Providing moisture and fungal protection to wood-based composites

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Abstract

The use of wood-based composites in structural applications is often limited because of their sensitivity to excessive levels of moisture and decay. The environmental conditions that exist in certain use categories can be so adverse that the performance of these composites is negatively affected. This paper discusses the evaluation of various water-repellent preservative systems as furnish treatments for a single-layer strandboard. After treating aspen strands and fabricating them into composite panels, we conducted physical, mechanical, and efficacy property tests on specimens cut from the experimental panels. The panels were tested for thickness swell, water absorption, modulus of rupture, and modulus of elasticity. Efficacy performance was evaluated in bioassay tests against deuteromycete and basidiomycete fungi. One of the waterbased treatments (WB-1) substantially improved the water-resistant properties of these panels. The thickness swell of control samples after 24 hours of water soaking was 23.8 percent compared to a thickness swell value of 8 percent for treatment WB-1. Similar results were obtained for the water absorption test. No significant deterioration in static bending properties was observed. Our studies showed that a water-repellent preservative system could be effectively applied to furnish that is subsequently used in strand panel production. The physical and fungal resistance properties of the panels were enhanced without decreasing their mechanical properties.

Wood-based composites are increasingly being used as replacements for solid sawn lumber. However, growth in some structural applications is still limited because of the adverse environmental conditions associated with them. These environments put many engineered wood materials, which are already decay and moisture sensitive, into conditions above their acceptable limits. Providing wood-based composites with inherent resistance to some of these challenging environmental conditions without sacrificing their structural integrity would further expand their use. Previous work in combining wood preservatives with strandboard has focused on inorganic systems such as ammoniacal copper arsenate (Hall and Gertjejansen 1979) and zinc borate (Brunette et al. 1999, Knudson and Gnatowski). Systems investigated in this work were organic waterborne water-repellent preservative systems similar to those used to protect solid lumber, such as millwork components.

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The treatments were applied to the furnish prior to fabrication of single-layer strandboard panels. The candidate formulations varied by biocide ingredient(s), water-repellent agents, and emulsion systems. Different concentration levels of the treating solutions were also tested to determine the effect on chemical retentions.

The main objective of this research project was to determine whether an organic water-repellent preservative treatment, introduced to the furnish before processing, would enhance the performance of subsequently fabricated strandboard composites without having a deleterious effect on physical and mechanical properties. Secondary objectives included evaluating different methods of introducing the water-repellent preservative treatments to the furnish and determining how well the organic components stood up to the processing conditions.

Materials and methods

Furnish

Dried aspen strands were obtained from Louisiana-Pacific Corporation. These strands are normally used at Louisiana-Pacific's plant in Hayward, Wisconsin, as furnish for oriented strandboard (OSB) production. The moisture content of the strands, as determined by ovendry weight, was found to be 5 to 6 percent prior to treatment. The appearance and performance of the strands were observed throughout the study to see if the additional processing steps (treating and re-drymg) had altered them.

Preservative treatments

Initially, three waterborne water-repellent preservative (WRP) formulations were evaluated as pre-treatments for the aspen furnish. These were designated as WB-1, WB-2, and WB-3. The general composition of each is given in Table 1. The active ingredients are all widely used EPA-registered organic fungicides. The water repellents are similar to those used in the protection of pressure-treated CCA lumber and in millwork treatment systems.

Each of the three preservative concentrates was diluted with water to make ready-to-use (RTU) treating solutions. The concentrations of the RTU solutions were varied in order to evaluate the effect ofdiffering chemical retention levels.

Controls

Controls in this study were: 1) no treatment of the furnish; and 2) treatment with water alone prior to fabrication into strandboard panels.

Application methods

Since one objective of this study was to evaluate different methods of introducing the WRP treatments to the aspen strands, three different application methods were explored:

- Tumbling the strands in a rotary drum while introducing the treating solution as a mist through a low-pressure (0.28 MPa, 40 psi) spray head.
- Dipping the strands in the treating solution. This was accomplished by tightly packing the aspen strands into mesh bags and submersing in the treating solution for 20 minutes.
- Pressure treatment. Strands were placed in a laboratory treating cylinder and subjected to an initial 15-minute vacuum cycle. The treating solution was then introduced and the cylinder was pressurized at 0.14 MPa (20 psi) for 5 minutes. After release of the pressure, the treating solution was removed from the cylinder.

Drying

For each treatment method, the furnish was allowed to air-dry at ambient temperature (21°C) for 4 to 6 days. This reduced the moisture content of the treated strands from approximately 25 percent to 6 to 8 percent by ovendry weight. No changes in the physical appearance of the strands were noted after drying.

Preservative retentions

One of the advantages of using 3-iodo-2-propynyl butyl carbamate (IPBC) as an active ingredient is that the molecule consists of 45 percent by weight of iodine, and the iodine atom is a convenient analytical tag. Solution concentrations of IPBC were measured by x-ray fluorescence of iodine atom content using a bench-top x-ray fluorescence spectrometer with an Fe-53 source. Solution concentrations were also checked using high performance liquid chromatography (HPLC) which confirmed the x-ray fluorescence technique. For measurement of IPBC retentions in treated strands and fabricated panels, the analytical method of choice was neutron activation analysis (NAA). This technique utilizes a low level nuclear reactor. Small samples of treated strands or OSB panels are exposed to this low level source of radiation. The resulting emissions from the iodine present in the IPBC can be used to accurately measure iodine and IPBC content at ppm levels (Ross 1990). All neutron activation analyses were carried out by the Ecole Polytechnique of the University of Montreal using their SLOWPOKE reactor. Neutron Activation Analysis for IPBC in treated wood has shown excellent correlation with other methods for analyzing IPBC in treated wood including x-ray fluorescence and extraction/HPLC (AWPA 2001).

Preservative retentions of strands and panels treated with WB-1 are presented in **Table 2.** Pressure treatment of strands afforded the highest preservative retentions, dip treatment gave the next highest retentions, while tumbling of strands in the rotary drum provided the

Table 1. - Preservative systems.

Preservative system	Description	Active ingredients	Water repellent content	Approx. surfactant content	Approx. cosolvent content
		(%)			
WB-1	Waterborne emulsion concentrate	2.5 IPBC	8	1 to 5	5 to 10
WB-2	Water dilutable microemulsion concentrate	3.4 IPBC	5	5 to 10	40 to 60
WB-3	Water dilutable microemulsion concentrate	0.71 IPBC	5	5 to 10	40 to 60
		0.71 tebuconazole			
		0.71 propiconazole			

lowest retention levels. Preservative retentions of WB-2 are presented in **Table 3.** The water-only control exhibited trace levels of IPBC in treated strands and panels, most likely from minor contamination of the rotary drum from previous treatments.

Table 4 presents preservative retentions for WB-3 treated strands and panels. Levels of propiconazole and tebuconazole were calculated based upon the measured values for IPBC.

Table 2. — Preservative retentions, WB-1 (2.5% a.i. IPBC).

Preservative dilution	Solution conc.	Application method	IPBC retention: Strands (single sample)	IPBC retention: Panels (composite of 3 samples)
	(% IPBC)		- - - - - - - - - (ppm)	- - - - - - - - -
9:1	0.148	Rotary drum	355	288 (23)[a]
4:1	0.263	Rotary drum	1,677	1,607 (101)
4:1	0.257	Dip	3,509	3,921 (156)
4:1	0.453	Pressure	8,824	9,073 (149)

[a] Numbers in parentheses are standard deviations.

Table 3. — Preservative retentions, WB-2 (3.4% a.i. IPBC).

Preservative dilution	Solution conc.	Application method	IPBC retention: Strands (single sample)	IPBC retention: Panels (composite of 3 samples)
	(% IPBC)		- - - - - - - - - (ppm)	- - - - - - - - -
9:1	0.287	Rotary drum	514	521 (29)[a]
5:1	0.499	Dip	4,595	6,731 (273)
Water	0	Rotary drum	48	10 (0.6)

[a] Numbers in parentheses are standard deviations.

Table 4. — Preservative retentions, WB-3 (0.7% IPBC, 2.1 % a.i.).

Preservative dilution	Solution conc.	Application method	IPBC retention: Strands (single sample)	IPBC retention: Panels (composite of 3 samples)
	(% IPBC, % a.i.)		- - - - - - - - (ppm)	- - - - - - - - -
9:1	(0.06, 0.18)	Rotary drum	214	204 (23)[a]
5:1	(0.12, 0.36)	Dip	1,604	1,590 (8)
Water control	0	Dip	0	14 (0.7)
No treatment control	--	--	0	7 (1.7)

[a] Numbers in parentheses are standard deviations.

Resin blending

Dried strands (treated or untreated controls) were placed in the rotary tumbler and blended with a liquid phenolic resin (a commercial phenol-formaldehyde resin obtained from Borden Chemical Inc., Columbus, Ohio). It had a solids content of 61 percent and a specific gravity of 1.2. The resin was introduced with an air-atomized metered spray system. It constituted 5 percent by weight of the furnish, based on solids content and ovendry strand weight. Because all of the preservative systems being investigated contained water repellents in their formulas, this study did not include the addition of any external waxes or water repellents to the furnish.

Panel preparation

A single-layer mat was formed immediately after resin was applied to the strands. Calculations were made to determine the specific weight of strands needed to produce a panel at the target length, width, thickness, and specific gravity. Strands were weighed out and formed into a mat on an aluminum caul plate using a 560- by 560-mm forming box. The strands were shaken into the forming box by hand with random orientation.

Mats were then pressed into panels in an oil-heated hydraulic press. The panel pressure was 3.39 MPa (492 psi). The pressure was maintained for 5 minutes at a platen temperature of 221°C. Control panels were prepared from strands that had been treated with water only and subsequently dried, and from dry, untreated strands. In Phase 1, four replicate panels were produced for each treatment.

Panel evaluation

Mechanical strength. — Modulus of rupture (MOR) and modulus of elasticity (MOE) of the experimental panels were evaluated on an Instron Test Machine in accordance with American Society for Testing and Materials Standard D 1037 (ASTM 1992).

Water resistance. — Panels were immersed in water for 24 hours at ambient temperature and measured for water absorption and thickness swell following ASTM Standard D 1037 (ASTM 1992).

Fungal resistance. — Small sections (50 mm by 50 mm) were removed from each experimental panel at various locations. These were placed in petri dishes containing a malt agar medium and inoculated with basidiomycete (decay) or deuteromycete (mold/mildew) fungal blends as noted in **Table 5.** One drop (about 0.1 mL) of homogenized culture inoculum was added to four spots around the perimeter of each sample. Panels were observed for fungal growth after 30 days of incubation at 32°C, 90 percent relative humidity. Panels were visually scored for resistance to fungal growth on a 0 to 100 percent scale with 100 percent representing complete surface protection and 0 percent representing complete fungal overgrowth. In this evaluation, the average of four replicates was utilized.

Results and discussion

Mechanical properties

Mechanical testing results for panels produced utilizing the rotary drum ap-

Table 5. — Fungal blends.

Organism	No.
Basidiomycete blend	
Gloeophyllum trabeum	617
Lentinus lepideus	534
Poria placenta	698
Coriolus versicolor	697
Deuteromycete blend	
Acremonium strictum	A10141
Chaetomium globosum	1602 1
Graphium rubrum	6506
Trichoderma spp.	K2
Trichoderma viride	13631
Aspergillus niger	A 1004
Aspergillus spp.	K1
Paecilomyces varioti	16023
Gliocladium spp.	K3
Cephaloascus fragrans	24950
Alternaria alternata	13963
Penicillium purpurogenum	52427
Cladosporum cladosprioides	16022
Aureobasidium pullulans	16622
Diplodia gossypina	9055
Chlorociboria aeruginascens	24028
Ceratocystis (Ophiostoma) picea	387A
Ceratocystis (Ophiostoma) fimbriata	14503
Ceratocystis (Ophiostoma) clavigerum	18086

Table 6. — Results of mechanical tests.

Preservative system	Preservative dilution	Application method	MOR	MOE
			(MPa)	(GPa)
WB-1	9:1	Rotary drum	26.4	5.27
WB-2	9:1	Rotary drum	28.9	5.65
WB-3	9:1	Rotary drum	18.7	4.63
WB-1	4:1	Rotary drum	23.8	5.12
Water control	--	Rotary drum	27.6	4.71
No treatment control	--	--	26.8	4.32
Minimum acceptable values (CSA 1993)			17.2	3.10

Table 7. — Water resistance results.

Preservative system	Preservative dilution	Application method	Thickness swell	Water absorption
			(%)	
WB-1	9:1	Rotary drum	21.6	59.4
WB-2	9:1	Rotary drum	27.8	71.4
WB-3	9:1	Rotary drum	34.7	84.8
WB-1	4:1	Rotary drum	8.0	18.8
Water control	--	Rotary drum	24.0	73.4
No treatment control	--	--	23.8	81.4
Minimum acceptable value (CSA 1993)			25.0	Not specified

plication method are presented in **Table 6.** Static bending properties of most of the panels were not negatively affected by the addition of a WRP treatment. All MOR and MOE values were above the minimums established by the Canadian Standards Association (CSA 1993). Canadian standards are used here for comparison of mechanical properties since there are no established minimums for strandboard in U.S. standards.

The purpose of this study was to investigate the preservative treatments for solid wood and how they affect flakeboard panels when the flakes are treated before being pressed into a panel. This initial study was to identify the most promising preservatives for use in this application. Therefore, only limited mechanical and physical tests (i.e., bending and water absorption tests) were used at this time. After determining the best preservative, a more comprehensive study could be made.

Water resistance

Water resistance test results for thickness swell and water absorption are presented in **Tables 7** through **9.** Preservative system WB-1, when applied to the aspen strands at a 4:1 dilution, significantly reduced the thickness swell and water absorption of the fabricated panels. The thickness swell of control samples after 24 hours of water soaking was 23.8 percent compared to a thickness swell value of 8 percent for treatment WB-1. Water absorption was reduced from 81.4 percent in the untreated control panels to 18.8 percent in the WB-1 treated panels.

Fungal resistance

Table 10 outlines the laboratory fungal resistance testing results. In general, treated panels were more resistant to the deuteromycete (mold, mildew) fungal blend than the basidiomycete (decay) blend. Performance followed a dose-response relationship regardless of the preservative or the method utilized to introduce the preservative to the furnish (i.e., higher preservative retentions resulted in higher levels of surface protection from the fungi).

With the exception of the lowest treatment level for WB-1, all treatments demonstrated improved protection against both deuteromycetes and basidiomycetes compared to the untreated controls.

Table 8. — Water resistance results.

Preservative system	Preservative dilution	Application method	Thickness swell	Water absorption
			(%)	(%)
WB-1	4:1	Dip	5.8	17.2
WB-2	5:1	Dip	28.6	64.6
WB-3	5:1	Dip	22.2	62.4
Water	--	Dip	28.2	72.7
No treatment	--	--	23.8	81.4
Minimum acceptable value (CSA 1993)			25.0	Not specified

Table 9. — Water resistance results.

Preservative system	Preservative dilution	Application method	Thickness swell	Water absorption
			(%)	(%)
WB-1	4:1	Pressure	5.2	15.3
Water control	--	Pressure	28.8	74.4
No treatment control	--	--	23.8	81.4
Minimum acceptable value (CSA 1993)			25.0	Not specified

Table 10. — Fungal resistance results.

Preservative system	Application method	Preservative retention	Percent surface protection	
			Deuteromycete	Basidiomycete
		(ppm)	(%)	(%)
WB-1	Rotary drum	288	37 (26)[a]	0 (0)[a]
	Rotary drum	1,607	83 (24)	73 (17)
	Dip	3,921	100 (0)	80 (14)
	Pressure	9,073	100 (0)	77 (33)
WB-2	Rotary drum	521	33 (47)	33 (25)
	Dip	6,731	100 (0)	100 (0)
WB-3	Rotary drum	204	53 (41)	37 (45)
	Dip	1,590	100 (0)	100 (0)
Water control	All	--	22 (21)	17 (33)
No treatment control	--	--	7 (9)	17 (24)

[a] Numbers in parentheses are standard deviations.

Table 11. — Phase 2 results of mechanical and water resistance tests, WB-1.

Application method	Type of preservative	Preservative dilution	Property: Static bending MOR	Static bending MOE	Thickness swell	Water absorption
			(MPa)	(GPa)	(%)	(%)
Rotary drum	WB-I	4:1	23.1	4.97	7.8	26.1
Control panels (no treatment)	--	--	29.9	5.41	26.6	71.3

Table 12. — Phase 2 results of fungal resistance.

	Percent surface protection	
	Deuteromycete	Basidiomycete
	(%)	(%)
WB-I	93 (2)[a]	85 (24)[a]
Control panels (no treatment)	2 (9)	3 (9)

[a] Numbers in parentheses are standard deviations.

Phase 2 testing (verification of initial test results)

According to the test results, WB-1 was the most promising of the three candidate preservative systems. To verify the effectiveness of this treatment, a second set of panels was prepared using the rotary drum application to treat the furnish with a 4:1 dilution. Ten 560- by 560-mm panels were prepared as before. AS a control, 10 panels were prepared following the same regimen, except that no treatment was applied to the furnish. All panels in Phase 2 had the same thickness and specific gravity range as those in the initial phase of the project. **Table 11** summarizes the mechanical and water resistance test results for these panels. Again, WB-1 was shown to significantly reduce both thickness swell and water absorption compared to the untreated control panels. Mechanical properties were only slightly reduced from those of the controls.

A repeat of the fungal resistance testing was also carried out **(Table 12).** Again, treatment WB-1 was shown to significantly enhance resistance to both deuteromycetes and basidiomycetes compared to untreated control panels.

Conclusions

These results indicate that WRP formulations based on organic biocides can be introduced as integral furnish treatments to improve the water resistance and fungal resistance properties of fabricated aspen strandboard panels without negatively impacting their static bending properties. The mode of applying the biocide system to the furnish and the amount of biocide retained by the wood-based composite were critical factors when evaluating the panels' performance. In this experiment, preservative system WB-1 outperformed the other two formulas tested. Optimum dilution appeared to be 4: 1 (i.e., 0.5% active of IPBC). The preferred method of application of preservative to the furnish was a rotary drum/spray apparatus. This provided the resulting strandboard panels with effective WRP levels that produced water resistance and protection from fungal growth while still exceeding the minimum acceptable values for MOR and MOE.

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