Comparative Aboveground Performance of Pressure-Treated Copper Azole with Alternative Wood Protection Systems under Subtropical Conditions

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Abstract

The performance of several wood surface treatments as well as a silica treatment claiming to provide protection against fungal decay and termite attack in aboveground applications were examined in termite, ground proximity, and sandwich tests at a subtropical site near Hilo, Hawaii. In general, the surface treatments performed similarly to untreated controls and provided little or no protection against fungal or insect attack. The silicate treatment provided some termite and decay protection, but fungal decay resulted in rapid declines in condition after 50 to 54 months of exposure. Copper azole–treated lumber provided the best performance against both termites and fungal attack, illustrating the benefits of pressure treatment over surface treatments in high-decay-hazard environments. These results also illustrate the importance of rigorous testing and standardization protocols for any product that makes durability claims before it enters the market to ensure that it will perform as expected.

Wood exposed aboveground in exterior applications is invariably subjected to wetting that creates conditions conducive to fungal attack. Extending the useful life of timber requires either using naturally durable heartwood or impregnating nondurable timbers with chemicals toxic to wood-degrading organisms (Hunt and Garratt 1967). More recently, acetylated, furfurylated, and thermally modified woods have been developed as alternatives to preservative treatments and have shown good performance. All of these modified woods change the chemistry of the timber to reduce its water-holding capacity to limit the risk of fungal attack (Mai and Militz 2004, Flynn 2006, Hill 2007, Chen 2009, Kutnik and Reynaud 2015, Lahtela and Kärki 2015).

Other methods of wood preservation, such as dip treatments and spray-on treatments, are sometimes used in conjunction with protective coatings where the risk of decay is somewhat lower, such as the treatment of millwork (Ross 1988). Some recently developed spray-on or silica impregnation–type treatments claim to reduce chemical leaching into the environment while still imparting adequate durability to wood in applications where pressure treatments are recommended.

While there are a number of laboratory and field trials examining the efficacy of traditional preservatives as well as modified woods, there are few tests examining the efficacy of novel spray-on or silica-based treatments. Without proper testing, end users cannot make informed decisions about the efficacy of these products.

The objective of the following study was to compare the performance of untreated wood and wood pressure treated with copper azole with that of several commercially produced spray-on or silica-based treatments. Products were tested in an aboveground exposure test in a subtropical

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Forest Prod. J. 70(3):335–339.
doi:10.13073/FPJ-D-20-00023

climate as described for Use Category 3B in the American Wood Protection Association (AWPA) Use Category Standards. Wood applications in this category include decking, railings, millwork, fence pickets, and deck joists. All of these applications are exposed to periodic wetting that creates a higher risk of decay and insect attack.

Materials and Methods

All materials in this test were commercially treated and provided to Oregon State University as nominal 2 by 4 in. (50 by 100 mm, 38 by 89 actual) lumber that was then cut to lengths appropriate for each test method (Table 1). The first sets were exposed in November 2013. In June 2015, additional samples consisting of new, nontreated Douglas-fir lumber; the new EcoRed Shield (II); and disodium octaborate tetrahydrate (borate)–treated wood were placed in test. Eco Red Shield II was added because there were claims that the formulation had changed. Both EcoRed Shield and BluWood are reported to contain borate; however, an analysis of the outer 5-mm shell of selected samples from each treatment failed to find boron above the background level in untreated wood (data not shown). Wood pressure treated with borate was included because it is sometimes exposed outdoors in aboveground applications. The borates were commercially treated to the Use Category 3A retention, while the copper azole (Type B) was treated to Use Category 3B (AWPA 2019a).

Lumber was cut to the appropriate size for each exposure. All cut ends were dipped for 30 seconds in a solution of 4.8 percent pentachlorophenol (penta) in diesel oil or 2 percent copper naphthenate (as Cu) in diesel oil to protect the potentially untreated ends exposed by cutting. This was essential since most of the tested treatments function as barriers. Penta and copper naphthenate created a secondary barrier on the end cuts that should protect the wood from fungal and termite invasion through these exposed areas.

Although not specially called for with TimberSil, Eco Red Shield, or BluWood, AWPA Standard M4 requires that any wood exposed through cuts or drilling be supplementally treated with a preservative solution (AWPA 2019b). Copper naphthenate (2%) and oxine copper (0.12% as Cu) are currently listed in the standard; penta was also formerly used for this purpose but is no longer labeled for field treatment of cut ends.

Samples were exposed in test sites at Hilo, Hawaii. The Hilo site receives more than 5 m of rainfall per year and has average daytime temperatures between 27°C and 30°C. The Climate Index, which uses average monthly temperature and days with measurable rainfall to calculate the risk of decay aboveground, is over 200 at this site, which would classify the decay hazard as extreme for aboveground decay (Scheffer 1971, Freitag et al. 1995, Molnar et al. 1997, Preston et al. 2000).

The materials were tested in three configurations, discussed in the following sections.

AWPA E26 ground proximity termite test

Resistance to attack by Formosan termites (*Coptotermes formosanus*) was evaluated using a modification of AWPA Standard E26 (AWPA 2019d). Briefly, hollow concrete blocks were placed on the soil. Pine sapwood stakes were driven into the ground within the hollow blocks to attract termites, then the wood test blocks (38 by 89 by 100 mm) were placed on the concrete blocks in between nontreated wood that serves as feeder material for the workers to explore.

The blocks were covered with a water-shedding cap that produced a dry, nonsoil contact exposure equivalent to a Use Category 1 or 2 exposure. It is important to note that this test does not expose the wood to any rainfall, and, as a result, there is no potential for leaching of any active ingredients from the blocks.

Formosan termites are extremely aggressive, and untreated wood at the Hilo test site is typically destroyed within 6 months of installation. Control and test samples were evaluated at 6-month intervals for degree of termite attack on a scale from 10 (no attack) to 0 (failure) as described in the standard. Any residual termite-damaged feeder wood was removed, new stakes were driven into the ground, and test pieces were again surrounded by untreated feeder material to encourage renewed termite attack.

Fifteen blocks were tested for each treatment, and the test was evaluated after 7, 12, 18, and 30 months of exposure. These procedures were also used for the samples established in 2015, but the termite colony had declined for unknown reasons, and the test was abandoned after 1 year. Thus, only results for the first test are reported herein.

Ground proximity decay tests

Resistance to decay in a Use Category 3B–type exposure was evaluated in two aboveground tests. In the first, 125-mm-long blocks were cut and placed on concrete blocks following the procedures described in AWPA Standard E18 (AWPA 2019c). The blocks were covered with a mesh that limited direct sunlight exposure but allowed rain to enter.

Thirty-five blocks were installed for each treatment in the first phase, then 10 blocks were exposed in the second phase. Block condition was visually assessed at 6-month intervals for the first 48 months, then yearly thereafter. Condition was rated on scale from 10 (sound, no decay) to 0

Table 1.—Treatments evaluated for decay and termite resistance in aboveground exposures at sites located in Hilo, Hawaii.

Treatment	Source	Wood species	Year installed	Samples/test		
				E18	E26	Sandwich
Control	—	Douglas-fir	2013	15	35	10
Eco Red Shield I	Eco Building Products, Vista, CA	Douglas-fir	2013	15	35	10
BluWood	Conrad Wood Preserving, Coos Bay, OR	Douglas-fir	2013	15	35	10
TimberSIL (pressure treated)	Timber Treatment Technology, Greenville, SC	Southern pine	2013	15	35	10
Copper azole (pressure treated)	Exterior Wood, Washougal, WA	Douglas-fir	2013	15	35	10
Control	—	Douglas-fir	2015	10	10	10
Eco Red Shield II	Eco Building Products, Vista, CA	Hem-fir	2015	10	10	10
Borate (pressure treated)	Royal Pacific Wood Preserving, McMinnville, OR	Hem-fir	2015	10	10	10

(functional failure where specimen can be broken by hand or penetrated with a probe) as described by the standard.

Sandwich test

Samples of each treatment were evaluated in a sandwich test. Briefly, a total of 30 samples, 275 mm long, were cut from the boards in each treatment. Three pieces from a given treatment were combined and tied together using plastic zip ties.

The assemblies were then exposed with the narrow faces upward on aluminum racks approximately 300 mm off the ground. These assemblies were designed to trap water and encourage fungal colonization between the board faces. Test assemblies in this procedure sometimes use a nontreated sample in the middle to serve as a decay susceptible feeder for decay fungi to grow before they attack the treated test pieces on the outside. However, this was not done, and instead, all three pieces were composed of the same treatment.

The zip ties were periodically removed, and the assemblies were visually examined for degree of decay by probing all the surfaces to detect any visible decay and rating each piece on the scale previously mentioned for the ground proximity test. Ratings from the three pieces in each assembly were averaged. Decayed or suspicious areas were further probed with a sharp-edged tool to determine the extent of any damage. The sandwiches were reassembled and placed back on the racks for additional exposure. A total of 10 sandwiches was exposed per treatment.

Results and Discussion

Ground proximity termite test

Untreated wood was rapidly attacked by termites 7 months after installation, and all feeder material was destroyed (Table 2). The results indicate that the materials were subjected to extreme termite pressure. Untreated control blocks had average ratings of 5.53 after 7 months and were virtually destroyed after 12 months. New control blocks installed at the 12-month point were rated 3.1 six months later, attesting to the high termite pressure.

Copper azole–treated samples experienced very slight attack after 7 months of exposure, and the ratings remained at 9.9 for the remainder of the test, indicating that this system had good performance against Formosan termites.

TimberSIL-treated samples experienced slight attack after 7 months with average ratings around 8.5, and the condition of the samples remained stable for the remainder of the test. The results suggest that the treatment provided some protection to the wood, but users would have to expect some level of termite attack as the workers explored the area for suitable substrate.

Table 2.—Condition of blocks treated with various preservative systems and exposed to Formosan termite attack for 7, 12, 18, or 30 months in Hilo, Hawaii, using an American Wood Protection Association E26 ground proximity termite test.[a]

Treatment	Sample condition			
	7 mo	12 mo	18 mo	30 mo
Untreated	5.53 (2.80)	1.3 (3.3)	3.1 (3.3)[b]	3.2 (3.2)
EcoRed Shield I	0.27 (1.03)	0	0	0
BluWood	4.00 (3.20)	0.6 (2.3)	1.8 (2.4)	1.8 (2.0)
TimberSIL	8.40 (2.02)	8.0 (3.3)	9.0 (1.1)	8.5 (1.8)
Copper azole	9.77 (0.37)	9.9 (0.3)	9.7 (0.8)	9.9 (0.3)

[a] Values represent means of 15 specimens per treatment. Figures in parentheses represent one standard deviation.

[b] New untreated control samples were installed at 12 months to confirm that termite attack was continuing.

BluWood samples were heavily attacked after 7 months of exposure and completely destroyed at the end of 12 months. These results were similar to those for the untreated controls, suggesting that this treatment had no noticeable effect on termite attack.

Similarly, EcoRed Shield I–treated samples were heavily attacked by termites 7 months after installation with average ratings well below 1 and were destroyed after 12 months. These results suggest that the EcoRed Shield I–coated samples were more attractive to termite attack than the untreated controls.

E18 ground proximity tests

Ground proximity testing is considered an extreme aboveground exposure, especially at the Hilo site (Preston et al. 2000, 2011; Cabrera and Morrell 2012; Zahora et al. 2012). Regular rainfall ensures that the wood blocks are almost always wet, and the concrete blocks create an environment that is highly conducive to decay.

While most of the samples were heavily discolored within 18 months of exposure in samples exposed in 2013, decay did not begin to appear until 30 months into the test (Table 3). This, in part, reflects the use of larger samples that made it more difficult to detect decay beyond the wood surface.

However, all of the samples except copper azole–treated pieces experienced a steady increase in the presence of decay over the next 42 months. Douglas-fir heartwood is moderately durable and should perform slightly better than untreated material of southern pine sapwood or hem-fir (Scheffer and Morrell 1998). Untreated control samples reached an average rating of 4.39 at 72 months, compared with a rating of 3.72 for EcoRed Shield I and 5.03 for BluWood samples. Most of the samples in these treatment groups exhibited evidence of advanced decay, and the small differences in the ratings suggest that EcoRed Shield I or BluWood provided little added protection against fungal attack.

The most interesting results were obtained with TimberSIL-treated samples. These samples had ratings that were similar to those for the untreated control for the first 42 months of exposure, although it is important to note that they tended to absorb a large amount of water. While southern pine is very permeable and will tend to absorb water, these samples tended to be far heavier than other southern pine samples at the site. Sample condition declined precipitously between 42 and 48 months of exposure, and all of the samples failed at 72 months.

In all instances, the failures were a combination of biological and physical damage. In many cases, the samples became extremely fibrous and broke apart, suggesting that the excessive moisture sorption by these samples exacerbated any biological activity.

Copper azole–treated samples were sound on the lateral, treated surfaces, but a number had begun to experience decay on the cut surfaces that had been treated with penta. While this did not affect the ratings, which were still approaching 9, it did highlight the value of end coating as well as the fact that it does not provide permanent protection.

Table 3.—Condition of various wood samples exposed to fungal attack in an American Wood Protection Association E18 ground proximity test for 18 to 72 months in Hilo, Hawaii.[a]

Treatment	Sample condition							
	18 mo	24 mo	30 mo	37 mo	42 mo	48 mo	58 mo	72 mo
Control	9.90 (0.20)	9.84 (0.32)	9.62 (0.60)	8.89 (1.10)	7.89 (1.01)	8.50 (1.65)	6.74 (1.55)	4.39 (2.33)
EcoRed Shield I	9.86 (0.20)	9.61 (0.58)	9.54 (0.44)	9.00 (1.36)	7.98 (1.70)	7.25 (1.61)	6.00 (2.61)	3.72 (2.79)
BluWood	9.90 (0.20)	9.77 (0.35)	9.50 (0.89)	8.90 (1.14)	8.24 (1.09)	7.71 (1.69)	6.45 (1.75)	5.03 (2.06)
TimberSIL	9.90 (0.20)	9.53 (0.76)	9.42 (0.40)	8.58 (1.28)	7.73 (1.41)	2.65 (2.48)	1.65 (2.17)	0 (0)
Copper azole	9.98 (0.08)	10.00 (0)	10.00 (0)	10.00 (0)	9.92 (0.23)	9.94 (0.25)	9.77 (0.43)	8.87 (1.50)

[a] Samples were visually assessed on a scale from 10 (no damage) to 0 (complete failure). Values represent means of 35 samples, while figures in parentheses represent one standard deviation.

Both EcoRed Shield II–treated and borate-treated samples exposed in 2015 were beginning to show evidence of decay after 54 months of exposure (Table 4). Ratings for Eco Red Shield II in this test were similar to those for the Eco Red Shield I system at the same time point, suggesting that whatever changes had been made to the system had not markedly improved performance.

Decay found in borate-treated samples was expected since this product is not recommended for exterior exposures unless it is protected from wetting. It was included in the test since it is often sold in Hawaii and used outdoors against the manufacturer's recommendations. These results support those recommendations.

Sandwich tests

While the ground proximity decay test creates an extreme water trap on the bottom of samples, the sandwich test avoids the continuous water trapping but creates two excellent locations for water intrusion that should create ideal conditions for fungal colonization and decay development.

Decay progressed slowly but in much the same pattern as was seen in the ground proximity samples (Tables 5 and 6). Ratings for the control and BluWood-treated samples were similar after 72 months, while Eco Red Shield I–treated samples were in slightly poorer condition.

As with the ground proximity tests, the TimberSIL-treated samples were extremely hygroscopic. While this did not initially affect the evaluations, which were similar to those for the untreated controls, it did raise serious questions about the effects of such a large weight gain on properties. For example, the increased mass of the materials, which have been proposed for use as decking, could markedly increase the dead loads on the underlying joists. As with the ground proximity tests, the condition of TimberSIL-treated materials also declined precipitously, but the effect was not noticed until 72 months of exposure.

The condition of EcoRed Shield II–treated samples exposed in 2015 were following a trend similar to that found in the first test, again suggesting that this treatment had no noticeable effect on decay resistance.

Ratings for borate-treated sandwiches tended to decline more slowly than the samples in the ground proximity test, with the ratings at 54 months still above 6. The differences can be explained by the leaching conditions created by each test. The ground proximity test places wood directly on concrete blocks and tends to create a continuous water film on the bottom of specimens. The ability of borates to

Table 4.—Condition of various wood samples exposed to fungal attack in an American Wood Protection Association E18 ground proximity test for 54 months in Hilo, Hawaii.[a]

Treatment	Sample condition				
	18 mo	24 mo	30 mo	40 mo	54 mo
Control	9.98 (0.11)	9.57 (0.41)	9.68 (0.95)	8.47 (1.68)	
EcoRed Shield II	9.95 (0.16)	9.50 (0.40)	8.95 (1.36)	8.05 (1.50)	5.70 (2.30)
Borate	10.00 (0.00)	9.63 (0.36)	8.90 (1.92)	7.95 (2.09)	5.55 (3.50)

[a] Samples were visually assessed on a scale from 10 (no damage) to 0 (complete failure). Values represent means of 10 samples, while figures in parentheses represent one standard deviation.

Table 5.—Condition of various wood samples exposed for 18 to 72 months as sandwiches in an aboveground test in Hilo, Hawaii.[a]

Treatment	Sample condition							
	18 mo	24 mo	30 mo	37 mo	42 mo	48 mo	58 mo	72 mo
Control	9.90 (0.23)	9.75 (0.42)	9.40 (1.30)	9.60 (0.90)	8.65 (2.04)	8.50 (1.74)	5.93 (2.67)	5.87 (3.06)
EcoRed Shield I	9.47 (0.27)	9.02 (0.72)	8.90 (0.98)	8.60 (1.03)	7.57 (1.64)	7.07 (2.04)	5.60 (1.99)	3.73 (2.68)
BluWood	9.90 (0.18)	9.89 (0.27)	9.90 (0.18)	9.80 (0.20)	9.43 (0.65)	9.40 (0.40)	8.67 (1.08)	6.49 (2.11)
TimberSIL	9.90 (0.18)	9.83 (0.33)	9.40 (0.57)	9.50 (0.40)	7.57 (1.50)	7.67 (0.93)	6.30 (1.43)	2.20 (3.29)
Copper azole	10.00 (0.0)	10.00 (0.0)	10.00 (0.0)	10.00 (0.0)	9.93 (0.21)	10.00 (0.00)	10.00 (0.00)	9.56 (1.08)

[a] Samples were visually assessed on a scale from 10 (no damage) to 0 (complete failure). Values represent means of 10 samples, while figures in parentheses represent one standard deviation.

Table 6.—Condition of various wood samples exposed for 18 to 54 months as sandwiches in an aboveground test in Hilo, Hawaii.[a]

Treatment	Sample condition				
	12 mo	18 mo	30 mo	40 mo	54 mo
Control	9.78 (0.55)	8.92 (1.64)	7.93 (1.98)	5.93 (2.67)	3.41 (3.19)
EcoRed Shield II	9.95 (0.11)	9.75 (0.31)	9.03 (1.17)	7.97 (1.57)	3.71 (3.63)
Borate	10.00 (0.00)	9.90 (0.15)	9.33 (0.80)	7.78 (1.82)	6.49 (2.14)

[a] Samples were visually assessed on a scale from 10 (no damage) to 0 (complete failure). Values represent means of 10 samples, while figures in parentheses represent one standard deviation.

migrate with moisture is well documented, and this test creates ideal conditions for that process, leading to depletion and eventually decay.

The sandwich test, while creating excellent opportunities for wetting and fungal growth, does not create the continuous leaching environment, resulting in improved performance relative to the ground proximity test.

Conclusions

In general, surface-treated timbers performed similarly to untreated wood, suggesting that these treatments provided little added benefit. Silicate-treated timbers performed well for 50 to 54 months, but then their condition declined rapidly. Wood pressure treated with copper azole outperformed all other treatments in every test conducted, while borate-treated wood performed well in the less aggressive sandwich test. The results presented here highlight the importance of rigorous testing prior to commercialization using standardized protocols for wood treatments claiming to enhance durability to protect consumers from ineffective products.

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