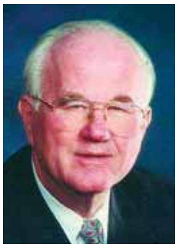
Galvanized fasteners and corrosion in wood

By Thomas J. Kinstler

Part II: Fastener Corrosion and Treated Wood

Wood, when viewed from the perspective of corrosion mechanisms, is somewhat unique, but has some similarities to other "matrix" materials such as soil and concrete. This is supported by similarities in corrosion kinetics and corrosion products for metals, such as zinc, embedded within the material.



Thomas J. Kinstler

Thus, much of what is known about corrosion in "matrix" materials can aid in predicting likely corrosion effects in wood.

Dry wood is primarily composed of cellulose, lignin, hemicelluloses, and minor amounts of extraneous materials.[1] The celluloses are polysaccharides, long chain sugar polymers, the hydroxyl radicals that are combined with acetic acid radicals (acetylated) in the form of ester (organic salt) groupings.[2] These groupings can combine with water (hydrolyze) and slowly release acetic acid. Acetic acid is volatile, and the most easily demonstrated effect of acetic acid corrosion is external to the wood, such as corrosion of metal parts occurring within wood boxes such as oak.

Moisture, a condition necessary for corrosion (an electrolyte), is present in wood. But below the fiber saturation point (about 30 percent), all of the water is "bound" in the cell walls. For this reason, it has often been expected that corrosion activity within wood requires a moisture content of 20 percent or greater.[3] Below the fiber saturation point the moisture content of wood is a function of both relative humidity and temperature of the surrounding air. For example, at 80 degrees Fahrenheit and 80 percent RH, the equilibrium moisture content would be about 16 percent over the long term. At very high moisture levels, corrosion is stifled by reduced availability of oxygen, the "fuel" for the reduction reaction.

The cellular and fibrous structure of wood also adds another effect relative to moisture. The passage of moisture across the "grain" (transverse direction to fiber orientation) is a slow process, often two orders of magnitude less than that of diffusion along the grain.[4] Indeed, in order to ensure deep penetration, it is common to dry wood and apply pressure in sealed vessels to drive preservative chemicals into the cellular structure.

The threshold of about 25 to 30 percent moisture content is also the approximate threshold for attack on wood by fungi.[5] Thus, the general conditions that initiate bio-decay in wood (oxygen, water, favorable temperature) are also the conditions that can initiate corrosion of fasteners.

Not only can wood affect corrosion, but corrosion can affect wood.[6] As discussed in an earlier article in the January 2005 issue of *Frame Building News* regarding corrosion mechanisms, the reduction of oxygen results in the formation of hydroxyl ions (OH^-), however wood is generally resistant to alkaline attack at a pH below about 10. In the case of zinc corrosion in wood, the very low solubility of $Zn(OH)_2$ should result in a lowering of free hydroxyl ions and therefore inhibit the local formation of high or threatening alkalinity. Attack on wood by iron salts, a by-product of corrosion, will not occur while the steel nail is encapsulated in zinc, and the zinc protective product "cocoon."

With the exception of certain naturally resistant species, wood exposed outdoors generally should be treated or protected to prevent decay by fungi, insects, and in some application, marine borers. Over the years a number of oil borne and water borne materials have been used, including solutions containing copper, chromium, and arsenic. Various agreements and accords have now resulted in the transition to a new generation of materials such as Alkaline Copper Quat (ACQ), Copper Azole (CA), and others.

While the earlier multi-metal type of preservatives such as Chromate Copper Arsenate (CCA) were somewhat more corrosive to fasteners, the new generation have been reported as having an even higher corrosivity in practice. The determination of that corrosivity has suffered from the same problems in inadequate or low-relevancy corrosion testing methods, and the exact composition of the various preservatives is still being refined.

Galvanized Fasteners

To provide protection to fasteners in preservative treated wood, manufacturers' recommendations and building codes have specified, for specific applications, the use of "corrosion resistant" fasteners, without clarification as to the meaning of "corrosion resistant." Other cases have required hot dip galvanized, stainless steel, or other resistant materi-

TABLE 1: Zinc Requirements for Nominal 0.120 Diameter Nails and Sheet Products for Various Coating Types

Coating Type	Coating Weight oz/sq ft	Coating Thickness ⑤m	ASTM Standard	ASTM Standard Class	Application Process or Wire Diameter in Inches
Zn	0.35	15	A641	1	EG – Wire Diameter 0.148
Zn	0.93*	40	A653	G185	Galvanized Sheet, 0.60 oz (28 μm) min. each side
Zn	0.85	36.5	A641	3 or A	Electrodeposited Wire
Zn	1.00	43	A153	D	Hot Dip as Required in F 1667-97

*Per side

als.[7,8] The amount of zinc on the surface of a fastener greatly influences the corrosion life of the fastener. Indeed, the requirements for zinc coating thickness are beginning to increase in some cases. For example, in August 2000 APA tests showed that electro galvanized or mechanically galvanized nails appear satisfactory when further protected by a yellow chromate coating. APA recommends a Class 2 zinc (galvanized) coating per Supplementary Requirements of ASTM Standard A641/641M-98, Standard Specification for Zinc-Coated (Galvanized) Carbon Steel Wire, for use where corrosion resistance is of importance in sheathing and siding applications.[9] In September 2002, a subsequent document stated: "APA tests also show that electrically or mechanically galvanized steel nails appear satisfactory when plating thickness meets or exceeds the requirements of ASTM A641, Class 3 coatings, and are further protected by a yellow chromate coating. However, extensive in-service experience with such fasteners is lacking."[10] Between the August 2000 and the September 2002 documents, the APA raised the A641 zinc thickness requirements from Class 2 to Class 3 (or A) or from 21.5 μm to 36.5 μm, an increase of about 70 percent. In addition, the "yellow chromate" subsequent treatment requirement remained.

Manufacturers of chemicals and fastening systems have published concern about increasing corrosivity. For example, "Traditionally, the treated wood industry has recommended hot dipped galvanized or stainless steel fasteners for use with treated wood. However, the widespread misapplication of 'electroplated' galvanized nails, screws and other fasteners that are only suitable for use in weather protected applications and untreated wood, has led to poor fastener performance in more severe environments".[11] Other manufacturers and trade associations have expressed similar concern about traditional thinking and new generation preservative materials.[12]

Table 1 summarizes current zinc thickness requirements for nominal 0.120 diameter wire nails and sheet products.

Studies of corrosion performance are continuing as the formulations of preservative chemicals are evolving, and a number of facts are becoming clear. It has been stated that the corrosivity of preserved wood treated with ACQ and CA is higher than the corrosivity with CCA, perhaps by a factor of 2, and that heavier galvanized coatings generally should extend the service life.[13] In addition, testing compared mild steel, stainless steel (SS), electro galvanized (EG), and hot dip galvanized steel (HDG) fasteners in blocks treated to 6.4 kg/m^3 with ACQ type C, and CCA type C, each with and without a water repellent, for 120 days in accordance with modified AWPA E-12. Field exposure in decks constructed in the Mid-Atlantic region of the U.S. with data reported corrosion after 7 months for one, and 42 months

TABLE 2: Visual Performance Rankings of Metal Fasteners in Field and Lab Tests

Exposure	Time	Metal	CCA	CCA	ACQ-C	ACQ-C	Untreated
Water Repellent			N	Y	N	Y	N/A
Mod. E-12	120 d	SS[1]	1.0	1.0	1.0	1.0	1.0
Mod. E-12	120 d	HDG[2]	2.0	1.5	2.0	1.5	1.5
Mod. E-12	120 d	EG[3]	2.0	1.0	3.5	2.0	2.0
Mod. E-12	120 d	Steel[4]	4.0	2.0	5.0	3.5	5.0
Deck	7m	SS[1]	1.0	1.0	1.0	1.0	1.0
Deck	7m	HDG[2]	1.0	1.0	1.5	1.0	1.0
Deck	7m	EG[3]	2.0	1.0	4.0	1.0	1.0
Deck	7m	Steel[4]	4.5	1.0	5.0	2.0	3.0
Deck	42m	HDG[2]	1.25	1.0	3.5	1.0	N/A

[1]SS - Stainless steel
[2]HDG - Hot dip galvanized steel
[3]EG - Electrogalvanized steel
[4]Steel - Mild steel

for the other.[14] Assessment scale was non-linear, as follows:

Rank	Visual Assessment
1	Less than 5 percent of surface area corroded
2	5 – 25 percent surface area corroded
3	25 – 50 percent surface area corroded
4	50 – 75 percent surface area corroded
5	75 – 100 percent surface area corroded

Relevant results are listed in Table 2 (lower numbers are better performance):

The preceding summary shows that for these tests:

1. Hot dip galvanized fasteners are equivalent to stainless steel for the case where either preservative chemical is used with water repellent. This result is entirely consistent with corrosion cell theory discussed earlier in the technical article in the January 2005 issue of *Frame Building News*.

2. Hot dip galvanized fasteners are superior to both untreated and electroplated fasteners. This result is entirely consistent with known zinc corrosion kinetics.

3. The use of water repellent has a significant beneficial effect on common kinetics in wood.

4. The modified E-12 test is significantly more "corrosive" than actual field exposure.

This last result is not surprising given that the field exposure consists of natural wet and dry cycles, where as the modified E-12 procedure is at a constant 90 percent RH, and 120 degrees Fahrenheit (49 degrees Celsius). In addition, this result is entirely consistent with an earlier study, wherein nails with various zinc coatings (and coating weights) were subjected to exposure in wood blocks treated with CCA-I, CCA-II, and ACA for period of 17 years in soil burial, and 14 years in a 97 to 100 percent RH, 80 degrees Fahrenheit (29 degrees Celsius) cabinet. Nail weight losses were reported at 1, 3, and 17 years for soil burial, and at 1, 3, and 14 years for humidity cabinet exposure.[15]

Notwithstanding that the preservative treatments used in this study are less relevant today, the results are entirely consistent with known zinc corrosion kinetics, and are similar to those reported in Table 2 in that they clearly indicate:

1. The laboratory test is significantly more aggressive than soil burial exposure.

2. The beneficial effect of heavier zinc coatings was plainly evident.

Several fasteners, designed to improve corrosion resistance and overall performance, are now available. Fasteners galvanized using a new procedure called "the Ingalloy process" have shown significant promise. This new process results in a thicker galvanized coating that provides superior corrosion resistance. Because the coating is more uniform, it does not adversely affect mechanical fastening properties by filling in ring shanks and screw threads.

Plastic coatings may offer increased corrosion resistance, but their application for post-frame may be deterred unless the coating can resist scratches caused by screwing them through metal cladding. Ceramic coatings may be an option, although they are expensive and the coating may also affect mechanical fastening properties. Chemical manufacturers suggest that type 304 or better stainless steel fasteners provide more than adequate resistance to corrosion with the new wood treatment chemicals, although they may provide more corrosion resistance than is necessary in conditions where the wood and fasteners remain dry.

Some fastener manufacturers have performed testing to determine which of their products will withstand the corrosive effects of the new generation of treated woods, and make recommendations for their application in the post-frame industry. Recommendations from some of these manufacturers are presented in an accompanying article in this issue of *Frame Building News* (page 41). It is certainly advisable to ask your fastener supplier if it has tested its products to determine the compatibility of its products with the new wood treatments.

After earning degrees in chemistry and marketing, and gaining experience in lab research and sales development, Thomas J. Kinstler joined the galvanizing industry. Over the past 30-plus years Kinstler has researched, written, and published on a wide number of technical and marketing topics. Kinstler recently retired from Industrial Galvanizers America to focus more intensely on consulting projects and partnerships involving galvanizing technical and marketing matters through the consulting group GalvaScience, LLC. He may be reached via e-mail (GalvaScience@alltel.net) or phone (205) 296-7236.

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