

Structural Bolting

ASTM F3125/F3125M is a structural bolt specification covering inch and metric bolt grades. This specification contains 4 inch series bolting grades: A325, F1852, A490, and F2280. These will be addressed in this article. When looking at the mechanical requirements of bolts it appears that a grade A325 and SAE J429 Grade 5 are identical as do the grade A490 and the SAE J429 Grade 8.

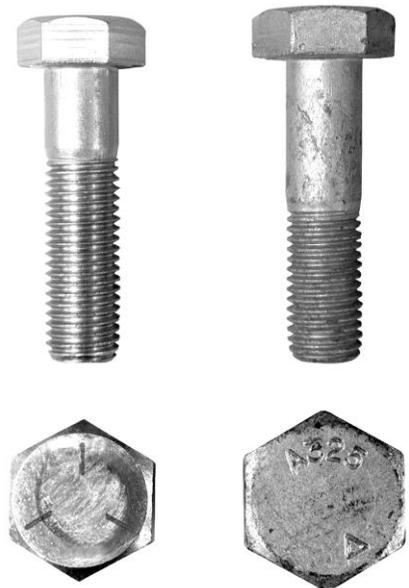
This begs the question, “Can an SAE J429 Grade 5 be used when an ASTM F3125 grade A325 is specified?” The answer is definitely no. This is also the case for substituting a Grade 8 when grade A490 is specified, and here are some reasons why:

First, grade A325 and A490 bolts are produced with a heavy hex head configuration which provides a wider bearing surface over which to distribute the load. Grade 5 and 8 bolts are produced to standard hex cap screw configuration and therefore cannot distribute the load as much as is needed for structural applications.

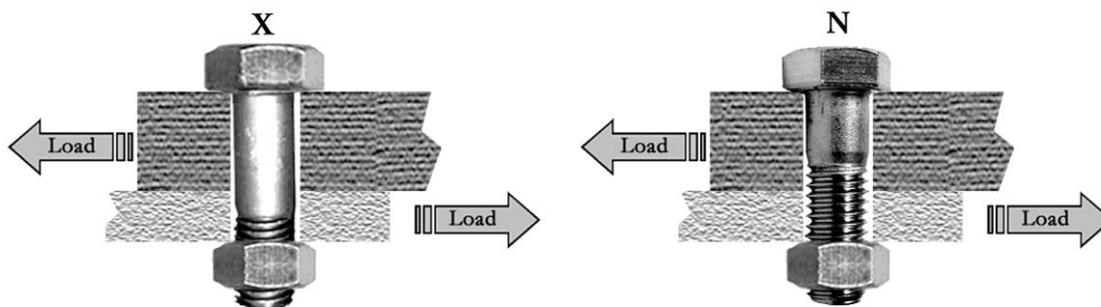
Second, the shank length (non-threaded portion of the body) on the grade A325 and A490 bolts is designed to be greater (shorter thread lengths) than your standard hex bolt or hex cap screw. Remember, the weakest section of standard carbon steel fasteners is through the threaded region. Minute design changes such as this can create a stronger tensile connection.

Third, the difference in thread length is also likely to result in a change in shear strength. The following two diagrams demonstrate this difference:

If both bolts are 3/4-10 x 4, Bolt X has the shear plane acting through the body of the bolt, while Bolt N has its shear plane acting through the threaded portion. Assuming that both fasteners have an ultimate shear capacity of 72,000 PSI, just how many pounds would each fastener be capable of handling? To determine the load in pounds, one must first calculate the area of material for each example.



Notice the Grade 5 has a much smaller head configuration and a shorter shank than the grade A325 structural bolt.



Bolt X has the cross sectional area in the shank (body diameter). Therefore, in the worst case scenario the minimum body diameter is 0.729 inches. By applying the principles of geometry one can calculate the area of a circle with this diameter.

Bolt X has a material cross sectional area of 0.417 square inches. Take 0.417 sq-in. and multiply by 72,000 PSI and you're left with nearly 30,000 pounds.

For Bolt N's calculation the root area must be used (as the shear plane intersects the threads), which is 0.302 sq-in. Now take this and multiply by the same 72,000 PSI and it results in approximately 21,740 pounds.

By merely ensuring that the shear load is applied to the body of the bolt, the shear strength can improve by 8,260 pounds. On the other hand, if the application calls for the shank to be in the shear plane, substituting a Grade 5 (with its longer thread length) would place the threads in the shear plane, resulting in an 8,260 lbs. reduction in shear strength. Oftentimes, drawings and blueprints indicate the structural bolt with an **X** or an **N designation**. The X indicates that the threads are excluded from the shear plane whereas the N indicates that the threads may be included in the shear plane.

Structural bolts are specifically designed for use with heavy hex nuts in the connection of structural members (as opposed to tapped holes). The nuts for structural connections shall conform to ASTM A563 or ASTM A194. The following chart will assist in proper structural nut selection. The washers used for structural connections shall meet ASTM F436 specifications. This specification covers both flat circular and beveled washers.

Mechanical Properties of ASTM F3125/F3125M Grades A325 & A490 Structural Bolts with Nut Compatibility

Grade	Type	Material	Style	Min. Proof Strength (psi)	Min. Tensile Strength (psi)	Core Hardness Rockwell		Min. Yield Strength (psi)	Grade Identification Marking		Compatible Nuts
						Min.	Max.		Type 1	Type 3	
A325	Type 1	Carbon steel, carbon boron steel, alloy steel or alloy steel with boron addition	Heavy Hex Head	85,000	120,000	C25	C34	92,000			ASTM A563 Grade C Heavy Hex, DH or A194/A194M 2H if Galv ASTM A563 Grade C3 or DH3
	Type 3	Weathering steel									
F1852	Type 1	Carbon steel, carbon boron steel, alloy steel or alloy steel with boron addition	Twist-Off	85,000	120,000	C25	C34	92,000	A325TC	<u>A325TC</u>	ASTM A563 Grade C Heavy Hex, DH or A194/A194M 2H if Galv ASTM A563 Grade C3 or DH3
	Type 3	Weathering steel									
A490	Type 1	Alloy steel with or without boron	Heavy Hex Head	120,000	150,000 (min) 173,000 (max)	C33	C38	130,000			ASTM A563 Grade DH or A194/A194M 2H ASTM A563 Grade DH3
	Type 3	Weathering steel									
F2280	Type 1	Alloy steel with or without boron	Twist-Off	120,000	150,000 (min) 173,000 (max)	C33	C38	130,000	A490TC	<u>A490TC</u>	ASTM A563 Grade DH or A194/A194M 2H ASTM A563 Grade DH3
	Type 3	Weathering steel									

Grade A325 bolts are available in diameters from 1/2 to 1-1/2 inch (for diameters greater than 1-1/2, ASTM A449 specifications should be considered) with a minimum tensile strength of 120,000 PSI. They also come in two types. Type 1 is a medium carbon steel and can be galvanized; Type 3 is a weathering steel that offers atmospheric corrosion resistance similar to that of ASTM A242 or A588 steels. Type 3 grade A325 bolts shall be marked "A325" to distinguish them from standard grade A325s.

ASTM A490 bolts are available in diameters from 1/2 to 1-1/2 inch diameters with a minimum tensile strength of 150,000 PSI for all diameters, and are offered in two types. Type 1 is alloy steel, and Type 3 is weathering steel that offers atmospheric corrosion resistance similar to that of ASTM A242 or A588 steels. Type 3 grade A490 bolts shall be marked "A490".

Grade A490 bolts should not be galvanized or electroplated. The problem with hot dip galvanizing is that the molten bath of zinc exceeds the fastener's tempering temperature and would cause the fastener to anneal in the bath. In addition, a major problem with hot dip galvanizing and electroplating grade A490 bolts is the potential for hydrogen embrittlement.

This scenario may occur when atomic hydrogen is introduced during the pickling process that takes place prior the plating or hot dip galvanizing process.

When a protective coating is required or specified, the only coating allowed by the ASTM F3125/3125M standard on grade A490 is the ASTM F1136 Grade 3 or ASTM F2833 Grade 1. These coatings have undergone extensive hydrogen embrittlement research in accordance with IFI 144. This is a great opportunity for those interested in corrosion resistant high strength structural bolts. For more information on the F1136 and F2833 coatings, please contact the FEDS Group at engineer@fastenal.com.

According to the Research Council on Structural Connections; *American Institute of Steel Construction (AISC)*, for structural applications there are generally three types of connections in which a bolt is used; snug-tightened, pre-tensioned, and slip critical connections. In accordance with the AISC, bolts used in pre-tensioned or slip-critical connections are required to be installed to within 70% of the minimum tensile strength of the bolt.

Due to the uncertainties involved with torque, it is not valid to use published values based on a torque-tension relationship from a formula to obtain the accuracy required for structural connections requiring a minimum clamping force of 70% of the minimum tensile strength of the bolt.

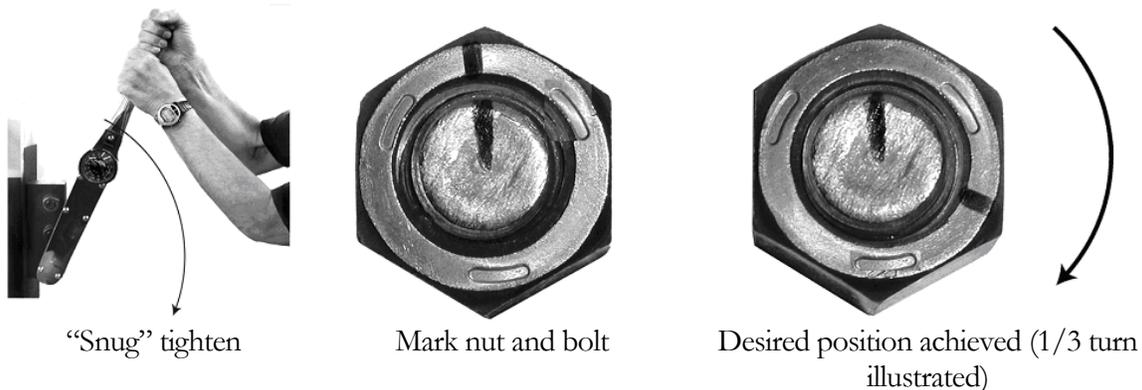
There are four methods of installation procedures recognized by the AISC to achieve the tension required for the fully tensioned bearing or the slip critical connection:

1. Turn-of-nut method
2. Alternative design bolt method (tension control bolts)
3. Direct tension indicating method (DTI)
4. Calibrated wrench method.

Turn-of-Nut

This method involves tightening the fastener to a low initial “snug tight” condition and then applying a prescribed amount of turn to develop the required preload. The actual preload will depend on how far the nut is turned as well as how much preload was established prior to the turning.

1. Snug the joint to bring the assembly into firm contact. Apply a few impacts with impact wrench until solid sound or apply full effort with a spud wrench.
2. Inspect the joint to verify “snug tight”.
3. Match mark bearing face of the nut and end of the bolt with a single straight line. Note: match marking is not a part of the RSCS requirements, but can be helpful.
4. Using a systematic approach which would involve the appropriate bolting pattern, apply the required turns as given in the table below



Bolt Length	Condition Under Bolt Head and Under Nut		
	Both Faces Flat (normal to bolt axis)	One face sloped, but not more than 1:20	Both faces sloped, but not more than 1:20
Less than or equal to 4D	1/3 Turn	1/2 Turn	2/3 Turn
More than 4D and less than or equal to 8D	1/2 Turn	2/3 Turn	5/6 Turn
More than 8D and less than or equal to 12D	2/3 Turn	5/6 Turn	1 Turn

D = Bolt Diameter
 Applicable only to steel joints

Alternative Design Bolts (Tension Control Bolts)

Tension control bolts use design features that indirectly indicate tension. The most common alternative design bolt is the twist-off bolt or tension control (TC) bolt.

An assembly tool holds this bolt from the nut end while an inner spindle on the tool grips a spline section connected to the end of the bolt. An outer spindle on the tool turns the nut and tightens the fastener. When the designated torque has been reached, the spline snaps off. This type of torque control system allows for quick inspection, if the spline is gone then, in theory, the bolt has been properly tightened.

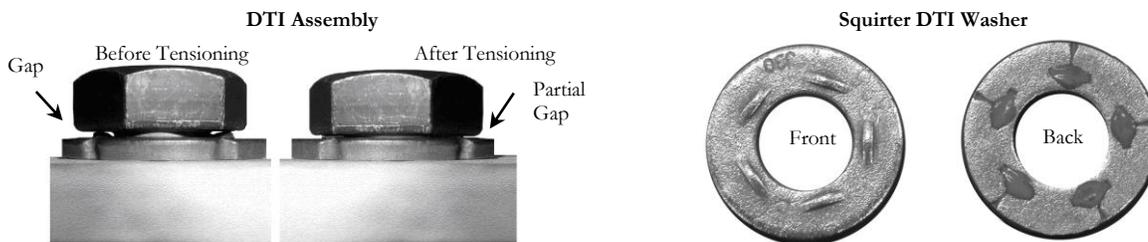


Although each tension control bolt assembly (bolt, nut and washer) lot is tested by the manufacture to ensure it meets the minimum required clamp load, this system is based on torque control to snap the spline. Because of this torque based system, bolt assemblies must be used in their as-received (clean and lubricated by the manufacture), and strict adherence to the requirements of the appropriate standard, particularly those for storage, cleanliness, and verification is necessary.

The grade A325 equivalent TC bolts is grade F1852. The grade A490 equivalent TC bolts is grade F2280. Each bolt is preassembled with an ASTM F436 flat washer and the appropriate heavy hex nut and sold as an assembly. The grade F1852 bolts are available plain finished or mechanically galvanized. The grade F2280 bolts are only available in plain finish.

Washer Control

Several types of **DTI washers** are available. The most common type of washer involves the use of hollow bumps on one side of the washer. This style of washer is covered by the

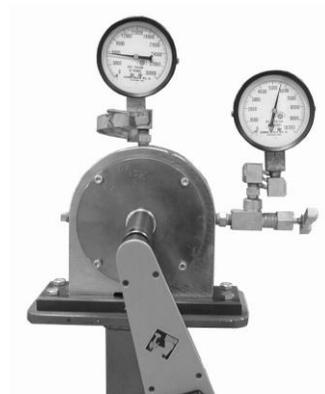


ASTM F959 (Standard Specification for Compressible-Washer Type Direct Tension Indicators for Use with Structural Fasteners) standard and has both A325 and A490 washers. These bumps are flattened as the fastener is tightened. A feeler gage is used to measure the gap developed by the bumps. When the fastener has developed the appropriate tension, the feeler gage will no longer fit in the gap. Some newer types fill the void under the bumps with colored silicone. The silicone squirts out once the bumps are compressed, thereby indicating proper tension. The DTI washer has been used in the structural bolting industry for years and is now starting to carry over into other fields as well.

It is important to consider that DTI washers can only indicate the minimum tension required to close the gap. If over-tightening occurs, the washer would not be able to indicate the amount of over tensioning. Moreover, this type of system cannot monitor or display the amount of bolt relaxation. Since the bumps on the washer deform plastically, they will not return to their original dimensions if the bolt relaxes.

Calibrated Wrench Method

As mentioned initially, for structural bolting, it is not valid to use published values based on a torque-tension relationship. In other words, you cannot use torque from a formula. The calibrated wrench method is only valid if installation procedures are calibrated on a daily basis by tightening not fewer than three representative fastener assemblies (typical) for each lot, diameter, length, and grade with nuts from each lot, diameter, and grade and with a hardened washer tightened in a device (Skidmore-Wilhelm) capable of measuring actual bolt tension.



The Skidmore-Wilhelm tester is one of the only devices that is able to directly measure bolt clamp load.