

TECHNICAL NOTE

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On Cold-Formed Steel Construction

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FASTENER CORROSION

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

Introduction

Light gauge steel construction has many of the same corrosion issues as other types of construction. Is the project in a coastal area subject to salt laden air or in a urban area where acid rain will attack exterior components of the building? How long will the structure be under construction, exposing interior components to the elements prior to the building being enclosed?

There are also unique features of light gauge steel that will impact structures differently than some alternative building materials. The shape of the common steel track section can act as a trough during construction, collecting rain water and morning dew. The type and location of thermal insulation used in the wall system and the relative humidity can result in water vapor condensing within exterior walls. Since steel framing members are inherently straight and true, it is easier to attain quality construction with less air infiltration through walls. This reduced air movement in wall cavities can cause moisture to accumulate, corroding steel studs and fasteners, if protection is not provided.

WHAT IS CORROSION?

Metals are seldom found in their pure state. They are usually found in chemical combinations with one or more nonmetallic elements. Metal corrosion is generally defined as "the 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 both chemical reactions and the flow of electrons. Protecting metal from corrosion can be accomplished using barrier or cathodic protection.

Barrier protection acts by isolating the metal from its environment. Properties that effect the quality of protection offered include adhesion to the base metal, abrasion resistance and thickness of the coating. Paint

is an example of barrier protection.

Cathodic protection works by adding a sacrificial element to the corrosion circuit. In a galvanic cell, electrical current is generated internally by physical and chemical reactions. The cell, like a simple battery, consists of an anode, a cathode, an electrolyte and a return current path as shown in Figure 1. The anode generates electrons, corrodes, while the cathode receives electrons. The electrolyte is the conductor through which the current is carried and is usually a water solution of acids, bases and salts. The return path is a metallic connection from the anode to the cathode and is often the underlying metal. By introducing an element to the corrosion circuit that is more anodic than the base metal, such as zinc to steel, the zinc will give up electrons to the steel. The zinc is sacrificed while the steel is protected. Any one of the metals shown in Table 1 will theoretically corrode while offering protection to any other which is lower in the series, so long as the two are electrically connected. This explains how galvanized steel studs can be field cut or penetrated by fasteners and not have the exposed steel corrode. The adjacent zinc continues to offer cathodic protection to the steel.

Figure 1

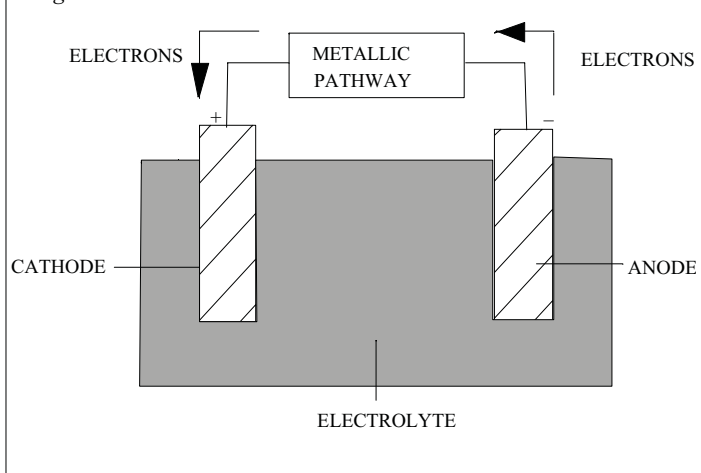


Table 1

**ARRANGEMENT OF METALS
IN GALVANIC SERIES**
CORRODED END - ANODE

Magnesium
 Zinc
 Aluminum
 Cadmium
 Steel
 Tin
 Nickel
 Bronze
 Copper
 Nickel-Copper Alloys
 Stainless Steel
 Gold
 Platinum

PROTECTED END - CATHODE
TYPES OF CORROSION PROTECTION

Fasteners are most commonly protected from corrosion by plating or coating. In addition to corrosion protection, these surface finishes provide lubricity during drilling and tapping of threaded fasteners which can help to reduce the tapping torque required to install them. The major types of finishes are as follows:

Phosphate coating. This black or gray appearing finish is most commonly used on drywall screws. Phosphate is a porous coating, which is usually applied in combination with oil. It is the lowest cost of all fastener finishes and as such, offers only a minimal barrier to corrosion. It is suitable for indoor applications only, where there is minimal chance of exposure to moisture.

Mechanical zinc plating. Powdered zinc is applied to the fastener surface by tumbling the fasteners with water, a chemical catalyst, and glass beads which pound the zinc onto the fastener surface. The thickness of the zinc can range from 0.2 to 3 mils (1 mil = .001 inch = 25.4µm where µm is microns) with increasing thickness of zinc improving the corrosion resistance. The zinc coating remains relatively porous, resulting in a coating with good galvanic protection, but a lesser degree of barrier protection. A chromate sealer can be applied over the zinc for increased barrier protection. This application method cannot uniformly apply zinc to the root diameter of threaded or knurled parts, and thus can provide maximum protection only on smooth fasteners.

Electro-zinc plating. This most common fastener finish offers good galvanic and barrier protection. The steel fasteners are first cleaned in acid to insure satisfactory adhesion of the zinc. The fasteners are then introduced to a solution of zinc and an electrical current is passed through the fasteners.

The fasteners, acting as a cathode, attract zinc from the solution which builds up on the surface of the fasteners. The length of time the fasteners are left in the solution determines the coating thickness which can range from 3 to 25 µm. The most common zinc thickness on fasteners is called commercial grade, which is 3.5 to 5 µm. Clear or yellow chromate is applied as a sealer over the zinc.

There is often confusion concerning the words "galvanized" and "plated" when referring to fastener finish. For fasteners, the term "plated" generally means a zinc coating less than 1 mil thick and "galvanized" refers to a zinc coating greater than 1 mil thick and generally implies application by hot dipping. Table 2 shows the relative thickness of zinc coating on typical building components.

Acid cleaning and the electroplating process cause hydrogen to form on the surface of the steel. Once hydrogen is formed, it is difficult to remove and can lead to hydrogen embrittlement cracking. Of greatest concern is that hydrogen embrittlement failures are typically a delayed failure, occurring months or years after the fastener was installed. The failure occurs because hydrogen atoms migrate through the steel to the point of highest stress. If too much hydrogen is in the part, the hydrogen will build up and eventually cause the steel to crack. The higher the yield strength of the steel and the greater the hardness achieved after heat treating, the more likely hydrogen embrittlement will occur. High strength bolts, powder actuated drive pins and pneumatically driven pins are examples of fasteners with these characteristics.

Hydrogen embrittlement can be minimized by baking the parts after plating. Quality control tests can then be run on the fasteners to insure the possibility of a hydrogen embrittlement failure is reduced.

Table 2

TYPICAL ZINC COATING THICKNESS

Coating Designation	Thickness (µm)
Commercial Grade (fastener)	5.0
G40 (stud)	8.5
G60 (stud)	12.7
G90 (stud)	19.4

Specialty coatings. These coatings are formulations consisting of proprietary mixtures of phosphate, zinc, chromate, and/or aluminum in combination with a binder material. The coatings may be organic or inorganic and are sold under tradenames such as Aericote®, Climaseal®, and Lifecoat®. Fasteners receive these coatings in a dip spin operation and then go through a bake oven to cure the coating. Coatings offer higher initial corrosion resistance because of greater barrier protection combined with cathodic protection from the zinc ingredient which works to contain the corrosion and

Table 3

GUIDELINES ON CORROSION REQUIREMENTS

"All screws shall be corrosion resistant..." - *Prescriptive Method For Cold Formed Steel Framing*

"Screws shall be given a corrosion-resistant treatment." - *Uniform Building Code Standard for Drill Screws*

"Where corrosion preventative or decorative finishes are required, screws shall be plated or coated as specified by the user." - *SAE J78 standard for Self-Tapping Screws*

prevent its spread through the steel base material. Like plain zinc, the thicker the coating is applied, the greater the corrosion protection offered. Although some coatings are applied over electro-zinc, many are applied directly to alkaline cleaned fasteners. A coating applied in this manner eliminates the possibility of hydrogen embrittlement in even the highest strength fasteners. Although more costly than the previously discussed finishes, these coatings offer the highest level of corrosion protection to ferrous fasteners.

Stainless Steel. This general term is given to alloys of iron, chromium and nickel that have a high resistance to rust. This material does not corrode because as the chrome oxidizes, a protective film is formed over the steel. The high cost of these fasteners generally limits their use to severe applications such as marine environments, highly corrosive industrial locations or the attachment of highly acidic cedar siding.

TEST METHODS

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

Salt Spray Test. In this test, fasteners are placed in a sealed cabinet and exposed to an atmospheric mixture of distilled water (H₂O) and 5% sodium chloride (NaCl). One hundred percent relative humidity is maintained in the test cabinet at a temperature of 100° F. The testing is continuous 24 hours per day, all per ASTM standard B-117. Fasteners are periodically inspected for corrosion. The test results are reported as hours of exposure to first appearance of rust.

Mebon Prohesion Test. This test is similar to the Salt Spray Test but utilizes alternating wet and dry cycles of one hour each. The test is meant to more closely simulate long term natural exposure. Researchers believe that the corrosion of iron occurs most rapidly during drying and rewetting episodes, not during the actual wet period. Only a few jurisdictions and manufactures currently utilize this test.

Kesternich Test. This method is much more severe than salt spray testing by simulating the conditions a finish encounters when exposed to a heavy industrial atmosphere. Sulfur dioxide (SO₂) and nitrogen oxide (NO₂) are introduced at a rate of 2 liters per cycle into an atmosphere of 100% humidity within a test chamber. These gases, when combined with water, form sulfurous acid (H₂SO₃) 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 endures with less than 5% red rust. This is the preferred test method for roofing fasteners which are required to meet Factory Mutual Standard 4470.

DURABILITY

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. Excerpts from three standards are shown in Table 3.

A better guide for the specifier may be found in the results of long range testing that has been conducted by ASTM and other organizations to determine the corrosion behavior of zinc coatings. The service life of zinc coating is a function of its thickness and the type of environment to which it is exposed. Table 4 is based on the results of worldwide

Table 4

SERVICE LIFE OF ELECTRODEPOSITED ZINC

Atmosphere	Mean Corrosion Rate
Industrial	5.6 µm/year
Urban non-industrial or marine	1.5 µm/year
Suburban	1.3 µm/year
Rural	0.8 µm/year
Indoors	less than 0.5µm per year

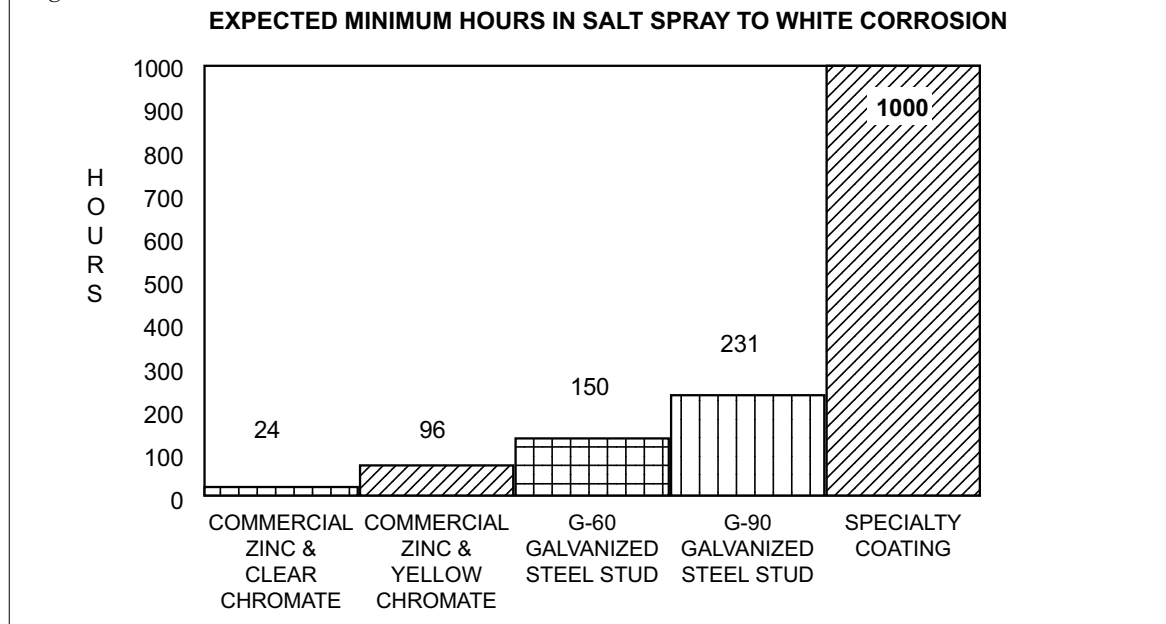
testing and compares the behavior of electrodeposited zinc in various atmospheres. These values are only relative, since individual studies in various parts of the world have provided results that vary widely from these averages.

While field studies have been done on zinc coated fasteners, this data does not allow comparison of different types of coatings. For fasteners, the most widely used guide for rating and selecting coatings is the relative performance

in salt spray testing. Although this test is not an indication of field life, it does give the specifier knowledge of how a finish compares to other types of finishes. Typical values of salt spray corrosion resistance are shown in Figure 2.

When specifying fasteners, consider the field conditions, relative level of finish performance desired and contact the manufacture for specific test information on their fasteners.

Figure 2



References

1. ASTM B201 Standard Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces, American Society for Testing Materials.
2. ASTM 633 Standard Specification for Electrodeposited Coating of Zinc on Iron and Steel. American Society for Testing Materials.
3. Galvanizing for Corrosion Protection, A Specifiers Guide. American Galvanizers Association, 1995
4. Durability of Coldformed Steel Framing Members. AISI, 1996
5. Atmospheric Corrosion Behavior of Aluminum-Zinc Alloy-Coated Steel, J.C.Zoccola, H.E.Townsend, A.R.Borzillo, and J.B. Horton. ASTM 1978
6. Aericoat® is a registered trademark of ET&F Fastening Systems, Inc., Climaseal® is a registered trademark of ITW Buildex and Lifecoat® is a registered trademark of Compass International.

Primary author of this Tech Note: David P. Nolan, P.E

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