Evaluation of Metal Fasteners Corroded from Contact with Preservative-Treated Wood

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ABSTRACT

This presentation will summarize work that was jointly funded by SPRI, the RCI Foundation, and the National Roofing Foundation. The objective of this research program is to determine the potential corrosive effects of new wood preservatives on metal fasteners used in low-slope commercial roofing systems, specifically those used to hold the assembly to wood nailers.

The presentation will provide the following information:

1. Background on the potential issues of corrosion of metal fasteners in treated wood.
2. Data developed in various laboratories that identify critical variables that initiate corrosion of metal fasteners in contact with wood using various types of preservatives, along with theories as to why this reaction is occurring.
3. Field data from the wood nailer location of low-slope roofing systems located in various regions of the country to determine if the critical parameters necessary to initiate corrosion are present.
4. Recommendations as to the proper combination of fasteners and wood nailers that should be used to prevent corrosion.

SPEAKER

Mike Ennis has been technical director for SPRI, the association representing single-ply roofing manufacturers and component suppliers for three years. Prior to this, he worked for the Dow Chemical Company and was the North American application technology leader for commercial products in Dow’s Building Solutions business, where he led the development of new products and applications. Mike has 32 years of building and construction experience to his credit. Ennis is an RRC with RCI, Inc., and is a member of the board of directors of the Roofing Industry Committee on Weather Issues (RICOWI) and the Cool Roof Rating Council (CRRC). He is a member of ASHRAE and ASTM Committees D08, Roofing and Waterproofing; E05, Fire Standards; and E60, Sustainability.
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ABSTRACT
This report will summarize work that was jointly funded by SPRI, the RCI Foundation, and the National Roofing Contractors Association (NRCA). The objective of this research program was to determine the potential corrosive effects of new wood preservatives on metal fasteners used in low-slope commercial roofing systems, specifically those used to hold the assembly to wood nailers and to hold the wood nailers in place.

Due to environmental and regulatory concerns, the wood industry began using new preservative chemicals. Concern has been expressed that some of these new chemicals may cause corrosion of certain types of metal fasteners. This has been observed in some instances. The report will provide the following information:

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2. Data developed in various laboratories that identify critical variables that initiate corrosion of metal fasteners in contact with wood using various types of preservatives, along with theories as to why this reaction is occurring.

3. Field data from the wood nailing location of low-slope roofing systems located in various regions of the country to determine if the critical parameters necessary to initiate corrosion are present.

4. Recommendations as to the proper combination of fasteners and wood nailers that should be used to prevent corrosion.

INTRODUCTION
Preservatives are used to reduce the potential for insect infestation and rotting of wood products to extend the service life of these materials. Historically, the most prevalent preservative used was Chromated Copper Arsenate (CCA). Effective January 2004, the Environmental Protection Agency (EPA) banned the use of this preservative for residential use due to health and environmental concerns. While the use of CCA was still allowed for certain applications it was more cost-effective for producers to switch to more widely accepted preservatives (Wieland, et al. 2004).

Two of the more common substitutes for CCA that emerged were:

- Alkaline Copper Quartenary (ACQ)
- Copper Boron Azole (CA-B)

These materials rely on high levels of dissolved copper to provide resistance to insects and fungi-induced rot. Standard industry tests for compatibility indicated that metal exposed to these new preservatives had a higher level of corrosion as compared to CCA preservative.

Third-generation wood preservatives that rely on finely ground copper in suspension, resulting in less free copper ions, are being produced. These new formulations include:

- Dispersed copper azole (µCA-C)
- Micronized copper azole (MCA)
- Micronized copper quaternary (MCQ)

These new formulations claim reduced corrosion rates compared to copper solution treatments.

In addition to these copper-based wood preservatives, there are also borate-based products available. Borate is reported to be no more toxic to humans than common table salt. However, borate is very water-soluble; therefore, wood treated with borate-based preservatives is not suitable for outdoor use.

The increased corrosion rate associated with ACQ and CA-B preservatives has the potential of being problematic for the low-slope commercial roof industry. Preservative-treated lumber is used as nailers for securement of roof membranes and roof-edge products. The nailers are attached to the building structure with metallic fasteners, which are then in direct contact with the preservative-treated lumber. In many applications, the wood nailer is also in direct contact with a steel roof deck. If corrosion of the metallic fasteners were to occur and weaken the attachment of the edge securement system, the entire roof assembly would be more susceptible to damage during high-wind events.

Posthurricane investigations conducted by the Roofing Industry Committee on Weather Issues (RICOWI) have consistently shown that in many cases, damage to a low-slope roof system during high-wind events begins when the edge of the assembly
becomes disengaged from the building structure. Once this occurs, the components of the roof system (membrane, insulation, etc.) are exposed. Damage then propagates across the entire roof system by peeling of the roof membrane, insulation, or a combination of the two (see Figure 1).

For this reason, a research project was initiated by SPRI to determine if corrosion of metal fasteners in contact with ACQ and other new wood preservatives was an issue in low-slope commercial roofing applications. This report summarizes the work completed to make this determination, which included laboratory studies to identify the critical temperature and humidity conditions necessary to initiate the corrosion process with various wood preservatives and fastener types. The study also involved determining the temperature and humidity conditions that exist in the wood nailer in various climate zones. This data is then compared, and conclusions are provided regarding potential corrosion of fasteners in wood nailers in low-slope roofing applications.

LABORATORY STUDIES

DURO-LAST ROOFING STUDY

Galvanic corrosion occurs when a metal corrodes preferentially when in electrical contact with a different type of metal and both metals are immersed in an electrolyte. The extent or rate of corrosion is a function of each metal’s electrochemical potential and the efficacy of the electrolyte as a media for ionic transport.

Gravimetric studies were conducted at Duro-Last Roofing, Saginaw, MI, to assess corrosion product weight growth as a function of time of exposure to different test environments.

CORROSION TESTS

The two experimental phases were based on the American Wood-Preservers Association (AWPA Standard E12-94).

The first phase was an accelerated test looking at corrosion of stainless steel and e-coated carbon steel fasteners, and determining their response in a controlled environment in various lumber treatments. The environment was extremely harsh and likely unrealistic; however, it was designed to maximize sensitivity to corrosion rates.

The second phase was to assess rates of corrosion at various temperatures and relative humidity (RH) conditions.
TEST PROTOCOL

- 1022 carbon steel e-coated fasteners were used for the experiments.
- The e-coated fasteners were weighed before and after the coating process to eliminate the weight of coating in the final results.
- Lumber with various treatments were equilibrated in their relative test environments until less than 1% weight change was observed (to allow moisture absorption equilibration).
- Four each of 5-in x 5-in by 1.5-in blocks of lumber treated with ACQ, CA-B, SBX, and CCA were prepared. Three e-coated carbon steel fasteners (as prepared above) were drilled into each wood block. All fasteners were drilled until the tip was observed to break through the backside of the board. The treated lumber blocks with installed fasteners were then placed into the following environments:

**Phase 1:**
1. Kesternich cabinet at 120°F with an RH of 90 ± 3%

**Phase 2:**
2. Kesternich cabinet at 140°F with an RH of 90 ± 3%
3. Kesternich cabinet at 75°F with an RH of 90 ± 3%
4. Environmental oven at 120°F with a relative humidity of 60 ± 5%
5. Ambient conditions in room at 75°F and an RH of 30 ± 5%
- The Phase 1 fasteners were exposed for 0.07, 0.17, and 0.29 years in condition 1 above to assess a worst-case environment.
- The Phase 2 fasteners were exposed for 0.1, 0.17, 0.34, and 0.46 years.
- In all samples, at the conclusion of their allotted time, the wood was split and the fasteners removed, cleaned, and weighed.
- The corrosion was removed from each fastener by gentle scrubbing and immersion in a 20 wt% ammonium citrate solution.
- A secondary corrosion removal step was accomplished with a two-minute immersion in a 100% HCl bath, followed by gentle scrubbing.
- Complete removal of corrosion was verified using optical microscopy.
- The samples were weighed and the corrosion products gravimetrically determined by difference.
- The data from both experimental phases were recorded, plotted, and modeled using JMP v. 5.0 statistical analysis software. Parabolic rate functions were determined from the gravimetric data for predictive modeling.

TEST RESULTS

**Figure 2** illustrates the gravimetric profiles of the treatments tested over time, reflecting a parabolic rate mechanism for the corrosion observed in all treatments studied (ACQ, CA-B, and CCA).

![Parabolic Regressioun and Actual Data](image)
1. Figure 3 illustrates the differences observed in the various treatments used in Phase 1 for extent of corrosion with stainless steel, e-coated carbon steel, and uncoated carbon steel. The stainless-steel fasteners exhibited no corrosion in any of the lumber treatments tested, and thus were eliminated from further studies. Further, little or no corrosion was observed in the untreated or SBX-treated lumber.

2. Corrosion was observed in the fasteners emplaced in CCA-, ACQ-, and CA-B-treated lumber.

3. Where corrosion was observed (only on samples exposed to 90% RF), the weight loss data from the e-coated carbon steel fasteners fit parabolic rate models with correlation coefficients (R-squared values) ranging from 0.87 to 0.99 (indicating good fits). The Arrhenius-like relationship was found to be:

\[ y = y_0 + k_p (t)^{0.5} \]  

(1)

Where:
- \( y \) is the oxide mass gain due to oxidation.
- \( t \) is time of exposure.
- \( k_p \) is the rate constant, directly proportional to the diffusivity of the ionic species, which are rate controlling.
- \( y_0 \) is a constant.

4. Parabolic rate mechanisms are commonly observed for lower temperature corrosion kinetics and suggest an ion-species diffusion-limited rate mechanism driven by temperature and humidity.

5. The temperature appears to be the key driver in the extent of corrosion, though a sustained presence of moisture within the wood is also required for corrosion to occur. It appears that the absorbed moisture becomes the medium (electrolyte) for electron transfer.

\[ CCA \text{ Response With Increasing Time} \]

\[ \text{CCA Response With Increasing Time} \]

\[ \text{CCA Response With Increasing Time} \]

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Figure 5 – Response curves for e-coated lumber in ACQ-treated lumber in the various environments tested.

Figure 6 – Response curves for e-coated lumber in CA-B-treated lumber in the various environments tested.
6. The data additionally suggested that the relative permeability of the e-coat was sufficient to allow the passage of moisture to create the galvanic circuit.

7. Figures 4 through 6 illustrate the various responses with increasing exposure time for the different treatments tested. Only those environments held at 90% relative humidity indicated corrosion.

8. Figures 7 and 8, respectively, illustrate the response for those treatments held at 90% RH.

9. Corrosion was only observed for those conditions where the relative humidity was held at 90% RH and at 140° and 75° respectively. No corrosion was observed for samples held at 120°F and 60% RH, or for those held at 75°F and 30% RH (Figures 9 and 10). The relative humidity has to be sustained at high levels approaching 90% in order for the wood to retain sufficient moisture for a galvanic cell to be functional, and thus is a requirement for corrosion to occur.

10. At typical ambient conditions, the responses observed for the treated lumbers are comparable to those observed with CCA-type treatments.

11. After the tests, the corrosion was observed to occur in areas where e-coating was lost in the initial drilling. Further, there was evidence of corrosion on e-coated portions of the fasteners with no evidence of coating loss, suggesting dif-
12. The mechanisms for corrosion for CCA lumber are the same as those for the ACQ and the CA-B. The ACQ and CA-B demonstrate higher rates of corrosion if sufficient moisture is present. It is suggested that the lumber needs to maintain saturation in order for corrosion to occur.

13. For conditions typical of a roof, the typical ambient temperature and typical levels of moisture saturation required to generate corrosion are not problematic.

14. In four years, Duro-Last has seen no indication that rooftop conditions are sufficient to cause accelerated fastener corrosion in ACQ or CA-B treated lumber.

15. For the temperature and moisture conditions observed in the field study, no corrosion issues would be expected.

LSU WOOD DURABILITY LAB (WDL) STUDY, T.F. SHUPE, ET AL.

OBJECTIVES

The objective of this study was to evaluate the corrosion effects of ACQ type D, ground-contact, treated lumber on 4-in and 5-in hot-dipped, galvanized (HDG) 4-in metal fasteners, and two e-coated metal fasteners, also 4-in and 5-in. The test included 10 fasteners for each metal tested. The wood samples were cut from a treated ACQ ground contact 4-in x 6-in x 8-ft board. A total of 40 metal fasteners were used in this test. Each unit contained one e-coated sample and one HDG-coated sample. Therefore, two fasteners were in each sample unit for a total of 20 samples units (wood and fasteners).
PROCEDURE

SYP-treated 4 x 6 ACQ-type D-treated materials were purchased locally from Lowes and milled on a tablesaw at the WDL into samples measuring 3 in x 3 in x 6 in. The test was started on 04/24/09 and concluded on 06/22/09. The test sample units consisted of two fasteners imbedded in a 3-in x 3-in x 6-in piece of SYP ACQ-treated 4 x 6. Fasteners were driven into the sample units using an electric drill. The fasteners were spaced at 12 times their respective diameter within the sample unit. Each sample unit contained one coated and one HDG fastener. After 60 days of exposure at 90°F and 90% RH, the fasteners were removed from the wood by splitting the wood with a wood chisel. The samples were visually rated and weighed. The samples were then cleaned with Evapo Rust to remove corrosion materials, oven-dried in a force-draft oven, and reweighed. Diameter measurements of the fastener were taken with a digital caliper to determine the amount of local rusting.

RESULTS

Fastener weight loss was minimal for the e-coated fasteners losing 0.01 grams when exposed to accelerated conditions inside ACQ type D, ground-contact, treated wood. Fastener weight loss was greater for 4-in HDG, losing 0.48 grams, and 5-in HDG, losing 0.53 grams when exposed to accelerated conditions inside ACQ type D, ground-contact, treated wood. Diameter loss values for the e-coated fasteners were unchanged for the 4-in sample and 0.001 cm for the 5-in sample. Diameter loss values for the 4-in HDG was 0.007 cm and loss for the 5-in HDG was 0.010 cm. Rusting was found to be very minor on all fasteners tested.

CONCLUSIONS

1. Weight loss and diameter loss for the 4-in HDG and 5-in HDG were greater than that of the e-coated fasteners while exposed in a accelerated condition chamber when set in ACQ type D, ground-contact, treated wood.
2. Rusting was very minor on all fasteners tested, with some minor spots found on the heads, shafts, and shanks.
3. Rust was not present on the HDG fasteners below the head of the fasteners; however, most of the coatings were removed and fixed to the wood surfaces.
4. There was minor coating loss on the shanks of the e-coated sample.

VISUAL TEST

One of the early evaluations conducted was a straightforward one that provided the ability to visually evaluate the corrosion potential of ACQ-treated lumber in contact with metal fasteners. This test started in March of 2004.

TEST PROTOCOL

• Epoxy-coated screws were installed into three 1-ft-long pieces of 2-in ACQ-treated 2 x 4s.
• One sample was left as received, a second sample was soaked for 24 hours in a bucket of water simulating rain on the nailer during construction, and the third sample has been soaked in a bucket of water for 24 hours the first business day of every month (64 months), which represents a very extreme condition.
• An aluminum term bar was also installed on each piece since aluminum is reported to be very susceptible to corrosion in contact with ACQ (see Figure 1).

TEST RESULTS

1. The screws show no evidence of accelerated corrosion. There was a very small amount of corrosion present in the recess from contact with the bit during installation. This would be observed with any screw that is soaked in water for 24 hours every month.
2. No unusual corrosion was observed on aluminum term bar.

FIELD STUDIES

TEST OBJECTIVES

The objectives of the field studies were:

1. Determine how long wood nailers stay wet if saturated with water prior to installation.
2. Gather field data in various climates and measure wood nailer moisture content.
3. Use the data to develop a model to predict drying times in various climate zones.
4. Compare collected data to the critical temperature/humidity levels identified in the laboratory test procedures that are required to initiate severe corrosion of metal.

TEST PROCEDURE

To satisfy the objectives of this test program, the following test protocol was developed.

Three test sites were chosen for this experiment. All test sites were located at SPRI member facilities so that any problems with the test equipment could be corrected quickly. Agawam, MA, was chosen as a test location representing a cold climate zone. Jackson, MS, was chosen as a hot and humid climate zone, and Grants Pass, OR, was chosen as a mild and humid climate zone. These sites were chosen because the climate conditions present would provide a variety of temperature and humidity levels.

Nominal 2-in x 4-in x 2-ft wood sections were saturated by submerging them in water for 30 days. After the submersion period, the samples were wrapped in plastic wrap to keep the moisture in place and were shipped to the test location.

Once at the test location the samples were unwrapped and instrumented with temperature and moisture-content sensors. Figure 11 is a schematic representation of the instrumentation used in this study. Figure 12 shows the actual test samples used in the experiment. Insulation was cut and removed so that the test samples could be installed directly on the roof deck (see Figure 13).

The temperature and moisture-content sensors were connected to a data acquisition system to allow for continuous monitoring of the information. The data were remotely downloaded once per week and maintained by Oak Ridge National Laboratory. In addition to monitoring the instrumentation connected to the test samples, the interior temperature and relative humidity near the roof cut were also monitored.

The initial installation of the saturated wood samples occurred on November 13, 2007, in Agawam, MA. Installation of the test samples at the Jackson, MS, location on January 15,
2008, followed. It was determined that the instrumentation in these initial tests was not adequately sensitive to gather the desired information. Test samples and instrumentation were reinstalled at the Jackson, MS, location on June 5, 2008, and at the Agawam, MA, location on July 24, 2008. After it was determined that the instrumentation was working properly, samples were installed at Grants Pass on September 24, 2008.

**TEST RESULTS**

The average daily temperatures within the wood nailers were highest at the Jackson, MS, test location. At this location, temperatures remained
above 70°F for the first 100 days of exposure (test was initiated June 5, 2008). Temperatures ranged from 40°F to 70°F for the next 205 days of exposure. The relative humidity within the wood nailer at this location ranged from 85% to 100% at the start of the test and dropped to a range of 60% to 70% after 120 days (except for the 200- to 220-days time period). See Figures 14 and 15 for a summary of these data.

At the Agawam, MA, location, the temperature within the wood nailer ranged from 70°F to 80°F for the first
50 days of the test (test started on July 24, 2008), dropped to a range of 50°F to 70°F for the next 60 days, and then dropped to a range of 35°F to 50°F for the subsequent 90 days before beginning to increase again. The relative humidity within the simulated wood nailers for this location started at 90% to 100% and dropped to a maximum of 60% after 80 days for the remainder of the test period (310 days). See Figures 16 and 17 for a summary of these test data.

At the Grants Pass, OR, test site, the test temperatures within the simulated wood nailers ranged from 30°F to 60°F for the duration of the test. At...
this location, the moisture content sensors in one of the test samples malfunctioned; however, the moisture content sensors in the duplicate sample performed well. The relative humidity at this location started at approximately 90% and dropped to a range of 45% to 55% after 70 days, where it remained for the duration of the test. See Figures 18 and 19 for a summary of these test data.

The maximum temperatures and relative humidities were observed at the Jackson, MS, test site. Previous studies have indicated that temperature and humidity are key drivers for the corrosion process when metal fasteners are in contact with treated lumber. Since this is the case, the Jackson, MS, location would represent the most likely location for corrosion to occur.

CONCLUSIONS

1. The relative humidity has to be sustained at high levels approaching 90% in order for the wood to retain sufficient moisture for a galvanic cell to be functional and, thus, is a requirement for corrosion to occur. This conclusion is based on exposure of 1022 carbon steel e-coated fasteners to wood treated with ACQ, CA-B, and CCA.

2. Temperature appears to be the key driver to the extent of corrosion, though a sustained presence of moisture within the wood is also required for corrosion to occur.

3. The mechanisms of corrosion for CCA lumber are the same as that for ACQ and CA-B. The ACQ and CA-B demonstrate higher rates of corrosion if sufficient moisture is present.

4. No measurable corrosion was noted on stainless-steel fasteners during this study.

5. No measurable corrosion was noted on fasteners exposed to SBX-treated wood.

6. Field studies demonstrated that the wood nailers dried from a saturated condition to a range of 45% to 65% RH within six months of exposure. The highest RH occurred at the Jackson, MS, test site.

7. Comparing conditions required for corrosion to occur in the laboratory test program with the conditions that exist in the nailer corrosion of e-coated or stainless steel fasteners will not be an issue.

8. There have been no reports of excessive fastener corrosion when installed in treated wood nailers, supporting conclusion #7.

RECOMMENDATIONS

1. Use either nontreated or SBX-treated wood for the nailers.

2. If treated wood is used, either e-coated steel fasteners or stainless-steel fasteners should be used.

3. In all cases, a Factory Mutual-compliant fastener or equivalent should be used.

REFERENCES

American Wood Products Association (AWPA) Standard E12-94.

