2nd Biennial

Movable Bridge Symposium

November 10, 11, & 12, 1987

St. Petersburg Beach, Florida

USE AND MISUSE OF GALVANIZED STRUCTURAL BOLTS

by

Michael E. Looram
Looram Engineering Inc.

and

Jesse R. Meisterling
Raymond Engineering Inc.

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Michael E. Looram
Looram Engineering Inc.
101 Hemlock Valley Rd.
East Haddam, CT 06423

Jesse R. Meisterling
Raymond Engineering Inc.
217 Smith St.
Middletown, CT 06457

Introduction

Galvanizing has long been an effective method of providing corrosion protection for steel and iron components, especially in marine environments. Galvanized nuts and bolts are commonly used in bridge structural connections. These joints are usually designed and assembled in accordance with the Specification for Structural Joints using ASTM A325 or ASTM A490 bolts. The bolts are procured in accordance with the ASTM A325 specification, the nuts to the A563 or A194 specification.

A number of problems can be encountered when using galvanized bolts, namely:

THREAD STRIPPING AT LOADS BELOW THE PROOF LOAD

LOW INSTALLATION PRELOAD

BREAKING OF BOLTS AT INSTALLATION DUE TO EXCESSIVE TORQUE

These problems have caused project delays, added testing costs, and in some cases, have almost resulted in litigation.

This paper will discuss these problems relative to the specifications, installation practice and testing methods. Recommendations are made for practices which should be adopted when using galvanized bolts.

Background

The nut, bolt and washer comprise a fastener system. The requirements for a fastener in a structural joint for a marine environment are:

- The system must have sufficient corrosion resistance.

- The nut and bolt must be easily assembled and preloaded.

- The system must provide high clamping forces on the joint members which allow the joint to sustain external loads for the life of the structure.

These three requirements are interrelated, and proper function of the system depends on a balance of factors which effect these requirements.

Corrosion

The corrosion resistance of the fastener system is directly related to the thickness of the zinc coating. Coating thickness of approximately 2.0 mils. is common for fasteners. An average corrosion rate for zinc coating in a marine environment is 0.06 mils per year; therefore a 2.0 mil coating would be expected to last for thirty years. Increased coating thickness improves corrosion resistance, but can have adverse effects on strength of the system and the clamp load.

Assembly

Nuts are normally overtapped to allow assembly with coated bolts. If the overtap is insufficient:

- The nut will not thread on the bolt.
- The parts may gall at assembly
- The torque required for assembly may become excessive which could result in low preload or torsional failure of the bolt at assembly.

Too much overtap, on the other hand, can result in thread stripping of either the nut or the bolt.

Clamp Load

A325 bolts are frequently used in slip critical joints. Proper function of these joints requires high bolt preload; the minimum specified preload being 70% of the bolt tensile strength. Installation is usually by turn-of-nut method which often produces bolt loads above the yeild strength. To develop these high preloads the fastener system must be ductile, have good lubricity and have strong threads to prevent thread stripping.

Problems

The majority of problems encountered with galvanized fasteners have been associated with the hot dip coating process. This process is often specified because the thick coating offers good corrosion resistance, and it is cheaper than other coating methods. The problems associated with hot dip coatings are most often traced to:

1. Uncontrolled, usually excessive coating thickness.
2. Excessive overtapping of nut to compensate for coating thickness.

Once the coating process for the bolt has been chosen, the specification mandates that the nut be coated by the same process. There does not seem to be any particular reason for this mandate, except possibly an attempt to keep the nut and bolt together as a system.

Yura et al [1] take issue with this mandate and found that nuts coated by mechanical deposition performed well with hot dipped bolts. They attributed the performance to less overtapping of the nuts and suggested that mixed coating methods between nut and bolt should be allowed if the nut and bolt meet the turn and tensile tests. They backed up this contention be installing twelve 7/8" hot dipped bolts with mechanically coated nuts in a floor beam, cantilever-to-girder web connection. This bolt and nut combination had been found to perform well in laboratory tests and the fasteners performed well in the field installation.

Manufacturing Practice

Normal manufacturing practice is to produce the uncoated bolt to a class 2A thread tolerance and the uncoated nut to a class 2B. This combination is the most common thread fit for the bolt and nut assembly. A convenient measure of the thread fit of the bolt and nut is called the interface. The interface may be thought of as the overlap of the threads as illustrated in figure 1. For example the interface of a 7/8"-9 bolt and nut with class 2A and 2B threads would range from 0.081 (a loose fit) to 0.118 (a tight fit). This spread of interface from loose to tight is acceptable manufacturing tolerance which ensures that parts will assemble and have sufficient thread strength to develop the tensile capacity of the fastener system.

Bolt Coating

When a zinc coating is applied to the bolt either by hot dip or by mechanical deposition, the standard practice is to apply the coatings to bolts which have a class 2A thread prior to coating. If hot dip coating is specified the coating is applied in accordance with specification A153; usually a class C coating is required which will produce a coating thickness of 2.0 to 2.5 mils. When bolts are coated by mechanical deposition, specification B695 applies. The thickness is usually specified as class 50 to achieve the desired 2.0 mil thickness.

Nut Coating

If the class 2B nut threads were treated like the bolt and simply coated, there would be obvious assembly problems. To preclude assembly problems, it is standard practice to tap the nuts oversize. The overtapping should be sufficient to allow for the coating thickness on both the bolt and nut threads.

When hot dip galvanized is used, specification A563 requires an overtap of at least 0.021" for a 7/8" diameter nut. This 0.021" applies to the maximum and the minimum limits for both pitch and *minor diameter*. An overtap on .021" seems excessive; since it is designed to provide clearance for a 2.0 mil coating on both the nut and bolt threads. There is no maximum overtap specified. A563 also states that the threads shall be tapped after the coating process.

When nuts are coated by mechanical deposition, A563 does not reccommend any specific overtap for nuts. *It simply states that the* nuts shall be tapped oversized sufficient to permit assembly. It also comments that retapping after coating should not be required.

A563, the metric counterpart of the A563 specification recommends a more reasonable overtap. For the metric equivalent of a 7/8" nut (an M20 to M22), the A563M specification recommends a maximum overtap of 0.021"(530mm). The wording of this specification clearly states that this is a maximum permitted oversize and the specification emphasises this with a caution:

"If the overtapping diametral allowance is greater than the limit specified in 7.8, the purchaser is cautioned that the nut may not meet the proof stress *specified in table 3.*"

Yura et al [1] make the observation that when a .021" allowance is applied to a loose fit assembly the interface is reduced from .081" to .061". With .061 interface the threads will most likely strip at loads well below the proof load.

TVA [2] experienced thread stripping at loads well below proof load on a variety of sizes of hot dip A325 hot dip galvanized bolts due to overtapped nuts.

Recommendations for Specification and Manufacture

1) Nut - *Specify galvanized nuts in accordance* with A563-DH for use with galvanized A325 bolts. If you choose A194-2H nuts, be sure to invoke supplementary specifications similar to these in A563-DH which address lubrication of the nut, turn test, and limits on overtapping the nut.

2) Coating - Specify zinc coating by mechanical deposition per specification B695. Bolts and nuts should be at least a class 50 thickness.

3) Overtapping Nuts - *Specify that the allowance for overtapping be* as follows:

SIZE	OVERSIZE
less than 7/16	0.016"
7/16 to 1.0	0.015"
over 1.0	0.025"

Conversations with Dr. Paul Guthrie of TVA [2] indicated that he would apply even more stringent maximum overtap limits. He suggested that for 7/8" nut an overtap of 0.010 would be sufficient for use with mechanically galvanized nut and bolt. He also noted that if assembly problems occured, they could be remedied by retapping the nuts.

Test and Reports

The most important factor in satisfactory performance of galvanized fasteners is the testing and reporting done by the manufacturer. Unfortunately, some of the tests detailed in the specification are optional. Other tests are mandatory, but in most cases test reports are not supplied unless specificly requested on the purchase order.

The tests which are important are:

- Coating Thickness
- Tensile Strength
- Turn Test
- Dimensional Measurement

Coating Thickness

A coating thickness measurement by microscopical method per paragraph 8.3 of A695 should be specified. The verification should be done in the thread area and a report provided. If you do not specify this measurement:

- Specification A695 for mechanical deposition makes a microscopical or magnetic thickness measurement optional.

- A153 for hot dip coating specifies the weight of coating determined the weight loss on a portion of the article that does not include any threads". This test obviosly does not tell much about the thread fit and is virtually useless for fasteners.

Strength

Tensile tests are required for the nut and the bolt to demonstrate the strength of the individual component. The bolt and nut are tested separately using a hardened test nut for the bolt and a hardened mandrel for the nut. None of the specifications (A325, A563, A194) requires tensile tests of the nut and bolt together as a system. Not tensile testing a nut and bolt as a system is probably a matter of convenience for the manufacturer due to the extra fixturing required to test the nut and bolt combination.

Turn Test

A turn test is required by A325 and A563 specifications for galvanized components. The test consists of assembling a nut, bolt, and washer in a steel joint. The bolt is snugged and then turned and additional angle which is approximately twice the angle of rotation specified for assembly by turn-of-nut method. The test is designed to demonstrate the following:

- That the nut and bolt can be assembled and that the assembly will provide the required preload.

- The ductility of the bolt- *The bolt must be ductile* enough to tolerate yeilding by turn-of-nut assembly. It must also have enough reserve to tolerate and inspection which would restart the nut and turn it an additional five degrees.

- That the nut has been properly lubricated and that *standard* tools will have sufficient torque capacity to produce the preload. If the lubricant is not sufficient the bolt will probably suffer torsion failure during this test.

- *This is the only test* specified which tests the nut and bolt as an assembly.

- That threads will not strip. This demonstrates that the nut overtap is not excessive and that the nut and bolt system have *the sufficient thread strength.*

Dimensional

A simple test of the thread fit is the thread interface which was discussed earlier. Using a vernier the interface can be determined by simply measuring the major meter (D) *of the bolt and the minor* diameter of the nut (d). Using the suggested allowances, the *interface* for various sizes should fall within the ranges given below:

DIAMETER	INTERFACE Min	Max	ALLOWANCE
Less than 7/16	.0376	.066	.016
7/16 to 1.0	.078	.118	.015
over 1.0	.083	.128	.025

Installation

There are two accepted methods for tightening structural joints; *turn-of-nut* and calibrated wrench. The AISC specification requires that a device capable of indicating bolt tension be used with both techniques to demonstrate that the procedure meets minimum tension requirements. The turn-of-nut tension test shows *that the method of* snugging and final tensioning used by the bolting crews meets the *bolt* load requirements. The calibrated wrench technique requires daily verification of the torques on each bolt diameter, length and grade fastener being installed. The calibrated wrench method requires hardened washers under the 'turning element'. Necessary for either technique to achieve a tight joint is a snug joint defined as a *joint with* all plies in contact. The specification calls out a definate procedure for snugging the joint:

> Tightening shall progress systematically from the most rigid part of the joint to its free edges....

Applying turn-of-nut or a calibrated wrench to a loose joint will not produce adequate bolt tension.

On site failure to follow bolting procedure leading to inadequate bolt tension has been documented by Notch [3]. The primary installation failures were:

- -Inadequate snugging (joints not together)
- -Arbitrary bolting sequence
- -Use of 'feel' as tightening control
- -Inadequate equipment (wrench, air supply, etc.)

If procedures are followed, design loads can be achieved in field tightened structural bolts.

Conclusions

Galvanized bolts and nuts can be used successfully if attention is given to basic concepts which are contained in the specifications governing the manufacture and installation of the fasteners. Failure of the galvanized fastener system is likely if you do not heed some of the precautions discussed in this paper.

Recommendations

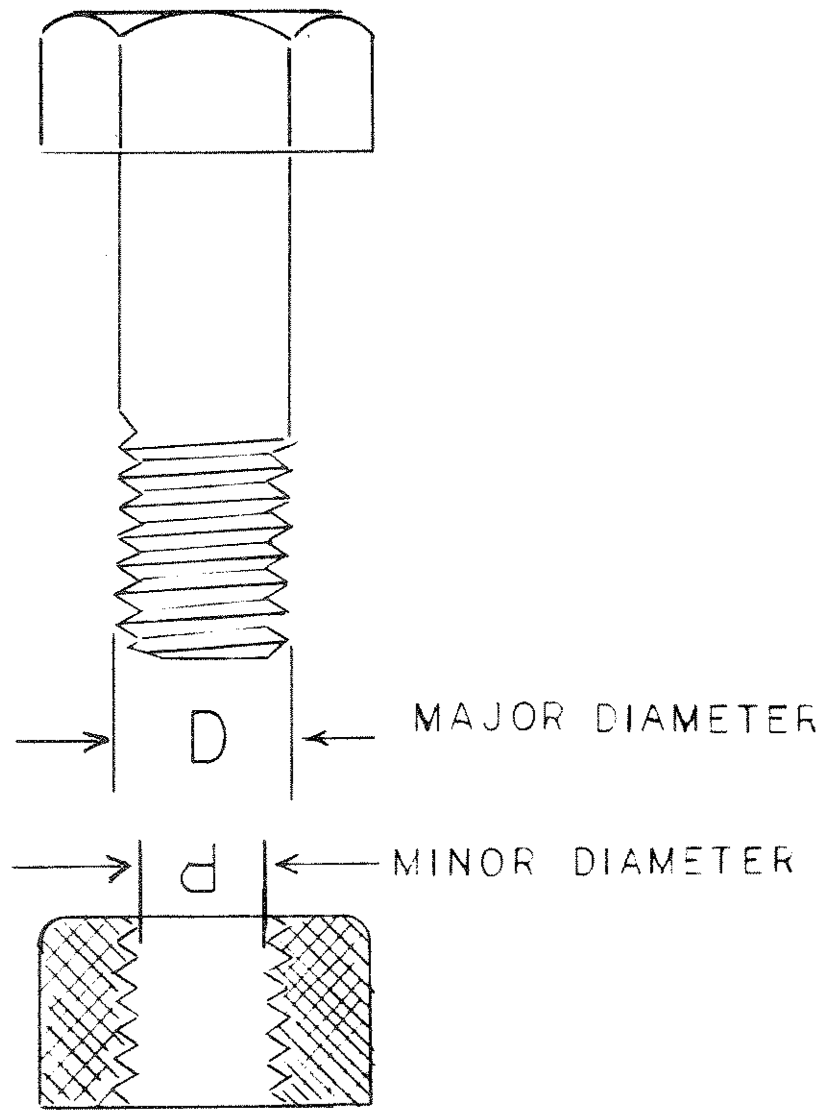
1. Specify mechanical deposited zinc coating for both and nut.

2. Specify a maximum overtap for the nut. Use the recommendations of this paper, or better, discuss the matter with your bolt supplier and agree and overtap value.

3. Require the manufactureror supplier perform and supply a report of the following tests:
   - Coating thickness by microscopical measurement
   - Turn test
   - Certification of lubrication
   - Tensile test of bolt and nut

4. Measure the bolt major diameter and nut minor diameter to get a measure of the interface (thread fit).

5. Pay attention to the assembly process.



INTERFACE = D-d

FIGURE I

References

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