



# Bolted Connections

Bolted connections are one of the most widely used, versatile and reliable methods for joining structural steel members. Some of the advantages of bolting over methods such as welding and rivetting are:

- Economy, speed and ease of erection;
- Reliability of service;
- Ease of inspection
- Fewer, and less highly skilled operators required;
- Reliable performance under fluctuating stresses;
- No pre-heating of high strength steels;
- No weld cracking or induced internal stresses;
- No lamellar tearing of plates;
- No heat damage to the coating on hot dip galvanized or painted structures.

## 13.1 TYPE OF STRUCTURAL BOLTS AND FASTENING DEVICES

Low carbon steel bolts, generally known as class 4.8, have been in use for many years. Continuing development has produced high strength structural bolts for use in high strength bearing type joints and high strength friction type joints, which are referred to as class 8.8 and 10.9. These newer strength bolting methods have greatly increased the scope of structural bolting.

In terms of the **SANS 1700-7-7; SANS 1700-7-8; SANS 1700-14-8; SANS 1700-14-9; SANS 1700-14-10**, strength of structural bolts is specified in terms of the tensile strength of the threaded fasteners. Two numbers separated by a full stop are stamped on the bolt head. The first number represents one hundredth of the nominal tensile strength and the second number represents one tenth of the ratio between nominal yield stress and nominal tensile strength expressed as a percentage. For example, a grade 4.8 bolt has:

- Tensile strength of  $4 \times 100 = 400\text{MPa}$ ;
- Yield strength of  $0,8 \times 400 = 320\text{MPa}$ .

A large variety of fastening devices, other than bolts and nuts, are used throughout industry and these include components such as spring clips where permanent retention of clamping force is essential.

## 13.2 CORROSION PREVENTION

While the mechanical properties of fastener assemblies are structurally dependable and cost effective, the durability of such connections will be influenced by the degree of corrosion encountered in service. Deterioration brought about by rusting can lead to the seizure of fasteners and premature



Figure 101. An assortment of zinc coated bolts showing the importance of coating thickness in a particular environment.



Figure 102 (left) and figure 103 (right). Corrosion protection of holding down bolts should be equal to that provided for main structures.

failure, in the form of corrosion fatigue. Adequate corrosion protection of fasteners is, therefore of paramount importance if the overall integrity of a structure is to be retained throughout its life (figures 101, 102 and 103).

In bolted steel structures the bolts and nuts are critical items on which the integrity of the entire structure depends. Protection from corrosion is provided by using corrosion resistant materials or by providing a protective coating, either before or after installation.

## 13.3 CORROSION RESISTANT METALS

The use of fasteners, manufactured from corrosion resistant metal alloys, frequently provides the most cost effective method of avoiding degradation by corrosion in very aggressive environments. Contact between dissimilar metals can result in galvanic corrosion, particularly where a large cathode is in electrolytic contact with a small anode. Austenitic stainless steel fasteners are used with success in many applications where there is contact with metals such as zinc and in mild to moderately corrosive environments, hot dip galvanized fasteners have proved successful for connecting components manufactured from Corten steel. The use of an organic coating over one or both metal coating interfaces of a joint prior to fastening, or the sealing of that joint after bolting, in an aggressive atmosphere will substantially increase the corrosion resistance of that joint.

Table 28 provides a guide to the compatibility of various metals and alloys in contact in building applications. For example, it will be observed from the table that a zinc coated fastener (anode) connected to 300 series stainless steel



Sheeting material	CONTACT MATERIAL (FASTENER/WASHER)											
	Aluminium and aluminium alloys		Copper and copper alloys		300 series stainless steels		Zinc coated steel and zinc		Aluminium/zinc coated steel		Lead	
	Industrial & marine	Rural	Industrial & marine	Rural	Industrial & marine	Rural	Industrial & marine	Rural	Industrial & marine	Rural	Industrial & marine	Rural
Aluminium and aluminium alloys	A	A	C	C	B	B	B	A	A	A	C	C
Copper and copper alloys	C	C	A	A	B	B	C	C	C	C	B	B
300 series Stainless Steels	C	B	B	B	A	A	C	C	C	B	B	B
Zinc coated steel and Zinc	A	A	C	C	B	B	A	A	A	A	B	A
Aluminium/Zinc coated steel	A	A	C	C	B	B	B	A	A	A	C	C
Lead	C	C	A	A	A	A	B	A	C	C	A	A

Legend:  
A = Acceptable. Increase in the corrosion rate of the sheeting or contact material will be zero or slight.  
B = Acceptable, but increase in the corrosion rate of the sheeting or contact material can occur.  
C = Do not use. Accelerated corrosion will occur, or the difference in the lives of the two materials is too great, or both.

Table 28. Metals and alloys between which direct contact is acceptable.

(cathode) is unacceptable in a corrosive environment whereas zinc coated steel connected with 300 series stainless steel is acceptable.

### 13.4 PROTECTIVE COATINGS

A coating applied to fasteners must, of necessity, be tightly adhering and resistant to damage during and after assembly. For this reason, metal coatings applied, prior to assembly, are preferred. Additional protection, after assembly by means of a paint coating, is beneficial in aggressive environments, particularly when these metal coatings have been applied.

Coating metals used include zinc, cadmium and noble metals such as nickel and tin. In the case of the more reactive metals, such as zinc and cadmium, coating thickness is of paramount importance with corrosion life being more or less proportional to the coating thickness. Where metals, such as nickel and tin are used, thinner coatings will usually provide long term protection provid-

ed that these coatings are free from imperfections and not subjected to mechanical damage which, in corrosive conditions, will lead to accelerated corrosion of exposed underlying steel. The cost of providing protection by means of the more noble metals is high and this has restricted the general use of these coatings for the corrosion protection of fasteners in the structural steel industry.

Table 30 provides corrosion results for fasteners, coated with various metals, after 1000 hours in a salt spray cabinet. These statistics emphasize the importance of thickness in the case of zinc coatings.

### 13.5 HOT DIP GALVANIZING OF FASTENERS

Hot dip galvanizing of fasteners is a specialised process and the products should, therefore, be purchased via an SABS approved bolt manufacturer who will ensure that the correct manufacturing and galvanizing procedures,

including oversize tolerances, etc., are adhered to.

Hot dip galvanized fasteners in various forms are available as ex stock items from bolt stockists countrywide. Contact the Association for further information.

### Upsize Tapping Allowance for Hot Dip Galvanized Nuts

The zinc coating on external threads shall be free from lumps and shall not have been subjected to a cutting, rolling or finishing operation that could damage the zinc coating. The zinc coating of an external standard metric thread that has not been undercut shall be such as to enable the threaded part to fit an oversized tapped nut (figure 104) in accordance with the allowances given in table 29 below.

On bolts greater than M24, undercutting of bolt threads is frequently preferred to oversizing of nut threads. The allowance should be increased to 0,4mm.

Refer to Note 1 in Chapter 10.

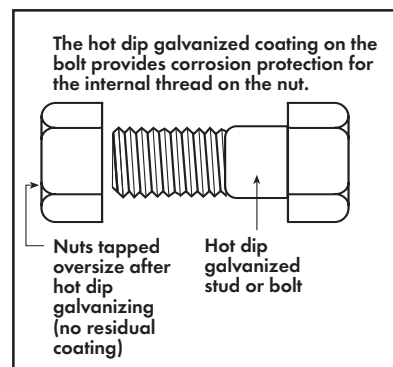


Figure 104.

Nominal Size of Thread	Allowance (mm)
M8 - M12	0.33mm
M16 - M24	0.38mm

Table 29. Upsize tapping allowance.

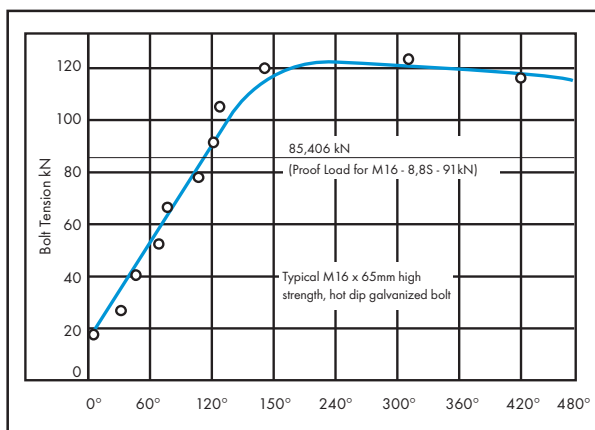


Figure 105. Demonstration of tensioning results obtained by the turn of the nut method.

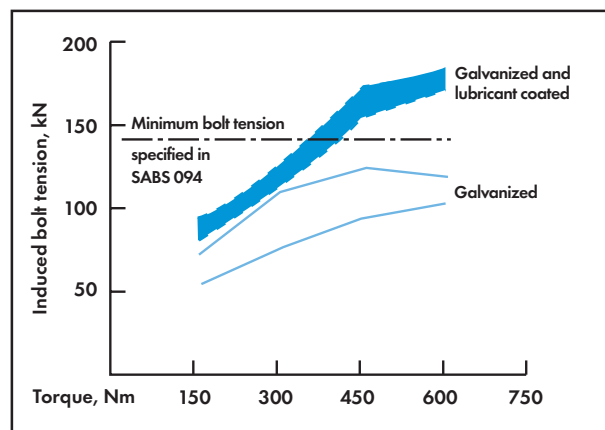


Figure 106. Torque/induced tension-relation for M20 high strength structural bolts, only galvanized and galvanized and lubricant coated.

Coating	Initial Coating Thickness $\mu\text{m}$	After 1000hrs Thickness $\mu\text{m}$	Coating Loss $\mu\text{m}$
* Oxysseal	20	10	10
HDG	60	50	10
Zinc Electroplated	23	10	13

\* Oxysseal is a specialised electroplated coating consisting of cadmium and other metals.

Table 30. Results of 1000 hours salt spray tests on coated fasteners.

Nominal bolt diameter	Length of bolt, mm	
	Nut rotation 1/2 turn with 60° tolerance over no tolerance under	Nut rotation 3/4 turn with 60° tolerance over no tolerance under
M16	up to 120mm	120 up to 240mm
M20	up to 120mm	120 up to 240mm
M24	up to 160mm	160 up to 350mm
M30	up to 160mm	160 up to 350mm
M36	up to 160mm	160 up to 350mm

Table 31. Nut Rotation from the snug-tight condition. Refer to SANS 10094.

### Influence of Galvanized Coatings on Thread Stripping Strength

In high strength bolting, correct tightening is essential, and the oversize tapping of galvanized nuts does not necessitate a reduction in the level of minimum tension which applies to uncoated fasteners. To meet this requirement, galvanized high strength nuts have a higher specified hardness than that demanded in the case of ungalvanized nuts.

### Bolt Relaxation

The possible effect of bolt relaxation, caused by the relatively soft outer zinc layer of the galvanized coating on mating surfaces has been investigated. Tests carried out by the Hot Dip Galvanizers Association and the SABS have revealed no substantial relaxation and this confirms international studies which show that a maximum loss of bolt load of 6,5% for galvanized plates and bolts can arise, as opposed to 2,5% for uncoated bolts and members. This loss occurs within about five days and little further loss is recorded. This loss can be allowed for in design and is readily accommodated.

### Slip Factor Effecting Mating Surfaces in Friction Type Joints

In the case of galvanized friction grip joints the galvanized coating behaves initially as a lubricant and the co-efficient of friction is normally less than 0,2. After the first few cycles, under alternating stress, the galvanized surfaces tend to lock up and further slip, under alternating stress, is negligible (figure 96). If initial slip is undesirable, the application of a zinc silicate paint, to mating surfaces prior to assembly, will provide a slip fac-

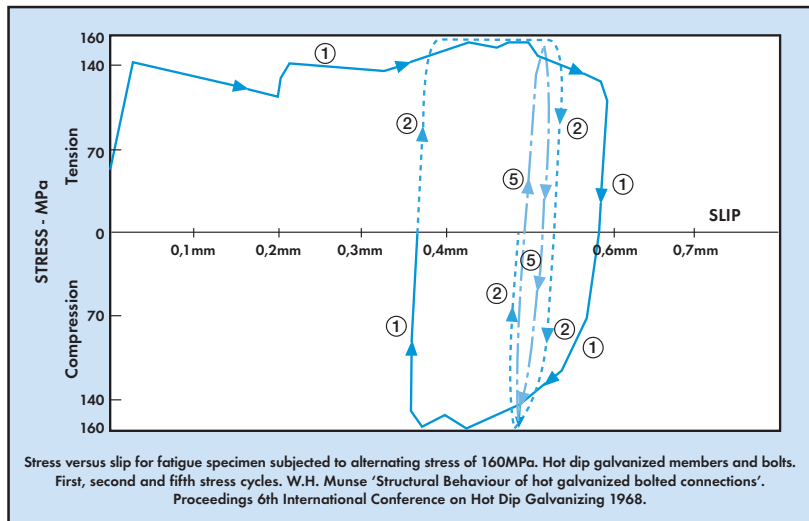


Figure 107.

tor in excess of 0,4 and, this enables hot dip galvanized assemblies to be designed for performance which is similar to that of uncoated steel.

Zinc metal spraying or alternatively light abrasive blasting of mating surfaces will also provide acceptable slip factors.

### Lubrication of Threads

For high strength galvanized fasteners to be tensioned to the required level, thread lubrication, by means of molybdenum disulphide based lubricant or alternatively a wax such as beeswax, is essential (figure 106).

### 13.6 BOLT AND NUT ASSEMBLIES

Hot dip galvanized bolts and nuts should ideally be supplied in the nipped-up condition. This ensures that bolts and nuts have been matched and supplied by the same manufacturer while the possibility of bolts being supplied with clogged threads is avoided.

### 13.7 WASHERS

High strength washers are required to be through hardened prior to hot dip galvanizing.

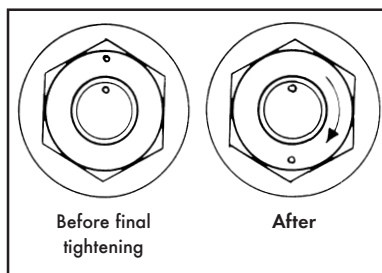


Figure 108. Where accurate tensioning is critical, permanent indication of the extent of part turn tightening can be identified by match marking.

### 13.8 RE-USE OF HIGH STRENGTH FASTENERS

This is not recommended.

### 13.9 BOLT TENSIONING PROCEDURES

Extensive tests have been carried out in order to arrive at the most effective method of tensioning hot dip galvanized fasteners while ensuring that this can be performed in a reliable fashion by semi skilled personnel. The torque required to tension hot dip galvanized fasteners, even after lubrication, can vary substantially from one fastener to another and, while this fact also applies to uncoated fasteners, the scatter is greater in the case of galvanized fasteners. It is recommended that reliable tensioning of high strength hot dip galvanized fasteners should not be based on torque/tension values, particularly in the case of friction grip connections. This recommendation is in line with results obtained in countries elsewhere and, for this reason, torque control tensioning is not encouraged either for coated or uncoated high strength fasteners.

### Recommended Method of Tensioning (Turn of the Nut Method)

If hot dip galvanized fasteners are to be used, it is recommended that the turn of the nut method of tensioning should be adopted. This method has proved to be reliable and slight variations in the degree of final nut turning do not significantly influence the ultimate bolt tension (figure 105). The procedure is simple and does not entail the use of specialised equipment. Nuts are tightened to a snug tight position and variations in tightness at this stage do not significantly influence the final result.

Snug tight is defined in many specifications as the full effort of a man on a standard podger spanner or the point at which there is a change in the note or speed of rotation when a pneumatic impact wrench begins impacting solidly. Podger spanners are graded in length, in relation to bolt size and strength and, for example, a spanner of some 450mm in length is regarded as appropriate for an M20 high strength structural bolt. It must be repeated that the clamping force supplied by snug tight is highly variable but this is not significant when bolts are subsequently fully tightened. The bolt tension/bolt elongation curve is relatively flat once the proof load is exceeded and, hence, variations in the snug tight condition result in only small variations in the final bolt tension.

For final tightening the standards in *table 31* are recommended. The table provides for rotation up to 60° in excess of the recommended nut rotation or a total of 240° in the case of M16 and M20 fasteners up to a length of 120mm. This level of tension is well within the capacity of high strength fasteners as laid down in **SANS 1700-7-7; SANS 1700-7-8; SANS 1700-14-8; SANS 1700-14-9; SANS 1700-14-10** (SABS 1282 is to be replaced by specific parts of SABS 1700) where, for test purposes, fasteners of this length are required to be tensioned by nut rotation after snug tightening to a minimum of 300° without fracture or the stripping of threads.

Where accurate tensioning is critical such as in the case of friction grip connections, permanent indication of the extent of part turn tightening can be identified by match marking the bolt end and nut, at the snug tightening stage, before final tightening (*figure 108*).

#### Part Torque - Part Turn Method

This procedure entails the use of a torque wrench to induce a snug tight condition to all bolts prior to applying full tension by turn of the nut procedures.

#### Alternative Methods of Tensioning Hot Dip Galvanized Fasteners

The use of load indicator washers provides effective tensioning but this entails the use of specially manufactured washers with protrusions which are flattened as tension increases and a reduction of the gap by a specified amount, indicates that minimum bolt tension has been reached.

Hydraulic tensioning equipment, which stresses the bolt to the required extent prior to nut tightening, is also available. These alternative methods entail the use of specialised equipment and for this reason

the use of the uncomplicated and reliable turn of the nut method is recommended.

### 13.10 THE EFFECT OF HOT DIP GALVANIZING ON STRENGTH PROPERTIES OF FASTENERS

The hot dip galvanizing process does not adversely effect the mechanical properties of high strength fastener steel or even material such as spring steel. Hardened steels <1000MPa yield strength, are not considered to be prone to hydrogen embrittlement as a result of pickling, prior to galvanizing, and any absorbed hydrogen would be diffused during immersion in the molten zinc at 450°C.

In the case of high strength grade 10,9 fasteners as well as products manufactured from spring steel, excessively thick galvanized coatings (>65µm) should be avoided since excessive growth of the hard Fe/Zn alloy layers can result in fatigue failure due to crack propagation from these layers into the substrate where a potential stress raiser may be present. In any case, excessively thick coatings on threads is undesirable as this will interfere with thread tolerance and may also result in gauling during tensioning. Ideally a minimum thickness of 65µm should apply to all threaded components. *Refer to Note 1, Chapter 10.*

#### INSTALLATION DO'S

- Do Wash off any cement splashes with clean water as soon as possible.
- Do Remove wet storage stain (white rust) if necessary with the aid of a bristle brush and water (not a wire brush). More stubborn stains can be removed in accordance with the methods given in *Chapter 5*.
- Do Avoid direct contact with dissimilar metals. If in doubt, insulate with some organic material or coating at the interface.
- Do Use hot dip galvanized fasteners with properly oversized nuts, in preference to zinc electroplated fasteners on hot dip galvanized structures.
- Do Seal the crevices formed between two bolted zinc coated mating surfaces in moist corrosive conditions.
- Do Use flexible grinding pads or abrasive paper when removing minor zinc protruberances left by the galvanizer.
- Do Use an approved lubricant on galvanized high strength steel bolts prior to bolt tensioning, e.g. molybdenum disulfide (Molyslip) or beeswax.
- Do Use a bristle brush and industrial abrasive (vim) with water to remove superficial rust stains (iron fillings, etc.) that have adhered to the coating surface. Should this method not be effective, replace the bristle brush with a 'scotchbrite' pad (abrasive pad). Should the stain still remain, ascertain by means of an electro-magnetic thickness gauge the residual coating thickness.

#### INSTALLATION DON'TS

- ◆ Don't Use electro-plated fasteners for fixing hot dip galvanized components. If hot dip galvanized fasteners are not available, overcoat suitably cleaned electro-plated fasteners with a reputable organic coating such as "Zincfix" (*Chapter 15 and 17*).
- ◆ Don't Unnecessarily disturb the matt grey zinc carbonate surface film by wire brushing.
- ◆ Don't Abuse hot dip galvanized articles by aggressive unloading, unnecessary hammering or banging when aligning two components. In spite of the excellent abrasion resistant properties offered by the coating, thicker coatings can be brittle and easily damaged.
- ◆ Don't Allow hot dip galvanized articles to be installed in acidic environments or allow liquids with a pH of less than 6,0 or greater than 12,5 to be conveyed in hot dip galvanized pipes.
- ◆ Don't Bend articles excessively after hot dip galvanizing for alignment or fitting.
- ◆ Don't Use steel files or inflexible grinding pads with inexperienced personnel to remove protuberances left by the galvanizer.

*Should any difficulty be experienced with the above, contact the Hot Dip Galvanizers Association Southern Africa.*