THE DURABILITY OF YELLOW-POPLAR AND AMERICAN BEECH TREATED WITH CREOSOTE AND BORATE

JEFFREY J. SLAHOR
H.M. BARNES*
BENJAMIN DAWSON-ANDOH
T.L. AMBURGEY*
CURT C. HASSLER*

ABSTRACT

Durability of yellow-poplar and American beech stakes treated with creosote and creosote/borate was evaluated in field plots in West Virginia and Mississippi. Results suggest that the use of beech heartwood treated to a retention of 8.0 pcf (128.2 kg/m³) is justified when a use-life of 5 years is acceptable. Stakes of American beech heartwood and southern yellow pine sapwood treated with creosote and a creosote/borate dual treatment exhibited an increase in durability performance with an increase in retention. Value of the addition of borate for a dual treatment is not clear. Results for beech sapwood and all yellow-poplar stakes generally were not adequate for most, if not all, retention levels of either treatment used in this study.

As stated in previous work,[1] the Timber Bridge Initiative[2] initiated work investigating the use of locally available species for timber bridge construction. Previous work, Slahor et al.[3] and Hassler et al.,[4] investigated the feasibility of treating hardwood species with several wood preservatives. Some of the wood species used in the aforementioned work were also treated as stakes for durability studies in field sites at Morgantown, West Virginia, and the Harrison Experiment Forest near Saucier, Mississippi. This paper presents the 5-year performance results for stakes of yellow-poplar and beech treated with creosote and creosote/borate and installed at these two sites.

MATERIALS AND METHODS

STAKE SAMPLES

Rough-cut, 2 inch (50 mm) by random width by random length lumber of yellow-poplar and American beech was obtained from local sawmills. The green material was air- or kiln-dried to below the fiber saturation point (< 30% moisture content) prior to final milling. Blanks were ripped from the rough-cut boards and separated out as sapwood or heartwood. Bark and wane on the rough boards were used to identify sapwood, while proximity to pith and color were used to identify heartwood of the two hardwoods. Further milling was done using a molder/planer producing 1.75-inch- (44.5-mm-) square stakes of at least 48 inches (122 cm) in length. Untreated stakes were sent to the Missis-

[1] Slahor, J.J., C.C. Hassler, and B. Dawson-Andoh. 2001. The durability of yellow-poplar and American beech treated with chromated copper arsenate. Forest Prod. J. 51(4):62-66.

[2] Duwadi, S.R., M.A. Ritter, and E. Cesa. 2000. Wood in transportation program – An Overview. Transportation Res. Record 1696, Pap. No. 5B0105. Transportation Res. Board, National Res. Council, Washington, DC. 7 pp.

[3] Slahor, J.J., C.C. Hassler, R.C. DeGroot, and D.J. Gardner. 1997. Preservative treatment evaluation with CCA and ACQ-B of four Appalachian wood species for use in timber transportation structures. Forest Prod. J. 47(9):33-42.

[4] Hassler C.C., J.J. Slahor, R.C. DeGroot, and D.J. Gardner. 1998. Preservative treatment evaluation of five Appalachian hardwoods at two moisture contents. Forest Prod. J. 48(7/8):37-42.

The authors are, respectively, Research Instructor, Appalachian Hardwood Center, West Virginia Univ. (WVU), P.O. Box 6125, Morgantown, WV 26506-6125; Professor, Mississippi Forest Prod. Lab., Mississippi State Univ. (MSU), Box 9820, Mississippi State, MS 39762-9820; Associate Professor, WVU; Professor, Mississippi Forest Prod. Lab., MSU; and President, Balkan Tier Consulting Co., 1143 Aarons Creek Rd., Morgantown, WV 26508-9558. The authors gratefully acknowledge the financial support of this project by the West Virginia Division of Forestry, Charleston, WV. The manuscript has been approved for publication by the Director of the West Virginia Agri. and Forestry Expt. Sta. as Scientific Article No. 2784. This paper was received for publication in January 2001. Reprint No. 9248.
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Forest Prod. J. 51(7/8):51-55.

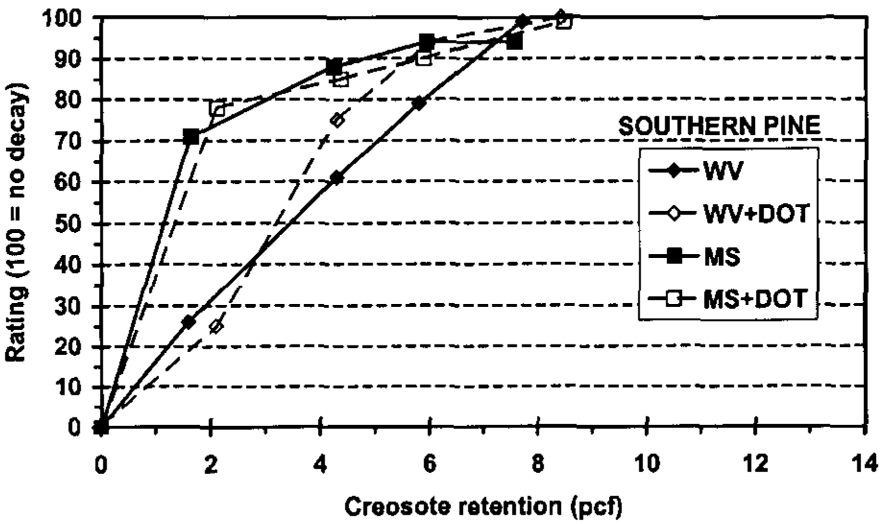

Figure 1. — Five-year decay results for southern yellow pine.

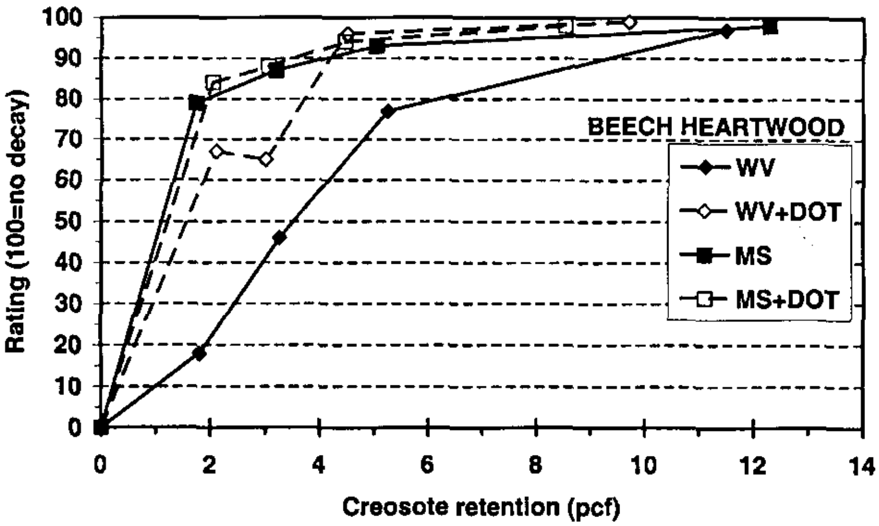

Figure 2. — Five-year decay results for beech heartwood.

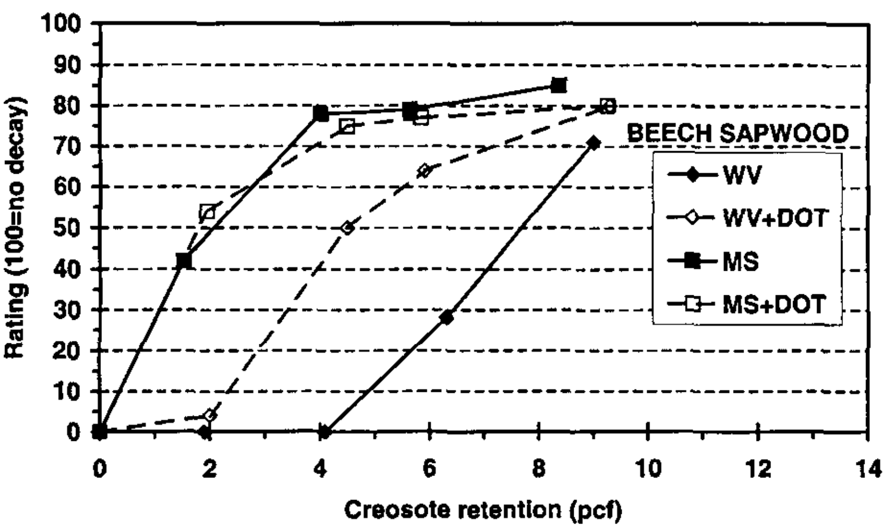

Figure 3. — Five-year decay results for beech sapwood.

sippi State University Forest Products Laboratory in Starkville, Mississippi, which performed the creosote and creosote/borate treatments. Further milling, prior to treatment, was required to remove surface mold formed during shipping. Final stake dimensions were 1 inch square by 40 inches long (28.6 mm square by 508 mm). Forty-four-inch-long stakes were tagged and cut into 18-inch-long (45.7-cm-) end-matched samples.

Wood preservative treatment

General target retentions of 2, 4, 6, and 8 pounds per cubic foot (pcf) (32.4, 64.1, 96.1, and 128.2 [kg/m^3]) creosote were used. The dual treatment with borates was done with one intended target retention of approximately 0.2 pcf as B_2O_3 (3.2 kg/m^3). The stakes were first treated with disodiumoctaborate tetrahydrate (DOT) using a conventional full-cell process. Retention was determined by weight gain. After allowing the samples to air-dry, they were dual treated with coal-tar creosote meeting AWPA *standard P1/P13-91, Standard for* Coal Tar Creosote for Land and Fresh Water and Marine (Coastal Water) Use,[5] using a full-cell treatment schedule. Toluene dilution of the creosote was done to obtain the desired creosote retention levels. Retention was determined by weight gain following treatment. With 5 species groups, 2 treatments with 4 levels of retention each, and 10 samples per target retention level, a total of 800 end-matched samples were treated. One matched half was placed at the Mississippi (MS) site and the other half at the West Virginia (WV) site.

Installation and inspection of stakes

Stakes were inspected once a year in late October or early November at the WV site by West Virginia University personnel and in December at the MS site by Mississippi Forest Products Laboratory personnel. During inspection, stakes were pulled from the ground, gently scraped to remove soil, and the percentage of cross-sectional area degraded by decay fungi or termites was rated. Damage was recorded as per AWPA standard E7-92, 9.3,[5] using the discrete scale where 10 = sound, no decay or termite damage, and 0 = failure.

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[5] American Wood-Preservers' Association (AWPA). 1998. Book of Standards. AWPA, Granbury, TX.

Following inspection and grading, stakes were returned to their original placements, excepting failures.

Soil type at the WV site is a Clarksburg silt loam with 15 to 25 percent slopes, which was formerly in pasture. Soil type at the MS site is a Poarch fine sandy loam with 5 to 12 percent grades partially cleared of trees, leaving a ground cover of mostly wire grass.

There were 10 each beech heartwood and sapwood, yellow-poplar heartwood and sapwood, and 10 southern yellow pine sapwood untreated control stakes placed at both sites.

RESULTS AND DISCUSSION

Remaining consistent with previous work presented[1] from this study, results are presented as dose-response curves. It gives an overall view of the performance of the stakes at the various retention levels and allows for the variation in retention results encountered in this work. Results for the treatments are shown in **Figures 1** through 5.[6]

As a reference, the AWPA standard (C2-93, Lumber, Timber and Ties — Preservative Treatment by Pressure Processes)[5] specifies (for material under 5 in. in thickness) a creosote retention of 10 pcf (160 kg/m^3) for aboveground and ground/fresh water contact end uses of maple. Retentions specified for black and red gum are 6 and 8 pcf (96 and 128 kg/m^3) for aboveground and ground/fresh water contact end uses, respectively. There are no retentions specific to the species used in this study as well as no specifications for use of borates with hardwood species.

Target retentions for the borates were all the same: approximately 0.2 pcf (3.2 kg/m^3) as B_2O_3. This would allow for consideration of treatments as either with borate or without borate supplementation. Post-treatment results were such that this was true for all groups except beech sapwood, which had statistically higher (∝ 0.05) retentions based on a one-way analysis of variance and Fisher's Least Significant Difference. The mean of the beech sapwood borate retentions was 0.195 pcf B_2O_3 (3.1 kg/m^3) and the remaining groups ranged

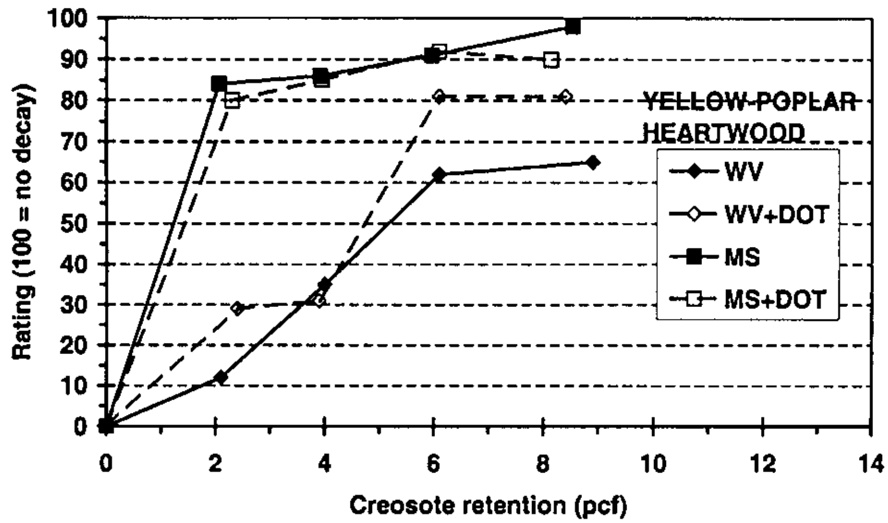

Figure 4. — Five-year decay results for yellow-poplar heartwood.

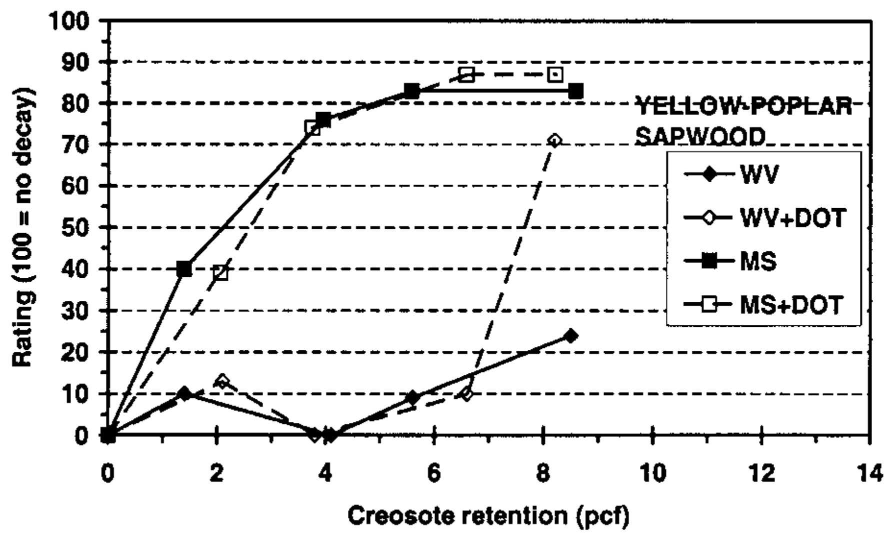

Figure 5. — Five-year decay results for yellow-poplar sapwood.

from 0.147 to 0.166 pcf B_2O_3 (2.4 to 2.7 kg/m^3).

UNTREATED CONTROL RESULTS

Performance of untreated controls varied slightly when compared by the test site. Except for all beech heartwood stakes and, to a lesser degree, yellow-poplar heartwood stakes at the MS site, most untreated controls failed by the second inspection (year 2). Some of the beech heartwood controls were not observed to fail until the year 5 inspection. Some yellow-poplar heartwood controls lasted into year 4 when 100 percent failure was recorded. This extreme variability might reasonably be explained by the presence of varying extractive levels. **Table 1** presents the percent failure by site, species, and year for the untreated controls.

TREATED STAKE RESULTS

The 5-year durability results of the treated stakes of the two hardwoods and southern yellow pine in this study can generally be summed up in the following order, from best performance to worst: southern yellow pine, beech heartwood, yellow-poplar heartwood, beech sapwood, and yellow-poplar sapwood. Stake failure was greatest at the WV site, possibly because of soil differences. Because the WV site was former pasture, it is high in organic material and well drained, yet rarely dry. This is compared to the very sandy soil of the MS site.

[6] The sum of the individual stake ratings (10 per group) was plotted vs. average retention in the dose-response curves, yielding a maximum rating scale of 100.

TABLE 1. — Percent of total number of untreated beech, yellow-poplar, and southern pine stakes that failed in a given year.[a]

	Starting no. of stakes	Year 1		Year 2		Year 3		Year 4		Year 5	
		WV	MS	WV	MS	WV	MS	WV	MS	WV	MS
Beech heartwood	10	0 (8 to 10)	0 (6 to 10)	40 (4 to 9)	0 (4 to 8)	40 (8 to 9)	30 (4 to 7)	10 (4 to 4)	50 (4 to 6)	10 - -	20 - -
Beech sapwood	10	0 (7 to 10)	10 (7 to 10)	100 - -	90 - -						
Poplar heartwood	10	0 (7 to 10)	20 (6 to 8)	100 - -	10 (4 to 7)		50 (4 to 7)		20 - -		
Poplar sapwood	10	20 (7 to 10)	80 (4 to 8)	80 - -	20 - -						
Southern pine sapwood	10	0 (7 to 10)	70 (4 to 10)	80 (9 to 9)	20 (4 to 4)	20 - -	10 - -				

[a] Numbers in parentheses indicate the range of decay ratings for remaining stakes; - - indicates no remaining stakes.

Beech heartwood and southern yellow pine at retentions above the lowest levels (> 2 pcf [32 kg/m^3]) of either the creosote treatment or the dual creosote/borate treatment clearly showed improved performance as described by lack of failure. Beech heartwood treated with creosote had substantial failure at this low level of retention but no failure in the higher retentions. Except for the lowest retention levels, southern pine stakes also had no failures. The remaining stake groups of beech sapwood, yellow-poplar heartwood, and yellow-poplar sapwood had extreme levels of failure due to decay at the WV site over the entire 5-year period (all the yearly inspections had yellow-poplar sapwood failures). At the MS site, results ranged from 0 percent failure (yellow-poplar heartwood) to 45 percent failure in year 5 for beech sapwood stakes treated with creosote. Failure at the WV site was attributed entirely to fungal decay. Except for one instance (pine stake/1.7 pcf creosote with a rating of 4-0, decay-termite), all failure at the MS site was from decay as well.

Southern yellow pine sapwood. — Treated southern yellow pine performed very well. The highest amount of stake failure was at the WV site with more than 55 percent failure recorded in the year 5 inspection for stakes with retentions of 1.5 to 1.8 pcf (24.0 to 28.8 kg/m^3) of creosote. For the dual creosote/borate treatment, stakes with total retentions in the range of 2.1 to 3.9 pcf (33.6 to 62.5 kg/m^3) had greater than 60 percent failure recorded in the year 5 inspection. The MS site produced much less failure: only 10 percent of the lowest retention creosote treated stakes (1.4 to 1.8 pcf, 22.4 to 28.8 kg/m^3) failed in the year 5 inspection. Mean ratings for year 5 in the higher retention groups were all 9 or greater. One stake was lost due to mechanical damage during a plot cleanup at the WV site. **Figure 1** is a dose-response curve after 5 years of exposure. For both test plots, the addition of borates to creosote had little impact on performance.

Beech heartwood. — **Figure 2** shows the dose-response curve for the beech heartwood stakes in the MS and WV sites. The beech heartwood stakes performed the best of all of the hardwood groups. There were no failures recorded at the MS site over the 5-year period. Beech heartwood stakes treated with creosote placed at the WV site had substantial failure by year 5 in the retention range up to 6 pcf. Above this retention level, there were no failures and mean ratings were greater than 9. The dual treatment of beech heartwood stakes at the WV site performed considerably better, based upon total failure over the entire 5-year period, with only 7.5 percent failure versus 37.5 percent for the creosote alone.

Beech sapwood. — **Figure 3** is the dose-response curve for beech sapwood stakes. There was substantial failure at the WV site for both treatments of beech sapwood stakes. Only the highest retentions of the stakes given a dual treatment of creosote/borate performed with no recorded failure. The beech sapwood stakes placed at the MS site performed somewhat better, with failure occurring only at the lowest retention levels in year 5. However, remaining treatment groups had mean ratings of 8 or lower. No improvement in performance at the MS site could be attributed to borate addition.

Yellow-poplar heartwood. — **Figure 4** shows the dose-response curve for yellow-poplar heartwood stakes. Durability performance of yellow-poplar heartwood stakes, generally, was not very good at any retention level at the WV site. Only at retention levels above 6 pcf (96.1 kg/m^3) creosote and 8 pcf (128.2 kg/m^3) creosote/borate were there no instances of failure. Stakes in these retention ranges also had mean ratings in year 5 above 9. As is the trend for all stakes in this study, the yellow-poplar heartwood stakes at the MS site performed markedly better than those at the WV site. No failures were recorded in the 5-year period, with year 5 ratings predominately greater than 8. Borates improved the performance for the highest retentions at the WV site only.

Yellow-poplar sapwood. — Yellow-poplar sapwood stakes had the worst performance of all the hardwood groups at all retention levels at the WV site **(Fig. 5)**. Greater than 50 percent failure was recorded by year 5 for all retention level groupings. The MS site results were better with drastically less failure, but all mean ratings for the year 5 inspection were below 9. Borates provided no practical improvement in preservative performance for yellow-poplar sapwood stakes.

CONCLUSIONS

The sapwood stakes of both beech and yellow-poplar performed so poorly over the 5-year period of this study as to limit, if not rule out, any structural applications of the same. The yellow-poplar heartwood stakes performed moderately better, especially at the MS site. The southern yellow pine and beech heartwood stakes performed extremely well for the entire 5-year inspection period, with the exception of the lowest retention levels. Creosote-treated beech heartwood should perform well in structural applications such as timber bridges.

There clearly appears to be a site effect at work in this study. Bolstered by similar results, presented earlier,[1] for stakes of the same species treated with chromated copper arsenate (CCA), the WV site is a more severe decay environment compared to the MS site. It is unknown whether this is due to the difference between the grass-covered pasture land of the WV site and the very sandy MS site, and hence, differences in organic content, pH, site aspect, and soil moisture content, etc.

While tempting, any direct comparison of the results presented in this paper to those presented earlier[3] for the CCA-treated stakes cannot be made because of the difference in stake size. The smaller stake size used in the work presented in this paper may readily explain the more rapid deterioration of the stakes.

The dual treatment of creosote/borate produced mixed results. Generally, it can be said that the addition of borate moderately improved performance as exemplified by the lower percentage of failure and higher mean ratings. However, there were instances where the opposite was true, as with the beech sapwood stakes that actually had a statistically higher retention of the borate than the other species. Based on these mixed and marginal results, the extra time and cost such a treatment would require casts doubt on its practical application as an in-service treatment. Rather, it might serve well as a pretreatment of timbers and ties in the seasoning yard to prevent deterioration during drying. Beech heartwood and southern pine treated to 8 pcf (128.2 kg/m^3) of creosote should perform adequately if not better in situations where at least a 5-year life expectancy is specified. The same cannot be said of any of the other treatment groups for the retentions used in this study. Yellow-poplar heartwood treated to higher retention levels (6 pcf [96.1 kg/m^3]) did perform fairly well, which indicates a specified creosote retention of 10 to 12 pcf may suffice for some end uses.