a slope not greater than 1:20 with respect to the plane normal to the bolt axis. American standard beams (S-shapes) and channels are rolled with beveled flanges that exceed this limit. Because bolt holes are made perpendicular to the outside face of these flanges, a beveled washer must be used at the inside face to provide the required parallelism. Beveled washers are made square or rectangular so that they can more easily be prevented from turning to assure that the bevel is oriented in the proper direction.

**6.10.2. Why must washers completely cover the hole in the outer ply of slotted connections?**

Two reasons for this requirement are to prevent "dishing" of the washer (which would become more critical if an edge were unsupported) and to prevent moisture from entering the connection (thus creating a corrosion concern).

**6.10.3. Why are plate washers required over long-slotted holes?**

For long-slotted holes, thicker plate washers are required per RCSC *Specification* Section 6.2.5 because the high clamping pressures generated during pre-tensioned installation and the increased amount of material removed with a long-slotted hole can result in collapse of thinner standard F436 washers into the hole.

### 6.11. Other General Information

**6.11.1. Why is the design strength of a bolt calculated in the AISC *Specification* on the basis of the nominal cross-sectional area rather than the net tensile area that remains after threading?**

The ratio of stress area to nominal bolt area ranges from 0.75 for ¾-in. diameter to 0.79 for 1⅛-in. diameter (per the Guide to Design Criteria for Bolted and Riveted Joints). Accordingly, to simplify calculations, the lower bound reduction of 0.75 is incorporated in AISC-tabulated nominal strength values for use with nominal bolt areas.

**6.11.2. When is it permissible to reuse high-strength bolts?**

High-strength bolts that have not been previously subjected to significant pretension are suitable for reuse. However, high-strength bolts that have been pre-tensioned may or may not be suitable for reuse as follows.

As stated in the RCSC *Specification* Section 2.3.3, ASTM A490 bolts and galvanized ASTM A325 bolts are never suitable for re-use if they have once been pre-tensioned in accordance with the procedures in the RCSC *Specification* Section 8.2. Reuse of non-galvanized ASTM A325 bolts is acceptable if approved by the SER. As a simple rule of thumb, a black ASTM A325 bolt is suitable for reuse if the nut can be run up the threads by hand.

Note the qualification in the RCSC *Specification* that "Touching-up or re-tightening bolts that may have been loosened by the installation of adjacent bolts shall not be considered to be a reuse." Similarly, fit-up bolts (which are snug-tight when initially installed) may be left in place and subsequently fully-tensioned, if required, as permanent bolts in the connection.

A discussion of the performance of high-strength bolts repetitively tightened can be found in the *Engineering Journal* article "Reuse of A325 and A490 High-Strength Bolts" (3rd Quarter 1991; available at **www.aisc.org/ej**).

**6.11.3. What minimum stick-through is required for high-strength bolts?**

None. As defined in the RCSC *Specification* Section 2.3.2, "The bolt length used shall be such that the end of the bolt extends beyond or is at least flush with the outer face of the nut when properly installed." Some contract documents include a stick-through requirement (minimum protrusion of the bolt point beyond the nut). However, because the threaded length for any given bolt diameter is constant regardless of the bolt length, a stick-through requirement (which may require a longer bolt) increases the risk of jamming the nut on the thread run-out. Because a stick-through requirement does not enhance the performance of the bolt, its specification is discouraged. Note that there is no specified maximum limitation on bolt stick-through. However, in order to properly tension high-strength bolts, sufficient thread must be available. The use of additional flat washers under the head and/or nut is a common solution when there is a risk of jamming the nut on the thread run-out. Multiple washers are permitted under either or both the head and the nut. Nut jamming is not a concern for fully threaded ASTM A325T bolts. (See 6.2.6.)

**6.11.4. When an extended end-plate moment connection is specified as slip-critical, must the slip resistance of the bolts at the tension flange be reduced for the tension present?**

No. Because the tensile and compressive flange forces are equal and opposite, any loss of slip resistance adjacent to the tension flange of the beam is compensated for by an increase in slip resistance adjacent to the compression flange.

**6.11.5. As indicated in the AISC *Specification* Table J3.2, when the pattern of fasteners in a bolted joint exceeds 38 in. in length, tabulated design strengths should be reduced to 83.3 percent of the tabulated values. Why?**

As indicated in the *Guide to Design Criteria for Bolted and Riveted Joints*, the average shear strength per bolt varies with the number of bolts in the joint due to the non-uniformity of force distribution; see Figure 5.28 herein. To simplify joint design, bolt shear strengths in the RCSC *Specification* (see Commentary Section 5.1) and 2010 AISC *Specification* incorporate a reduction to allow the use of consistent per-bolt design strength for joints up to 38 in. in length. However, if joint length exceeds 38 in., the designer must further reduce the design strength. This phenomenon is a by-product of shear lag in the connection.

**6.11.6. How do hot-dip galvanizing and mechanical galvanizing processes differ?**

In the hot-dip galvanizing process, the piece is first degreased and cleaned with a combination of caustic and acidic solutions. After rinsing, the piece is dipped into a tank of molten zinc for a specified period of time. The full process is described in ASTM A153. In the mechanical galvanizing process, the piece is similarly cleaned and rinsed. The piece is then tumbled in a mixture of various-sized glass beads and a predetermined amount of water, with small amounts of chemicals and powdered zinc added periodically. Collisions between the glass beads, zinc and the piece cause a cold-welding process that applies the zinc coating. Powdered zinc is added until the specified thickness is attained. The full process is described in ASTM B695. ■