Corrosion of metals in preservative-treated wood

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Wood and metal are compatible in most construction and furniture uses and few corrosion problems occur. However, if there is sufficient moisture at the wood-metal interface, some corrosion can be expected with susceptible metals. The corrosion of metal in contact with moist wood is an electrochemical process (1). The rate and amount of corrosion depends on the metal, the conductivity of the wood, and the duration of the damp conditions. The risk of corrosion depends somewhat on the wood species, presence of external corrosive contaminants, and condition of the wood (untreated or treated with certain preservative or flame-retardant chemicals). Not only does moist wood in contact with metals cause some metals to corrode, but the products of corrosion result in slow deterioration of the wood around the metal. Thus the fastener can get smaller and the hole around the fastener can get larger.

Most woods are slightly acidic, with a pH of 3 to 6. In some species, acetic acid generated from acetyl groups is responsible for the low pH, but other organic acids also cause acidic conditions. Corrosion of steel and galvanized steel is accelerated at these acidic conditions.

If the moisture content of the wood is below about 18 percent on a dry basis, the corrosion rate of metals is very low. It must be remembered, however, that only the moisture content of the wood in contact with the metal is important. This means that metal, such as a fastener that has been cooled by ambient conditions and kept cool by the surrounding wood, can corrode when it becomes wetted by condensation from warm moist air, such as on a warm, humid day following a cool night or in humid conditions in a factory during cold weather. The condensed moisture wets the wood at the wood-metal interface. This does not usually result in structural damage but it does mar the appearance when iron discolors wood surfaces. Corrosion can be severe in situations where manufacturing processes cause high humidity (e.g., in roof decking above paper machines) and destructive corrosion of the fasteners and degradation of the surrounding wood can occur after several years.

Corrosion of metals in untreated wood

For a single or isolated metal fastener in moist wood, corrosion can be explained in terms of crevice corrosion. This type of corrosion is observed in crevices along riveted and welded joints of metal tanks and pipes. For a steel nail in moist wood, the head becomes the cathode and the Shank in the “crevice” becomes the anode. The reaction at the anode is:

\[ \text{Fe} \rightarrow \text{Fe}^{++} + 2e \]

The cathode reaction is:

\[ \text{O}_2 + 2\text{H}^+ + 4e \rightarrow 2\text{OH}^- \]

As corrosion proceeds, hydroxides of iron precipitate around the anode. This leaves an excess of hydrogen ions in the water phase and the pH decreases. At the cathode, alkaline conditions result from the formation of hydroxyl ions.

Dissimilar metals that are in good physical contact with each other in moist wood can result in galvanic corrosion in which the corrosion rate of the least corrosion-resistant metal increases and the corrosion rate of the most corrosion-resistant metal decreases. The chemical reactions at the anode and cathode are the same as for single-metal corrosion. Metal ions and acidic conditions form at the anode, and alkaline conditions form at the cathode.

Wood surrounding the anode is affected by both the formation of metal ions and the acid conditions. With iron, for instance, in addition to the effects of the acid conditions that can slowly hydrolyze the cellulose as the iron goes from Fe$^{2+}$ to Fe$^{3+}$, cellulosic components of the wood are oxidized, and the wood is weakened. At the cathode, alkaline conditions with a pH of 14 have been measured in wood surrounding cathodic silicon bronze on a wooden ship. These alkaline conditions cause alkaline hydrolysis and oxidation of the wood.

Corrosion of metals in preservative-treated wood

Oil-type preservatives

Corrosion of metals in wood treated with oil-type
preservatives is usually not a problem except in rail crossties. This inhibition of corrosion is probably due to the presence of heavy oils that tend to coat the surfaces of the fasteners. In wood bridge decks, steel dowels are suitable for use in wood treated with preservatives in heavy oils (1). In wharf and shoreline bulk-head construction where metals are exposed to salt water, hot-dipped galvanized steel is usually recommended. Corrosion of the galvanized steel within the wood is inhibited by the oil for these uses because the holes are most often drilled before impregnation of the preservative. With rail crossties, preservatives often do not penetrate the central portion of the tie, and the rail spikes are usually driven into the moist untreated wood.

**Waterborne preservatives**

Waterborne preservatives containing copper salts can cause corrosion because of small quantities of soluble copper ions. Corrosion in moist treated wood is probably directly related to the presence of copper ions because of deposition by copper ions on a more electronegative fastener. This results in a galvanic corrosion couple consisting of the fastener, moist wood, and the copper metal deposited on the fastener. Corrosion rates are related to electrical conductivity of the moist wood, which is influenced by the moisture level and the presence of soluble preservative byproduct salts. Under conditions of low moisture content, corrosion is negligible; however, when the moisture content of the treated wood approaches about 18 percent, the electrical conductivity increases to where corrosion can occur. The preservative byproduct salts can result from the various forms of the chemical ingredients used in the chromated copper arsenate (CCA) preservative. For instance, the CCA preservative can be made from a mixture of potassium dichromate, copper sulfate, and arsenic acid, or from a mixture of chromium trioxide, copper carbonate, and arsenic acid. The former mixture will result in a preservative byproduct of potassium sulfate, which will increase the electrical conductivity, whereas the latter will result in a byproduct of carbon dioxide, which will dissipate and not affect the conductivity. Cox and Laidlaw have shown the increased corrosion caused by the byproduct salts (3).

Experience has shown that in aboveground portions of treated utility poles and crossarms, waterborne salt preservatives do not present corrosion problems to hot-dipped galvanized steel. Some corrosion of utility pole hardware has been noticed on salt-treated poles, but I believe this happens only when the pole is still moist from the treating solution. As the pole dries, in about a year or so, the corrosion rate decreases and no long-term problem remains. Aboveground zinc identification tags held in place with hot-dipped galvanized nails on test stakes treated with CCA or ammoniacal copper arsenate (ACA) do not show corrosion after 40 years of exposure.

**Corrosion testing**

*Long-term exposure.* – A study was started in 1973 to obtain some information on the corrosion rates of various metals and metal coatings in wood treated with waterborne preservatives. Eleven different types of nails were chosen to represent metals, alloys, and coatings from among those commercially available. These types of nails were AISI type 316 and 304 stainless steel, monel, type B silicon bronze, ETP copper, hot-dipped galvanized steel, 5056 aluminum, mechanically coated zinc on steel, electrolytically coated zinc on steel, cadmium-coated steel, and tin-cadmium coated steel. Exposure samples were constructed by nailing 9-inch-long pieces of 1-by 2-inch southern pine sapwood to 2-by 2-inch pieces. The samples were treated with CCA type I, CCA type II, and ACA. Preservatives were made with ingredients that did not leave any precipitation reaction byproducts. The wood was weighed before and after treatment to insure proper loading of the preservative. Two exposures were chosen to try to simulate exposure at close to use conditions. One exposure was in a chamber maintained at nearly 100 percent relative humidity at 80°F. In the other exposure, the samples were buried 10 inches deep in soil at the Madison exposure site. The nails were weighed before exposure, and placement was recorded so that they could be retrieved and weighed after exposure. Results of 1-year and 3-year exposure periods have been reported (2). The samples buried in soil have not been examined since the 3-year review.

The percentage weight losses of the nails after 1, 3, and 10 years of exposure at nearly 100-percent relative humidity at 80°F are shown in Table 1. These data and visual examination of the nails prompted the following statements:

1. AISI type 316 and 304 stainless steel nails showed virtually no visual corrosion and little weight loss. Monel nails showed some shallow surface pitting after 14 years with all three preservatives.
2. Type H silicon bronze and ETP copper nail shanks and heads showed a thin coating of a green corrosion product. Weight loss and appearance were about equal in all exposures at the same times.
3. Hot-dipped galvanized nails showed the most weight loss in ACA-treated wood and the least in wood treated with CCA II. After 14 years in wood treated with ACA and CCA I, the cross sections and diameters of the heads were considerably reduced. In wood treated with CCA II, the cross section was only somewhat reduced. Only traces of the zinc
coating remained on the nails in the CCA II-treated samples, and none was evident on the CCA I- and ACA-treated samples.

4. The 5056 aluminum nails showed elongated pitting of the nail shanks after 1 and 3 years. After 14 years the nail heads were completely gone and the shanks had fallen apart into long strands. The nails could not be cleaned and weighed.

Data from the first report of the study showed weight loss after 1 and 3 years for steel nails mechanically and electrolytically coated with zinc, tin-cadmium, and cadmium (2). After 14 years, the cross sections of the nails were so reduced that the nails broke on removal from the wood.

**Rapid testing.** – In an attempt to use a rapid technique to estimate corrosion tendencies of metals in moist preservative-treated wood, the corrosion rate of aluminum was determined by a rapid electrochemical test. The results appeared in the first report of my study (2). Since then, Simm and Hutton have recommended similar testing procedures to compare various materials (4). They tabulated various metals according to estimated corrosion rate; zinc had the highest corrosion rate and stainless steel had the lowest in CCA-treated wood. This test is useful to obtain a relative comparison of the risk of corrosion of metals, alloys, and coatings, but it is difficult to estimate the useful life of the fastener in the treated wood.

**Conclusions**

The study’s exposure conditions of high humidity and warm temperature are somewhat more severe than expected for a structure. Thus, the failure of aluminum nails and some coated steel nails and the loss of the zinc coating and cross section from hot-dipped galvanized steel nails may have come sooner than would be expected in most use conditions. The exposure conditions, however, are not too different from the conditions expected for many structures during several months of a year, and therefore caution is advised when selecting nails.

The results showed that, where long service life is desired, metals that are cathodic to copper in the galvanic series should be chosen for use in contact with ACA- and CCA-treated wood in moist conditions. Results from this study showed what type 304 and 316 stainless steel, silicon bronze, copper, and monel nails are suitable for these conditions.

**Literature cited**