

Exposure Test of Fasteners in Preservative-Treated Wood

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Summary

This study examined nails and screws exposed to ACQ-treated wood for up to 12 months in a controlled environment. The environment (27°C, 100% relative humidity) was chosen so that comparisons could be made with previous exposure tests run using CCA-treated wood in the same environment. Five types of fasteners (common 8d nail, hot-dipped galvanized 8d nail, 4d aluminum alloy nail, 64-mm electroplated galvanized screw, 64-mm stainless steel screw) were inserted into wood treated with ACQ to a retention of 4 kg m⁻³ and exposed to a 100% relative humidity environment for periods from 1 to 12 months. The fasteners were cleaned and weighed to quantify corrosion rate.

1. Introduction and Motivation

Because of the voluntary withdrawal of chromated copper arsenate (CCA) for residential use, many designers are now choosing wood treated with alternatives to CCA, such as alkaline copper quaternary (ACQ) and alkaline copper azole (CuAz). Published research on the effect of alkaline-based preservatives on corrosion rate is limited, although ACQ and other new preservatives are generally believed to be more corrosive than CCA (Zelinka and Rammer, 2005). Although electrochemical test methods show great promise for rapidly evaluating corrosion of metals in contact with wood, they need to be validated by real-world exposure data.

The 27°C, 100% relative humidity condition has been used by several researchers to evaluate the corrosion of metals in CCA- and zinc-chloride-treated wood (Baker, 1992; Simm and Button, 1985). Furthermore, Baker (1992) showed that corrosion rate of fasteners in CCA-treated wood is constant for exposure times of 1 to 17 years in this environment. For these reasons, this environment was chosen to evaluate the corrosion of fasteners in ACQ-treated wood.

2. Experimental

2.1 Lumber

Select structural grade Southern Pine boards, 100% heartwood, nominally 50 by 100 mm, and treated with ACQ, were purchased from a commercial supplier. The wood was selected so that grain angle was approximately tangential to the 50-mm face. The ACQ-treated lumber was intended for use aboveground according to American Wood Preservers' Association use category UC3-B (AWPA, 2005) and had a specified nominal retention of 4 kg m⁻³. The exact ACQ type and formulation were not specified on the commercially purchased lumber. Before the test began, the wood was equilibrated in a room at 27°C, 90% relative humidity

2.2 Environment and time of exposure

The 100% relative humidity environment was created in sealed glass desiccators that were partially filled with water, allowing water and water vapor to be at equilibrium. The temperature was kept constant by placing the desiccators in a conditioned room at a constant 27°C. Assuming uniform corrosion, the measured corrosion rate should be constant, regardless of the exposure time. To determine if shorter exposure times could accurately predict corrosion rate, tests were run for periods of 1, 2, 3, 6, 9, and 12 months.

2.3 Fasteners

Five types of fasteners were tested: a common 8d nail, a hot-dipped galvanized 8d nail, a 4d aluminum alloy (UNS AA5056) nail, a 64-mm electroplated galvanized screw, and a 64-mm stainless steel screw.

2.4 Pre-Exposure Procedure

Prior to insertion into the wood, the fasteners were cleaned, degreased, and weighed. The fasteners were cleaned in a three-step process: soaked in ultrasonically agitated soap solution for 5 min; rinsed under flowing distilled water; soaked in ultrasonically agitated distilled water bath for 5 min. The fasteners were degreased by rinsing with a 50/50 mixture of toluene and ethanol and again rinsed with distilled water. The fasteners were then allowed to dry, weighed to the nearest 0.1 mg, and driven on the 50-mm face of the wood into predrilled 2.26-mm-diameter holes to prevent wood splitting and ensure uniform contact between the nail surface and the wood. The predrilled hole corresponds to approximately 90% of the diameter of the smallest fastener. The fasteners were each driven into a separate piece of wood to prevent cross contamination between fasteners.

2.5 Post-Exposure Procedure

The fasteners were removed in such a way to minimize damage to the fastener. Initially, two grooves were cut in the wood surrounding the fastener with a band-saw. The wood was then placed in a vise. As pressure was applied, the wood split along the sawn grooves, and the fastener was removed without damaging the corrosion products.

Several high-resolution digital images of each fastener were recorded to visually document the amount of corrosion products. Black and white photographs taken under special lighting recorded a silhouette of each fastener.

The fasteners were then cleaned using methods similar to those presented in ASTM G1-03 (ASTM, 2003). After cleaning, each fastener was weighed and the mass (m_f) was measured. Weight loss due to cleaning (m_c) was calculated by using the same cleaning and weighing process on uncorroded fasteners (Table 1).

TABLE 1—Cleaning methods used to remove corrosion products

Material	Solution	Cleaning time ^a (min)	m_c Weight change due to cleaning (mg)	σ_{m_c} Standard deviation (mg)
Steel and stainless steel	50/50 mixture of distilled water and Evapo-Rust ^b	60	−1.2	0.9
Galvanized	Saturated ammonium acetate	60	−1.6	1.2
Aluminum	Concentrated nitric acid	5	+0.1	0.2

^aCleaning was performed with ultrasonic agitation.

^bEvapo-Rust is a proprietary chelating agent manufactured by Harris International Laboratories, Inc, Springdale, Arkansas.

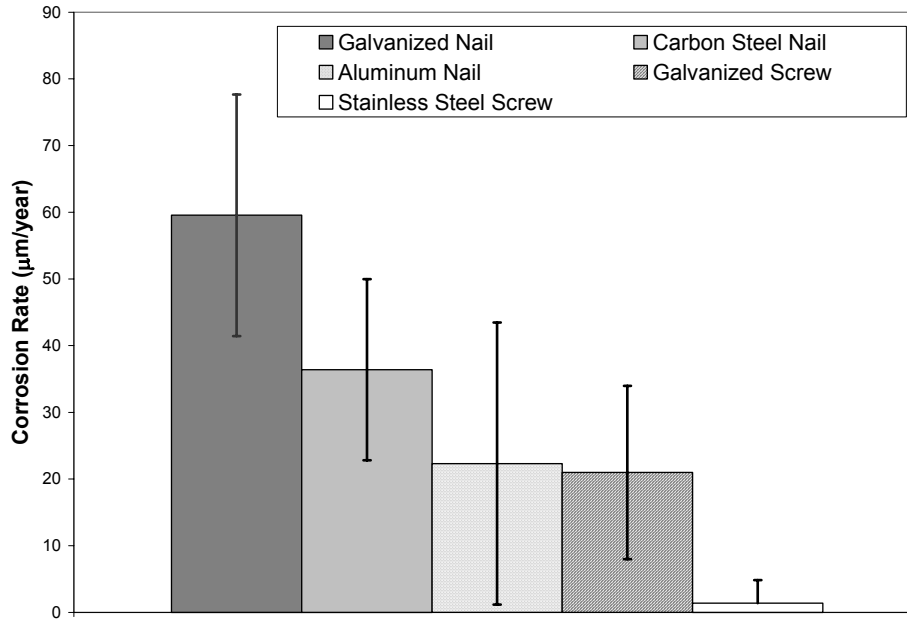


Figure 1—Results of corrosion tests conducted in a 27°C, 100% relative humidity environment. Values represent the average of 9 replicates, which were exposed for times between 6 and 12 months. Error bars represent one standard deviation.

The silhouette photographs were analyzed using a computer program written by the authors to compute surface area of the fastener, which was used for corrosion rate calculations. This program contained an algorithm, also written by the authors, to compute the surface area of a threaded fastener with given thread characteristics. Ideally, the pre-test surface area should be used in corrosion rate calculations; however, no silhouette photographs were taken prior to insertion, so post-test surface area was used in corrosion rate calculations.

3. Results

Previous researchers reported their data as percentage mass loss, which can be misleading if comparing fasteners with different densities. A more informative figure is corrosion rate, which was calculated from the familiar equation

$$R = K \frac{m_f - m_i + m_c}{A\rho(t_f - t_i)} \quad [1]$$

where m_i and m_f are initial and final masses (g), t_i and t_f are initial and final times (h), A is surface area (cm^2), ρ is density (g/cm^3) tabulated in ASTM G1-03 (ASTM, 2003), and K is a constant ($87,600 \text{ mm cm}^{-1} \text{ h year}^{-1}$). The term m_c (g) was added by the authors to represent the additional loss of base metal that results from removing the corrosion products. Assuming uniform corrosion and a constant corrosion rate (as reported by Baker (1992)), the corrosion rate should be the same regardless of exposure time.

However, Zelinka (in press) showed that uncertainties in corrosion rate measurements decrease with time and that uncertainty is less than 5% for these alloys after 6 months in this environment. Therefore, the data (Fig. 1) represent the average of the corrosion rates collected at 6, 9, and 12 months. Error bars represent one standard deviation above and below the mean. The uncertainty in the measurements is small, but standard deviation is large. (Uncertainty inversely reflects accuracy

of the measurements; standard deviation reflects range and variability of the measurements.) Standard deviation may be so high because there were so few (9) replicates.

4. Discussion

The most surprising result is that the electroplated galvanized screw outperformed the hot-dipped galvanized nail. Several researchers have shown the corrosion performance of hot-dipped galvanized fasteners to be superior to that of electroplated galvanized fasteners in the CCA-treated wood environment (Wallin, 1971; Baker, 1992). The most likely explanation for this dramatic difference is that the alloying elements in the galvanizing process were different. It should be noted that as of this time, no metallurgical analysis has been completed on the fasteners or their coatings. The electroplated galvanized screw may have had a chrome conversion coating, whereas the hot-dipped galvanized fastener did not. In short, more research needs to be done to determine the affect of the metallurgy of the fastener on its corrosion performance in treated wood.

5. Conclusions

This report contains data on the corrosion rate of fasteners exposed to ACQ-treated wood in a 27°C, 100% relative humidity environment. Corrosion rate was hypothesized to be sensitive to the alloying elements in the galvanizing coating. Before these data can be compared with previous research conducted using CCA-treated wood, the data in those reports need to be converted from percentage weight loss to corrosion rate. The authors are currently working with photographs in those reports in conjunction with their algorithm to make this comparison.

6. References

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