MECHANICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF BORATE-MODIFIED ORIENTED STRANDBOARD

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ABSTRACT

Borate-modified oriented strandboard (OSB) was manufactured using zinc and calcium borate to provide resistance to Formosan Subterranean Termites (FSTs). Mechanical, physical, and biological properties of the product were evaluated. It was shown that static bending properties of the OSB were affected little at the room condition by the added borate. The internal bond strength was, however, generally smaller at the higher borate loading levels. Thickness swelling (TS) under the 24-hour water soaking increased with increased borate content, especially for calcium borate. Part of the borate leached out under the water soaking condition due to the glueline washing and decomposition of the borate to form less water-soluble boric acid. The use of borate with a smaller particle size helped reduce TS and leaching rate significantly. Laboratory no-choice termite tests indicated that both zinc and calcium borate modified OSB resisted FSTs well. Thus, termite resistant OSB with required mechanical and physical performance could be successfully developed using southern wood species. This technology will allow more OSB producers to manufacture chemically modified OSB to meet increasing market demands.

KEYWORDS

Borate, leaching, treated wood composites, stiffness, strength, swelling, termites

INTRODUCTION

The Formosan Subterranean Termites (FSTs) pose a growing threat to all structural wood materials in residential construction. The species is one of the most aggressive and voracious insects in the world, eating cellulose - a main component of wood material. FSTs cause over $1
billion structural damage per year in the United States, with a large portion of that in Louisiana (Henderson and Dunaway 1999, Ring1999.) Chemical treatments of wood members with chromated copper arsenate (CCA) and borate have been shown to be effective against the termites (Laks 1988, Barnes et al. 1989). Structural lumber and plywood can be successfully treated after manufacturing (e.g., pressure treatments with CCA). Structural composite panels such as oriented strandboard (OSB), however, cannot be pressure-treated once it is made into panel form due to its large swelling characteristics. The product is made of wood flakes glued with a thermal-setting resin. It is widely used as sheathing, flooring, and I-joist materials in light-frame wood construction, replacing more traditional plywood. Thus, alternative techniques for protecting OSB against FSTs have to be developed.

Work has been done to combine powder borate with wood flakes during the manufacturing of OSB to provide termite resistance of the finished products (Laks et al. 1988; Laks et al. 1991; Sean et al. 1999). However, information on the effect of wood species, borate type, borate particle size, initial borate content level, and other panel processing variables on long-term durability of borate-treated OSB is still missing. The information is highly desired for developing durable structural panels for residential construction using southern wood species.

This project was conducted to incorporate powder borate into OSB furnish in order to provide required biological performance characteristics of OSB. The objectives of this work were to investigate the effects of wood species, borate type and content on short-term loading stiffness and strength, swelling, water leaching, and biological performance of the product. Long-term structural performance of the modified OSB under sustained loading conditions is discussed in other related publications.

**MATERIAL AND METHODS**

**Panel Manufacturing and Testing**

Green boards from eight southern wood species were selected from a local sawmill in south Louisiana. These species included ash (Fraxinus spp.), cottonwood (Populus spp.), cypress (Taxodium distichum L.), elm (Ulmus americana L.), locust (R. pseudoacacia L.), pecan (Carya spp.), red oak (Quercus spp.), and southern pine (Pinus taeda L.). The boards were cross-cut into 152-mm sections, which were flaked to produce 76-mm long flakes using a disc flaker. The flakes were dried to 2-3% moisture content. They were screened to eliminate fines and stored in polyethylene bags until needed. The wood flakes were used to manufacture single species of OSB for zinc borate (ZB) and mixed hardwood and southern pine OSB for calcium borate (CB).

During the panel manufacturing, certain amounts of dry wood flakes, liquid phenol formaldehyde resin, wax, and borate were blended together. The loading rates for resin and wax were 4 and 1% based on the oven-dry wood weight. There were one type of zinc borate (2ZnO3B2O33.5H2O) and two types of calcium borate (Ca3B6O15H2O) with two different particle sizes. Both types of borate are considered as water insoluble at room temperature. The loading rates for zinc borate were 0 (control), 0.5, 1, and 3% based on dry flake weight in the panel. The loading rates for calcium borate were 0 (control), 0.75, 1.5, 3, and 4.5%. Several
single species panels with zinc borate were made with addition of PEG, \( \text{H(OCH\textsubscript{2}CH\textsubscript{2})\textsubscript{n}OH} \), to study its effect on panel properties. The formed mats were hot pressed in a single opening press with the regulated platen temperature of 200°C for 5 minutes. The target thickness and panel density were 12.7 mm and 0.75 g/cm\textsuperscript{3}, respectively. Two replicate panels at each borate level were made. Samples were taken from each panel to test its chemical content. Each sample was ground to pass through a 20-mesh screen with a Wiley mill. Approximately 5 g oven-dry wood meal was extracted under acid condition for 2 hours at boiling temperature. After extraction, the wood meal was filtered out and the liquid filtrate was analyzed with an Inductively Coupled Plasma (ICP) spectrograph. The percent of boron in the sample was calculated based on the oven-dry weight of wood meal. The result was expressed as boric acid equivalent (BAE).

Tests were conducted to determine the panel’s static bending stiffness and strength, internal bond (IB) strength, and thickness swelling (TS) according to the American Society for Testing and Materials standard D1037-96 (ASTM 1998). Water leaching experiments were done to evaluate the leachability of the modified products. Laboratory no-choice tests were conducted according to the American Wood Preservation Association (AWPA) Standard E1-97, Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites (AWPA 1997) to evaluate termite resistance of the products.

**RESULTS AND DISCUSSION**

*Mechanical Properties*

The specific modulus of elasticity (static bending modulus/sample specific gravity) was affected little at room condition (i.e., 5% moisture content at 70°F temperature) by borate up to the 3.5% BAE level (Figure 1A for zinc borate and Figure 2A for calcium borate).

![Figure 1. Bending Properties of Zinc Borate OSB (A: Bending Modulus of Elasticity/Specific Gravity and B: Bend Modulus of Rupture/Specific Gravity)](image-url)
There was some reduction for the specific modulus of rupture (i.e., bending strength/sample specific gravity) at higher borate loading levels (Figure 1B for zinc borate and Figure 2B for calcium borate), indicating a negative effect of borate on panel strength. Wood species and borate type had an insignificant influence on both properties as shown in the graphs.

![Figure 2. Bending Properties of Calcium Borate OSB (A: Bending Modulus of Elasticity/Specific Gravity and B: Bend Modulus of Rupture/Specific Gravity)](image)

The effect of borate on the specific IB strength varied with borate type and wood species. Zinc borate generally showed less negative effects on the IB values (Figure 3A), compared with calcium borate (Figure 3B) for hardwood OSB. Southern pine OSB showed an IB reduction at higher BAE levels for both zinc and calcium borates. For calcium borate, the particle size had some influence on the IB strength. At a comparable BAE level, CB2, which had a smaller particle size, led to a higher IB strength compared with boards made of CB1, which had a larger particle size. For both types of borate, acceptable bending stiffness, strength, and IB values (based on the industry standard) can be achieved.

**Physical Properties**

Thickness swelling from the 24-hour water soaking (Figure 4) generally increased with borate content in the panel for both ZB and CB OSB, indicating a negative effect of borate on the panel properties under high moisture content levels. For the given exposure condition, ZB-modified OSB had a smaller TS than CB OSB at a comparable BAE level. Borate particle size had a significant influence on the swelling properties. Calcium borate with a larger particle size (CB1) had large TS, especially at the higher BAE levels. However, reducing the particle size of the chemical (CB2) helped bring the thickness swelling to a stable and acceptable level (Figure 4B). Wood species had a large influence on TS for single species OSB with ZB. The single species hardwood OSB had relatively smaller TS.
A significant amount of borate leached out under the water soaking condition (Figure 5). The leaching of the OSB occurred upon the initial water exposure, and the leaching rate decreased as the leaching time increased. Wood species, borate type, initial BAE level, and sample TS
significantly influenced the leaching rate. This was due to a combined effect of water washing on
the glueline under the swelling condition and decomposition of the borate to form a more water-
soluble chemical (i.e., boric acid). Calcium borate with a smaller particle size (CB2) helped
reduce sample thickness swelling and leaching rate. There was no consistent effect of
polyethylene glycol (PEG) on zinc borate leaching. Thus, boron fixation with other chemical
agents is necessary for borate-modified OSB under the extreme water exposure condition.
Protection of the panel from direct water exposure can help reduce this problem significantly. A
unified method specifying sample size and exposure condition for testing the leachability of
treated wood composite materials is highly needed.

![Figure 5. Leaching Properties of Zinc (A and B) and Calcium (C and D) Borate OSB.](image)

**Biological Performance**

Laboratory no-choice termite tests indicated that both zinc and calcium borate modified OSB resisted FSTs well (Figure 6 and Table 1 for ZB OSB). As the borate loading increased, termite mortality rate (Figure 6A) increased and wood sample weight loss (Figure 6B) decreased. At the higher borate levels, there was little damage on wood samples, showing a significant deterring effect of boron on termites. The observed weight loss in these samples was due to loss of volatile materials in the samples. A similar behavior was seen for calcium borate OSB. Wood species showed an insignificant effect. There were strong correlations among the visual damage rating as
stipulated in the AWPA standards (AWPA 1997), wood sample weight loss, and termite mortality. The established correlations among the three variables allow predicting FST damage and mortality based on visual rating for treated OSB at various borate levels.

Figure 6. Termite Resistance Properties of Zinc and Calcium Borate OSB. A) Termite Mortality and B) Wood Sample Weight Loss.

Table 1. Results of Laboratory Termite Tests for Zinc-Borate Modified OSB from Southern Pine and Mixed Hardwoods.

<table>
<thead>
<tr>
<th>Wood Species</th>
<th>Zinc Borate Weight (%)</th>
<th>Sample Density (g/cm³)</th>
<th>Visual Damage Rating 2,3 (1-10)</th>
<th>Wood Weight Loss (%)</th>
<th>Termite Mortality (%)</th>
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</thead>
<tbody>
<tr>
<td>Mixed</td>
<td>0</td>
<td>0.74</td>
<td>2.96c</td>
<td>16.48a</td>
<td>17.50b</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>0.69</td>
<td>8.54b</td>
<td>4.58b</td>
<td>34.95a</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>0.59</td>
<td>8.52b</td>
<td>4.17b</td>
<td>40.05a</td>
</tr>
<tr>
<td></td>
<td>4.5</td>
<td>0.71</td>
<td>9.54a</td>
<td>3.08b</td>
<td>37.95a</td>
</tr>
<tr>
<td>Southern</td>
<td>0</td>
<td>0.74</td>
<td>2.36c</td>
<td>21.02a</td>
<td>19.50b</td>
</tr>
<tr>
<td>Pine</td>
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<td>0.72</td>
<td>9.80a</td>
<td>2.70b</td>
<td>32.45a</td>
</tr>
<tr>
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<td>3.0</td>
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<td>8.86b</td>
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<tr>
<td></td>
<td>4.5</td>
<td>0.67</td>
<td>9.18ab</td>
<td>3.51b</td>
<td>37.00a</td>
</tr>
</tbody>
</table>

1 Target weight percentage based on dry flake weight used for manufacturing the board.
2 1 showing the most amount of damage and 10 showing the least amount of damage.
3 Each mean represents five replicates. Means within each column followed by the same letter are not significantly different based on the Tukey’s multiple range tests at the 5% significance level.

CONCLUSIONS

Borate-modified OSB using southern wood species was manufactured and their performance characteristics were evaluated according to the industry test standards. The results of this study
indicated that termite-resistant structural OSB with desired mechanical and physical performance could be successfully developed with a right combination of wood species, borate type and content, and other processing variables. The results provide comparative properties between zinc and calcium borate modified OSB and an alternative treating method for structural OSB (i.e., using calcium borate). This technology will allow more OSB producers to manufacture chemically modified OSB to meet increasing market demands.

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REFERENCES


