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Ground-Contact Durability of Wood Treated with Borax–Copper Preservative

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ABSTRACT

This study evaluated the ability of a borax–copper(BC) preservative to protect wood exposed in ground contact. Southern pine sapwood stakes were pressure-treated with 0.9%, 1.4%, 2.3%, and 4.7% BC solution concentrations and placed into the ground at test sites near Gulfport, Mississippi, or Madison, Wisconsin. Untreated stakes and stakes treated with 1% chromated copper arsenate (CCA-C) or 1.1% disodium octaborate tetrahydrate (DOT) were included for comparison. Stakes were inspected annually for decay (Wisconsin test site) or decay and termites (Mississippi test site) and assigned a visual rating. The 2.3% and 4.7% BC concentrations were largely effective in preventing decay in Wisconsin but were much less effective in protecting the stakes exposed in Mississippi. Stakes treated with 0.9% and 1.4% BC concentrations performed slightly better than did DOT-treated stakes at both locations, indicating that even low levels of copper help to limit both decay and termite attack. As expected, the CCA-C treatment was highly effective at both locations. This study indicates that although pressure treatment with BC can extend the ground-contact durability of wood in northern climates, it may be better suited to protection of wood used aboveground.

Keywords: Borax–copper, ground contact, durability, Mississippi, Wisconsin

INTRODUCTION

A borax-copper (BC) preservative (trade name Cu-Bor) that is currently used for groundline remedial treatment of utility poles was also shown to protect the groundline area of untreated Southern Pine posts (Crawford et al. 2005). In these non-pressure applications, BC is applied as a concentrated paste (43.5% borax decahydrate and 3.1% copper hydroxide) and subsequently diffuses into the wood. To minimize borate losses in groundline treatments, impermeable sheets are used to cover the preservative and constrain the borax against the pole. The copper in the BC treatment is much less mobile than is the borate and is expected to provide long-term protection. Although primarily intended for non-pressure applications, pressure treatment is a use listed on BC's Environmental Protection Agency (EPA) label. Two factors make the performance of BC as a pressure-treatment preservative less certain than its application as a groundline paste. First, BC must be significantly diluted for pressure treatment, thus reducing the reservoir of preservative available to protect the wood. In addition, applications of pressure-treated wood will not necessarily include a bandage, wrap, or similar mechanism to prevent the borax from leaching out of the wood during service. In this study, we evaluated the ability of BC to protect pressure-treated stakes exposed in ground contact at test sites in Mississippi and Wisconsin. The performance of stakes treated with disodium octaborate tetrahydrate (DOT) and chromated copper arsenate (CCA-C) are included for comparison.

MATERIALS AND METHODS

Specimen Preparation and Treatment

Forty stakes (19 × 19 × 457 mm) per treatment group were cut from clear Southern Pine sapwood and conditioned to constant weight in a room maintained at 74°F (23°C) and 65% relative humidity. An additional 25 longer specimens (19 × 19 × 610 mm) were also prepared for each treatment group. The 65 stakes per treatment group were combined and treated together with one of the following solutions:

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- Borax-copper (BC) (trade name Cu-Bor) with an actives composition of 7.2% technical copper hydroxide and 92.8% sodium tetraborate decahydrate (10 mole borax)— This formulation was evaluated with treatment solutions containing 0.93%, 1.40%, 2.34%, and 4.66% actives (Table 1).
- Disodium octaborate tetrahydrate (DOT), considered 100% DOT actives— This formulation was evaluated with a 1.1 % solution concentration.
- Chromated copper arsenate type C (CCA-C), with an actives composition of 47.5% chromium (CrO₃ basis), 34.0% arsenic (As₂O₅ basis), and 18.5% copper (CuO basis)

Table 1. Borate and copper concentrations in treatment solutions

Treatment solution	Concentration (%)			
	Borax	B as B ₂ O ₃	Cu as Cu(OH) ₂	Cu as CuO
0.9% BC	0.86	0.29	0.07	0.06
1.4% BC	1.3	0.47	0.10	0.08
2.3% BC	2.2	0.80	0.14	0.11
4.7% BC	4.4	1.60	0.28	0.22
1.1% DOT	—	0.74	—	—
1% CCA-C	—	—	—	0.18

The 2.3% and 4.7% BC treatments were conducted with solutions heated to approximately 50°C; the remaining BC treatments and the DOT and CCA treatments were conducted at ambient temperature. All treatments were conducted using a full-cell pressure process. Initial vacuum was maintained at -75kPa for 30 min; pressure was maintained at 1.03 MPa for 1 h. Each stake was weighed before and after treatment to determine solution uptake and allow calculation of uptake retention (Table 2).

Table 2. Average borate and copper retentions in treated stakes

Treatment solution	B ₂ O ₃ (kg/m ³)		CuO (kg/m ³)	
	By uptake	By assay	By uptake	By assay
0.9% BC	1.76	2.00	0.27	0.20
1.4% BC	2.69	2.86	0.42	0.43
2.3% BC	4.72	4.35	0.74	0.71
4.7% BC	9.54	8.89	1.49	1.51
1.1% DOT	3.95	4.35	—	—
1% CCA-C	—	—	1.18	1.10

Following treatment, stakes were stacked in plastic bags for 1 week and then allowed to air-dry under room conditions. Twenty of the shorter (457-mm) stakes treated with each solution were assigned to the exposure plot in Mississippi; the remaining 20 were designated for exposure in Wisconsin. Sections (152 mm long) were cut from the longer specimens for assay of original treatment retention (Table 2), and the remaining 457-mm-long sections were placed at the Wisconsin site for leaching evaluation (leaching results reported elsewhere). Twenty untreated stakes were also installed in each test plot.

Stake Installation and Inspection

The Mississippi plot is located in a forested area within Harrison Experimental Forest (approximately 15 miles north of Gulfport-Biloxi). The location is within Deterioration Zone 5 (severe deterioration hazard, AWWPA 2006a). Although native subterranean termites are active at this site, the presence or activity of Formosan subterranean termites has not yet been reported. The Wisconsin plot is located in grassy field a

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few miles west of Madison, Wisconsin. The location is within Deterioration Zone 2 (moderate deterioration hazard). Because of the cold climate, the Wisconsin site is outside the current range of termite activity, and stakes at this location are typically rated only for decay. At each location, stakes were placed in rows with 305 mm of spacing between stakes within each row and 915 mm between rows. Stakes were randomly assigned locations within the plot and were buried vertically to half their length. An iron rod was used to create holes for stake placement. Stakes were installed in either October (Wisconsin) or January (Mississippi) and inspected at 1, 2, 3, 4, and 5 years after installation. At each inspection, the stakes were removed, scraped lightly to remove dirt, and given a visual rating for decay and/or termite attack according to the 10, 9, 8, 7, 6, 4, 0 scale as described in AWP Standard E7-01 (AWPA 2006b).

Calculation of Average Ratings for Mississippi

For purposes of this paper, we calculated average ratings using the lower of the two ratings (decay or termite) for each stake. Typically the lowest rating was associated with decay, but several stakes in the untreated, DOT, 0.9% BC, and 1.4% BC treatment groups were most severely attacked by termites.

Treatment Comparisons

Treatment comparisons were based on cumulative logit models of repeated, ordinal ratings following methods outlined in Molenberghs and Verbeke (2005). Separate models were fit to the minimum ratings for Mississippi and the decay ratings for Wisconsin. Contrasts were constructed for pairwise treatment comparisons within each of these models.

RESULTS AND DISCUSSION

As expected, deterioration of stakes was much more rapid in Mississippi than in Wisconsin (Figures 1 to 3). All but one untreated stake failed within 2 years in Mississippi, while two untreated stakes remained after 5 years in Wisconsin (Figure 3). With the exception of the CCA-C treatment, deterioration of treated stakes was also much more rapid in Mississippi. The average rating of DOT-treated stakes was less than 4.0 after 1 year in Mississippi but remained slightly above 4.0 after 5 years in Wisconsin. The pattern of degrade is also dissimilar between the two sites, at least for the least durable treatments. Stakes in Wisconsin tended to decline gradually over the first 4 years and then suffered a greater decline in the fifth year, whereas average ratings in Mississippi tended to drop rapidly for the first 3 to 4 years, with somewhat less dramatic decreases in the fifth year. However, the trend in Mississippi is somewhat misleading because a high proportion of stakes in each group had failed by the fifth year.

Average ratings of the 2.3% and 4.7% BC groups in Wisconsin remained high even after 5 years. Because approximately 90% of the borate but only 10% of the copper had been leached from these stakes within 3 years (data not shown), this finding suggests that these copper concentrations can be fairly effective in northern climates. Although copper did provide benefit in Mississippi, stakes with even the highest BC retention were severely degraded, with over 40% of the stakes failing within 5 years.

The poor performance of copper retentions equivalent to CCA in Mississippi may result from a combination of factors. Certainly the warmer climate would be expected to result in more rapid deterioration, so possibly within a few years the stakes in Wisconsin will have decay ratings similar to those now seen in Mississippi. It is also true that the Mississippi site has a substantial termite population, whereas the Wisconsin site does not have any termites. However, most of the damage to the 2.3% and 4.7% BC-treated stakes was caused by decay. A third factor that may have led to failure of the higher copper retentions in Mississippi is the presence of copper-tolerant fungi at that site. Assuming that the boron leached out of the stakes, they would have been vulnerable to attack by copper-tolerant fungi. The yellow mycelium of a fungus (possibly *Antrodia* spp.) that has previously been observed to attack copper-treated stakes was seen on some of the BC-treated stakes. The role of copper-tolerant fungi may be further supported by comparing the performance of the Mississippi stakes to a separate evaluation conducted with diffusion-treated stakes exposed in Hilo, Hawaii (Copper Care Wood Preservatives Inc. 2007). At the Hilo site, Cu-Bor-treated stakes continue to perform well after 4 years of exposure. Because the decay hazard in Hilo is at least as severe as that in Mississippi, this finding suggests that some factor other than climate is contributing to the failure of stakes in Mississippi. Some stakes at the Wisconsin site were also attacked by rodents, which seemed to prefer the BC treatment.

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Figure 1. Average decay ratings for stakes exposed in Wisconsin.

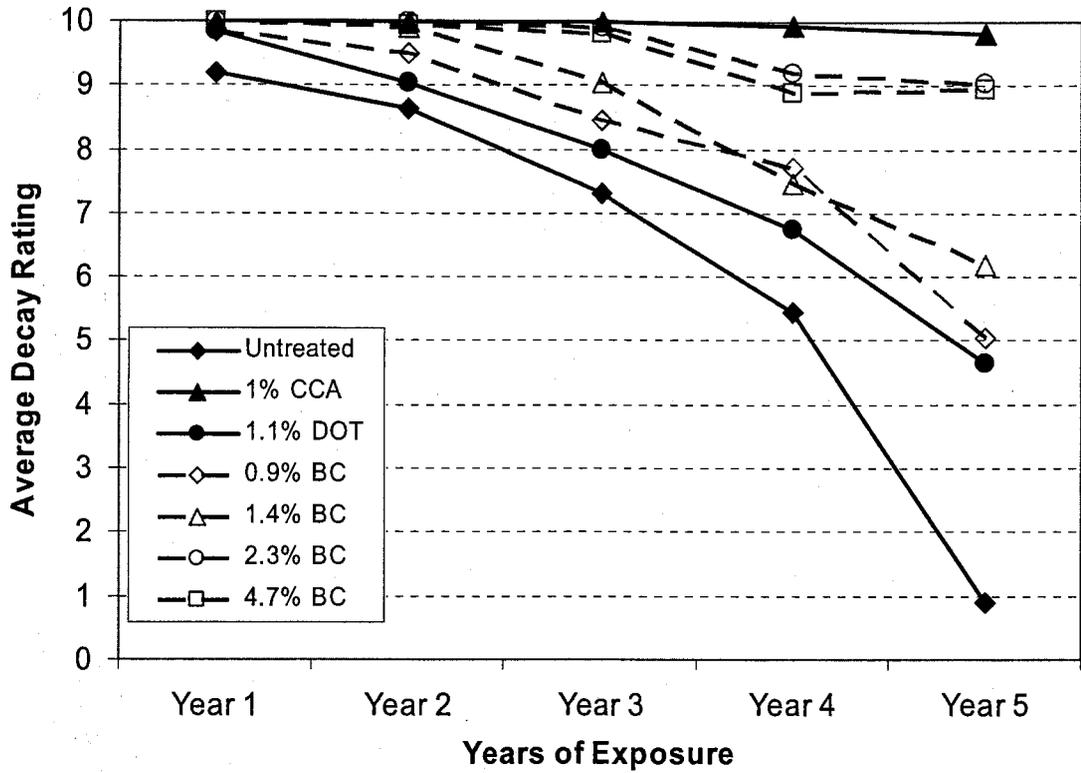
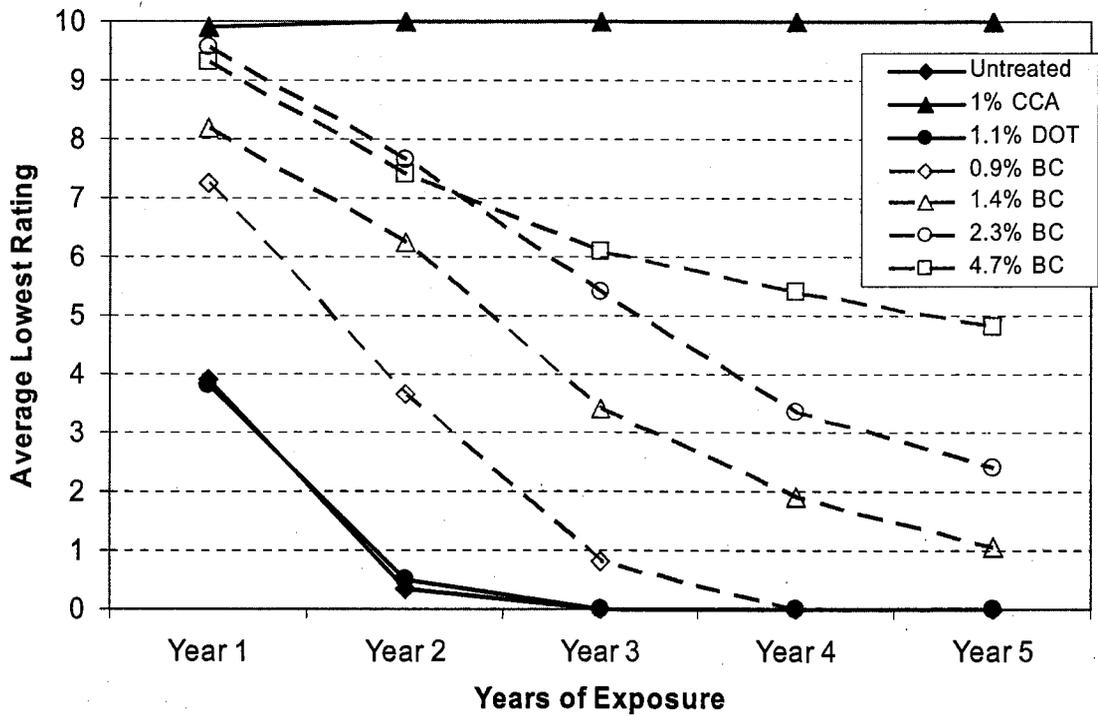
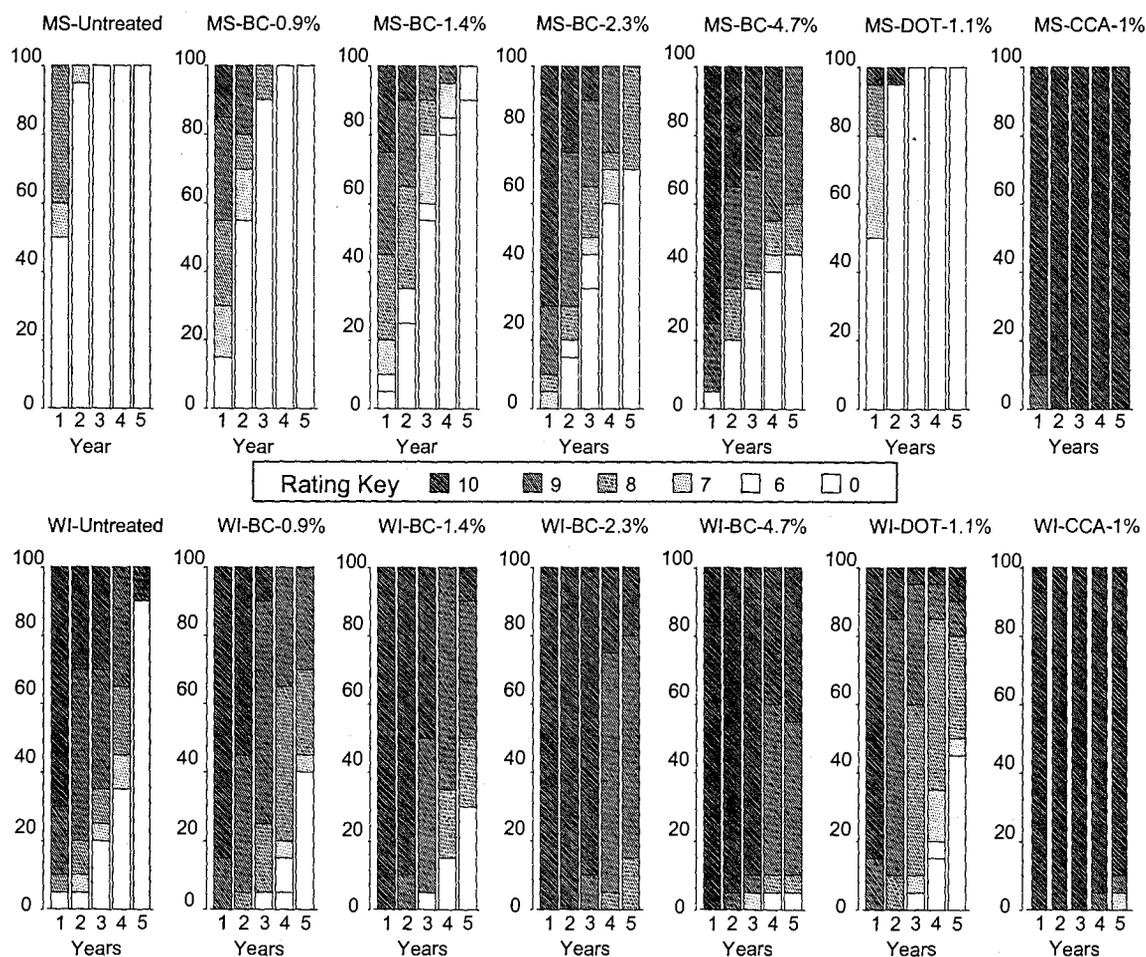


Figure 2. Average of the lowest rating (decay or termites) for stakes exposed in Mississippi



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Figure 3. Percentage of stakes in each rating category.



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Average ratings of the relatively small (19-mm) stakes used in this study were somewhat misleading, and this was true especially at the Mississippi site. As can be seen in Figure 3, stake ratings in Mississippi typically drop from 10, 9, or 8 directly to zero, with very few stakes receiving ratings of 7, 6, or 4. Even in Wisconsin, where degradation is more gradual, ratings below 7 are uncommon. As a result, the ratings tend to a bimodal distribution, and presentation of only average ratings may not provide a complete picture of the distribution of condition ratings for the stakes. The stakes treated with 10% BC and exposed in Mississippi provide an example. After 2 years of exposure, the average rating for the stakes was 7.4, but four of the stakes had already failed and the others were rated as 8, 9, or 10. After 5 years, the average rating was 4.9, with all the stakes rated as 0, 8, or 9.

CONCLUSIONS

The presence of even low levels of copper in the BC-treated wood did impart improved decay resistance relative to a borate-only preservative. The two highest concentrations of BC also provided fairly effective protection against decay for stakes exposed in Wisconsin for 5 years. However, even the highest BC retention did not adequately protect stakes in Mississippi, possibly reflecting the combination of higher decay hazard, termite activity, and the presence of copper-tolerant fungi at the Mississippi location. This finding is not unexpected, given the severity of the exposure and the mobility of the borax component of the preservative. This study indicates that although pressure treatment with BC can extend the ground-contact durability of wood in northern climates, it may be better suited to protection of wood used aboveground.

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