The Fundamentals of Structural Bolting

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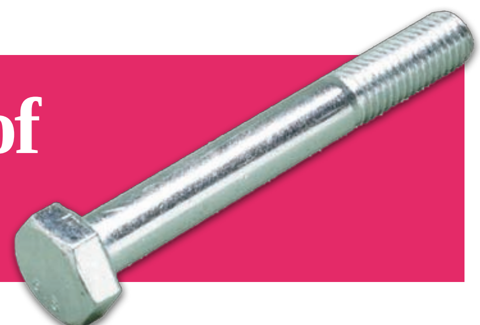

Most people probably never give the fasteners that hold together most of our modern contrivances a second thought. They simply take for granted that these components will do what they were designed to do. In fact, I believe that few people really appreciate that fasteners are perhaps the lowest cost, most highly engineered components in the products that they are used in. Many times they are truly critical and our lives depend on them working flawlessly.

Although it is likely that this notion can be applied to any application, it is especially true of structural bolting technology. These are the fasteners we depend on every day to hold up bridges, buildings, and other important structures. There is a great deal of information available for the production, installation, and proper use in the consensus standards pertaining to these fastener assemblies. This article will attempt to explore the fundamental principles related to this very important category of fasteners.

How are Structural Bolts Different?

Historically, structural bolts have been primarily manufactured to ASTM A325 and ASTM A490 standards or to the alternative bolt designs ASTM F1852 or ASTM F2280. However, when comparing these to Grade 5 or Grade 8 hex bolts, one might ask what is different, as to the untrained eye, they appear very similar. They are not the same, though, and possess two significant differences;

1. Structural bolts are produced to a heavy hex head configuration. This is compared to a standard hex or hex cap screw configuration. The heavy hex provides a wider bearing surface which is key in distributing the clamping pressure over a greater area. This is especially important in critical joints where maximum fastener preload in the joint is desirable. For the same reason that the heads on the bolts are larger, structural bolts are designed to be used with heavy hex nuts that conform to ASTM A563 or ASTM A194.
2. Structural bolts have longer unthreaded shank lengths and, thus, shorter thread length when compared with traditional bolts of equivalent overall length. This is important as it may provide a beneficial increase in tensile strength, but more importantly provides greater shear strength. It accomplishes this by allowing only the larger, unthreaded shank to span the total thickness of all parts being joined. By keeping the threaded section out of this area, the fastener will provide greater shear strength.

Two Types of Joints

There are basically two types of structural joints, Bearing Joints and Slip Critical Joints. In a Bearing Joint the load is transferred between components by bearing on the bolts. In a Slip Critical joint the load is transferred between components by friction generated between the bolted components.

About ASTM A325 and ASTM A490 Bolts

ASTM A325 bolts are inch fasteners ranging in size from ½” diameter to 1 ½” diameter. In former times, the standard delineated a tensile strength change at 1” diameter, but the most recent 2015 revision of the ASTM structural bolting standard changed this to a fixed 120,000 psi strength across the entire size range. ASTM A325 structural bolts can be made of medium carbon steel, which are referred to as Type 1 or of weathering steel referred to as Type 3. ASTM A325 Type I structural bolts are permitted to be galvanized. ASTM A325 bolt geometry is defined by ASME B18.2.6.

ASTM A490 structural bolts also come in sizes ranging from ½” diameter to 1 ½” diameter but are stronger than ASTM A325 bolts with a minimum tensile strength of 150,000 psi. Like ASTM A325 bolts, these come in two types, Type 1 made from alloy steel and Type 3 from weathering steel. ASTM A490 bolts are not allowed to be electroplated or galvanized. Both processes may potentially expose the parts to hydrogen embrittlement during cleaning processes and hot-dip galvanizing has the potential of exposing the fastener to temperatures above the minimum tempering temperature. This can have a negative impact on part strength. ASTM A490 bolt geometry is defined by ASME B18.2.6.

In addition to the inch grades defined by ASTM A325 and A490, there are similar metric versions defined by ASTM A325M and A490M. Although strengths are similar, it should not be assumed that the strengths are exact equivalents, and so, each grade is unique onto itself.

Research Council on Structural Connections (RCSC) - Joint Assembly

The guiding principles for applying structural bolts can be found in RCSC's "Specification for Structural Joints Using High-Strength Bolts". RCSC defines three different bolting scenarios, 1. Snug-tightened, 2. Pre-tensioned, and 3. Slip Critical. Both Pre-tensioned and Slip Critical joints are highly stressed since they are tightened to at least 70% of their minimum tensile strength.

RCSC recognizes only four methods for installation of structural bolts:

1. Turn-of-nut
2. Alternate Bolt Design (Tension Control Bolts)
3. Direct Tension Indication Method
4. Calibrated Wrench Method

Although these installation methods are described in detail in the RCSC standard and other resources, it is important to remember that not every method is actually recognized and approved by users. In fact, some users may only accept one or two of these methods.

Turn-of-Nut

The Turn-of-Nut installation method is, in fact, a crude but effective torque-angle tightening strategy. In this installation method, the installer will tighten the joint to "snug tight", mark the starting position of the nut and bolt, and then turn the nut a fraction of a turn (as defined by the RCSC standard). This additional turn is equivalent to turning the part through a defined angle of turn and effectively tensions the joint to a desired tension level.

Alternate Design Bolts

The most common "Alternate Design" is referred to as Tension Control Bolts. This description is technically a bit of misleading since these bolts incorporate a spline which breaks off when the special installation tool reaches a determined torque value. As one might deduce from this, uniformity within lots and even lot-to-lot is extremely important. For this reason, these parts are specified to be delivered preassembled with a washer per ASTM F436 and a heavy hex nut per ASTM A563 or A194.

ASTM F1852 are Tension Control bolts that are intended to be mechanically equivalent to ASTM A325 structural bolts. ASTM F2280 are Tension Control Bolts that are intended to be mechanically equivalent to ASTM A490 structural bolts. Similar to ASTM A325 and A490 structural bolts, ASTM F1852 Tension Control Bolts may be supplied either plain or mechanically galvanized, while the higher strength ASTM F2280 may only be supplied with a plain finish.

Direct Tension Indication Method

The most common form this method takes is to utilize a Direct Tension Indicating (DTI) Washer. These are special and highly engineered washers that have raised bumps that will "collapse" when the desired tension is reached. Proper installation methodology includes the use of a feeler gage (normally supplied by the fastener assembly or DTI supplier) to assure proper and complete flattening of the bumps. In some cases the depressions of the bumps on the underside of the washer are filled with silicon. When the bumps collapse this silicon is propelled radially outward providing an indication that the bump has flattened out. These are known as "squirters". Although this positive indication enhances the ease of installation, it does not relieve the installer of their responsibility to utilize the feeler gage.

Besides DTI washers, there are a number of bolt designs that perform in a conceptually similar fashion. Many people refer to these as "smart bolts". They have some sort of indicator that shows the installer that the desired tension has been reached.

Calibrated Wrench Method

In this method an onsite tester, such as a Skidmore device is used to daily test a minimum of three samples to set an installation device by. (In fact, a number of the other methods may also require daily testing with a Skidmore to monitor any within lot or lot-to-lot changes.)

What is "Snug- Tight"?

Perhaps one of the more debated subjects of these installation methods is what constitutes "snug tightness". The RCSC document defines it as, "Full effort of a typical personas applied using an ordinary spud wrench. A bolt in snug tight condition will carry no less than 10% of its pre-tension load. Snug tight conditions can also be achieved with a few impacts of an impact wrench." (In case the term spud wrench is unfamiliar, it is a long handled wrench with either a socket or wrench end. It is a common tool utilized by iron workers for tightening bolts and nuts.) Although this may still seem vague, remarkably, following these guidelines "snug tightness" is usually consistently achieved.

Storage

As is hopefully evident by now, performance consistency is critical and highly dependent on lubrication and part surface uniformity. Therefore, it is extremely important that parts be properly stored so that their surface characteristics are not negatively altered. For this reason, fasteners should be stored at all points in the supply chain, and particularly once they arrive on-site, in closed containers and under protective shelter so that they are protected from dirt and corrosion. In this same vein, only enough parts should be removed from storage as are necessary and any unused parts should be promptly and carefully returned to protected storage.

Combination of ASTM Standards

Prior to 2015 ASTM A325, A325M, A490, A490M, F1852, and F2280 were all separate standards. In an effort to simplify and put all the information together in one spot, Subcommittee 2 of the ASTM Fastener Committee F16, diligently worked together to combine all six standards into one. In 2015 this work culminated in the publication of ASTM F3125. This document represents a great deal of hard work and effort by this Subcommittee, and truly served to simplify matters. In reality, besides creating a good deal of efficiency, for the most part little has changed from the old version to the new version. Parts will still be identified by the same numbers (i.e. A325, A490, etc..), although instead of being stand-alone, they will now be considered a grade number. (For example, what was formerly referred to as an ASTM A325 bolt will now be referred to as ASTM F3125 Grade A325 Type 1.)

Conclusion

Many of our most important bolted connections fall in this structural bolting category. For those that either are simply interested in fastener engineering and technology or work in this sector of the fastener industry, understanding the fundamentals and the things that make structural fasteners special or different is important. The preceding information is very fundamental but the documents referenced in this article are an excellent source of further, more detailed guidance and knowle«e.

References:

ASME B18.2.6, 2010, "Fasteners for Use in Structural Applications", ASME. New York, NY, www.asme.org

ASTM F3125/F3125M-15a, 2015, "Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions", ASTM International, West Conhohocken, PA, www.astm.org

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