Steel Bridge Group

Guidance Note

Protective treatment of fasteners

No. 8.02

Scope
This note covers the various metal coatings that are applied to bolts used in bridgework, and the practical aspects to be considered.

Why apply metal coatings to bolts?
With the exception of structures of weather resistant steel (WRS), the long-term corrosion protection to bolt groups in bridge structures is given by the full coating system. (For WRS steel structures the bolts, nuts and washers should be of WRS material and are not given any protective treatment, unless the steelwork is painted for some reason.)

Threaded components are very difficult to blast clean effectively, and even more difficult to metal spray effectively. The normal and recommended approach is therefore to procure bolts that are protected by metal coatings during manufacture in order to avoid blasting and metal spraying of bolted joints in the assembled steelwork.

The metal coating provides primary protection during construction until the rest of the coating system is applied. (For a major structure, this may involve a long period of exposure for the metal coating.) Thereafter, the metal coating provides additional protection, depending on its thickness, in the event that the paint system suffers local breakdown in the long term; it also offers continuing protection to the concealed surfaces of the bolts.

Beware of cadmium coatings
Cadmium plating was frequently specified and used up to the early 1990s. It is now prohibited for health and safety reasons. Cadmium is highly toxic if vaporised; this could happen if a cutting flame or welding arc came into contact with a cadmium-coated surface.

On earlier structures, even when zinc electroplated coatings were specified, it was common for fabricators to seek and be granted a concession to use zinc-plated bolts with cadmium plated nuts, it being well known that such a combination gave lower thread friction and reduced tightening problems.

Extreme caution is therefore necessary when dealing with any bolted connections made before 1995, as cadmium may be present even if the original specification suggests otherwise.

Zinc coatings used in bolt manufacture
There are three methods of applying zinc coatings to fasteners:

- Electroplating
- Sherardizing
- Hot dip galvanizing

BS EN 14399 does not specify a standard for electroplating or sherardizing and leaves the coatings to be negotiated with the manufacturer.

(1) Electroplated zinc coatings
The coating of zinc is applied by the electrolysis of an aqueous solution of a zinc salt. The minimum local thickness typically used in bridge construction is 8 μm.

As a precautionary measure, the Specification for Highway Works (SHW) (Ref 1) requires that any electroplated bolts are heat treated to drive out any possible entrapped hydrogen, because of the danger of hydrogen embrittlement[‡] during the plating process. Current practice is to follow BS 7371-3 (Ref 2), which states that bolts of property class 8.8 do not need to be de-embrittled, but property classes where the tensile strength exceeds 1040 N/mm^2 must be de-embrittled (this may require a formal Departure from Standard). Bolts of grades higher than 8.8 are not normally electroplated.

Chromate passivation is essential for all zinc electroplated components. It is a process by which the surface of the zinc coating is

[‡] Hydrogen embrittlement results from the absorption of monatomic hydrogen during the plating process. After installation, and under load, hydrogen atoms can migrate to dislocations in the crystal structure of the metal where they can gather to form gaseous hydrogen, which generates very high levels of internal stress. This can lead to a catastrophic failure of the fastener. Such breakages can occur hours or even weeks after tightening.

converted to extend its life. There are four levels of passivation. If no passivation is applied, zinc salts of a powdery appearance will form on the surface very quickly. This is known as white rusting. The use of chromate is frowned upon for environmental and safety reasons.

The SHW, Series 1900, states that chromate passivation shall not be applied to electroplated bolts which are to be painted. The reason behind this is that many commonly used paint systems will not adhere to zinc-coated surfaces without some form of etching to that surface. The higher levels of chromate passivation can resist such an etching process. Current practice is to apply a basic passivation (designation A, Table 3 of BS 7371-3) to ensure that the bolt arrives on site in a reasonable condition. Class A is the lowest level of passivation, which will not resist a subsequent etching process and which should therefore be deemed to be compliant with the SHW.

The thickness of the coating is such that no special measures are required with respect to thread clearance.

The SHW calls for all zinc plating of bolts up to 36 mm diameter to be carried out in accordance with BS 3382 (Ref 3). The maximum bolt size covered by that standard is ¾ inch and therefore the maximum standard metric bolt size covered is M16. The majority of bolts used in bridgework are of larger diameter. Despite the wording of the SHW, the common approach for bolts over 20 mm diameter is to supply to BS 1706:1960 (Ref 4). Note that the 1990 revision to BS 1706 cannot be used as it was converted from a specification to a method of specifying.

Specifying zinc electroplated bolts to BS 7371-3, grade Zn8A, or to BS EN ISO 4042 (Ref 5), grade Fe/Zn 8c1A, would avoid the use of obsolescent codes. BS 7371-3 was published in 1993 and BS EN ISO 4042 in 2000; both cover bolt diameters up to 64 mm, which comfortably covers the range of sizes normally used in bridge construction.

(2) Sherardized coatings

Sherardizing is a diffusion process in which the components are heated in close contact with zinc dust. The process is normally carried out in a slowly rotating and closed container at a temperature in the region of 385°C.

The resulting coating has a matt grey appearance. Orange staining may become apparent on sherardized coatings early in their exposure, but this is not detrimental to their performance.

Sherardizing tends to be used mostly to protect higher tensile steels (greater than 1000 N/mm^2), to avoid the risk of hydrogen embrittlement (which can occur with electroplating). It is also the normal treatment for direct tension indicators‡. Note that sherardizing is only suitable for protecting higher tensile steels if the method of cleaning the bolts prior to sherardizing is mechanical. (For grades 10.9 and above, if the method of cleaning is acid pickling, there is a risk of hydrogen embrittlement.)

Sherardized assemblies for preloading must be passivated to remove loose dust from the threads of bolt the bolt and nut; dust could cause problems when tightening to achieve the preload.

The thickness of the coating requires the nut to be over tapped to create sufficient thread clearance. (See Section 7 of BS 7371-8 for details.)

For bridgework, Class S1 coatings to BS 7371-8 (Ref 6) are normally specified. This gives a coating of minimum thickness 30 μm.

(3) Hot dip galvanized coatings

Bolts and nuts are dipped in molten zinc and then centrifuged to remove excess zinc. Such products are commonly referred to as spun galvanized.

Hot dip galvanizing provides the highest level of corrosion protection as it gives a consid-

‡ DTIs can also be 'mechanically galvanized', with a coating thickness of 55 μm.

erably thicker coating than either sherardizing or electroplating

The galvanizing process does not cause hydrogen embrittlement, but embrittlement can be caused by acid pickling, which is used to clean the bolts prior to galvanizing. There is no problem for bolts up to and including grade 8.8, but for higher grade bolts only mechanical cleaning can be used.

High temperature galvanizing is now available from some manufacturers. The normal galvanizing bath has a temperature of approximately 450°C. However, it has been found that if the temperature is raised to approximately 550°C, a more even coating of zinc is achieved. By careful choice of suitable material and processing, manufacturers can ensure that the high temperature galvanizing process does not have any significant retempering effect on the bolt. This process is covered by BS EN ISO 10684 (Ref 7).

Currently, grades up to and including 10.9 can be obtained in a high temperature galvanized finish, and in sizes up to 24 mm diameter.

The major fastener manufacturers have made considerable investments in developing improved methods of galvanizing. However, extreme caution should always be exercised if galvanized bolts are procured through stockists, especially if the galvanizing is being arranged by the stockist; the process used must be identified reliably.

Passivation is not necessary on a galvanized finish.

Bolts are galvanized after threading. Nuts are over-tapped to create thread clearance. This is achieved by galvanizing the nuts as blanks and then tapping them over size after galvanizing. Although this approach results in an uncoated female thread, this will be protected by the coating on the male thread when the fastener is assembled.

Hot dip galvanizing to BS EN ISO 10684 is specified for assemblies to BS EN 14399 (Ref 8); BS 7371-6 (Ref 9) is currently specified for assemblies to other national standards. The main difference between BS EN ISO 10684 and BS 7371-6 is the degree of over-tapping to accommodate the zinc coating; whichever standard is used, the corresponding requirements for over-tapping should be observed. The minimum local thickness specified by these standards is 40 μm and 43 μm respectively.

Tightening zinc-coated preload bolts

The tightening of zinc coated preloaded fasteners (nuts and bolts to BS EN 14399) requires special care. Zinc coated surfaces tend to bind under high interface pressure; this phenomenon is known as galling. Lubrication is essential to avoid a high proportion of bolt breakages in the latter stages of tightening.

In the UK, all bolts manufactured to BS EN 14399 are supplied in a lubricated condition K0. Furthermore, HRC assemblies to BS EN 14399-10 (TC bolts) must not have their lubrication modified in any way. Similarly, any assemblies supplied for use in either of the K-class conditions K1 or K2 must not have their lubrication modified.

The most effective and economic lubricant is tallow which for the best results should be sparingly applied to the leading threads within the nut and the face of the nut that contacts the washer.

Over-application of tallow, for example dipping complete assemblies in molten tallow, gives no advantage and can create additional problems in cleaning prior to painting.

Some specialist bolt suppliers whose products require consistent torque / tension relationships during tightening apply wax-based lubricants to plated nuts under factory conditions. These are often water-soluble and can be readily washed off after installation. Some manufacturers add a dye to the wax coating to distinguish such bolts from untreated items.

Oils and greases should not be used for the lubrication of preloaded assemblies, as there is a high risk of contaminating faying surfaces and significantly reducing slip factors.

Painting zinc-coated fasteners
Most paint primers will not satisfactorily adhere directly to zinc-coated surfaces.

Two approaches are commonly used to provide a key for paint systems. The first is to fix the bolts in the structure, as supplied, and then utilise a paint system for the bolted joints that includes, as a first coat, an etch primer. The second is to T-wash the bolts before fixing.

T-wash is a solution containing phosphoric acid and copper carbonate. The phosphoric acid etches the surface of the zinc and the copper carbonate produces a blue/black surface colouration showing that the surface reaction is complete. This discolouration is not absolutely uniform and it is not necessary to try to achieve absolute blue/blackness, as long as it is clear that the solution has been applied over the whole area. Further application will only remove more zinc than is necessary.

T-wash should not be applied after installation as contamination of adjacent surfaces is inevitable and the acid content may damage them.

The data sheets from most paint manufacturers state that T-wash should be brushed on, but this is impractical for fasteners; the normal approach is to batch dip. However, care should be taken to remove the items from the solution as soon as they discolour. If the items are left in the solution for too long, the zinc will be stripped. It is also very important to rinse clean and dry the bolts thoroughly.

Some primers, other than etching materials, are now available that will give satisfactory adhesion directly on zinc plated surfaces. These provide an attractive alternative to T-wash, the use of which now creates many problems under environmental and health and safety legislation. However, it is strongly advised that adhesion tests are carried out to verify the performance of such primers prior to their use.

Alternative pre-treatments to replace T-Wash are also becoming available. Proper testing should be undertaken before using one of these materials.

Bolts are generally supplied with a lubricant on the threads of the nut. The use of T-wash prior to assembly will remove/destroy the lubricant. Therefore, tightening methods that rely on torque should not be used, as the friction in the threads will be different from that assumed by the manufacturer and the suitability test for preloading (BS EN 14399-2).

The part-turn method of tightening (which is added as an acceptable method of tightening in the MPS, Ref 10) is a predominantly strain-control method that takes the bolt beyond its yield point. Consequently the final preload developed is not sensitive to a change in lubricant such as that caused by T-washing or by the application of tallow. Similarly the use of direct tension indicators (in accordance with BS EN 14399-9) does not rely on controlled lubrication.

Treatment of plated bolts after installation
Normally the specification of the protective system for slip-resistant bolted joints requires surface preparation of the joint contact surfaces (faying surfaces) by abrasive blast cleaning. This should not be taken to include the bolts, nuts and washers, as they are not 'joint material'. It is less satisfactory to blast off the fasteners' coating and then reapply coatings than simply to degrease the fasteners and apply the remainder of the coating system. However, if the fasteners have only thin plating and there has been lengthy exposure that results in corrosion, then blast cleaning of the fasteners may be required.

Recommendations
The following table gives an indication of the costs of the various types of zinc coating relative to that of the untreated fastener:

Coating	Cost
Zinc electroplated	20%
Spun galvanized	30%
Sherardized	35%

Note: The total cost of bolts is usually less than 1% of the cost of the structural steelwork.

Of the three processes, the most effective in terms of corrosion protection is spun galvanized.

It is recommended that spun galvanized bolts be specified (in accordance with BS EN ISO 10684 or BS 7371-6) wherever possible.

References

1. Manual of Contract Documents for Highway Works, Volume 1: Specification for Highway Works, Series 1900, Protection of steelwork against corrosion, 2005.
2. BS 7371-3:1993, Coatings on metal fasteners. Specification for electroplated zinc and cadmium coatings. (Replaced by BS EN ISO 4042:2000 but remains current.)
3. BS 3382: Parts 1 and 2:1961 Specification for electroplated coatings on threaded components. Cadmium on steel components. Zinc on steel components. (Withdrawn)
4. BS 1706:1960, Specification for electroplated coatings of cadmium and zinc on iron and steel (Withdrawn)
5. BS EN ISO 4042:2000, Fasteners. Electroplated coatings
6. BS 7371-8:1998 Coatings on metal fasteners. Specification for sherardized coatings.
7. BS EN ISO 10684:2004. Fasteners. Hot dip galvanized coatings
8. BS EN 14399, High-strength structural bolting assemblies for preloading (in 10 Parts)
9. BS 7371-6: 1998, Coatings on metal fasteners. Specification for hot dipped galvanized coatings.
10. Steel Bridge Group: Model Project Specification for the execution of steelwork in bridges (P382), SCI, 2009.