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Effect of Concrete on the pH and Susceptibility of Treated Pine to Decay by Brown-Rot Fungi

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Abstract: Treated wood timbers employed in ground contact are often installed with a cement collar to firmly fix the structural wood post in place. Few prior studies have determined the effect of concrete on decay efficacy on treated wood, however. Treated wood nominal 4 × 4 posts were installed at four locations, with the upper ground-contact portion of each post encased in concrete, and the samples removed at various times for pH measurements. The wood alkalinity quickly increased at all four sites for the portion of the treated wood in concrete contact compared to the wood in ground contact without concrete. In laboratory decay tests employing three decay fungi, untreated wood which was first exposed or unexposed to concrete had no consistent difference in decay susceptibility. For wood treated with three different commercial copper/organic systems, cement exposure had no effect on wood treated with an amine copper azole system, while treatment with amine copper quat showed a statistically significant fungal efficacy enhancement for cement-exposed samples with both copper-tolerant fungi. Conversely, with a micronized copper azole preservative, cement exposure resulted in reduced fungal efficacy compared to treated samples which were not cement-exposed for all three decay fungi.

Keywords: cement; wood decay; soil block test; wood preservatives

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1. Introduction

Treated wood products are often used as posts in ground contact to support decks and various other structures. To minimize lateral movement, cement is often applied around the posts. Presently, it is unknown what effect the alkaline cement, which contains high levels of alkaline calcium compounds that would increase the pH of the wood, has on the efficacy of the treated wood against brown-rot decay fungi. If the cement does increase the susceptibility of treated wood to decay, it could reduce the service life of the posts and pose serious issues due to early collapse of structures and resulting injuries.

Early studies indicated that for chromated copper arsenate (CCA) treated wood the inclusion of concrete collars may enhance soft-rot decay in some applications [1–3]. In a more recent lab study using agar block microcosms [4], it was shown that both $CaCl_2$ and $CaSO_4$ inhibited decay of untreated sapwood by *Serpula lacrymans* and *Serpula himantioides*. Another study evaluated the effect of $CaCl_2$ on decay of untreated wood and copper-citrate-treated wood when exposed to *S. lacrymans* in a soil block test [5]. They concluded that $CaCl_2$ inhibited decay by this fungus for the copper-citrate-treated wood, but not for untreated wood. Another study reported that sapwood pine samples in soil block decay tests with 2% $CaCl_2$ added to the soil significantly reduced the extent of decay by both *Gloeophyllum trabeum* and *Rhodonia placenta* [6].

On the basis of the above limited studies it appears that calcium, which is a major component of cement, can in some cases influence the rate of wood decay by common wood-degrading fungi. However, it is not known what effect cement, which contains high levels of CaO and has a pH of 13, has on the performance of wood treated with commercial copper-based wood preservatives currently being used in soil contact applications. To provide some insight into the influence of concrete exposure on treated wood performance, our first goal of this study was to determine to what extent the Ca compounds in cement diffuse into treated wood when a cement collar is applied during installation of posts in soil. The second goal was to determine what effect cement has on the decay resistance of untreated wood or wood treated with commercial copper-based wood preservatives used in residential applications in North America.

2. Materials and Methods

2.1. Cement Diffusion Study

Four 12-foot nominal 4 × 4 southern pine (*Pinus spp.*) posts commercially treated with micronized copper azole (MCA) with a labeled retention of 2.4 kg/m^3 were obtained from a local lumber dealer in Starkville, Mississippi (MS). (Confusingly, in the US the actual size of lumber is smaller than the nominal size. This is due to lumber being sold over 100 years ago in the green and rough state; in later years when lumber was kiln dried then planed before being sold, the original green and rough size was still employed but denotated as nominal size. Further, the US Federal Code specifies that while the dimensions are to be in inches, the inch unit is not given. Thus, the actual size of a nominal 4 × 4 is 3.5 × 3.5 inches, or 89 × 89 mm.) Each of the four posts were then crosscut into four 864 mm long by 89 × 89 mm pieces, with each tagged. Four pieces, one from each of the four posts, were then installed in soil to a depth of 500 mm at each of four outdoor test sites which had soil pH values ranging from acid to alkaline. Three of the selected test sites were in the Starkville MS area and the fourth was at our Saucier MS test site in southern MS. Before backfilling with soil, Sakrete™ cement was applied to an area from the ground line to approximately 60 mm below the ground line. Following this, to determine whether cement components would diffuse into the posts, one post section was removed from each site at three exposure periods ranging from 42 to 340 days (Table 1). These post sections were then crosscut to provide 5-mm-thick samples (longitudinal direction) from both above ground areas and also two ground-contact areas, with and without cement contact. Each of these samples was then cut into sections at three depths, representing the outer 4.5 mm, second 4.5 mm and third 4.5 mm zones. Representative samples from these sections were then ground in a Wiley mill using a 20-mesh screen. One wood meal sample from each section was then evaluated by adding 10 mL of deionized (DI) water to 1 g of wood meal and the pH measured after one hour with a calibrated pH meter.

Table 1. Effect of cement on the pH of micronized or particulate copper azole system (MCA) treated wood after exposure of nominal 4 × 4 posts to soil contact at four different locations in Mississippi.

Post Exposure Site	Exposure Time (Days)	Wood pH at Var. Sample Depths and Vert. Location [1] in Posts											
		0–4.5 (mm)				4.5–9 (mm)				9–13.5 (mm)			
		A	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
Dorman	42	5.4	6.3	8.4	5.8	5.3	5.5	6.4	5.4	5.2	5.4	5.5	5.2
Dorman	208	5.0	5.1	8.1	5.8	5.0	5.0	6.8	5.3	4.8	4.9	6.0	5.1
Dorman	320	5.3	6.1	8.5	5.9	5.2	5.4	6.9	5.4	5.0	5.1	5.9	5.1
Saucier	39	5.3	6.4	9.3	5.7	5.3	5.6	8.4	5.5	5.3	5.3	6.6	5.4
Saucier	173	4.8	4.8	8.9	5.7	4.7	7.8	7.8	5.5	4.7	4,7	6.8	5.2
Saucier	340	5.0	5.6	9.1	5.8	5.0	5.1	7.9	5.4	5.0	5.1	7.0	5.5
Hillbrook	42	5.3	5.4	8.0	5.9	5.2	5.2	6.0	5.4	5.1	5.1	5.5	5.3
Hillbrook	177	5.2	5.0	7.3	5.9	5.0	5.0	6.1	5.6	4.9	4.9	5.7	5.4
Hillbrook	320	5.1	5.2	7.8	5.9	5.1	5.2	6.0	5.4	5.0	5.0	5.8	5.5
Longs Lk	42	5.4	5.6	8.3	6.0	5.2	5.5	6.3	5.6	5.1	5.3	5.8	5.4
Longs Lk	173	5.1	5.2	7.4	5.6	5.3	5.0	6.6	6.0	4.9	5.0	6.0	5.2
Longs Lk	320	5.3	5.4	8.0	5.4	5.1	5.3	6.5	5.8	5.0	5.2	6.1	5.4

[1] **A** denotes aboveground sample, **B** denotes aboveground samples adjacent to the ground line, **C** denotes sample in contact with concrete belowground, **D** denotes sample belowground not in contact with concrete.

Since cement contains high levels of calcium oxide, which has an approximate pH of 13, the pH of wood in contact with the cement should increase if appreciable amounts of the alkaline calcium salt diffuse into wood. Consequently, measuring the pH of wood in contact with cement was considered to be a good measure of calcium migration into wood.

2.2. Laboratory Decay Test

To determine the effect of cement on wood decay, a soil block test was performed with three brown-rot fungi. The decay test was carried out in accordance with American Wood Protection Association (AWPA) Standard E22-15 using three different brown-rot fungi, *Gloeophyllum trabeum* (ATCC 11539; American Type Culture Collection, Old Town Manassas, Virgina, VA, USA), *Rhodonia placenta* (ATCC 11538) and *Fibroporia radiculosa* (TFFH 294, USDA FPL). The fungal cultures were maintained on 2% malt extract agar (Difco Laboratories, Detroit, Michigan, MI, USA). A total of eight replicate wafers were used in each test, using four and six weeks of exposure time for each decay test.

The wood test samples for the decay test were produced from three flatsawn pine (*Pinus glabra* Walt.) boards. Three defect-free sapwood sections measuring 19 × 70 × 1120 mm (radial × tangential × longitudinal) were cut from each of the boards, providing one sample for each of the three test fungi. These samples were then rip sawn into three 19 × 19 × 1120 mm sticks which were randomly assigned to each of the three preservative treatments. Each stick was then crosscut into two 560-mm-long pieces to provide end-matched untreated material for controls. The sticks designated for treatment were then pressure treated to a target of the specified ground-contact residential retention with three commercial copper-based systems (with the actual retention obtained shown in parenthesis): the amine copper azole system (CA-C, 2.3 kg/m^3), the amine copper quaternary system (ACQ-D, 6.3 kg/m^3) and micronized or particulate copper azole system (MCA, 2.4 kg/m^3). The full cell pressure treatment used an initial vacuum of 95 kPa for 30 min followed by 1034 kPa pressure for 30 min. The samples were then wiped clean and weighed to determine the actual treating solution retention before air drying the samples. The actual retentions for all three preservatives were within 0.1 kg/m^3 of the specified AWPA UC4A retention.

Both the untreated and treated sticks were then crosscut into two 280-mm-long pieces to provide samples for cement-exposure and non-cement-exposure controls. The sticks designated for cement exposure were end-sealed with a wax emulsion (seal type ISK Biocides, Memphis, Tennessee, TN, USA) and then coated with a thin layer of wet Sakrete™ cement purchased at Lowes, Starkville, Mississippi, MS, USA, approximately 5 mm thick, on all the lateral surfaces and allowed to air dry. Following this, the cement-coated sticks were wrapped in nylon stocking material and placed vertically into plastic buckets containing wet soil obtained from the Dorman MS wood preservation test plot. After 45 days of exposure the sticks were removed and allowed to air dry. The cement was then removed from the sticks followed by a thorough cleaning to remove all visible cement from the surfaces.

Each of the twelve 280-mm-long sticks was then crosscut to provide three groups of 5-mm-thick wafers for the soil block test. Within each stick, one group of wafers was designated as unexposed controls and the other two groups were assigned to the two fungal exposure of four and six weeks. After fungal decay exposure the compression strength was measured as per AWPA E22 Standard, with the extent of deterioration reported as the strength loss of the fungal-exposed samples relative to the unexposed matched controls. On sets where the strength difference between the treated samples that were cement-exposed compared to non-cement-exposed appeared appreciably different at four and six weeks of exposure, a *t*-test was run using the individual eight replicate samples using Minitab at the 95% confidence level.

3. Results and Discussion

The data in Table 1 clearly show that when cement is applied to nominal 4 × 4 posts in soil contact, alkaline components diffuse into the wood. As expected, the alkalinity is greatest in the outer 0–4.5 mm zone for belowground wood adjacent to the cement (samples C) compared to the lower portion of the wood with no cement (samples D), with good diffusion into the wood outer shell occurring at all four test sites. The middle zone of 4.5–9 mm also shows greater alkalinity for cement-exposed C samples as compared to D samples, and the inner 9–13.5 mm zone also shows greater alkalinity with the alkalinity increasing somewhat at the longer exposure times. The data also indicate that diffusion occurs rapidly in the outermost layer, with no appreciable increase with the longer exposure times. With regard to the effect of exposure sites, greater diffusion occurred at the Saucier test site.

Results of the soil block decay test with three brown-rot fungi for samples with and without cement exposure are presented in Tables 2–4. The results are presented as the average percent compression strength loss after exposure to the fungus for four and six weeks of exposure, with greater values indicating higher deterioration. Table 2 represents the copper-intolerant fungus *G. trabeum*; Tables 3 and 4 show the highly aggressive copper-tolerant fungi *R. placenta* and *F. radiculosa*, respectively.

Table 2. Comparative decay resistance of untreated and preservative-treated pine wafers with and without cement infusion and exposed to *Gloeophyllum trabeum* in a soil block test. Each value is the average of eight replicates, with high values representing extensive decay.

Preservative Treatment	Cement Treatment	Percent Compression Strength Lost after Exposure to the Fungus for:	
		4 Weeks	6 Weeks
None	No	97	98
None	Yes	98	98
CA-C	No	6	10
CA-C	Yes	0	0
None	No	98	99
None	Yes	99	100
ACQ-D	No	11	8
ACQ-D	Yes	6	12
None	No	96	97
None	Yes	98	97
MCA	No	22	14
MCA	Yes	27	40

Table 3. Comparative decay resistance of untreated and preservative-treated pine wafers with and without cement infusion and exposed to *Rhodonia placenta* in a soil block test. Each value is the average of eight replicates, with high values representing extensive decay.

Preservative Treatment	Cement Treatment	Percent Compression Strength Lost after Exposure to the Fungus for:	
		4 Weeks	6 Weeks
None	No	88	91
None	Yes	93	94
CA-C	No	91	96
CA-C	Yes	82	96
None	No	96	96
None	Yes	95	97
ACQ-D	No	63	94
ACQ-D	Yes	16	84
None	No	90	96
None	Yes	96	98
MCA	No	36	64
MCA	Yes	46	78

Table 4. Comparative decay resistance of untreated and preservative-treated pine wafers with and without cement infusion and exposed to *Fibroporia radiculosa* in a soil block decay test. Each value is the average of eight replicates, with high values representing extensive decay.

Preservative Treatment	**Cement Treatment**	**Percent Compression Strength Lost after Exposure to the Fungus for:**	
		4 Weeks	**6 Weeks**
None	No	92	95
None	Yes	95	98
CA-C	No	90	95
CA-C	Yes	85	97
None	No	91	94
None	Yes	94	97
ACQ-D	No	82	94
ACQ-D	Yes	26	69
None	No	89	92
None	Yes	84	96
MCA	No	89	91
MCA	Yes	93	96

For the untreated wood samples, extensive deterioration occurred with all three fungi for samples both exposed and unexposed to concrete, even at the shorter exposure time of four weeks. No consistent deterioration effect was observed between the concrete- and non-concrete-exposed untreated samples. Thus, we conclude that exposure to concrete gives no consistent difference in deterioration effect in short duration laboratory tests for pine samples which are untreated and exposed to three common decay fungi.

With the CA-C-treated samples, no or minor deterioration was obtained with the copper-intolerant *G. trabeum* fungus (Table 2). Conversely, with the copper-tolerant fungi *R. placenta* (Table 3) or *F. radiculosa* (Table 4), extensive deterioration occurred. However, with all three fungi no consistent practical differences were observed in the deterioration between the concrete-exposed versus concrete-unexposed CA-C-treated samples.

For the ACQ-D-treated samples, minor deterioration was obtained with the copper-intolerant fungus *G. trabeum* (Table 2) for both cement-exposed and unexposed samples. As expected, greater deterioration was observed with the copper-tolerant fungi *R. placenta* (Table 3) and *F. radiculosa* (Table 4). Interestingly, with both of these two copper-tolerant fungi, samples that were first exposed to concrete exhibited greater decay resistance compared to ACQ-D-treated samples which were not exposed to concrete. A *t*-test comparing cement-exposed versus non-cement-exposed samples showed that the greater efficacy was significant at the 95% or greater level for all four sets at both incubation times with the two copper-tolerant fungi. We hypothesize that greater alkalinity upon concrete exposure results in a stronger complex between the quat cation and the acidic anion groups in wood and, thus, enhanced fungicidal efficacy.

For MCA, or micronized copper azole, the copper is mainly present as submicron-sized particles, with even the smallest particulate copper particles composed of many millions of insoluble and thus nonfungicidal copper atoms; these copper atoms are slowly solubilized over time to form individual and therefore fungicidal copper ions with the solubilization rate increasing as the wood acidity increases. With MCA-treated samples, moderate deterioration was obtained with the copper-intolerant *G. trabeum* fungus (Table 2), with the concrete-exposed samples showing slightly more but not significant deterioration at four weeks and much greater and statistically significant deterioration at six weeks compared to the non-concrete-exposed samples based on a *t*-test. As expected with the aggressive copper-tolerant fungi *R. placenta* (Table 3) or *F. radiculosa* (Table 4), extensive deterioration occurred with the MCA-treated samples. While greater deterioration occurred for the concrete-exposed samples relative to the non-concrete-exposed samples at both four and six weeks for exposure with *R. placenta*, neither difference was statistically significant. With *F. radiculosa*, slightly greater decay was again obtained with the concrete-exposed samples, and while the difference at four weeks was not significant, the decay at six weeks was statistically greater for the concrete-exposed samples. We propose that the greater alkalinity for concrete-exposed samples, as determined in the first part of this study, results in reduced solubilization of the particulate copper and, consequently, lower amounts of soluble and, thus, fungicidal copper ions in concrete-exposed MCA-treated samples as compared to treated wood which is not exposed to concrete.

4. Conclusions

Commercial MCA-treated ground-contact posts surrounded by a concrete collar installed at four outdoor sites quickly increased to a greater pH than the lower portion of the post below the concrete at all four test sites locations. In laboratory soil block decay tests, untreated pine sapwood which was exposed or not exposed to concrete prior to fungal testing showed no deterioration effect upon exposure for 4 and 6 weeks to three different fungi. With wood samples treated with three commercial copper organic preservatives and exposed to three decay fungi, different decay efficacies were obtained for samples which were exposed to concrete depending on the particular preservative employed; for all three systems greater deterioration was always observed with the two copper-tolerant fungi than the copper-intolerant fungus. Specifically, the amine copper azole preservative CA-C showed no difference in deterioration with all three fungi. The amine copper quat system ACQ-D showed significantly greater decay resistance for the cement-exposed samples with both exposure times and the two copper-tolerant decay fungi. Conversely, for micronized copper azole MCA-treated wood, the cement-exposed samples had greater deterioration with all three fungi compared to the non-cement-exposed samples, with some of the greater decay statistically significant. We conclude that for wood treated with copper-based preservatives and then exposed to concrete when installed in ground contact, decay susceptibility may be unaffected, reduced, or enhanced, depending on the particular copper/organic wood preservative employed.

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