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CORROSION PERFORMANCE OF GALVANIZED ARTICLES IN CONTACT WITH PRESSURE TREATED WOOD

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Summary

An accelerated test, using daily spraying with deionized water in a 49°C saturated humidity cabinet, was used to evaluate the corrosion rates of galvanized and Galvalume® coated sheet and galvanized fasteners in several pressure treated wood formulations. Coatings on thicker steel substrates exhibited higher rates of weight loss than those on thin gauge sheets. Most corrosion occurred during the initial exposure periods in each case: 30 days out of a total 180 day exposure for sheet and 15 days out of a total exposure of 90 days for fasteners. Wood treated with CA and ACQ formulations gave higher corrosion rates then untreated or CCA treated reference samples, with CA usually showing the highest corrosion rates. Acrylic coated sheet samples usually gave superior corrosion resistance to chromated sheet samples. A roughly twofold acceleration of corrosion rates on galvanized sheet was seen with the ACQ and CA formulations compared with CCA. Galvalume acceleration rates were higher. Little effect of pressure treatment formulation was seen on the corrosion behavior of galvanized screws and nails. Galvanized screws showed significantly higher corrosion resistance than the other fastener types tested.

1. Introduction

To enhance their use outdoors and also in earth contact applications, wood products are frequently treated with preservative formulations. Traditional formulations, including chrome copper arsenic (CCA), creosote and pentachlorophenol, control wood rot resulting from insect and fungus attack and increasing service life. Moisture and temperature, which vary greatly with local conditions are important factors affecting the rate of wood decay. In the presence of moisture, conditions are favorable for fasteners such as nails or screws in contact with wood treated with certain preservative or fire retardant salts to corrode. The expected service life of both the wood and the galvanized hardware used together with this wood is affected by the details of wood preservative formulations used, together with conditions of exposure. The use of CCA treatment was voluntarily withdrawn from most residential applications as of December 2003 as a result of a voluntary agreement between the wood preservative industry and the US Environmental Protection Agency. A number of alternative treatments to CCA have

®Trademark of BIEC International, Inc., Vancouver, WA, USA entered the market as substitutes, of which two of the most widely used are now copper azoles (CA) and acrylated copper quaternary (ACQ). Compared with CCA, the copper content in some of these treatments is significantly higher. This had lead to higher observed corrosion rates in galvanized steel connectors and fasteners. Initial studies on the corrosivity of alternative wood preservative formulations including a 2004 study by Simpson Strong-Tie[1] showed higher corrosion rates of galvanized fasteners with the new products. Steels with thicker zinc coatings, stainless steels, or alternative protective coatings on carbon steel such as ceramics were recommended. However these are more costly then traditional galvanized fasteners. The Simpson Strong-Tie test, conducted using American Wood Preservers Association Standard E12-94, "Standard Method of Determining Corrosion of Metal in Contact with Treated Wood" showed that the CA and ACQ treatments gave roughly double the corrosion rates on galvanized hardware of the traditional CCA formulation. However, it is well known that the AWPA E12 method is not representative of common exterior corrosion environments and therefore does not allow prediction of corrosion rates for specific conditions. Latitude in the E12 testing protocol allows for different testing conditions to be used and the E12 specification gives no guidance as to acceptable corrosion rates. In particular the "sandwich" nature of the E12 specimen, in combination with specified corrosion conditions, were viewed as producing unduly severe conditions. It was therefore decided to develop a new test method for evaluation of the corrosion behavior of common galvanized articles in contact with ACQ and CA wood preservative formulations in Southern yellow pine. Untreated wood, and wood treated with CCA were used as reference samples.

2. Methodology

Discussion of the actual environments present in pressure treated wood in common service conditions with authoritative persons in the field, lead to development of the following test method:

- Prepare specimens and place in environmental chamber with the following conditions:
    - Temperature 49°C (± 1°C)
    - Relative Humidity 90% (± 1%)
    - Water spray specimens in the cabinet daily using deionized water
    - Period of exposure of sheet samples in chamber: 30, 60 and 180 days
    - Period of exposure for fastener (nail and screw) specimens in cabinet: 15, 30 and 90 days.

Rather than a sandwich sample, a "half-sandwich" sample was used for testing of steel sheet. Sheet samples were cut into rectangles 38 X 101 mm (1.5 X 4 in). Each specimen was then labeled as to coating type. Wood blocks were cut to slightly larger dimensions and lightly sanded to ensure a smooth surface. Each steel sample then had two holes drilled, one close to each of the long ends with a 4.76 mm (3/16 in) diameter bit. A hammer with a rubber head was then used to drive nails through the wood blocks and steel samples. The nails used were J-148 hanger nails of 3.96 mm (0.156 in) diameter and 38 mm (1.5 in) length for the thick gauge steel and Maze S263 nails for the thin gauge steel. There were no strict limits on the dimensions of the wood test blocks as long as they were larger than the area of the sheet and completely contacted the steel samples. These specimens were then placed on trays in the humidity test cabinet with sufficient space between them to allow spraying of deionized water as detailed in the procedure described above. Good drainage from all trays holding samples was ensured. Three specimens from each type of wood treatment and each coating type were retrieved after exposure periods of 30, 60 and 180 days. After removal the wood block was carefully split to retrieve the specimen without damaging it and specimens weighed as they came out of the wood block. Sheet specimens were first mechanical cleaned by lightly brushing corrosion products from the specimen. They were then chemically cleaned by dipping them for 15 seconds duration in room temperature 8.5% hydrochloric acid solution (1.5 specific gravity). The dipping operation was repeated six times, after which specimens were dried and then immediately weighed.

All fasteners were weighed, and their diameters measured before being driven into wood blocks. The same number and type of fasteners as those being driven into the wood blocks were weighed and set aside for reference. A hammer with a rubber head was used to drive nails through the wood. No pre-drilling was used in the wood blocks. Fasteners were spaced at a distance of 10 diameters apart, roughly 38 mm (1.5 in). The prepared samples were placed in the environmental chamber and groups removed after 15, 30 and 90 days.

The wood specimens used for testing are described in Table 1. All treatments were applied by commercial wood preservative applicators and were intended to be applied to the retention level shown in Table 1. Table 2 shows the analysis of active chemicals in the tested wood samples. The CCA and CA retention levels slightly exceeded the intended loading amounts while the ACQ measured levels were somewhat less than the intended retention level.

Steel sheet specimens used for testing represented a variety of thicknesses and coating types commonly found in construction applications. The regular galvanized sheet coatings (G60, G90 and G185) had a small amount of aluminum, about 0.18-0.25% added to the zinc per normal industrial practice. The Galvalume (AZ) coatings were nominally 55% aluminum, 1.6% silicon and 43.4% zinc. The chromate (Cr) layer on AZ is lighter than that of the zinc samples because of the different reactivity of these coatings with Cr. All steel sheet samples were tested with sheared, unprotected edges and are described in Table 3.

96 sheet samples for which data are reported here were retrieved after 30, 60 and 180 days of exposure. Three samples for each coating/treatment were retrieved. For the

fasteners, 48 fastener samples for which data are reported here were retrieved after 15, 30 and 90 days of exposure. For the sheet samples, final weights and weight losses after each exposure period were calculated; for the fasteners, weight loss and diameter change were recorded.

3. Results and Discussion

Figures 1 and 2 show the average loss by coating type for the heavy gauge and light gauge groups of sheet samples. Figure 5 shows the average fastener mass loss comparison for the 15, 30 and 90 days retrievals. In each case, the corrosion rate of the galvanized articles can be seen to significantly slow after the first exposure period. Much of the attack on the steel's protective coating thus occurs during the first exposure period, either 30 days for sheet or 15 days for fasteners. Only in the case of the chromated Galvalume in both light and heavy gauges, did corrosion weight losses significantly increase with excessive exposure periods. At the same time, it should be noted that the overall magnitude of weight losses for these samples is relatively low. The benefit of an acrylic coating over the zinc coating, rather than use of a chromate passivation treatment, was seen particularly with the heavy gauge Galvalume samples. Marginal benefit, or even a detraction from performance, was seen with the light steel samples. The acrylic coating was particularly beneficial when heavy gauge Galvalume samples were exposed to the CA-treated woods. Curiously, the chromated heavy gauge, heavy coating (G180) samples had the highest weight loss in all conditions. It is not surprising that weight loss would be high for heavy gauge samples, in which a large steel cathode is present that the zinc anode needs to protect. However, the higher weight loss seen with the thicker zinc coating, (G180 vs. G60) both in chromated condition could not be explained. In all cases, corrosion appeared to be uniform on these samples, as seen in Figures 3 and 4. Although Figures 3 and 4 show specimens removed after 30 days exposure, Figures 1 and 2 indicate that weight loss differences between the various sample types are already apparent, because so much of the observed corrosion occurred during the initial exposure period, as noted above. For the sheet samples, the CA formulation environment resulted in significantly higher weight losses for all of the conventional galvanized coatings, regardless of gauge coated thickness or use of a chromate or acrylic treatment. For the Galvalume specimens, the results are mixed: for the chromated light gauge Galvalume, behavior was equivalent in CA and ACQ while on the acrylic coated heavy gauge Galvalume corrosion in ACQ was found to be higher than CA. In the other two Galvalume cases (chromated heavy gauge and acrylic light gauge) the CA environment was more corrosive to the sheet samples than ACQ.

The acceleration factor of corrosion rate for the CA and ACQ samples relative to CCA for the regular galvanized samples (G60 and G90), irrespective of post treatment type, was usually below 2, although in three cases it was only slightly over 2 for the CA environment. In the case of Galvalume, the acceleration factor was much higher, being never less than 2.45 and in one case reaching 5.12. Thus, the test developed in this work appears to be less aggressive for regular galvanized than the AWPA E12 test. Prior work using the AWPA E12 test with Galvalume is shown in reference 2. In this work, Galvalume, either in the form of chromated AZ55 on an 0.6 mm (0.0235 in) substrate or acrylic coated AZ55 on a 0.4 mm (0.0163 in) substrate was used. Therefore the substrate thicknesses in the past work were thinner than the thin gauge Galvalume used in the present work and were also smaller, being only 25.4 x 50.8 mm (1 x 2 in). These were exposed to ACQ and CCA samples with the same retention rate as those used in the current work, 6 mg/cm^3 (0.4 lb/ft^3). Samples were held for 366 hours after which very little corrosion of samples exposed to the ACQ solution was observed. Therefore the test was continued until a total of 1,008 hours of exposure were accumulated similar to the present work. Lumber treated with ACQ was found to be much more aggressive to Galvalume than lumber treated with CCA, regardless of whether it was chromated or acrylic coated. The acceleration factor between the chromated samples exposed to ACQ vs. CCA in the past work using the AWPA formula was approximately 1.77, slightly lower than the value of 2.35 seen in the light gauge samples after 60 days of exposure in the current work. The basic weight change data from that paper gave an acceleration factor of 1.94. For the acrylic coated samples, the acceleration factor was approximately 6.9 for ACQ exposed vs. CCA exposed samples using AWPA formula and 3.23 using the basic weight change data, lower than the acceleration factor of approximately 12 observed in the current work, however it should be noted that the rate of attack of the CCA formulation on resin-coated light gauge Galvalume in the present work was so small as to be practically undetectable. Moreover, after 180 days, the acceleration factor in the current work declined to 5.12. As demonstrated in the current work, corrosion rates can slow significantly even between 30 and 60 days of exposure. Like the previous study, the current work also shows the insufficiency of short exposure times, less than approximately 1,000 hours, in assessing relative corrosion performance of the specimens examined in this work.

Figure 5 shows the average fastener mass loss data for all three retrievals. The most striking result is the much lower corrosion rates of hot dip galvanized screws compared to the other fasteners. As in the case of the sheet samples, most corrosion occurred within the initial period, in this case 15 days, after which corrosion weight losses out to the 90 day termination of the exposures occurred at a much slower rate. Although the hot dip galvanized screws had a very low amount of weight loss after cleaning, this figure is not necessarily indicative of a low amount of corrosion. Figure 6 shows the visual condition of all four varieties of fasteners removed from CCA and ACQ environments (as in all cases triplicate samples were tested, and are shown here), indicating the corrosion products observed on the hot dip galvanized fasteners. These were similar in appearance to the corrosion products observed on the other screws. Overall, very low weight loss or corrosion was observed after 90 days of exposure of all samples tested.

4. Conclusions

1. An accelerated test was developed and used to evaluate the corrosion rates of galvanized and Galvalume-coated sheet, and galvanized fasteners in pressure treated wood.

2. Coatings on thicker steel substrates exhibited higher rates of weight loss then coatings on thin gauge sheet and this could be explained by the higher mass of steel requiring protection by the galvanized coating. However, the thickest galvanized coating showed the highest rate of mass loss which could not be explained.

3. Most coating mass loss occurred during the first exposure period: 30 days for the sheet samples for which the exposure ran to 180 days and 15 days for fasteners for which exposures ran to 90 days. Therefore, significant passivation must occur during initial exposure.

4. Wood treated with CA and ACQ formulations gave higher corrosion rates than untreated or CCA treated reference samples. Usually, CA samples showed the highest corrosion rates, although several varieties of Galvalume showed higher corrosion rates in ACQ compared with CA.

5. The benefit of acrylic coatings on steel samples was greatest in the CA exposures, although they reduced corrosion rates in many other incidences.

6. ACQ and CA environments caused a roughly twofold acceleration of corrosion rates of galvanized steel compared with CCA. For Galvalume the acceleration rate was higher and also higher than accelerated corrosion results of others.

7. There is little influence of treatment type on fastener corrosion rate. Hot dip galvanized screws showed far superior corrosion resistance compared to the hot dip galvanized nails and hot galvanized nails and screws.

5. Literature

1. Simpson Strong-Tie, Inc., Technical Bulletin "Preservative Treated Wood" Issued January 2006, www.strongtie.com/ftp/bulletins/t-ptwood06.pdf

2. G.M. Smith, "Zincalume and HDG in Contact with Pressure Treated Lumber – A Comparative Corrosion Analysis," Proceedings of Interzac 2004, Luxembourg, September 6-10, 2004, BIC International, Vancouver, WA.

Tables

Table 1. Treated Wood Specimens Used for Testing

Wood Species	Treatment	Retention
Southern Yellow Pine (SYP)	Chromated Copper Arsenate (CCA)	0.4 lb/ft^3
	Copper Azoles (CA-B)	0.2 lb/ft^3
	Alkaline Copper Quaternary Ammonium Compound (ACQ)	0.4 lb/ft^3
Spruce Pine Fir (SPR)	Un-treated (UN)	0
For SI: 1 lb/ft^3 (pcf) = 16 Kg/m^3		

Table 2. Analysis of Active Species in Treated Wood Specimens, based on Wood Density of 32 pcf

Preservative	CuO	Cr O_3	AS_2O_5	Cu	Teb or Quart	Total Cu	Total Actives
CCA	0.083	0.193	0.138	NA[1]	NA[1]	0.066	0.414
CA-B	NA[1]	NA[1]	NA[1]	0.211	0.0074	0.211	0.219
ACQ Type D w./carboquat	0.237	NA[1]	NA[1]	NA[1]	0.0979	0.189	0.335

NA = Not Applicable

Table 3. Zinc and Zinc Alloy Coated Steel Sheet and Fastener Specimens Used for Testing

Sheet Steel Specimens			Fastener Specimens
Steel Type	Coating	Coating Weight	
Chromated Galvanized	G60	0.6 oz./ft^2 [a]	Hot Galvanized Nails HD Galvanized Screws Hot Galvanized Screws HD Galvanized Nails (Maze S263)
	G90	0.9 oz.ft^2 [a]	
	G185	0.185 oz/ft^2 [a]	
Chromated plus Acrylic	G90	0.9 oz/ft^2 [a], [b]	
Chromated Galvalume	AZ50	0.5 oz/ft^2 of Zn-55% Al-1.5% Si[a]	
Galvalume plus Acrylic	AZ55	15 mg/m^2 of Acrylic per side	
For SI: 1 oz/ft^2 = 304 g/m^2 [a] Weight on both sides [b] 10 to 20 mg/m,^{2} of Acrylic per side			

Figures

Figure 1. Comparison of Average Mass Losses for Heavy Gauge (1.37 mm or 0.054" thick, 16 gauge) Steel Sheet Samples

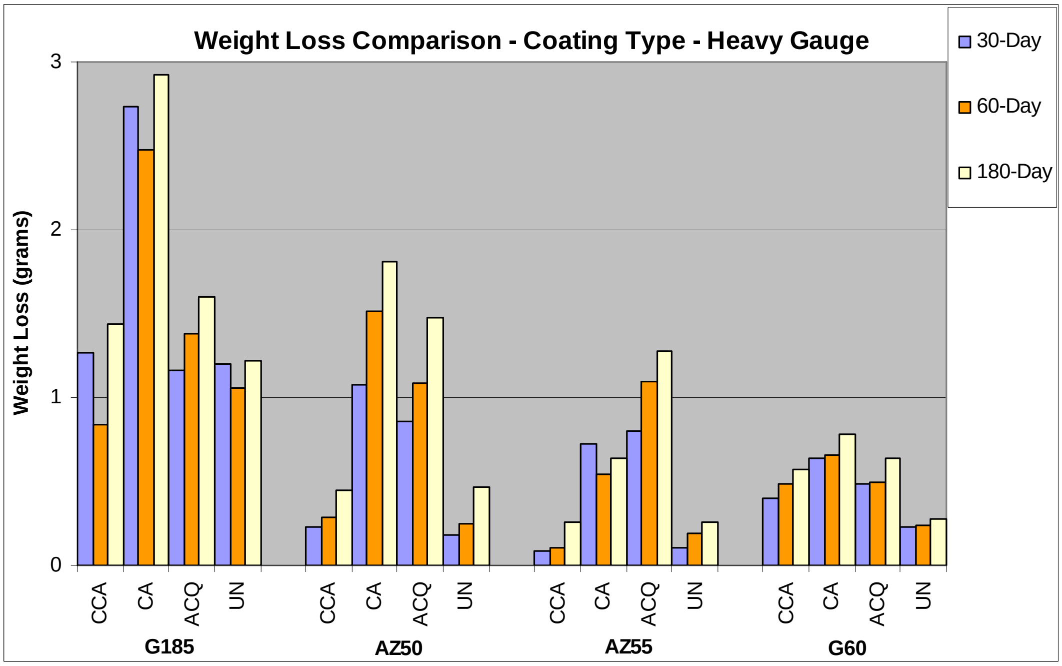

Figure 2. Comparison of Average Masses for Light Gauge (0.51 to 0.84 mm, 0.020-0.031" 23 to 20 gauge) steel Sheet Samples

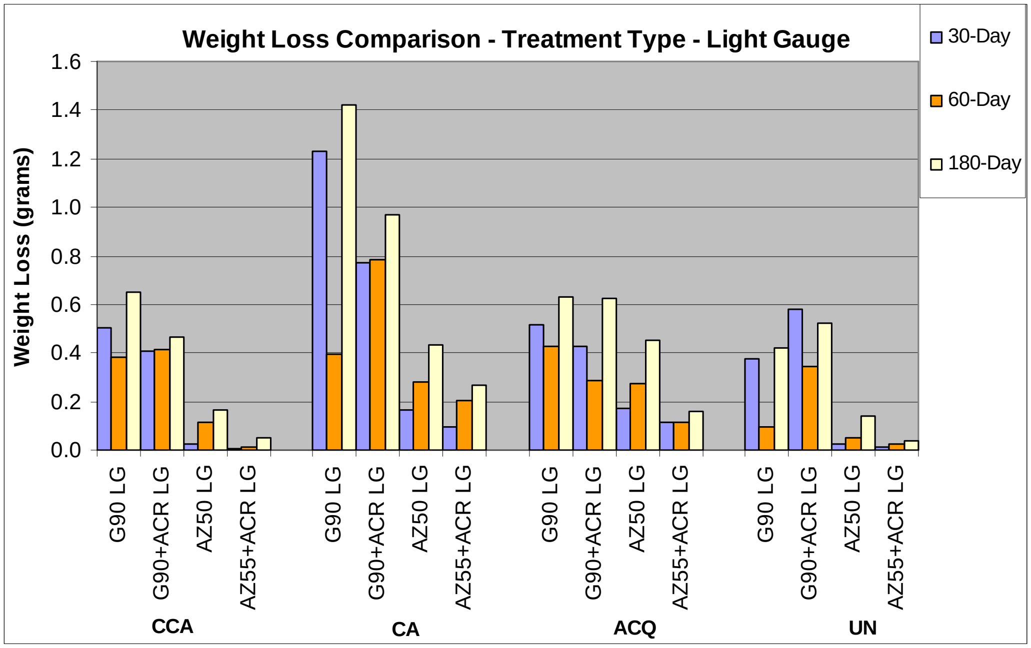

Figure 3. Visual Appearance of Sheet Steel Samples after 30 Days Exposure, Before Cleaning: ACQ and Untreated Wood Exposures

Figure 4. Visual Appearance of Sheet Steel Samples after 30 Days Exposure, Before Cleaning: CCA and CA Exposures

Figure 5. Comparison of Average Fastener Mass Losses

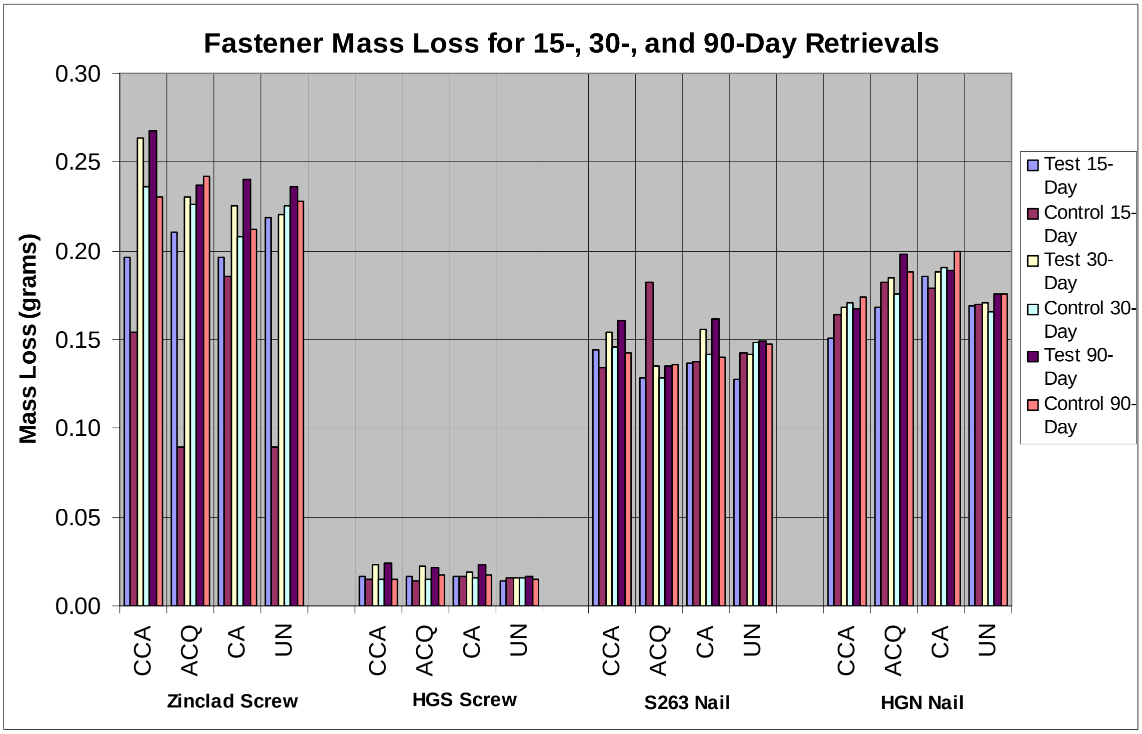

Figure 6. Visual Appearance of Fastener Specimens after 90 Days Exposure, Before Cleaning