High Strength Structural Bolting

Author: *Clark Hyland*
Affiliation: *Steel Construction New Zealand Inc.*
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Introduction

High strength structural bolting offers significant benefits to erection of structural steelwork. It is relatively quick and can be executed on site in all sorts of conditions. However to achieve reliable structural performance the quality of the bolt assemblies and the installation procedures need to be appropriately controlled. This article summarises the key aspects of high strength structural bolting that need to be understood by those specifying, purchasing and installing these bolts.

Problems can occur when there is inadequate attention to ensuring that :

1. The purchasing specification complies with the requirements of AS/NZS1252:1996.
2. The manufacturer has auditable quality control procedures in place and supplies material test certificates for the specific bolts supplied.
3. The bolts are tracked from the steel and bolt manufacturer through to their installed location in a building
4. The bolts are installed with adequate grip thread length between the nut and the unthreaded shank.
5. The bolts are snug tightened correctly prior to being tensioned using the part-turn method with appropriate equipment.

AS/NZS1252 Galvanised High Strength Bolts & Nuts

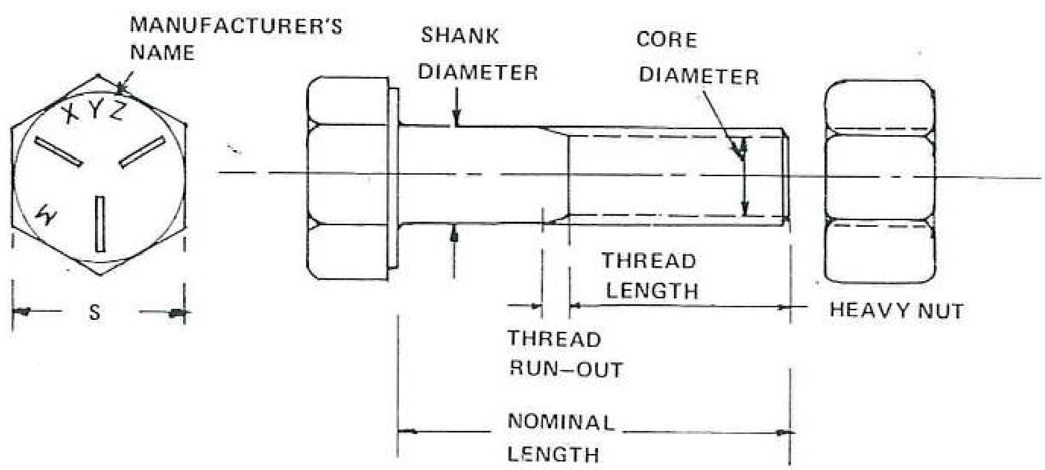

Figure 1 Bolt Terms

In New Zealand High Strength Structural Bolts & Nuts (Figure 1) must comply with the joint Australian and New Zealand Standard AS/NZS1252 High Strength Bolts with Associated Nuts and Washers for Structural Engineering, and conform to the strength Property Class 8.8 of AS4291.1 Mechanical Properties of Fasteners Made of Carbon Steel and Alloy Steel.

The use of high strength bolts means that fewer or smaller bolts can be used in steelwork connections requiring less fabrication in the workshop and allowing faster erection on site.

To achieve the higher strength than commercial bolts the bolt uses a different steel rod feedstock and is then quenched and tempered. Galvanising occurs after this. Nut threads are then tapped oversize to run on the galvanized bolt shaft threads. The nuts themselves are required to have a higher hardness and strength than the bolt and have enough threads to ensure that under tensile loading failure should always occur in the bolt rather than the nut or the threads. The unthreaded shaft is proportioned so that tensile failure of the bolt should occur in the threaded portion of the bolt.

Three radial lines, in some cases an 8.8, and the manufacturers trademark on the bolt head are seen on AS/NZS 1252 High Strength Structural bolts. Similarly three circumferential lines on the nut face and three nibs at third points on the washers designate the HSFG nuts and washers. The bolt heads and nuts are also larger than the equivalent diameter commercial bolt. A letter M on the bolt head indicates that the bolt has a metric coarse pitch series thread.

Strength Designations

AS/NZS 1252 bolt assemblies are classified using the ISO property class grading system as Property Class 8.8.. This property class designation should be used by the specifying engineer on the design documentation to identify high strength bolts. Two numbers separated by a point should be seen on the bolt head and are referenced in the Consent Drawings by the specifying engineer e.g. 8.8. The first number indicates the minimum ultimate tensile strength of a bolt of that Property Class divided by one hundred. So in the case of an 8.8 bolt the minimum ultimate strength is approximately 800 MPa. The second number identifies the ratio of the proof stress of the bolt relative to its tensile strength. So for the 8.8 bolt the proof stress is approximately 640 MPa being 0.8 times the tensile strength.

Force Transfer in Bolted Joints

Bolted joints are designed to transfer loads between the components of the connection in the following modes:

- Shear or bearing mode: designated as 8.8/S and 8.8/TB respectively
- Friction mode: 8.8/TF
- Axial tension mode: 8.8/TB or 8.8/TF

The first letter of the postscripts identifies the level of tightening required:

- S = snug tightened only
- T = fully tensioned

The second letter of the postscripts identifies the mode of force transfer:

- B = shear or bearing
- F = friction

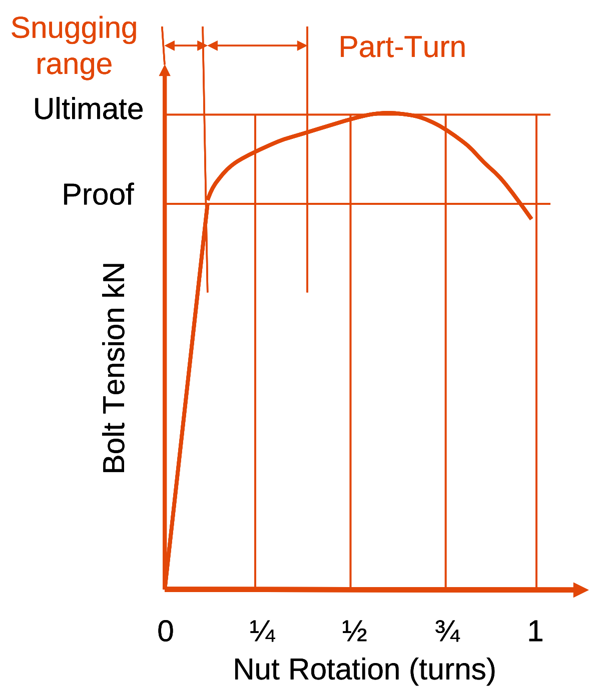

Figure 2 Indicative Bolt Stress Relative to Part Turns

Snug Tightening Procedures for High Strength Bolts

There are two criteria to satisfy when snug tightening

1. Bring the mating plates into "snug" contact
2. Use the full effort of an average man on podger spanner

Podger spanners are a standard length for each bolt size to avoid over-tightening the bolt during snugging by the installer.

- 300mm for M16 bolt
- 450mm for M20 bolt
- 600mm for M24 bolt

However as can be seen by the diagram in Figure 2 the level of snugging force is not overly critical to the performance of the fully tensioned bolt. In fact the snugging force can vary from 10% to 100% of Proof Load. A rotation of approximately 20^{o} or a 1/16 turn is needed to get close to the proof load. The Part Turn method ensures that the final bolt tension is:

1. Above the Proof Load
2. Below the Ultimate or breaking load of the bolt

A fit person can typically fully tighten an M20 8.8 bolt manually with a spanner with extension bar. However anything from an M24 and larger will always require mechanical assistance to achieve the Part Turn requirements. It is worth remembering that the force required to tension a bolt increases by the square of the diameter of the bolt.

Problems with Snug Tightening

While snug tightening sounds simple, a number of problems can occur that may affect the performance of the connection. This particularly so if the bolts are then to be fully tensioned. The most common problem is lack of contact of the mating plates. It is fundamental to the tensioning of high strength structural bolts that the plates are in contact so that as the bolt is tensioned the bearing plies clamped by the bolt are compressed. Over-stressing and fracture of the bolt, particularly with bolts of 20 mm or less diameter, can result during tensioning or in service if plate contact at snug tightening stage hasn't been achieved. Alternatively the bolt may be under-stressed if inadequate effort has been applied to the bolt during snug tightening to pull the plates together.

Tensioning of High Strength Structural Bolts

High strength structural bolts are designed to permanently stretch in the grip threads, between the underside of the nut and the unthreaded portion of the shank, during tightening. The threaded tensile area is approximately 80% of the area of the unthreaded shank. For this reason high strength structural bolts should be tightened once only and never be reused after being loosened.

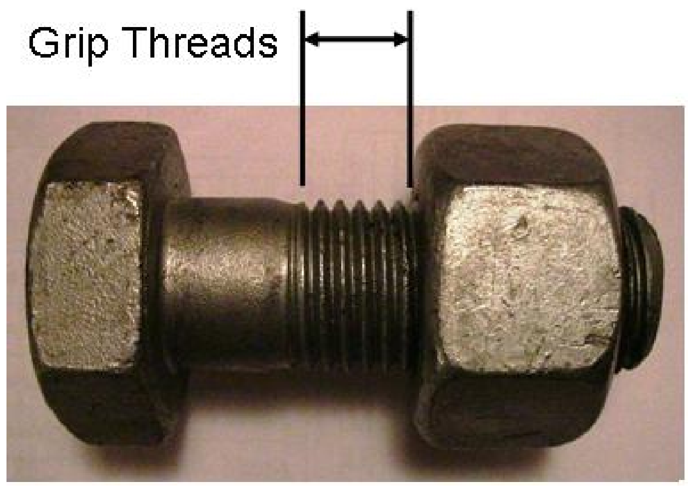

Figure 3 Grip Threads between nut and unthreaded shank

This is quite different to the way high strength mechanical bolts are designed to behave on tensioning. Mechanical bolts are required to be able to removed and reinstalled a number of times during their design life to allow maintenance of the components that are connected. For this reason mechanical bolts are typically only tightened up to 65% of their proof load ensuring that they don't develop any permanent stretch and remain structurally elastic. To achieve this lower level of tightening, torque control methods are required. Torque wrenches calibrated for a particular material, thread and lubrication are used. Prior to reinstallation mechanical bolts of critical components such as crane booms have to be measured and crack tested to ensure no distress has occurred to the bolt.

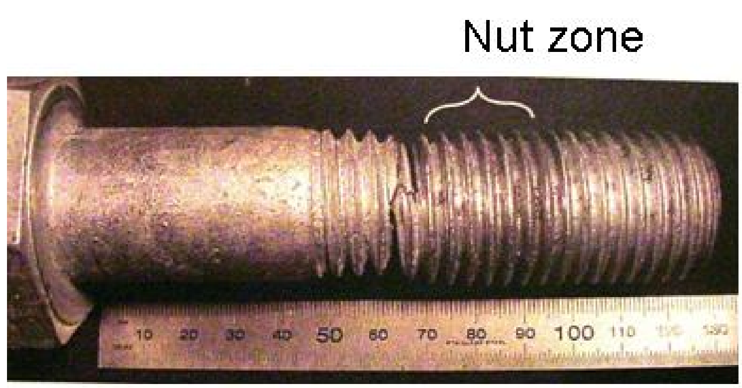

Figure 4 Fractured bolt showing initiation at base of nut

The torque control method however is impractical and unreliable for galvanized structural bolts as the galvanizing markedly and unpredictably increases the friction developed on the threads of the nut and bolt. This can mean that the bolts are under tightened. This can lead to fatigue, slop or loosening of the nut as the connection works in service when the pre-stress in the bolt is exceeded. Alternatively if the bolts have varying levels of lubrication they may be over-tightened leading to fracture.

It is therefore important that when tightening high strength structural galvanized bolts that installers do not rely on feel, particularly with air guns, whose performance varies with age and air supply.

Grip Thread Stretch

As noted before the grip threads (Figure 3) permanently stretch during tensioning of high strength structural bolts. A bolt may break unexpectedly if not enough threads in grip zone between the underside of the nut and the unthreaded shank (Figure 4). According to the High Strength Structural Bolt standard AS/NZS 1252:1996 and the companion bolt properties standard AS 4291.1-2000 the minimum allowed elongation of a bolt at fracture is 12%. To ensure the bolt doesn't fracture during tightening the following minimum number of grip threads are recommended. The dimensional limitations for the pitch and unthreaded AS/NZS 1252 bolts means that the amount to strain induced in the threaded core of the bolts by the various part turns will be approximately 6.5%

- 1/3 turn: 5 grip threads
- ½ turn: 7 grip threads
- 2/3 turn: 10 grip threads

If it isn't possible to achieve the necessary number of grip threads with a given bolt with a single washer then use additional packers under the hardened washer. If there is not at least one full run out thread available at the end of the bolt after tightening then a longer bolt should be used.

Part Turn Tightening Procedure

The part-turn procedure can be broken down into the following steps:

1. Line up the holes
2. Fit remaining bolts with hardened flat washers directly under the nut. If the surface is sloping then fit a tapered washers
3. Snug tighten all bolts starting from the rigid and moving to the free edge. Then repeat the procedure.
4. Match mark the nuts and bolts using a cold chisel striking across both the nut and bolt threads so that the part turn can be measured.
5. Conduct the part-turn tightening working from the rigid part of the joint to the free edge
6. Mark the completed joint to indicate to someone from below that the joint has been tensioned.

Bolting Quality Control

It is important to track the bolt from the steel mill that made the rod right through to the location where it is finally installed. This is not a difficult process if the bolt supplier is asked during the ordering phase to ensure traceable Rod Mill and Bolt Manufacturer test certificates are supplied to matching bolt box labelling.

- <u>Rod Mill Test Certificate:</u> should include the Heat Number
- <u>Bolt Manufacturer Test Certificate:</u> should include the Rod Mill Heat Number, the Order Number and state that it complies with AS/NZS 1252 8.8 HSFG. In particular there should be verification of dimensional conformance, hardness, yield stress, ultimate tensile stress, elongation at fracture and galvanised coating thickness.
- <u>Bolt Supplier Packing Note</u>: prepared by the local distributor should have the Order Number, Box Number and AS1252 8.8HSFG printed on the label
- <u>Erection Drawings</u>: should be marked up by the erector to identify Order Number and Bolt Box numbers used on each part of the structure and indicate where tightening has been completed. The local bolt distributor loses control of bolt traceability once the bolt box is opened. So it is important that the Erector has a reliable system in place to record where each box of bolts has been installed.

Inspection of Bolted Joints

The part-turn method makes inspection by supervisors and independent inspectors relatively straight forward. The following need to be confirmed:

- Communicate that the joints will be inspected and any particular marking requirements.
- Bolt diameter and length needs to be sufficient to allow for necessary grip thread lengths

- Bolt numbers in a joint need to match the specified number.
- Washer type and location should be correct
- Damage to bolts or nuts needs to be looked for in case of over-tightening or arc strikes from adjacent welding
- Match markings on the nut and bolt should indicate that the correct amount of turn has been applied to the nut.

References

Standards Australia / New Zealand, AS/NZ1252: 1996, High-Strength Steel Bolts with Associated Nuts and Washers for Structural Engineering, North Sydney, 1996

Standards Australia, AS4291.1-2000, Mechanical Properties of Fasteners Made of Carbon Steel and Alloy Steel, Strathfield, 2000