INSTALLATION AND INSPECTION OF HIGH STRENGTH BOLTS IN THE BUILDING CONSTRUCTION INDUSTRY

While high strength bolts are one of the most important elements of the structural system of modern steel frame buildings and other structures, their installation is frequently misunderstood. Some of the misunderstanding is a holdover from methods used in earlier times, and some is due to a misunderstanding of the principles of connections using high strength bolts.

The first question that must be answered by the designer in a bolted connection is "is this a slip critical connection?" It is not in the scope of this article to delve into the design of bolted connections, so I will only state that this is a design determination on the part of the Engineer of Record.

There are still many people in our industry who refer to a "friction" connection. This terminology is no longer in use; however, many of the characteristics of the friction connection are now covered by the "slip critical" connection. At the least, slip critical connections are required to be fully pre-tensioned in accordance with table 4 in the chapter "Specification for Structural Joints Using ASTM A325 or A490 Bolts" in the AISC manual.

Many people ask such questions as "what's the torque required for a 1" A325 bolt?" This indicates a misunderstanding of what we do when we tighten a bolt. The idea is that we "stretch" the bolt by tightening the nut. The tension induced in the bolt then compresses the plies of the connected elements. So the correct question is "what's the tension required for a 1" A325 bolt, and how do we know when we have it?"

Since we achieve this tension by turning the nut it is natural to think that the amount of tension can be determined by the degree of turning effort. This is in fact true. The problem arises when we attempt to generalize the procedure and assume that, since it took 850 foot pounds of torque to bring the 1" A325 bolt at the last job to correct pre-tension, that the same torque will work at the current job. Or when we take out our handy "bolt torque slide rule" that the guy who got us started in the industry gave us when he retired 15 years ago.

What's wrong with these methods? When we tighten a nut, we are overcoming a combination of forces. These include the tension in the bolt, the friction between the nut thread and bolt thread and the friction between the nut and the washer or the outer ply of the connection. The problem is that we don't know how much of the resistance to turning we feel in the wrench comes from each of the forces.

The coefficient of friction in the threads and between the nut and the surface it is turning against depends on any number of things, most of which we can't accurately measure. These include the finest details of the thread geometry, the lubrication and cleanliness of the bolt and the nut, and the surface conditions of the washer or outer ply of the connection. This means that we don't know the crucial item – how much of the torque we have applied has gone to inducing tension in the bolt. Studies have shown that the amount of torque required to produce a given amount of tension can vary by as much as 40%.

This is the reason that we must always use a tension-indicating device when we install high strength bolts. This is almost always the Skidmore-Wilhelm Bolt Tension Indicator (pictured at left). This device measures the tension in the bolt by measuring the hydraulic pressure in a cell that is squeezed when the nut is tightened. It can be used to verify the tension induced in a bolt by any tightening method, and is required for ALL high-strength bolt applications designed to follow the AISC code or any of its derivatives.

The indicator, known in the field as the "Skidmore," is fastened to a fixed member, typically a column flange, and the appropriate plates for the size of bolt are installed. The bolt, nut and hardened washer are then installed through the central hole and tightened by whatever method is to be employed in the project (see photo at left for a bolt, nut and washer installed in the device, ready for testing). This may be turn of the nut, calibrated wrench or "alternate fastener design" such as splined "TS" (torque and snap) bolts or load indicator washers.

The gauge on the Skidmore is marked to show the required tension for each size and grade of bolt. To qualify the installation procedure, at least three representative bolts of each diameter, length and grade to be used in the work are checked in the Skidmore. The bolts must average a minimum of at least 5% over the required pre-tension. Details of the actual installation procedures may be located in the AISC manual, but the key point is that in every case, a tension indicating device ("Skidmore" or equivalent) must be employed to verify that the installation method selected is producing the required pre-tension.

Further, if the "calibrated wrench" tightening method is to be used, the installation procedures must be calibrated with the tensioning device each day. The indicator itself must be calibrated no less frequently than once per year. The inspector and any other interested parties should verify this. A certificate or sticker should be available for examination.

Twining, Inc. is sometimes asked to "come out to our project and verify that the bolts are tight enough." It is a difficult diplomatic task to explain why this may not be possible. At the least, this would be an "arbitration inspection" to use the AISC terminology. This type of inspection requires that five bolts from the lot being examined be tested in the tension indicating device, the torque required to tighten each bolt to the minimum tension recorded, the highest and lowest readings discarded and the inspection wrench set to the average of the remaining three.

Should there not be any bolts available (perhaps they have all been installed), then the bolts can only come from the connection. Then the problem becomes one of bolt reuse - another can of worms. In any event, even when this procedure can be successfully employed, the AISC manual strongly discourages reliance on it. It is simpler, faster, cheaper and vastly more reliable to provide the proper installation inspection in the first place.