



## Engineering Bulletin 027

### RE: What are the Differences Between Structural and Mechanical Nuts and Bolts?

#### The Nuts and Bolts of Choosing the Right Hardware

If you've been around the trades or involved in engineering for a while, you've probably become numb to just how much detail goes into each and every aspect of what most people think of as a simple system or structure. Especially in heavy things suspended above people's heads (all roofs, of course) or systems that can explode, there is a depth of detail only visible to the knowledgeable that separates our safe (and mundane) reality from the one where dramatic catastrophe is common. In the built environment, a significant part of that detail lies in the nuts and bolts that hold elements of mechanical and structural systems together.

While most people imagine that ordering a particular bolt requires that they specify only a size, the reality is much more complicated and includes strength, fatigue life, corrosion protection, head size, head shape, what fraction of the shank is threaded, and more. Nuts also have a wide variety of parameters, many of which get fixed by the choice of bolt. Any bolt can be inserted into a hole as long as the diameter and thread pitch match, but well-engineered systems consider a great amount of detail when specifying these fasteners.

One primary way engineers categorize bolts is to differentiate structural bolts from mechanical bolts. Structural bolts are designed to bear loads and stresses within a structure, ensuring its stability and safety. Their primary application is in construction projects, notably in steel framing and infrastructure. Mechanical bolts are used to assemble or repair machinery and equipment. They come in various sizes, grades, and materials. Bolts in this category are much more commonly available to consumers and generally less expensive than structural bolts.

#### Structural Bolts and When to Use Them

These bolts are characterized by their high strength, which allows them to maintain structural integrity under dynamic loads and varying environmental conditions. The American Society for Testing and Materials (ASTM) sets stringent standards for structural bolts<sup>1</sup> to ensure they meet the demands of structural applications, are [assembled](#) and tested properly to meet design expectations, and even stored according to protocol.

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<sup>1</sup> Primarily in ASTM F3125 "Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions"

While there are several different types of structural bolts available, ASTM Grade A325 and A490 are two the most commonly used in structural applications. Although A490 are higher strength than A325, most projects call for A325: understanding why this happens gives a good introduction to the subtlety involved in careful design. Both of these bolts have a heavy hex head that provides a larger bearing surface to distribute the clamping load to the structural members in the joint. The threading on both of these bolts stops well short of the head so that the bolt presents a solid full-diameter shank to the shear plane of the joint. Because the threaded portion of the shank is weaker than the unthreaded portion, ensuring that the unthreaded portion is located at the shear plane of the joint makes for a stronger connection. Bolts used for structural connections almost always require a nut (rather than a blind threaded hole) to complete the joint, and the type of nut often follows from the bolt selection.

### **A325 Structural Bolts**

A325 bolts are commonly used in bridge and highway construction projects. They can be made of Type 1 medium carbon steel, and bolts of this material can be further galvanized to dramatically slow corrosion. A325 bolts can also be made from Type 3 weathering steel in which the alloyed elements “passivate” when exposed to air with moisture in it. This passivation process creates a strong and well-bonded impervious oxide layer on the bolt that inhibits further corrosion. A325 bolts have a minimum tensile strength of 120 ksi for diameters of one inch or less (105 ksi for bolts over one inch diameter).

### **A490 Structural Bolts**

These bolts can be made from Type 1 higher carbon alloy steel or Type 3 weathering steel, but unlike Grade A325, A490 bolts cannot be galvanized because of possible hydrogen embrittlement that could occur in the [hot dip or mechanical galvanizing process](#). Grade A490 specifies a minimum tensile strength of 150 ksi, 25% stronger than the A325 spec. This high strength comes with penalties including a higher susceptibility to stress corrosion and hydrogen cracking, consequently many structures are engineered to utilize the more robust A325 bolts.

The differences between these two specifications give a peek at the many factors that go into selection of a structural bolt and the design of a bolted connection. It also illustrates just how specialized structural bolts are and why they are not used in applications that don't demand their strength and their highly specialized (and more expensive) manufacturing, storage, and installation process.

In fabric structures, structural bolts are used extensively in the engineered connections between framing members. Relying on these highly specified and certified nuts and bolts assures us that our structures will be safe over their long lifespan.

## **Mechanical Bolts and When To Use Them**

With their strength graded according to SAE (Society of Automotive Engineers) standards, mechanical bolts are selected for use based on the specific mechanical properties required for the equipment in question including shear strength, tensile strength, the ability to withstand vibration and fatigue, corrosion resistance, and extreme temperature performance.

SAE has assigned several different grades to bolts, starting with Grade 2 and ending with Grade 8 (the strongest), although Grades 2, 5, and 8 are the most common.

### **SAE Grade 2 Bolts**

Bolts that conform to this grade have a tensile strength between 60 – 74 ksi and generally used for non-critical joints and applications that include maintenance, fastening non-structural components such as cowlings or brackets, and general non-engineered fastening. These bolts are a cost-effective option and can be fully or partially threaded in lengths between ¼” up to 4”.

### **SAE Grade 5 Bolts**

Specified to be made from medium carbon steel and hardened for greater strength and durability, a Grade 5 bolt displays tensile strengths between 105 ksi and 120 ksi which puts in on par with an ASTM A325 bolt. These two specifications have quite a few similarities, however some differences include the following.

- Grade 5 bolts usually have a finished hex head while A325 have a heavy hex head.
- The nuts that accompany a Grade 5 bolt also have a finished hex head, while the A325 bolts require heavy hex head nuts. The standard thread length for a Grade 5 bolt is twice the bolt diameter plus ¼ inch for bolts less than 6 inches long and for bolts more than 6 inches long, twice the bolt diameter plus ½ inch. On an A325 bolt there are standard thread lengths, but these bolts are generally shorter than SAE bolts for a given diameter.
- Often, because of the tighter specification of the A325 bolt, SAE Grade 5 bolts are significantly less expensive than an A325 bolt.

### **SAE Grade 8 Bolts**

These bolts have the highest strength of the SAE grading scheme with a minimum tensile strength of 150 ksi. SAE Grade 8 is roughly comparable to the ASTM A490 specification. These bolts are often used for the high-capacity mechanical linkages in earth moving equipment, in automobile suspensions, and other mechanical applications where very high static and dynamic forces are involved.

While they have a similar range of strength, bolts graded in the SAE framework find use in a wider variety of applications than structural bolts graded in the more targeted ASTM standard. Used

extensively in sectors such as automotive, heavy equipment, pumps, generators, and turbines, SAE graded bolts are used often in both blind threaded holes and with nuts. Parameters such as thread length, material, and finish have more variability in SAE graded hardware primarily because of the wide range of mechanical equipment applications. SAE graded fasteners are used in our fabric structures where appropriate such as door opening hardware, and ventilation louvers. It is vital that the hardware specified on the building drawings be used for construction of the building, no substitutions can be made without approval of the building engineer.

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