

CORROSION PROTECTION OF FASTENERS

Summary: Moisture, airborne chemicals and pollutants can all combine to reduce the life of ferrous fasteners through corrosion. This Technical Note examines the corrosion process, available fastener finishes, methods of measuring corrosion and the relative durability of fastener finishes.

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INTRODUCTION

Fasteners are commonly used to connect cold-formed steel framing members together and allow the structural loads to be transferred in accordance with the engineer's design. Fasteners experience many of the same corrosion issues as the framing members themselves. For example, the project may be located in an area subject to salt laden air. During construction, the fasteners and other interior components are exposed to the elements prior to the building being enclosed. Also, the geometry of cold-formed steel is such that the bottom track section can collect rainwater and wet debris during the construction period. Other situations may also exist in which the fasteners are reliant on their corrosion resistance.

Just as with other critical components of cold-formed steel framed structures, fasteners should be selected to ensure sufficient longevity for the design life of the building. This Tech Note is published as an information guide for engineers about the various fastener corrosion resistant treatment available. It is not intended as a design document for fastener corrosion protection selection.

ICC-ES AC118 provides the construction industry with a means of fastener product evaluation and recognition to the latest International Building Code (IBC) requirements. This is an excellent source for specifiers to ensure they use code approved fasteners on their projects.

CORROSION AND ITS PREVENTION

Metal corrosion is generally defined as an undesirable deterioration of a metal or alloy; an interaction of the metal with its environment that adversely affects the properties of the metal. Corrosion of metals is an electrochemical process involving chemical reactions, moisture (electrolyte) and the flow of electrons.

Protecting metal from corrosion can generally be accomplished by using coatings that isolate the metal substrate from the surrounding environment. Alternatively, products can be made from certain metallic alloys, such as stainless steel, that are inherently corrosion resistant in many environments.

Properties of the barrier coating that affect the quality of protection include adhesion to the base metal, abrasion resistance and thickness of the coating. Paints and various zinc-based coatings are examples of barrier coatings (Figure 1A and 1B).

Fasteners used in steel framing are generally protected from corrosion by zinc plating that provides adhesion and abrasion resistance and will not degrade over time as with organic based coatings. However, zinc is a reactive material and will corrode over time. For this reason, the protection offered by metallic zinc coatings is proportional to the coating thickness and the exposure environment.

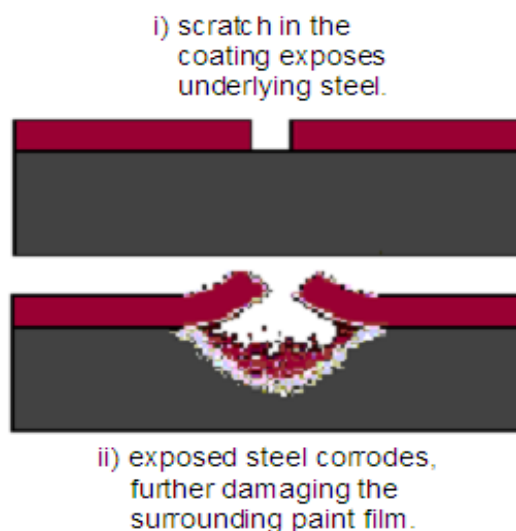


FIGURE 1A: PAINT COATING

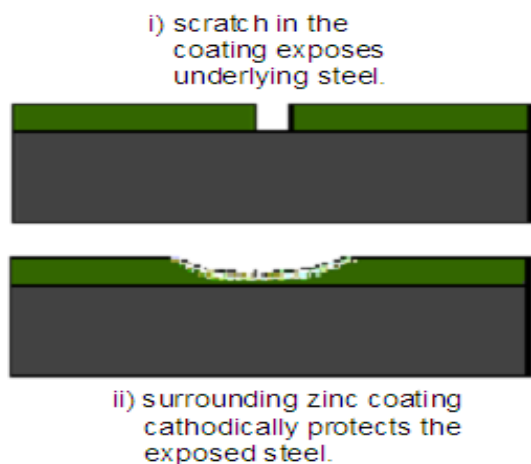


FIGURE 1B: ZINC COATING

Zinc based coatings have the added advantage of providing sacrificial or galvanic corrosion protection to steel. When base steel is exposed, such as at a cut edge or scratch, the steel is cathodically protected by the sacrificial corrosion of the zinc coating adjacent to the steel (Figure 1b). This occurs because zinc is more electronegative (more reactive) than steel in the galvanic series, as shown in Table 1.

In particularly corrosive environments, zinc plated coatings may be augmented by additional proprietary coatings. In many cases, insulated, non-conductive gaskets are also an integral part of the fastener and act to minimize direct contact with the steel framing member.

TABLE 1:
GALVANIC SERIES OF METALS AND ALLOYS
(in seawater)

Corroded End
Anodic
<i>(Electronegative)</i>
Magnesium
Zinc
Aluminum
Cadmium
Iron or Steel
Tin
Copper
Lead
Silver
Stainless Steel (passive)
Gold
Protected End
Cathodic or Most Noble
<i>(Electropositive)</i>

Note: Any one of these metals and alloys will theoretically corrode while protecting any other that is lower in the series as long as both form part of an electric circuit.

COATINGS FOR CORROSION PROTECTION

Fasteners used in cold-formed steel framing are generally protected from corrosion by electroplated coatings containing zinc. Zinc plated coatings are typically thinner (and therefore not as durable) than the coatings used for the framing members themselves. In addition to corrosion protection, these surface finishes also provide lubrication during the self-drilling and tapping process. The major types of corrosion protection finishes are as follows:

Phosphate Coating. This black or gray finish is most commonly used on drywall screws. The phosphate is a porous coating, which is usually applied in combination with light oil. It is the lowest cost of all fastener finishes and as such, offers only minimal barrier corrosion protection. It is suitable for indoor applications only, where there is minimal exposure to moisture. Specific phosphate treatments can be specified according to ASTM F1137, *Standard Specification for Phosphate/Oil and Phosphate/Organic Corrosion Protective Coatings for Fasteners*.

Mechanical Zinc Plating. Powdered zinc is applied to the fastener surface by tumbling the fasteners with water, a chemical catalyst and glass beads that pound the zinc onto the fastener surface. The thickness of the zinc can range from 5 microns to about 25 microns ($25.4\mu\text{m} = .001 \text{ inch} = 1 \text{ mil}$ where μm is microns) with increasing thickness of zinc, providing improved corrosion resistance. The zinc coating is relatively porous but still provides good galvanic protection. A variety of proprietary sealers can be applied over the zinc for increased barrier protection. This method of mechanical tumbling cannot uniformly apply zinc to the root diameter of threaded or knurled fasteners. Mechanical zinc plated coating thicknesses can be specified according to ASTM B695, *Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel*.

Electro-Zinc Plating. This is the most commonly used fastener finish offering good galvanic and barrier protection. The steel fasteners are first cleaned in acid to ensure satisfactory adhesion of the zinc. The zinc is then electroplated on to the steel fastener. The most common zinc thickness on fasteners is called commercial grade, which is approximately 4 to 8 microns thick. A clear or yellow inorganic sealer is applied over the zinc for additional temporary protection. Bear in mind, however, that cold-formed steel framing members have zinc-coating weights of at least 13 microns, in the case of exterior framing members. Electroplated zinc coating thicknesses can be specified according to ASTM B633, *Standard Specification for Electrodeposited Coating of Zinc on Iron and Steel*.

Hot Dip Galvanized. Thicker zinc coatings can be applied by immersing fasteners in a bath of molten zinc, hence the name "hot dip". The process produces a continuous metallic zinc coating providing good galvanic and barrier protection. The nature of the hot dip process can result in excessive zinc coating in the root of the fastener thread. Excess zinc is removed by "spinning" the basket of fasteners after galvanizing. Hot dip galvanized coatings can be specified according to ASTM A153, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*.

Due to the relatively small size of fasteners and threads, hot dip galvanizing of fasteners is not very common.

Specialty Coatings. For more aggressive environments, improved fastener corrosion protection can be achieved with different metallic and polymer coatings or even duplex systems (i.e.,

Metallic coating plus organic or inorganic topcoats). These coating formulations are proprietary and information on these systems can be obtained from fastener manufacturers. Typically, these fasteners receive the proprietary coatings in a dip spin operation and then go through a bake oven to cure the coating. Although these may be more costly than the previously discussed finishes, these coatings may offer higher levels of corrosion protection for ferrous fasteners.

Stainless Steel. This general term is given to fasteners made from ferrous alloys (typically stainless steel type 304 or 316) containing chromium and nickel that imparts very good corrosion resistance to the steel. Chromium at the steel surface oxidizes forming a protective film that passivates the steel surface and significantly reduces further corrosion. Due to the different electromotive potential of stainless steel and zinc coatings (Table 1), a non-conductive gasket is recommended but may not be required between the stainless steel fastener and the zinc-coated steel-framing member. The fastener supplier should be contacted for guidance. The properties of stainless steel will typically reduce strength values; therefore, a structural engineer should be consulted prior to making a fastener substitution for increased corrosion protection to ensure that strength loss is not of concern. The high cost of these fasteners generally limits their use to high corrosive environments.

TEST METHODS

The relative performance of the various corrosion protection coatings applied to fasteners is determined by standard laboratory testing. While these tests cannot predict installed service life, they are an important part of the fastener manufacturer's quality control program and provide the fastener specifier an understanding of the relative performance of various coatings.

Neutral Salt Spray Test: In this test the fasteners are placed in a sealed cabinet and exposed to a 5% sodium chloride (NaCl) spray. The test cabinet is maintained at 100% relative humidity at a temperature of 38°C (100°F). The testing is performed in accordance with ASTM Standard B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*. The fasteners are periodically inspected for corrosion. The test results are reported as hours of exposure to first appearance of red rust.

ICC-ES AC118 provides additional criteria regarding the appearance of white corrosion products on screw fasteners after 3 hours of the ASTM B117 salt spray test and appearance of red rust at the end of the test period (usually in 24 hour increments).

Prohesion Test: This test is similar to the Salt Spray Test but is acidic (pH 5.2) and utilizes alternating wet and dry cycles of one hour each. This test is popular in Europe and is gaining acceptance in North America. The test is meant to more closely simulate long-term natural exposure in acid rain type environments. Researchers believe that the corrosion attack occurs most rapidly during the drying cycles, compared to during the actual wet period. The recommended procedure for conducting this test is described in ASTM Standard G85, *Standard Practice for Modified Salt Spray (Fog) Testing*, Method A5.

Kesternich Test: This test is much more severe than the salt spray or the Prohesion test. This test simulates the environmental conditions of a heavy industrial atmosphere.

Sulfur dioxide (SO₂) and nitrogen dioxide (NO₂) are introduced at a rate of 2 liters per cycle into a test chamber maintained at 100% relative humidity. These gases, when combined with water, form sulfurous acid (H₂SO₂) and nitric acid (HNO₃), respectively. One cycle consists of twelve hours wet with the cabinet closed, and twelve hours dry with the cabinet open, all per DIN Standard 50018. Results are usually reported as the number of cycles (24 hour periods) the fastener withstands with less than 5% red rust. This is the test method for roofing fasteners specified in *Factory Mutual Approval Standard for Class 1 Roof Coverings, Class Number 4470*.

CONCLUSION

Unlike many building components for which the designer can look to codes or industry standards for guidance, these sources offer little help with the issue of fastener corrosion. Most codes are very general, requiring fasteners to have a corrosion resistant treatment with no further detail or service life expectations.

Some guidance on the corrosion rate of metallic zinc coatings in indoor environments can be found in CFSEI Technical Note *Durability of Cold-formed Steel Framing Members*.

When specifying fasteners, consider the field conditions and level of corrosion protection required. Contact the fastener manufacturer for performance data and fastener recommendation for the end use.

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