Minimum Bolt Tension for Full Tensioning – Recommendation for NZS 3404

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Date: *May 2024*
Ref: *ERC1006*

Key Words
High Strength Bolts; Property Class 8.8; Property Class 10.9; NZS 3404; Full Tensioning; Bolt Tension

Introduction
The minimum bolt tension required for full tensioning in NZS 3404 is currently approximately equal to the bolt proof load. Recent experience made known to the authors has shown that this approach is inadequate for property class 10.9 bolts and a recommendation is made that the P3404 committee responsible for the revision to NZS 3404 consider a change to the minimum bolt tension for full tensioning both property class 8.8 and 10.9 bolts to overcome the issues arisen and to bring in line with other international standards.

Background
Torquing a bolt until failure results in a reduction in both ultimate load and ultimate deformation as compared with the corresponding values determined from a direct tension test. As torque is applied to the nut, the portion not resisted by friction between the nut and the gripped material is transmitted to the bolt and, due to friction between bolt and nut threading, induces torsional stress into the shank. This tightening procedure results in a combined tension-torsional stress condition in the bolt. In torquing a bolt to failure, a reduction in ultimate strength of between 5 and 25% was experienced in tests on both A325 and A490 bolts (Kulak et al, 2001) and this is shown in figure 1 below. The average reduction in ultimate strength experienced in the tests was equal to 15%. Property class 8.8 bolts and 10.9 bolts to AS/NZS 1252 are considered similar to A325 and A490 bolts respectively and would be expected to have similar performance.

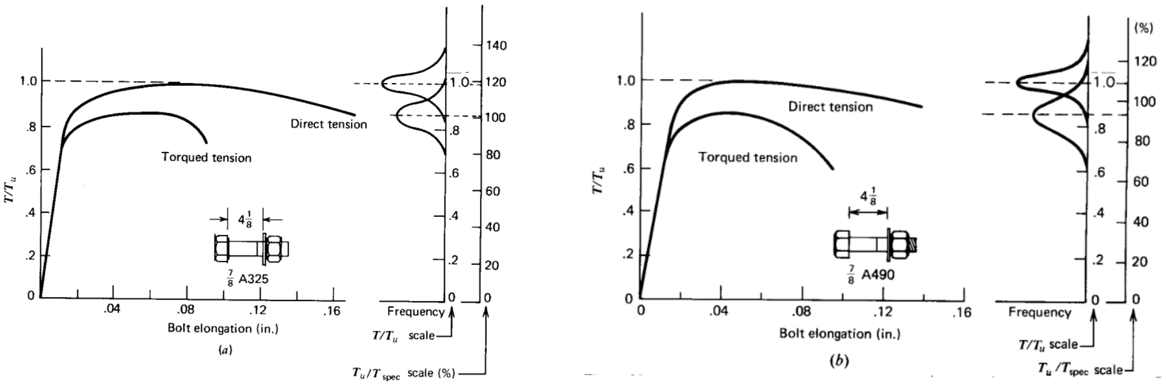

Figure 1: (a) Load versus elongation relation and frequency distribution of A325 bolts tested in torqued tension and direct tension; (b) A 490 bolts (Kulak et al, 2001)

These tests are likely to have been carried out on black bolts and a greater reduction in ultimate strength would be expected for dry galvanized bolts. Comparison of bolt load versus elongation relationships between 1-in black and galvanized A325 bolts are shown in figure 2 (Kulak, 2001) Dry galvanized bolts had a reduction of greater than 30% of ultimate tensile strength as compared to direct tension. The ultimate tensile strength reduced to just above the minimum tension required by North American standards equal to 70% of nominal tensile strength.

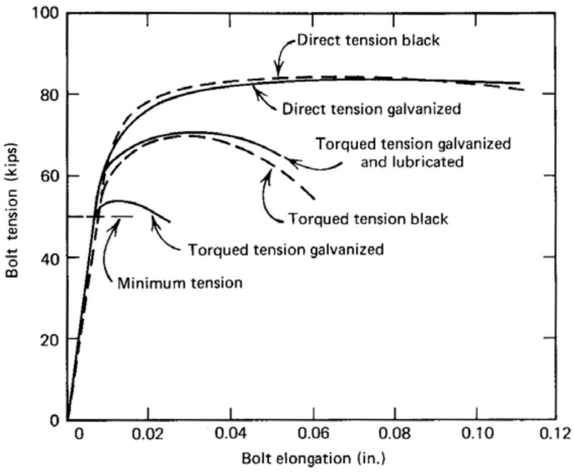

Figure 2: Comparison of bolt load versus elongation relationships between 1-in black and galvanized A325 bolts (Kulak, 2001) Note: Minimum tension required equal to 70% of nominal tensile strength.

The importance of adequate lubrication was also found in Australian tests done on galvanized M20 bolts. Tests on M20 bolts in Australia found that galvanized bolts without lubrication reduced ultimate strength leading to bolt fracture prior to reaching the minimum bolt tension specified in the Australian standard AS 4100.

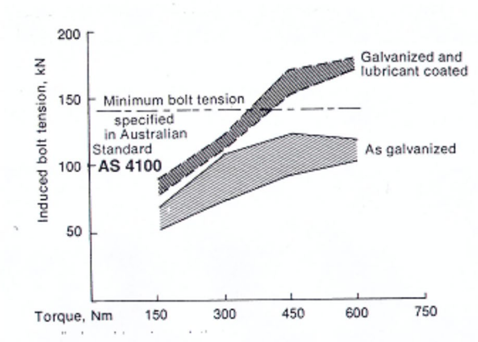

Figure 3: Torque/induced tension-relation for M20 high strength structural bolts, galvanized and lubricated coated, and as galvanized (GAA, 2018)

The current minimum bolt tension requirements in NZS 3404 and AS/NZS 5131 is approximately equal to the bolt proof load. The bolt proof load to ultimate strength is 80% for property class 8.8 and 90% for property class 10.9 bolts. Therefore, property class 10.9 bolts are more susceptible to bolt failure when tightened beyond the proof load due to the presence of torsional stresses reducing ultimate load and ultimate load deformation. Figure 1(b) shows that if the minimum tension was set at 90% of the nominal tensile strength for A490 bolts that this would not be able to be achieved due to the presence of torsion stresses reducing bolt tension ultimate strength.

International Standards

A comparison of international standards has been undertaken. All standards required minimum tensioning to be 70% of the ultimate strength. The following international standards were reviewed:

1. Eurocode 3. Design of steel structures – Design of joints, BS EN 1993-1-8:2005, British Standards Institution
2. High-strength structural bolting assembles for preloading Part 2: Suitability for preloading, BS EN 14399-2:2015, British Standards Institution
3. High-strength structural bolting assembles for preloading Part 3: System HR – Hexagon bolt and nut assemblies, BS EN 14399-3:2015, British Standards Institution
4. Design of steel structures, CSA 16-19, Canadian Standards Association
5. Specification for Structural Joints Using High Strength Bolts, Research Council on Structural Connections, Research Council on Structural Connections

Recommendation for NZS 3404

A recommendation is made to the P3404 committee to consider a change to the minimum bolt tension for full tensioning both property class 8.8 and 10.9 bolts to overcome issues during bolt tightening and to bring in line with the other international standards.

The following table is recommended to be included in NZS 3404

Table 15.2.2.2 - Minimum bolt tension

Nominal diameter of bolt	Minimum bolt tension, kN	
	Bolt Property Class	
	8.8	**10.9**
M12	47	59
M16	88	110
M20	137	172
M24	198	247
M30	314	393
M36	458	572

NOTE - The minimum bolt tensions given in this table are approximately equivalent to 70 percent of the tensile strength of property class 8.8 and 10.9 fasteners computed as the product of their nominal tensile strengths and tensile stress areas, as specified in AS 4291.1.

References

BSI, Eurocode 3. Design of steel structures – Design of joints, BS EN 1993-1-8:2005, British Standards Institution, 2005

BSI, High-strength structural bolting assembles for preloading Part 2: Suitability for preloading, BS EN 14399-2:2015, British Standards Institution, 2015

BSI, High-strength structural bolting assembles for preloading Part 3: System HR – Hexagon bolt and nut assemblies, BS EN 14399-3:2015, British Standards Institution, 2015

BSI, Execution of steel structures and aluminium structures Part 2: Technical requirements for steel structures, BS EN 1090-2:2018, British Standards Institution, 2018

CSA, Design of steel structures, CSA 16-19, Canadian Standards Association, Canadian Standards Association, 2019

GAA, Bolting Galvanized Steel Chapter 4, Galvanizers Association of Australia, 2018

Kulak, G., Fisher, J., Struik, J., Guide to Design Criteria for Bolted and Riveted Joints Second Edition, American Institute of Steel Construction, Chicago, 2001

RCSC, Specification for Structural Joints Using High Strength Bolts, Research Council on Structural Connections, Chicago, 2020

SA/SNZ. Structural steelwork - Fabrication and erection, AS/NZS 5131:2016 A1, Standards Australia/Standards New Zealand, NSW, Australia/Wellington, New Zealand, 2020

SNZ, Steel Structures Standard (Incorporating Amendments 1 and 2), NZS 3404:1997, Standards New Zealand, Wellington, 2007