

Corrosion Behavior of Metals

Nature of Metals and Corrosion

Metals occur in nature as a component of minerals. Minerals also contain other elements, such as carbon or oxygen, and must be refined in order to produce the metals that we are familiar with. The refining process introduces instabilities into the metal, and those instabilities are the driving force behind corrosion. Corrosion is the mechanism by which the refined metal constantly attempts to regain its stable mineral state. Under a given set of conditions, some metals will tend to corrode more quickly than others. A system has been developed for ranking metals according to their corrosion tendencies in given environments. This rating system is known as the Galvanic Series.

The Galvanic Series for seawater is often used to predict performance of metals under real-life conditions because it approximates corrosion behavior of metals in many other corrosive environments, (as well as in seawater) such as those encountered by buildings. It is important to note, however, that the behavior of a metal will be affected by the conditions to which it is subjected. This is largely due to the fact that chemical reactions on the surface of the metal can form a protective film which alters corrosion behavior. Understanding how and why protective surface films are formed is the key to understanding corrosion behavior of metals.

Corrosion of Metals in Building Applications

Aluminum

Aluminum is certainly a common building material and also a good example of how surface films affect a metal's corrosion behavior. According to the Galvanic Series, aluminum is a very reactive metal with a high tendency to corrode, but it is highly regarded for its low maintenance and slow corrosion rate under service conditions. This apparent contradiction results from the fact that a tightly bonded surface film of protective aluminum oxide forms when aluminum is exposed to the atmosphere. This aluminum oxide film prevents further corrosion under nearly all atmospheric conditions.

One condition under which aluminum does not always perform well is a saltwater environment. Alloys containing high percentages of pure aluminum are very reactive in seacoast applications because the sodium chloride component in saltwater destabilizes the protective aluminum oxide film. Once the integrity of the oxide film is compromised, the aluminum suffers from localized areas of pitting. For this reason, aluminum to be used in seacoast applications is alloyed with other

Technical Bulletin

compounds, such as manganese or magnesium-silicide, to establish an effective level of corrosion resistance. Many of the alloys used in building products such as roofing, siding, and flashings are of the type that resists saltwater corrosion. All of the aluminum alloys used by Sentrigard for panels and flashings are 3000 series alloys, and can be exposed bare or unprotected in seacoast and industrial applications due to their high level of corrosion resistance under these conditions. Even though aluminum performs well in industrial environments, lead and copper are better suited to the conditions encountered in industrial applications.

Lead

Lead is perhaps less common today as a building material, but lead flashings can still be found in service. Lead also develops a protective film as a result of corrosion. Films of sulfates, oxides, and carbonates are common to lead. These films adhere so strongly to the underlying lead that they inhibit further corrosion. Lead's ability to react with sulfur to form lead sulfate is what enables it to perform so successfully in sulfur-laden climates; namely heavily industrial and acid rain.

Copper

Copper is often perceived as a highly corrosive metal due to the green patina associated with aged or aging copper. The patina is a corrosion product comprised of copper carbonates and copper sulfates. Copper, like lead, exhibits a high resistance to corrosion in sulfur-rich atmospheres, as indicated by the presence of sulfate films in the patina. The green patina of copper diminishes but does not eliminate corrosion of the underlying copper.

Galvanized Steel

Galvanized products have a zinc coating which protects the underlying steel in two ways. First, the coating prevents direct surface exposure of the steel substrate in general. Secondly, once the galvanized coating is penetrated or mechanically damaged, the zinc and steel will form a galvanic couple; the zinc assuming the role of the sacrificial anode corroding to protect the steel (see bulletin 106 on dissimilar metals corrosion). Unpainted galvanized steel does not fare so well as stainless steel, aluminum, lead, or copper in extremely heavy industrial or seacoast applications, but has been quite successful in commercial, rural, and residential markets. This success can be attributed to the field performance of galvanized products, and to the paint systems currently available which enhance their beauty and versatility. These two factors explain the wide use, and acceptance and success of the product in commercial, rural, and residential situations where it offers proven corrosion performance and aesthetic appeal.

Bare Iron and Steel

Bare iron and steel exhibit server corrosion tendencies in many environments due to the nature of surface oxides that they form. Instead of the dense, tightly adhering films that form with aluminum, lead, copper, iron, and steel oxides are loose, porous, and non-adhering. The oxide flakes off easily soon after it is formed, continuously revealing a fresh layer of metal and subjecting it to further corrosion.

Cor-Ten

Cor-Ten is a product developed by U.S. Steel, and is an alloy of steel and copper. The addition of copper enhances the integrity and adhesion of the oxide layer, resulting in additional protection for the underlying metal. The oxide film will not prevent corrosion, but corrosion will occur much more slowly and uniformly than with bare steel.