FIRE-RETARDANT-TREATED STRANDBOARD: PROPERTIES AND FIRE PERFORMANCE

*Jerrold E. Winandy**

Research Wood Scientist
USDA Forest Service, Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53726-2398
jwinandy@fs.fed.us

Qingwen Wang

Professor
Northeast Forestry University
Harbin, China

and

Robert H. White

Wood Scientist
USDA Forest Service, Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53726-2398
rhwhite@fs.fed.us rec]

(Received May 2007)

ABSTRACT

This study evaluated a series of single-layer, randomly oriented strandboard panels made with one resin type, a single resin loading level, and four fire-retardant-treatment levels. The fire retardant (FR) evaluated was a pH-buffered combination of boric acid and organic phosphate. Siberian larch strands were separated into five batches. One batch of strands served as the untreated control group and was not treated with water or FR; the four other batches were individually treated using a vacuum–pressure–soak process of the strands in water or three progressively higher concentrations of FR solutions. Targeted water- or FR-loading levels were no FR (0% FR-weight gain, water-treated control), 32 kg/m^3 FR (~5% weight gain), 64 kg/m^3 FR (~10% weight gain), and 96 kg/m^3 FR (~15% weight gain). All water- or FR-treated strands were redried to less than 8% moisture content prior to diphenylmethane diisocyanate (MDI) resin application in rotary blenders using an aerosol sprayer. Three replicate specimens for each treatment level of 12.5-mm-thick, randomly oriented strandboard at a density of 650 kg/m^3 were evaluated. FR-treated strandboard had higher dry- and wet-internal bond strength and lower flexural strength than matched untreated strandboard. A Class B flame-spread rating was achieved near 10% FR-loading. These results suggest that better ratings seem possible at higher loadings.

Keywords: Strandboard, composites, fire retardant, treatment.

INTRODUCTION

Composite panel products, manufactured by compressing particles, strands, or flakes of wood, are often used as untreated structural roof and wall sheathing in traditional North American light-frame construction. In North America, oriented strandboard (OSB) has surpassed plywood as the premier structural sheathing product for roof and wall sheathing. Yet FR-treated composites, such as OSB, have not been used as roof

* Corresponding author

or wall sheathing products. The problem is that the traditional (post-manufacture) pressure-treatment processes using either FR or preservative chemicals induce irreversible thickness swell and/or negatively affect the structural properties of the treated composites. Further, roof sheathing composite panels can experience temperatures approaching 80°C (Winandy et al. 2000), and previous research showed that some FR- and preservative-treated wood products can experience in-service strength losses due to hydrolytic thermal degrade of FR-treated wood products when used as roof sheathing or trusses (LeVan et al. 1990; Winandy 2001).

Three major problems are often encountered when attempting traditional pressure-treating processes with composite panel products such as OSB. The first relates to interference of treatment chemicals with resin curing and bond development if FR treatment is attempted prior to hot-pressing. This interference seems to either inhibit or alter the chemical mechanisms required for the adhesives to bond together the panel constituents. The second problem relates to the ensuing physical/mechanical damage (i.e., irreversible thickness swelling) resulting from the waterborne pressure-treatment process, or chemical effects on the wood constituents themselves, or some combination of both. In either case, FR chemicals and/or traditional pressure-treatment processes significantly and negatively affect the internal bonding critical to structural performance of the panel. The final problem is that because of the first two problems, the field performance of FR-treated OSB is not accepted by building codes. This field performance issue will need specific documentation to establish that treated OSB can hold up under rigorous field conditions, including thermal and moisture cycling, imposed when used as roof sheathing.

For a FR-treated composite timber or sheathing product to be accepted in the commercial marketplace, a series of performance evaluations must be conducted to assure users and building code authorities that the FR-treated product will successfully perform when used as roof or wall sheathing. The relative resistance of wood composites to fire has been documented by White and coworkers (White and Schaffer 1981; White et al. 1999; White 2003). White and Winandy (2006) discussed numerous performance-related issues critical to achieving adequate fire performance for a number of FR-treated composite products and their various uses. Failure to verify acceptable performance when FR-treated products are exposed to elevated temperatures has resulted in subsequent in-service field failures (LeVan and Collet 1990). To address that early 1990s problem, a test methodology and an evaluation procedure were developed for structural plywood sheathing by ASTM International and accepted by most building codes as a means of documenting long-term performance at elevated temperatures (ASTM International 2005b,c). These problems and the pertinent research were reviewed by Winandy (2001), who detailed both the need for and the development of procedures to document field performance in addition to laboratory-based evaluations of new wood composite products.

OBJECTIVES

We evaluated a new pH-buffered, fire-retardant (FR) chemical—a combination of boric acid and organic phosphate (BOP)—for its effects on physical and mechanical properties and fire performance characteristics of 12.5-mm-thick Siberian larch (*Larix russica* (Endl.) Sabine ex Trautv.) strandboard.

METHODS AND MATERIALS

A series of 15 strandboard panels were made to evaluate the effects on physical, mechanical, and fire-performance properties for a new pH-buffered synergistic combination of boric acid and organic phosphate (BOP) FR formulation. This BOP-FR formulation was composed of 30% boric acid and 70% guanylurea phosphate (GUP) (Wang et al. 1999). Because of the high purity, near-neutral pH, and non-hydrophilic nature of the synthesized GUP, the BOP-FR system has been shown to have little effect on the properties of lumber (Wang et al. 2005). Exposure tests at elevated temperatures of solid wood treated with BOP-FR further indicated that this BOP-FR would probably experience less in-service deterioration in mechanical properties than would some currently used and previously reported phosphate fire retardants (Wang et al. 2005). BOP-FR-treated lumber has also earned a First Class fire-performance rating for waterborne fire retardants under China Public Safety Standard GA159 (NCI 1999) and a B_1 Class rating under China National Standards GB8624, GB8625, and GB8227 (National Bureau of Quality and Technology Inspection 1988a,b, 1997). The preliminary tests indicated that BOP-FR was compatible with diphenylmethane diisocyanate (MDI) resin and could be used as an additive for OSB without interfering with thermoset resin curing. At the Forest Products Laboratory (FPL), we made strands from 2 × 4 lumber, treated those strands to various target BOP-FR loading levels, redried the strands, applied 5% MDI resin (on a dry-weight basis), laid up 508- by 508-mm mats, and hot-pressed the mats to a 12.5-mm thickness (Table 1). We then cut specimens and conducted a series of mechanical, fire, and physical property evaluations to determine the potential effects of the BOP-FR on the properties of random-oriented strandboard (Table 2).

TABLE 1. *Experimental design and general details of composite panel construction.*

Furnish type	Siberian Larch strands
Furnish moisture content	7%–8%
Total number of panels	15 randomly oriented strandboard (ROF)
Size of panels	508_508 mm (20_20 in.) @ 12.5-mm (1/2-in.) thick
Target panel specific gravity	0.65 (untreated)
Type of panel	Single layer (5 treatment groups @ 3 replicates)
BOP-FR treatment groups (5)	Untreated (@40.6 lb/ft^3)
	Water-treated (0% weight gain)
	BOP-FR 32 kg/m^3 (~5% target weight gain)
	BOP-FR 64 kg/m^3 (~10% target weight gain)
	BOP-FR 96 kg/m^3 (~15% target weight gain)
Resin type	Diphenylmethane diisocyanate (MDI)
Resin amount	5% MDI
Press temperature	200°C (392°F) for 240–300 s

Initial breakdown

At FPL, 120 pieces of 1.5- to 1.8-m-long Siberian larch (*Larix russica* (Endl.) Sabine ex Trautv.), 2 × 4 lumber (38- by 89-mm), were cut to 150-mm-long sections with an approximate moisture content (MC) of 10% to 12%. Those 150-mm-long sections were processed into structural strands on the FPL disk flaker. The strands were approximately 75 mm long, 38 mm wide, and 0.64 mm thick. The strands were then dried to approximately 3% to 4% moisture content.

Treating

Once dry, the appropriately designated strands were placed in a tank in a pressure–vacuum retort and treated with BOP-FR. The treatment cycle consisted of 10 min vacuum at –78 kPa, followed by introduction of the appropriate BOP-FR treating solution, and another 15 min vacuum. The vacuum was released, and a 207-kPa pressure was held for 4 min to expunge the treating solution from the tank. This was followed by a second 10-min vacuum. Based on preliminary tests, the three BOP-FR treating solutions were 5.4%, 10.8%, and 16.3% BOP-FR solutions. The concentrations of these solutions were selected to achieve BOP-FR target retentions in treated strands after subsequent drying of 32 kg/m^3 BOP-FR (5% weight gain), 64 kg/m^3 BOP-FR (10% weight gain), and 96 kg/m^3 BOP-FR (15% weight gain), respectively. After treating, the strands were re-dried to 7% to 8% MC.

Composite types, blending, and mat formation/lay-up

Diphenylmethane diisocyanate (MDI) resin was applied to the strands in a rotating-drum blender. To make the strandboard panels, a randomly oriented mat was formed because, at that

TABLE 2. *Cutting pattern and eventual mechanical/fire/physical property test specimen sizes and number of replicates for each panel mad at each treatment level.*

Test	Specimen size (mm)	Specimens per panel	ASTM test standard
Bending (MOR and MOE)	76 × 406 (456-mm test span)	2 (parallel)	D 1037
Internal bond-dry (IB-D)	51 × 51	3	D 1037
Internal bond-wet (IB-W)	51 × 51	3	D 1037
Water soak (2 h and 24 h)			
Water absorption	152 × 152	1	D 1037
Thickness swell	152 × 152	1	D 1037
Humidity exposure (90%)			
Water absorption	76 × 76	1	D 1037
Thickness swell	76 × 76	1	D 1037
Fire test			
Unleached	152 × 152	1	E 2102
24-h leached	152 × 152	1	E 2102

time, FPL did not have properly ventilated forming/orientation equipment to allow making oriented strandboard when using strands sprayed with MDI resins.

Hot-pressing

Panel pressing followed the general instructions of the resin manufacturer. Using a 200°C platen temperature the 12.5-mm-thick panels were hot-pressed using a 30-s uniform-rate initial press closing time to the 12.5-mm target thickness, held for 240 s at target thickness, and followed by a 30-s degassing/press opening time (300 s total).

Mechanical and physical tests

After the panels had been pressed, they were weighed and measured to determine specific gravity, and individual test specimens were cut from each panel in the number and sizes specified in Table 2. Mechanical and physical property specimens were conditioned at 23°C, 65% relative humidity (RH) prior to testing. Mechanical and physical properties were tested in accordance with ASTM D 1037 (ASTM International 2005a). The fire test specimen designated for water leaching prior to fire testing was submerged and suspended below 1 L of water and leached for 24 h at 20 ± 2°C; it was then oven-dried for 24 h at 103°C. A second matched fire test specimen was not leached. The physical and mechanical property data were statistically analyzed using a Tukey test of means at a significance level of $\alpha \leq 0.05$.

Fire performance tests

Effectiveness of the FR treatments to reduce the contribution of burning strandboard to fire growth was evaluated by measuring heat release rate (HRR) due to combustion in a cone calorimeter (ASTM E 1354-04a (ASTM International 2004a)). Mass loss and effective heat of combustion (heat release per unit mass loss) of the 100-mm-square burning specimen were also obtained. Obscuration of a laser beam in the exhaust duct was recorded as a measure of visible smoke development from the burning specimen. Ignitability was determined by observing the time for sustained ignition of the specimen. A 10-s criterion was used to define "sustained ignition." External heat flux was 50 kW/m^2, and the retainer frame (without the wire grid) was placed over the test specimen. The electric spark igniter was placed above the horizontal test specimen until sustained ignition of the test specimen was observed. Unexposed surfaces of the test specimen were wrapped in aluminum foil, and the specimen was placed on a piece of low-density refractory fiber blanket within the holder. Three replicates of each treatment were tested. Samples were conditioned at 23°C, 50% RH prior to testing.

TABLE 3. *Results for mean and standard deviation (in parentheses) for thickness swell, linear expansion, and weight gain when equilibrated for 60-days at 27°C and either 30% or 9)% relative humidity.*

BOP-FR loading level	27°C, 30% RH				27°C, 90% RH			
	Thickness swell (%)	Weight gain (%)	Linear expansion (%)		Thickness swell (%)	Weight gain (%)	Linear expansion (%)	
			Length	Width			Length	Width
Control: untreated	8.42 (0.67)	3.81 (0.07)	0.35 (0.06)	0.39 (0.08)	15.46 (1.01)	13.39 (0.14)	0.31 (0.10)	0.50 (0.16)
Control: water-treated	8.05 (0.69)	3.77 (0.08)	0.25 (0.08)	0.28 (0.08)	15.04 (0.94)	12.86 (0.11)	0.27 (0.14)	0.36 (0.12)
5.3%	6.87 (0.36)	3.87 (0.18)	0.24 (0.07)	0.24 (0.05)	13.77 (0.51)	14.22 (0.30)	0.28 (0.10)	0.34 (0.06)
9.8%	6.77 (0.26)	4.30 (0.08)	0.14 (0.12)	0.17 (0.11)	13.13 (0.44)	14.97 (0.12)	0.25 (0.13)	0.28 (0.16)
13.8%	6.22 (0.54)	5.17 (0.11)	0.12 (0.04)	0.10 (0.07)	11.93 (0.60)	16.21 (0.10)	0.17 (0.09)	0.22 (0.06)

RESULTS AND DISCUSSION

Treatment

Eventual BOP chemical loadings actually achieved were 5.3%, 9.8%, and 13.8% for the three target loadings of 5%, 10%, and 15%, respectively. Accordingly, BOP-FR retentions were 32.0, 60.8, and 83.2 kg/m^3, respectively.

Physical properties

Although the addition of phosphate-based FR treatments to solid wood has traditionally increased dimensional moisture-induced swelling and increased eventual equilibrium MC, our strandboard test specimens did not exhibit these changes. Our evaluation of vaporous moisture absorption at 30% and 90% RH for BOP-FR-treated strandboard found the expected increased absorption of moisture from air, but that absorbed moisture did not produce increased thickness swelling or linear expansion for treated material (Table 3). Rather, thickness swelling of treated strandboard was significantly ($\alpha \leq 0.05$) reduced and linear expansion was significantly ($\alpha \leq 0.05$) reduced at 30% RH and unchanged at 90% RH. While thickness swell and linear expansion were noticeably lessened by increasing the BOP-FR loading, total absorbed moisture was directly related to BOP-FR loading.

A somewhat similar but less consistent phenomenon was also noted in the D 1037 2- and 24-h water-soak tests (Table 4). Although the absorption of liquid water in both the 2- and 24-h water-soak test was sometimes higher and sometimes lower, the BOP-FR treatment clearly resulted in significantly ($\alpha \leq 0.05$) less thickness swell. Further, the more pH-buffered chemistry of BOP-FR clearly seemed to facilitate the progressive ability of MDI-bound strandboard to resist thickness swell from absorption of both liquid (Table 4) and vaporous moisture (Table 3) because as BOP-FR retention increased, thickness swelling was progressively reduced.

Mechanical properties

Internal bond (IB) strength is often considered an indicator of the quality of bonding and bond

TABLE 4. *Results for mean and standard deviation (in parentheses) for thickness swell and water absorption of 150- by 150-mm blocks when soaked in water for either 2- or 24-hr as specified in ASTM Standard D 1037.*

BOP-FR loading levels	2-h water soak: Thickness swell (%)	2-h water soak: Water absorption (%)	24-h water soak: Thickness swell (%)	24-h water soak: Water absorption (%)
Control: untreated	4.5 (0.7)	8.4 (0.7)	17.0 (1.1)	25.9 (1.6)
Control: water-treated	5.7 (1.0)	10.7 (0.9)	20.5 (2.2)	32.2 (2.6)
5.3%	3.4 (0.5)	9.7 (1.2)	12.9 (1.2)	28.1 (2.6)
9.8%	2.6 (0.5)	8.2 (0.9)	10.5 (1.0)	24.0 (2.1)
13.8%	1.9 (0.3)	6.9 (1.0)	8.5 (0.4)	20.0 (2.2)

development within strandboard. The addition of BOP-FR to wood strands prior to application of 5% MDI resin resulted in significantly ($\alpha \leq 0.05$) increased dry and wet IB strength (Table 5). The magnitude of these results indicates that BOP-FR treatment did not interfere with MDI bond development during hot-pressing and may have instead somewhat enhanced that bond development. This promotion of bond development may be related to the mildly acidic BOP-FR acting as a catalyst for the nucleophilic addition reaction between the hydroxyl group of wood and the isocyanate group of the MDI. However, although more study will be needed to confirm this idea, it seems plausible. There also seems little practical difference between the ratios of treated-to-untreated IB strengths for either dry or wet IB results. This suggests that MDI-bond development is stable even with BOP-FR-treated strands.

For flexural properties, the effects of BOP-FR treatment were mixed and few practical differences were noted between treated and untreated strandboard (Table 5). Modulus of elasticity (MOE) values of BOP-FR strandboard varied from –5% to +10% of untreated strandboard controls with no statistical difference. Bending strength was generally reduced by 1% to 10%, but these differences were not significant ($\alpha \leq 0.05$). Two potential issues might explain why FR chemicals usually negatively affect the strength of strandboard. First, because most FRs are either acidic or alkaline, they potentially modify the pH regime of the treated wood fiber or strand surface from that required for optimal resin curing, which probably impedes optimal bond development. A second potential reason for poor bond development may be related to the FR system interfering with the physical permeability of the wood fiber or strand surface, which in turn restricts the penetration of uncured resin. Penetration of liquid resin is critical to mechanical entanglement at levels deeper than just purely a surface phenomenon. Again, the use of MDI, which is a very robust resin system, and the apparent ability of the borate-buffered organic phosphate system to not directly impede either resin cure or penetration, or both, may explain why strength is apparently not as severely affected as with some other FR–resin combinations.

The previous discussion shows that structural and serviceability issues should not present overt problems for BOP-FR-treated strandboard. We

TABLE 5. *Mean and standard deviation (in parentheses) of physical and mechanical tests of flexural and internal bonding properties when evaluated as specified in ASTM Standard D 1037.*

BOP-FR loading levels	Static bending properties: MOE (GPa)	Static bending properties: MOR (MPa)	Specific gravity	Internal bond strength (MPa): Dry	Internal bond strength (MPa): Wet
Control: untreated	5.274 (0.863)	28.508 (7.686)	0.60 (0.05)	0.72 (0.26)	0.64 (0.14)
Control: water-treated	4.725 (0.762)	25.414 (3.934)	0.60 (0.03)	0.73 (0.10)	0.55 (0.16)
5.3%	5.503 (1.298)	28.380 (8.972)	0.65 (0.04)	1.20 (0.12)	0.79 (0.27)
9.8%	5.043 (0.443)	25.775 (5.336)	0.69 (0.03)	1.14 (0.22)	1.11 (0.17)
13.8%	5.804 (0.370)	27.762 (5.563)	0.75 (0.04)	1.20 (0.10)	1.00 (0.27)

now consider two critical aspects of using chemical treatments to achieve enhanced resistance to fire: (1) how effectively the FR system decreases flammability and (2) how the FR system affects structural and serviceability characteristics of the base product.

Fire performance

The primary result from the cone calorimeter test is a heat release rate (HRR) curve over the duration of the test. Except for the 13.8% FR leached samples, the HRR curves were typical of classic curves for wood products. They first exhibited an initial increase in HRR, built to a peak HRR, dropped to a steady-state HRR, and finally exhibited a second peak as the last portion of the specimen was consumed (Fig. 1). For reporting purposes, the heat release and mass loss curves are often reduced to single numbers, such as initial peak HRR, average HRR over specified time, total heat release over the duration of the test, and effective heat of combustion (Table 6). The higher levels of FR treatment resulted in greater reductions in the initial peak HRR. This reduction in initial peak HRR was significantly less when the samples were leached with water but still higher than for untreated strandboard. Leaching of the samples also had the effect of reducing the increases in the times for sustained ignition caused by the FR treatment. In the case of the 13.8% treatment level, an observation of sustained flaming was not recorded until near the end of the test for the samples not leached. Visual observation of sustained flaming can be difficult with effective FR treatments. The HRR is normally averaged from the time that sustained ignition is observed. With delayed observation of ignition, the 60-s average HRR is not included for the unleached 13.8% treatment level samples (Table 6). As with initial peak HRR, the 60-s average HRRs were higher for the samples leached with water. Test results for average mass loss rate, average effective heat of combustion, and total heat released reflect behavior during the entire test. The FR treatment reduced the mass loss rate, effective heat of combustion, and total heat released. As is observed with the HRR curves (Fig. 1), leaching the samples with water mainly affected behavior during the initial segment of the test and had little effect on results that are averaged over the duration of the test (Table 6).

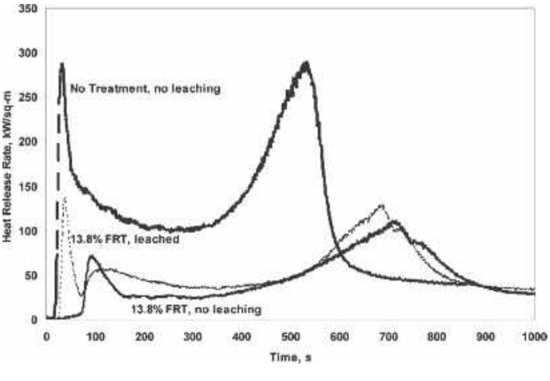

FIG. 1. Selected heat release rate curves for untreated and treated samples.

In the case of the 13.8% FR leached samples, a second peak was noted immediately following the initial peak (Fig. 1). These two initial peaks suggest that the leaching reduced the amount of chemicals largely in the outer portion of the panel. Once this outer layer was consumed, the HRR was at the level of the unleached samples and the rest of the curve, including the second peak, was similar to that of the unleached samples. With the lower treatment levels, the difference between the leached outer layer and the treated interior core was not sufficient to produce a noticeable second peak.

One screening method for FR treatments is to measure the mass loss rate and the residual mass fraction. The method described in ASTM E 2102 (ASTM International 2004b) is the cone calorimeter without the oxygen consumption measurement of heat release. The FR treatment reduced the average mass loss rate and also reduced the effective heat of combustion of mass loss that did occur (Table 6). The final residual mass fraction increased with FR treatment, and the total heat released decreased with FR treatment. We noted a 75% to 100% improvement in residual mass regardless of whether the BOP-treated strandboard was leached or not leached with water prior to the test.

TABLE 6. *Average heat release rate (HRR) and other fire performance results from cone calorimeter tests.*

Treatment	Leached	Time for sustained ignition (s)	Peak (HRR (kW/m^2)	Average HRR, 60 s (kW/m^2)	Average mass loss rate (g/s m^2)	Residual mass fraction	Average effective heat of combustion (MJ/kg^1)	Total heat release (MJ/m^2)	Average specific extinction area (m^2/kg)
Water	No	26	238	169	12.2	0.23	12.75	108	90.8
Untreated	No	25	271	179	13.0	0.20	12.54	109	92.1
5.3%	No	31	144	92	10.7	0.38	8.08	62	14.9
9.8%	No	73	90	64	10.0	0.40	7.04	52	4.2
13.8%	No	279	66	—[a]	9.6	0.42	6.25	50	18.8
Water	Yes	20	241	160	11.5	0.23	12.78	112	92.1
Untreated	Yes	18	243	158	12.4	0.21	12.14	105	105.9
5.3%	Yes	22	190	114	10.6	0.36	8.69	64	40.9
9.8%	Yes	24	149	88	10.1	0.38	7.73	57	17.6[b]
13.8%	Yes	30	130	56	9.9	0.40	6.90	53	14.4

[a] Observation of sustained flaming delayed beyond initial peak heat release rate.
[b] Average of two values, other averages are for three replicates.

Several characteristics measured in the cone calorimeter affect surface flammability. One option for combining these characteristics is the model of Dietenberger (Dietenberger and White 2001; White and Dietenberger 2004). Based on this model, fire growth propensity can be plotted (Fig. 2). Initial peak HRR (*x* axis in Fig. 2) is used to represent the fire growth propensity due to surface properties. A fire growth propensity parameter reflecting the material bulk properties (*y* axis in Fig. 2) is calculated from total heat release, thickness, and the inverse of the time for sustained ignition. Plotting these values illustrates that the BOP-FR treatment effectively reduced both surface properties and material bulk properties (Fig. 2).

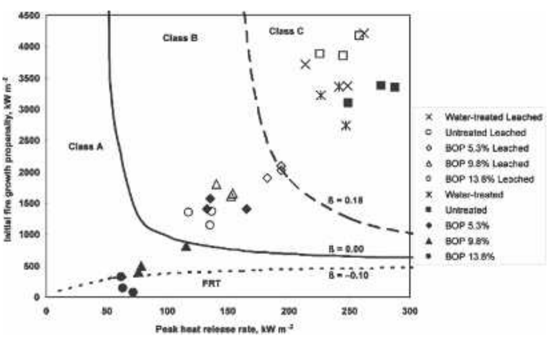

FIG. 2. Fire growth propensity as predicted from models of Dietenberger and White (2001) and White and Dietenberger (2004). The initial peak HRR (*x* axis) represents the fire growth propensity due to surface properties, and a fire growth propensity parameter is calculated using the total heat release, thickness, and the inverse of the time for sustained ignition to predict the material bulk properties (*y* axis). The three zones shown on the graph represent classes of materials having class A, B, or C flame spread ratings.

The U.S. regulatory requirements for flammability of building products are based on the flame spread index (FSI) obtained in the 7.32-m (25-ft) tunnel test (ASTM E 84) (ASTM International 2004c). In the model of Fig. 2, an acceleration parameter, β, is also calculated. This parameter is used to divide the plot into areas where the flame spread model predicts performance that satisfies the A, B, and C classification that U.S. building codes use to regulate materials for surface flammability based on their ASTM E 84 FSI. Untreated wood products are generally in class C, as was predicted for the untreated strandboard specimens of the study (Fig. 2). Class A is the more restrictive classification that requires FR treatment of the wood product. Estimates of the FSI can be calculated using a logarithmic correlation between FSI and β (Dietenberger and White 2001).

Using this methodology to interpret our results supports the ideas that a class B flame spread rating (FSI ≤ 75) seems attainable for all unleached BOP-treated strandboard samples and for leached BOP-treated material at 8% to 10% loadings or greater (Fig. 3). The model also predicts that the class A flame spread rating (FSI ≤ 25) is achievable at loadings above 8% to 10%

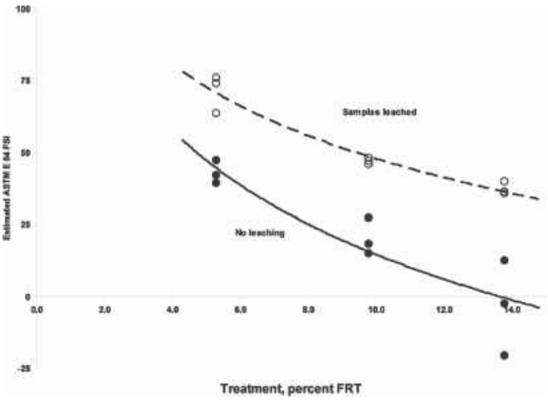

FIG. 3. Estimated ASTM E 84 flame-spread rating for leached and unleached strandboard treated with various levels (0%, 5.3%, 9.8%, and 13.8%) of fire retardant. Predictive estimates are based on the model of Dietenberger and White (2001).

for the unleached samples (Fig. 3). Estimates are for the standard test duration of 10 min as specified in ASTM E 84. In U.S. building codes, the requirements for "fire-retardant-treated" (FRT) requires the ASTM E 84 test be conducted for a longer time period than specified in ASTM E 84. A β of –0.1 is used to identify materials that might qualify for such classification (White and Dietenberger 2004) (Fig. 2). These predictive results imply that the FRT rating may be achievable at loadings above 13.8%. Although significantly more research is needed to better understand these relationships and control them, the potential advantages are obvious and may have commercial implications. Supporting the predicted results of the FSI model that the FR was effective is the observation that the addition of BOP-FR over the ~5% to 14% weight range improved the residual mass fraction (that is, the residual mass remaining after the burn test is completed) by sizable amounts. The equation used to estimate FSI is not sensitive to variations in FSI greater than about 75 and does not produce a numerical estimate of FSI for most untreated wood.

The average specific extinction area (in square meters per kilogram) was computed from the smoke obscuration data (Table 6). The FR treatment reduced these visual smoke results averaged for the duration of the test. The timing for the visual smoke is different for the untreated and treated samples. After some smoke at the start of the test, the smoke from the untreated samples mainly occurs at the end of the test as the flaming is reduced. With the treated samples, there is more smoke than with the untreated samples at the beginning of the test, which is consistent with the delayed ignition and reduced flaming at the start of the test.

CONCLUSIONS

While it is important to note that these evaluations are based on small laboratory samples and not production strandboard, the laboratory strandboard made with 5% MDI resin and strands treated prior to resin application with a borate-buffered, organic phosphate FR was found to achieve measurable fire retardancy. Final BOP-FR loading retentions were approximately 5%, 10%, and 14%. Both the untreated and treated MDI-bonded strandboard absorbed moisture in a similar manner, but the treated strandboard experienced much less thickness swelling and linear expansion when exposed to high humidity or when soaked in water. Treatment of strands with BOP-FR prior to strandboard manufacture resulted in increased dry- and wet-IB strength. For flexural properties, MOE was generally unaffected, whereas bending strength was reduced from 1% to 10% by BOP-FR treatment. The results indicate that a class B flame-spread rating was possible at BOP-FR levels of ≤8% to 10% and that a class A flame-spread rating might be possible at higher loadings.

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