PROPERTIES AND DECAY RESISTANCE OF PRESERVATIVE-TREATED DOUGLAS-FIR FLAKEBOARD[1]

Asghar Jeihooni
Research Assistant

Robert L. Krahmer
Professor Emeritus

and

Jeffrey J. Morrell
Associate Professor

Department of Forest Products
Oregon State University
Corvallis, OR 97331-7402

(Received July 1993)

ABSTRACT

The effect of pretreatment of Douglas-fir flakes with CCA-C, borate, and azaconazole on properties of flakeboard was studied. Flakes had higher retention levels of CCA-C and borate in their ends than in their centers. The distribution of chemicals was uniform in panels, which indicates that the chemicals did not migrate during hot-pressing. Treatment markedly enhanced resistance to brown rot (*Postia placenta*). Borate-treated panels had large thickness swelling and often delaminated when exposed to hot, wet conditions. In static bending and internal bond tests, strength reduction for borate- and CCA-C-treated panels was evident. Azaconazole showed no deleterious effect on strength.

Keywords: Flakeboard, Douglas-fir, CCA, borate, azaconazole, physical properties, durability.

INTRODUCTION

The use of wood-based composites in exterior environments has led to renewed interest in preservatives for the protection of these products against biological deterioration. Not all preservatives developed for non-glued products are applicable for composites. Incompatibility with the adhesive is particularly likely when wood furnish is preservative-treated prior to being consolidated into a panel. The effects of the preservative on adhesion, on the resistance of the product to biological deterioration, and on physical properties need to be considered before a pretreatment method is adopted.

Three wood preservatives that may be applicable to composites are chromated copper arsenate Type C (CCA-C), disodium octaborate tetrahydrate (borate), and azaconazole [1-[(2-(2,4-dichlorophenyl)-1,3-dioxolan-2-yl)-methyl]-1H-1,2,4-triazole]. In laboratory and field tests (Nurmi 1990), CCA wood preservatives have demonstrated excellent resistance to leaching and long-term efficacy. Borate is effective against insects and decay fungi, and has low mammalian toxicity; however, it is susceptible to leaching (Barnes et al. 1989). Azaconazole is a triazole-type preservative that is effective against basidiomycetes, sapstains, and molds, and can be used for the preservation of solid and modified wood products (Valcke and Goodwine 1985). It shows resistance to leaching and is suitable for treatment

[1] This is Paper 2933 of the Forest Research Laboratory, Oregon State University, Corvallis.

Wood and Fiber Science, 26(2), 1994, pp. 178–184

of wood above ground contact. Azaconazole has exceptionally low mammalian toxicity.

In this study, we investigated the distribution of CCA-C and borate in Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] flakes and panels, and the effect of the three chemicals on the decay resistance and on the physical properties of panels. There was no reliable method for analysis of azaconazole in wood-based materials.

MATERIALS AND METHODS

Panel fabrication

Clear blocks (50 × 100 × 150 mm), free of knots, pitch, and bark were cut from freshly cut Douglas-fir dimension lumber that contained both sapwood and heartwood. The blocks were submerged in water for 30 h and flaked with a CAE (Canadian Equipment) flaker, which produced flakes about 30 × 20 × 0.8 mm in length, width, and thickness, respectively. Flake width was more variable than was length or thickness.

Flakes were dried and screened to remove "fines" (material passing through a screen with 4.76-mm diameter circular openings), which were discarded. Flakes then were conditioned at 21 C and 65% relative humidity (RH) until they reached an equilibrium moisture content (EMC), which averaged 11.9%.

Flakes were immersed in CCA-C or borate solution for 7 min. For CCA-C, solution concentrations of 0.6, 1.6, and 2.4% (oxide basis) were used to give target loadings of 2.4, 6.4, and 9.6 kg/m^3, respectively. These target levels were selected to meet the standards of the American Wood-Preservers' Association (1992c, d) for structural lumber in ground contact (6.4 kg/m^3) and in permanent wood foundations (9.6 kg/m^3). The 2.4 kg/m^3 level was chosen to represent a light treatment that might be susceptible to decay. Borate was used at solution concentrations of 0.20, 0.33, and 0.67% boric acid equivalent (BAE) based on the oven-dry weight of the flakes.

A 7-min dip was used because in a preliminary study, Jeihooni (1992) found that considerable water uptake occurred in 7 min of soaking and was minimal after that point. These water-soaked flakes were at about 110% moisture content (MC). After treatment, flakes were drained and then stored at room temperature in sealed plastic bags for 30 h to allow diffusion to occur. The treated flakes were dried at room temperature for several days and then reconditioned at 21 C and 65% RH.

Azaconazole was applied as a powder at concentrations of 0.2, 0.4, and 0.6%, based on oven-dry weight of flakes.

Calculated oven-dry weights of untreated and treated flakes were used to determine the amount of flakes, adhesive, and wax needed to make each panel. Flakes were sprayed with heated slack wax (1.1%) ("Indrawax 210" petroleum paraffin slack wax, Georgia-Pacific Resins Inc., Crossett, AR) in a rotary drum blender. Then flakes were blended with powdered phenol-formaldehyde resin (3.4%) for 3 min. For the azaconazole treatment, the powdered preservative was added to the furnish and blended for an additional 3 min.

Flake mats were formed by hand, felting the furnish on a stainless steel caul plate placed under a forming (deckle) box. Mats were pressed in a steam-heated hot-press at a platen temperature of 154 C for 12 min. Press closing time was 1–1.5 min. After pressing, the panels (305 × 305 × 13 mm thick) were cooled to room temperature, stickered, and conditioned at 21 C and 65% RH. Twelve panels were made for each of the nine preservative treatments and for the untreated control (120 total). Approximately 13 mm were trimmed from each panel to remove any edge effects produced during panel fabrication. Panel densities, based on oven-dry weight and volume, ranged from 650–680 kg/m^3. There were no statistical differences between treatments.

Test methods

The following tests were made on flakes and on specimens cut from each panel.

Retention of preservative in flakes.—Chemical analyses of the ends and centers of CCA-C- and borate-treated flakes were made. Ap-

proximately 25% of the flake length was cut from each end and analyzed separately from the center portion. Randomly selected whole flakes also were analyzed. The amounts of copper, chrome, and arsenic present in CCA-C-treated flakes were determined with an ASOMA 8620 X-ray fluorescence analyzer (ASOMA Instruments, Inc. 1988). The quantity of borate in treated flakes was analyzed by titration of ashed samples (Wilson 1958) and expressed as % BAE. Retention and distribution of azaconazole in flakes and panels were not tested.

Distribution of preservatives in panels.—A 13- × 350-mm strip was cut from six panels each of CCA-C and borate-treated flakeboards and subdivided into five 70-mm sections. Each of these sections was then cut into three equal layers (top, middle, and bottom) according to orientation in the hot-press. Preservative in these layers was analyzed by the same procedures as for flakes.

Preservative loss after leaching.—The amount of preservative leached from panels by water was determined with AWPA Standard, E 11-87 (American Wood-Preservers' Association 1992a) on a 25.4-mm square sample from six panels in each preservative treatment group. Preservative removal (percent weight loss based on original weights) was measured after conditioning at 21 C and 65% RH. Because preliminary studies showed that some samples began to delaminate during leaching, all samples were placed in individual mesh bags for testing.

Decay resistance.—Soil block tests were conducted in accordance with AWPA Standard E 10 91 (American Wood-Preservers' Association 1992b) on two 25.4-mm square pieces from six panels in each treatment group. The samples were incubated on feeder strips inoculated with *Postia placenta* (Fr.) Cooke, a brown-rot fungus. The measure of decay was percent weight loss, based on weight of the test samples dried at 54 C.

Static bending properties.—A static bending specimen (51 × 13 × 305 mm) from each panel was equilibrated at 22 C and 50% RH, then center-loaded, and tested to failure. American Society for Testing and Materials (1993) ASTM D 1037-93 for composites was used with a span-to-depth ratio of 20:1 because standard-length specimens with a span-to-depth ratio of 24:1 could not be cut from the panels. Equilibrium moisture content based on oven-dry weight was measured on two pieces cut from each static bending specimen.

Internal bond strength.—Internal bond strength (IB) was measured on 51-mm square specimens from 10 panels in each treatment, equilibrated at 22 C and 50% RH (ASTM D 1037-93, American Society for Testing and Materials 1993).

Dimensional stability.—Linear expansion in the plane of the panel and thickness swelling were measured on 51- × 64-mm pieces from each panel. Specimens were conditioned to equilibrium at 21 C and 65% RH, weighed, and measured. They were then placed in a hot-wet room at 32 C and 90% RH for 6 weeks. Dimensions and weights were measured weekly.

Statistical analysis.—Statistical Analysis System (SAS Institute 1987) was used for data analysis. Data were subjected to analysis of variance (ANOVA), and the Fisher's Protected Least Significant Difference Test (Little and Hills 1978) was used for comparisons between treatment groups.

RESULTS AND DISCUSSION

Retention of preservatives in flakes

Chemical concentrations of CCA-C were significantly greater ($P = 0.0001$) in the ends of the flakes than in the centers (Table 1). The differences increased as treatment retentions increased. The proportions of copper, chromium, and arsenic were approximately the same in the ends and centers of flakes at the different treatment levels, which suggests that the elements were not selectively adsorbed in the wood matrix. Furthermore, because the percentages of these components in the wood after treatment were similar to those in the original solution, the components were not selectively adsorbed from solution.

As with CCA-C-treated flakes, the ends of borate-treated flakes had significantly (P = 0.0001) greater concentrations of chemical than the centers, although differences were slight (Table 1). Because flakes did not reach maximum MC (160%) during the 7-min dip, their centers probably were not saturated with preservative solution.

CCA-C is thought to strongly and rapidly fix with wood (Hartford 1986), which suggests that there is little chance of preservative redistribution or loss from the wood during drying. Because borate apparently is not fixed in the wood (Barnes et al. 1989), it might continue to diffuse when flakes are conditioned after treatment. This enhanced migration could possibly account for the smaller difference in concentration between ends and centers of borate-treated flakes than for CCA-C-treated flakes.

TABLE 1. *Average preservative retentions measured in Douglas-fir whole flakes, flake ends, and flake centers treated with CCA-C and borate.*

Flake location	CCA-C retention		Borate retention	
	Target	Actual[a]	Target	Actual[b]
	kg/m^3		(% BAE)	
Whole	2.4	3.25	0.20	0.21
Ends	2.4	4.12	0.20	0.22
Center	2.4	2.62	0.20	0.19
Whole	6.4	8.26	0.33	0.26
Ends	6.4	9.82	0.33	0.31
Center	6.4	7.33	0.33	0.27
Whole	9.6	14.19	0.67	0.55
Ends	9.6	17.21	0.67	0.59
Center	9.6	13.10	0.67	0.53

[a] Values represent the average of 4 replicates per treatment.
[b] Values represent the average of 3 replicates per treatment.

Distribution of preservative in panels

Average concentrations of CCA-C were not significantly different ($P = 0.05$) along the length of the panel strips. Through the thickness, however, the middle layers had slightly lower concentrations than surface positions, and the difference was significant. This difference probably was not caused by chemical migration, but was associated with the density profile through the panel thickness. Higher density surfaces produced during hot-pressing could result in correspondingly larger amounts of preservative per unit-volume when compared to the middle layer.

Borate concentrations (% BAE) at the different layers within the panel were not statistically different from each other, which indicates that the chemical did not migrate during hot-pressing.

Preservative loss after leaching

For untreated control samples, the average weight loss after leaching was 1.4%, which probably represented the removal of extractives from the wood. Azaconazole and CCA-C results were not significantly different from the control, which indicates that they were resistant to excessive leaching. Weight losses of 4-8% were associated with borate treatments. Titration of ashed samples indicated that virtually all of the borate was leached from the samples. Many of these samples completely delaminated.

Average values for CCA-C components indicated that there was some reduction in arsenic as a result of leaching. Differences between unleached and leached samples ranged from 11–16% of the unleached concentration, while copper and chromium were very stable. Copper has been found to be very resistant to leaching, while arsenic was the most leachable component (Arsenault 1975).

Decay resistance

Postia placenta readily attacked untreated control samples, causing substantial weight loss (Table 2). Weight losses of treated samples were significantly less than the control. Samples with the lowest retention of azaconazole had significantly higher weight loss than all other treated samples.

Average weight losses for borate-treated samples increased as chemical retention increased, which probably reflects preservative leaching during the incubation period because sample degradation was not noticeable and the fungus on the feeder strips appeared dead. This is encouraging because it suggests that only

TABLE 2. *Average equilibrium moisture content (EMC), modulus of elasticity (MOE), modulus of rupture (MOR), and internal bond strength (IB) of preservative-treated Douglas-fir flakeboard* before exposure to fungus and average weight loss after exposure to* Postia placenta *in a soil-block test.*

Preservative treatment	Target retention	EMC (%)	MOE (MPa × 10^3)	MOR (MPa)	IB (MPa)	Weight loss (%)
None (control)	—	8.1(bcde)	3.24(bc)	21.10(a)	0.50(bc)	50.30
CCA-C	2.40 kg/m^3	8.2(bcd)	3.01(cd)	17.53(b)	0.43(dc)	1.93
	6.40 kg/m^3	7.8(cde)	3.01(cd)	16.97(bc)	0.41(d)	1.58
	9.60 kg/m^3	8.3(b)	2.87(de)	14.64(c)	0.41(d)	1.24
Azaconazole	0.20%	7.7(e)	3.41(ab)	23.49(a)	0.66(a)	21.65
	0.40%	7.7(de)	3.25(abc)	21.53(a)	0.55(b)	4.76
	0.60%	7.8(cde)	3.54(a)	21.58(a)	0.53(b)	4.26
Borate	0.20% BAE	8.2(bc)	2.99(cd)	16.05(bc)	0.40(d)	1.97
	0.33% BAE	8.9(a)	2.51(f)	11.91(d)	0.30(e)	3.06
	0.67% BAE	9.2(a)	2.68(ef)	10.73(d)	0.26(e)	3.70

* Values with the same letter in each column are not significantly different by Fisher's Protected Least Significant Difference Test at $\alpha = 0.05$.

very low concentrations of borate are needed for panel protection. However, borate's leachability will probably preclude its use where high moisture levels exist.

The soil-block test for decay resistance was designed for solid wood. Appropriate criteria and methods for evaluating the effectiveness of preservative treatments of wood-composite panels must continue to be addressed.

Equilibrium moisture content

Average values for EMC ranged from 7.7–9.2% (Table 2). The EMC for samples treated with medium and high concentrations of borate was approximately 9%, which was significantly higher than the values for all other treatments where averages were about 8%.

No adjustments in results of strength tests were made for the differences in EMC, although it is well known that the strength properties of wood composite panels are highly influenced by their MC (Lee and Stephens 1988). All specimens were conditioned and tested under the same environmental conditions. In this approach, the link between environmental conditions (temperature and RH) and strength properties is relevant to service conditions; EMC may be regarded as an intermediate factor in such a relationship. A similar strategy was used by Winandy and Boone (1988) in evaluating CCA-treated lumber.

Static bending properties

Average modulus of elasticity (MOE) and modulus of rupture (MOR) are given in Table 2. For MOE, values ranged from 2.51 GPa (364,000 psi) (borate at 0.33% conc.) to 3.54 GPa (513,000 psi) (azaconazole at 0.60% conc.). Values for MOR ranged from 10.73 MPa (1,504 psi) (borate at 0.67%) to 23.49 MPa (3,407 psi) (azaconazole at 0.20% conc.). Panels treated with the two highest concentrations of borate and the highest concentration of CCA-C had the lowest MOE and MOR, while azaconazole-treated samples had the highest values.

Azaconazole-treated panels did not differ significantly from the controls; Schmidt and Gertjejansen (1988) found that azaconazole had minimal effects on MOE of aspen waferboard. Panels treated with CCA-C were weaker than the control and differed significantly in MOR; the differences, however, were not significant for MOE. Boggio and Gertjejansen (1982) also found that CCA-C caused some strength reductions in aspen waferboard.

Flakeboard that is required to bear structural loads over prolonged periods in North America must meet requirements of the American National Standards Institute (1979) ANSI A208.1. A minimum of 3.10 GPa (450,000 psi) for MOE and 17.2 MPa (2,500 psi) for MOR must be attained. In this study, samples treated with azaconazole and untreated control

samples exceeded the standard values for MOE and MOR.

Internal bond strength

Average values for IB ranged from 0.26 MPa (borate at 0.67% conc.) to 0.66 MPa (azaconazole at 0.20% conc.) (Table 2). Specimens treated with the lowest concentration of azaconazole had an average IB that was significantly greater than the untreated control. Specimens treated with the higher concentration of azaconazole also had greater average IB than the control, but the differences were not significant.

Panels treated with the lowest concentration of borate and the two higher concentrations of CCA-C had IB values that were not significantly different from each other, but were significantly lower than untreated controls. Borate samples treated with the two highest concentrations were significantly weaker in IB than were the controls and all other treated panels; this also was observed by Laks et al. (1988).

The American National Standards Institute (1979) ANSI A208.1 requires that phenol-formaldehyde bonded flakeboards and waferboards have a minimum average IB strength of 0.34 MPa (50 psi). In this study, all samples exceeded this value except for borate at the two highest concentrations.

Dimensional stability

The dimensions of panel specimens rapidly increased during the first 2 weeks of exposure in the hot-wet room, with very little change after the 4th week. After 6 weeks of exposure, the average linear expansion for the three concentrations of each preservative treatment was compared to the control samples (Fig. 1). All samples treated with azaconazole were as dimensionally stable as the controls. For CCA-C, a notable increase occurred only with samples treated at the highest concentration. As chemical retentions increased for borate treatments, linear expansion also increased.

The average thickness swell of all azaconazole-treated samples after 6 weeks was the same as for the controls (12%). CCA-C-treated samples were slightly larger in thickness swell (16%). Swelling of borate-tested samples was considerably greater than the controls and increased with increasing concentration of borate in the panels. Samples with low, medium, and high concentrations had thickness-swell values of 22, 38, and 69%, respectively. Many borate-treated samples showed considerable delamination between flakes.

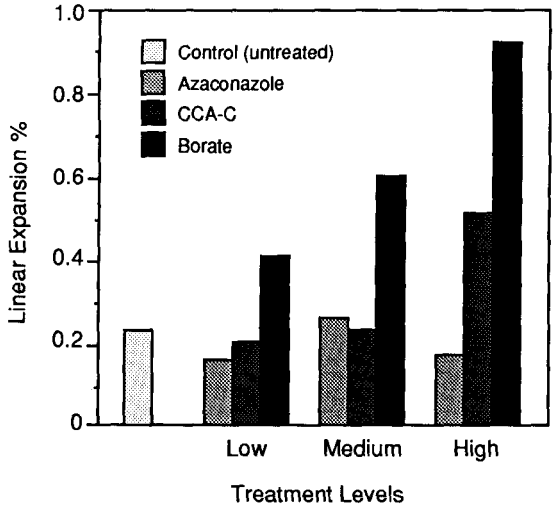

FIG. 1. Linear expansion of phenol-formaldehyde bonded Douglas-fir flakeboard samples treated with azaconazole, CCA-C, or borate and stored at 90% relative humidity for 6 weeks.

CONCLUSIONS

Composite panels made with Douglas-fir flakes pretreated with three concentrations of CCA-C or borate and bonded with phenol-formaldehyde resin showed no migration of treating chemicals during hot-pressing. Panels with the recommended concentrations of these two preservatives and azaconazole performed well in most tests for decay resistance and physical and mechanical properties. Only the lowest concentration of azaconazole did not provide good resistance to brown rot.

Azaconazole and CCA-C in treated panels were resistant to leaching with water, but borate was easily leached. Borate-treated panels readily delaminated in leaching, dimensional

stability, and soil block tests, and they were weakest in MOE, MOR, and IB. Strength properties also were reduced as concentration of CCA-C increased. Azaconazole did not adversely affect these properties. Azaconazole-treated panels were as dimensionally stable in thickness swelling as were nontreated panels; CCA-C panels were only slightly thicker.

REFERENCES

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI). 1979. Mat-formed wood particleboard. ANSI A208.1. ANSI, New York, NY.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). 1993. Standard methods of evaluating the properties of wood-base fiber and particle panel materials. D 1037-93. *In* Annual book of ASTM standards. ASTM, Philadelphia, PA.

AMERICAN WOOD-PRESERVERS' ASSOCIATION (AWPA). 1992a. Determining the leachability of wood preservatives. Standard E 11-87. *In* Book of standards. AWPA, Woodstock, MD.

———. 1992b. Testing wood preservatives by laboratory soil block cultures. Standard E 10-91. *In* Book of standards. AWPA, Woodstock, MD.

———. 1992c. Lumber and plywood for permanent wood foundations, pressure processes. Standard C 22-92. *In* Book of standards. AWPA, Woodstock, MD.

———. 1992d. Lumber, timbers, bridge ties, and mine timbers, pressure treatment. Standard C2-92. *In* Book of standards. AWPA, Woodstock, MD.

ARSENAULT, R. D. 1975. CCA treated wood foundations: A study of permanence, effectiveness, durability, and environmental considerations. Proc. Am. Wood Preservers' Assoc. 71:126–149.

ASOMA INSTRUMENTS, INC. 1988. ASOMA manual. Model 8620 X-ray fluorescence analyzer S/N 1306. Austin, TX.

BARNES, H. M., T. L. AMBURGEY, L. H. WILLIAMS, AND J. J. MORRELL. 1989. Borates as wood preserving compounds: The status of research in the United States. IRG/WP/3542. International Research Group on Wood Preservation, Stockholm, Sweden.

BOGGIO, K., AND R. GERTJEJANSEN. 1982. Influence of ACA and CCA waterborne preservatives on the properties of aspen waferboard. Forest Prod. J. 32(3):22–26.

HARTFORD, W. H. 1986. Practical chemistry of CCA in service. Proc. Am. Wood Preservers' Assoc. 82:28–43.

JEIHOONI, A. 1992. Distribution of preservative chemicals in flakeboard and its effect on board properties and fungal deterioration. Ph.D. thesis, Oregon State University, Corvallis, OR. 131 pp.

LAKS, P. E., B. A. HAATAJA, R. D. PALARDY, AND R. J. BIANCHINI. 1988. Evaluation of adhesives for bonding borate-treated flakeboards. Forest Prod. J. 38(11/12): 23–24.

LEE, A. W. C., AND C. B. STEPHENS. 1988. Comparative shear strength of seven types of wood composite panels at high and medium relative humidity conditions. Forest Prod. J. 38(3):49–52.

LITTLE, T. M., AND F. J. HILLS. 1978. Agricultural experimentation: Design and analysis. John Wiley and Sons, New York, NY. 350 pp.

NURMI, A. J. 1990. Leachability of active ingredients from some CCA treated and creosoted poles in service. A progress report after 10 years' testing. IRG/WP/3627. International Research Group on Wood Preservation, Stockholm, Sweden.

SAS INSTITUTE. 1987. SAS/STAT guide for personal computers. Version 6 Edition. SAS Institute, Inc., Cary, NC.

SCHMIDT, E. L., AND R. O. GERTJEJANSEN. 1988. Trials of two powdered preservatives for phenol-formaldehyde bonded and polymeric-isocyanate-bonded aspen structural composite board. Forest Prod. J. 38(3):19–21.

VALCKE, A. R., AND W. R. GOODWINE. 1985. Azaconazole, a new wood preservative. Proc. Am. Wood Preservers' Assoc. 81:196–202.

WILSON, W. J. 1958. The determination of boron in treated wood. Anal. Chim. Acta 19(6):509–512.

WINANDY, J. E., AND R. S. BOONE. 1988. The effects of CCA preservative treatment and redrying on the bending properties of 2 × 6 southern pine lumber. Wood Fiber Sci. 20(3):350–364.