

Biocide Treatments for Composite Panels



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Abstract

This study was designed to investigate the effect of biocide addition on the properties of randomly oriented wood strandboard. Included in the study were new-generation preservative systems including copper naphthenate, betaine, and copper betaine added to a southern pine furnish containing no more than 4 percent low- and medium-density hardwoods. Study variables included treatment level, mode of biocide addition (flake pretreatment, spray incorporation),

and biocide form (powdered, liquid). Comparison was with untreated panels and panels treated with the industry standard, zinc borate. Bending and dimensional properties were evaluated in this preliminary study. Results are discussed in terms of biocide and treatment mode. Few deleterious effects were found for boards treated with the copper compounds or betaine when compared to those for zinc borate treatments.

Introduction

Viable biological protection technologies for structural wood composite panels such as waferboard, strandboard, and oriented strandboard (OSB) have been in existence since the early 1990s (Knudson 1990, Laks and Palardy 1990) resulting from numerous studies in the 1980s and 1990s. These technologies continue to see increased importance as well as more publicity in academic and commercial venues. The largest category end use for structural wood composite panels is in residential construction. As Smith and Wu (2005) have noted, wood composites are being increasingly utilized and often are the principal structural elements in buildings. As structural wood composites (especially strand based) are being used more to replace solid-sawn lumber and plywood, they are sometimes placed in challenging environments. These more demanding environments often open the door to increased susceptibility. Problems are commonly a direct result of high moisture levels conducive to sustaining mold, decay, and stain fungi. Architectural design changes using shorter roof overhangs and closer proximity of siding to the groundline/soil have increased the chances of moisture ingress. Further compounding the problem in some areas of the country, is the use of building vapor membranes which decrease the ability of moisture to escape the building cavity (Morrell 2001). Typical symptoms may include but are not limited to excessive shrinking/swelling, insects (including termites), decay fungi, and mold. Many of these problems came to light during the 1990s as numerous civil lawsuits were filed concerning the failure of these composite products to perform in use. Many of these issues, however, may be abated by proper application design with correct installation and proper maintenance. Thus, the limitations and susceptibility of structural wood composites have been well-documented. This portrays the current need for more durable structural wood composites. Moreover, durability improvements may increase the end-use categories of some structural wood composites to include adverse environments (Baileys et al. 2003) and expand markets. Additional durability may be attained by several means, including but not limited to

improved biological resistance, improved moisture resistance, and improved physical properties. This paper focuses on improving durability through enhanced biological resistance.

Many biocidal systems for use on structural strand-based panels were examined throughout the 1980s with zinc borate emerging as the industry choice among preservatives added as an integral treatment. Copper ammonium acetate and copper ammonium carbonate are also being used commercially. These protection methods offered the first biologically durable structural sheathing product on the market since treated plywood became available in the 1950s. To date, most commercially treated panel products made from wood strands still utilize zinc borate as the preservative agent. A notable exception is in Hawaii, where all wood building materials are required to be preservative treated. Although not inexpensive, post-treatment of panels by using a light hydrocarbon solvent carrier for pressure treatment has been performed in Hawaii for a number of years. Emerging treatments for strand-based panel products include calcium borate, organic insecticide/ fungicide blends, and moldicides (Smith and Wu 2005).

The technologies used to protect wood composites from biological attack may encompass one or more methods to add a biocide to the wood product. Pre-treatment of wood flakes, integral treatment, and post-treatment methods have all been examined as application methods using various preservatives. Integral treatments are especially attractive since the biocide can be incorporated during the manufacturing process. This is usually accomplished by spraying the wood furnish with a liquid or powder biocide, or by pre-mixing the biocide with adhesive. However, the biocide must be compatible with the adhesive and compatible with the high temperatures generated during consolidation while not adversely affecting the structural performance and durability of the panel. This paper examines the compatibility of different biocidal treatment formulations for use on structural wood composites. Mechanical and physical properties were tested to determine deleterious effects resulting from biocidal addition. Biocide, form-

ulation type, and application method were included in this study.

Materials and Methods

Preservatives

Five preservatives including six different formulations were examined in this study. Copper naphthenate in powdered form and as a waterborne solution, betaine (waterborne solution), two copper betaine systems (waterborne solution), and powdered zinc borate (as a positive control) were each examined. Each of these preservatives have documented evidence to provide fungal and/or termite resistance, though little literature exists specifically relating efficacy of the above biocides with wood-based composites (excluding zinc borate). As higher loadings are usually required for protection against insects, this study was designed to test laboratory manufactured panels using anticipated threshold retentions for *Reticulitermes*. Target loadings are seen in **Table 1**. Higher retention loadings would establish any deleterious effects to strength performance of panels, and unsuitable preservatives could be excluded for further testing and evaluation.

Compatibility tests were performed to establish a viable integral treatment method for each preservative. Appropriate amounts of preservative were mixed with a particleboard-type liquid emulsion wax, and separately with a commercial OSB core type phenol formaldehyde (PF) resin. The formulations were tested for viscosity and compatibility with manufacturing equipment. The two powdered preservatives did not mix well with wax or resin. Therefore, the powdered solutions were added in powder form using a modified, low air pressure agricultural-type duster during the blending process. Waterborne copper naphthenate solution was mixed with PF resin and applied like an ordinary resin. The betaine and copper betaine formulations did not mix well with PF resin and thus were mixed with a particleboard type emulsion wax and applied in the manner of an ordinary liquid wax. Additionally, waterborne copper naphthenate was examined for a pretreatment application method. Strands were treated under solution using a vacuum process. The treating cycle consisted

Table 1.—Target retentions of treated strand-board specimens.

Treatment	Method of addition	Target retention
Untreated control	n/a	none
Cu + Betaine 102	wax	16 kg/m ³ (total ai)
Cu + Betaine 111	wax	18 kg/m ³ (total ai)
Betaine	wax	32 kg/m ³ (total ai)
Wb CuNap	adhesive	1.6 kg/m ³ (Cu as metal)
Wb CuNap	vacuum pretreatment	1.6 kg/m ³ (Cu as metal)
Powd. CuNap	powder	1.6 kg/m ³ (Cu as metal)
Zinc borate	powder	1.2% BAE

$$1 \text{ kg/m}^3 = 0.624 \text{ lb/ft}^3$$

of an initial 15 minute vacuum before beginning solution uptake. Total time under vacuum was equal to 30 minutes. Further tests with an additional vacuum cycle as well as pressure cycles showed no additional solution pickup. This vacuum cycle provided an adequate uptake of the waterborne copper naphthenate solution.

Wood Furnish

Wood strands were obtained from a cooperating commercial OSB manufacturing facility (Norbord, Guntown, MS). Strands consisted of primarily southern yellow pine (*Pinus* spp.) less than 150 mm in length with a mixed hardwoods content of less than 5 percent. Strand dimensions averaged 90 mm in length and 0.7 mm thick with varying widths. Fines were not screened out and were included in the furnish mix for manufacture of panels to better simulate a mill setting. Initial moisture content (MC) of the stands ranged from 4 to 6 percent (ovendry basis). Strands were dried in a tumbling dryer to a predetermined MC (ranging from 2% to 5%) according to the type and amount of preservative addition for an appropriate mat MC.

Panel Manufacture

Panels were manufactured in the Wood Composite Laboratory at the Mississippi Forest Products Laboratory (Starkville, MS). Materials were blended in an 1,825-mm diameter tumbling blender. Wax was applied with a low air pressure (1.4 kg/cm², 20 psi)

sprayhead and adhesive was then applied with a Concord EL-2 spinning disk atomizer (Coil Manufacturing Ltd., Surry, B.C. Canada) while tumbling strands. Total blending time varied by preservative type and application method. Mats were hand-felted (random orientation) in a forming box with indexing lines, and placed on steel caul plates.

Panels were consolidated under heat and pressure in a Dieffenbacher hot press with PressMAN computer controls and monitoring system. The press cycle consisted of a 5-minute schedule and 30 second decompression with platen temperature of 200°C. Platen pressure was computer controlled according to a programmed pressing schedule in order to maintain the desired thickness. Target panel density was 670 kg/m³ (42 pcf). All panels were manufactured with 4 percent resin (dry wood weight basis), 1 percent wax (dry wood weight basis), and a single preservative amount at or above an estimated threshold retention (**Table 1**). Finished panel size was 560 by 510 by 11 mm thick (22 by 24 in. by 7/16 in. thick). Four replicate panels for each combination of treatment and application type were made. To reduce variation due to blending and for differences in strand species, a blocking scheme was devised based on groups of strands. This included using two separate blends for each treatment and application type. The first and second blend of each treatment and application method used separate groups of strands (two). The two groups of strands were obtained at different times from the OSB manufacturing facility and contained slightly different percentages of strand species.

Panel Testing and Analysis

Finished panels of 560 by 510 by 11 mm were trimmed to 460 by 510 mm (18 by 20 in.) and weighed for density calculation. Panels were then trimmed into individual specimen sizes for physical, mechanical, and other tests. A cutting pattern is shown in **Figure 1**. Specimens were conditioned in a 12 percent equilibrium moisture content room for at least 96 hours before testing. Mechanical tests performed in accordance with ASTM D1037 (2004) included static bending tests with a center span of 266 mm (10.5 in)

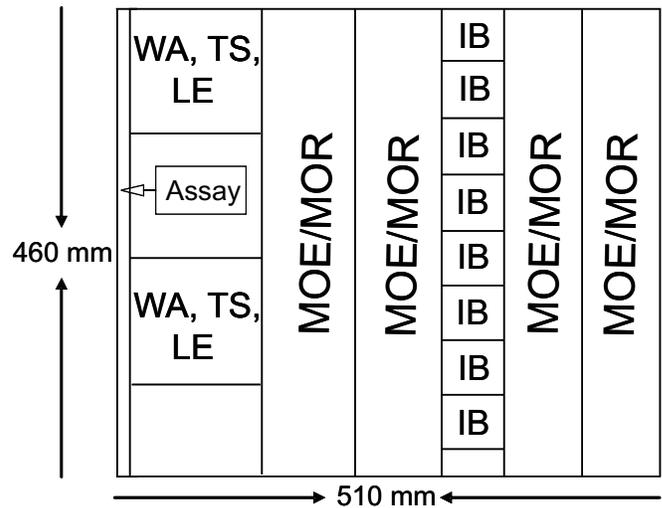


Figure 1.—Cutting diagram for sample preparation.

and internal bond (IB) tests. Water soak tests examining water absorption, thickness swell (TS), linear expansion (LE), and MC were also performed according to ASTM D1037. It should be noted that water soak tests used 127 mm (5 in.) square specimens instead of the prescribed 152-mm square specimens. Assays were conducted using a 6-mm (0.25 in.) strip cut from the lower edge of each panel and ground into sawdust passed through a 40-mesh screen. Statistical analysis on the resultant data was performed using SAS software version 8.2. The data were analyzed using an alpha level of 0.05 (for 95% confidence). The response variable(s) were analyzed for significant covariates and means were adjusted accordingly. The LSMEANS option was used for means separation.

Results and Discussion

Panel Manufacture

All panels were manufactured successfully. Some mat MCs were higher than the desired 10 percent (ovendry basis), but no blows were observed. The successful consolidation could be partially due to the long pressing time and conservative 30-second decompression. The finished panels exhibited colors different from controls (except betaine panels) and were directly attributed to the color of the biocide used. The copper naphthenate panels each had a different color tint ranging from light brown to dark

brown depending on the formulation used. The copper betaine panels had a dark brown appearance as well. The zinc borate panels had a lighter tint than untreated controls.

Static Bending

Bending results can be seen in **Table 2**. The modulus of elasticity (MOE) and modulus of rupture (MOR) values obtained can be compared against Canadian Standards Association O437, which contain specific grade property requirements for panels with randomly aligned strands or wafers. CSA standards are used because no United States standard exists for strandboard, i.e., panels with random strand orientation. MOE and MOR results were very similar, with the stronger treatments also being stiffer. Zinc borate treated panels did not meet the minimum CSA standards for MOE and MOR properties. All other treatments met minimum CSA standards. Statistical results, however, revealed more differences between treatments.

Across MOE, MOR, and work to maximum load (Wml), both copper plus betaine formulations and waterborne copper naphthenate (added to the adhesive) had superior performance. The three copper naphthenate combinations showed different performance suggesting the method of addition is a significant factor in designing a copper naphthenate biocide system for use on wood composites. Literature on method of biocide addition is conflicting. Baileys

and others (2003) found that the preferred method of addition was with a rotary drum/spray apparatus versus diffusion when making strandboard treated with organic waterborne water-repellent formulations. Conversely, Goroyias and Hale (2000) observed improved mechanical and physical properties of strandboards vacuum or diffusion treated with copper boron azole compared to boards spray-treated. This suggests the method of addition is related to the specific preservative and its formulation, as well as multiple processing factors.

Both powdered preservatives, zinc borate and copper naphthenate, had inferior performance compared to controls and others (except vacuum pretreated waterborne copper naphthenate), although not always significantly. It is not clear whether the negative strength effects are due to the nature of the powdered preservatives or to process equipment/application method. The method of zinc borate addition used in this study did not use an emulsion or other agent to deliver the preservative to the wood furnish. It is known, however, that zinc borate has superior performance with polymeric diphenylmethane diisocyanate adhesive compared to phenolic adhesives (Laks et al. 1988). Laks and Palardy (1990) also note borates adverse effect on mechanical properties of PF-bonded wood composites. Hence, any comparisons of zinc borate results to other academic or industrial studies should be made very carefully.

Table 2.—Static bending means and statistical differences of treated strandboard specimens.^{a,b}

Treatment	Method of addition	MOE	MOR	Work to maximum load
		----- (MPa) -----		(kJ/m ³)
Cu + Betaine 102	wax	3628 A	34.05 A	14.62 A
Wb CuNap	adhesive	3595 A	27.04 A	13.49 A
Cu + Betaine 111	was	3433 A	26.19 A B	12.30 A B
Untreated control	n/a	3392 A	25.13 A B C	11.59 B C
Betaine	wax	3260 A	24.16 A B C	10.82 B C
Powd. CuNap	powder	3241 A B	22.63 B C	10.25 B C
Wb CuNap	vacuum pretreatment	3229 A B	21.08 C D	9.63 B C
Zinc borate	powder	2734 B	16.66 D	8.07 C

^a Values followed by the same letter are not significantly different.

^b Values obtained are based on 16 bending specimens.

Internal Bond

IB results (Table 3) show three treatments with performance similar to controls: copper betaine-102, copper betaine-111, and waterborne copper naphthenate (added to adhesive). These three treatments (and controls) met the CSA minimum requirement, although values obtained from IB testing were considerably less than expected. The two powdered preservatives, copper naphthenate and zinc borate, both exhibited inferior performance. The powdered copper naphthenate was not statistically different from vacuum pretreated copper naphthenate or betaine

Table 3.—Internal bond means with statistical differences of treated strandboard specimens.^a

Treatment	Method of addition	Internal bond ^b (kPa)
Cu + Betaine 111	wax	426.62 A
Untreated control	n/a	422.47 A
Wb CuNap	adhesive	357.79 A
Cu + Betaine 102	wax	349.20 A B
Betaine	wax	272.16 B C
Wb CuNap	vacuum pretreatment	263.49 B C
Powd. CuNap	powder	248.99 C
Zinc borate	powder	125.67 D

^a Values followed by the same letter are not significantly different.

^b Values obtained are based on 32 specimens.

treatments. Two copper naphthenate treatments, waterborne copper naphthenate (added to adhesive) and powdered copper naphthenate, showed decreased strength compared to earlier studies (Kirkpatrick and Barnes 2005) using lower retentions indicating a dose effect with this system. The copper naphthenate (added to adhesive) performed similarly to an earlier study by Schmidt (1991) using an amine-based copper naphthenate with comparable levels of wax, resin, press variables, and copper loading on aspen waferboard.

Water Soak Results

Water soak results are shown in Table 4. For the values obtained, it should be noted that a particle-board type wax was used for manufacture, not the typical slack wax. No treatments outperformed untreated controls, although most treatments showed no differences from the untreated controls. Betaine and zinc borate each showed performance not typical of others. Across each of the three properties, after 2 hours betaine showed increases greater than all others. Although after 24 hours, betaine showed similar performance to the others. Zinc borate performance at 2 hours was not appreciably affected, though specimens fell apart after 24 hours. For LE after 24 hours, only zinc borate was statistically inferior to controls. After 24 hours, TS and water absorption for two treatments, betaine and zinc borate, differed statistically from untreated controls. Water soak results sug-

Table 4.—Physical property means with statistical differences.^a

Preservative	Application method	Linear expansion		Thickness swelling		Water absorption	
		2 hr	24 hr	2 hr	24 hr	2 hr	24 hr
----- (%) -----							
Control	n/a	0.1434 A	0.3196 A	15.88 A	35.32 A B	24.50 A B	70.69 A
Cu + Betaine 111	wax	0.2029 A B	0.3266 A	24.91 A B	35.97 A B C	37.07 B C	71.86 A B
Wb CuNap	vacuum pretreatment	0.1687 A B	0.3732 A	16.05 A	34.36 A	25.90 A B	70.25 A
Cu + Betaine 102	wax	0.1975 A B	0.3959 A	22.95 A B	40.55 A B C	42.27 C D	81.25 A B
Wb CuNap	adhesive	0.2075 A B	0.4180 A	20.29 A B	37.16 A B C	33.93 B C	74.09 A B
P CuNap	powder	0.1538 A	0.4596 A	15.45 A	45.04 B C	17.51 A	80.44 A B
Betaine	wax	0.2875 B	0.4839 A	29.48 B	45.49 C	50.53 D	86.06 B
Zinc borate	powder	0.1625 A B	0.9757 B	26.24 A B	92.53 D	22.59 A B	114.76 C

^a Values with the same letter are not significantly different.

gest an interior or protected exposure is perhaps more appropriate for zinc borate. The two copper betaine formulations provided superior properties compared to the betaine only formulation. The vacuum-pretreated waterborne copper naphthenate seemed to slightly outperform waterborne copper naphthenate (added to adhesive). Goroyias and Hale (2000) saw similar improved physical properties on vacuum pretreated copper boron azole strandboards versus spray-treated strandboards.

Conclusions

This study was an attempt to establish mechanical and physical properties for seven preservative treatments for structural wood composite products using a strandboard model. Overall, the only preservative treatment showing negative interaction with properties was powdered zinc borate. Other treatments such as both copper betaine biocides, waterborne copper naphthenate (added to adhesive) showed slightly better total performance versus other treatments. The vacuum impregnated waterborne copper naphthenate treatment showed overall performance no better performance than the other copper naphthenates. Based on the performance and the extra steps involved in its pretreatment process, the integral copper naphthenate treatments are more attractive than the vacuum impregnated waterborne copper naphthenate. Each of the preservatives evaluated here, with the exception of zinc borate, show promise for further evaluation as preservatives/biocides for use on structural wood composites.

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