BENDING AND TENSILE PROPERTIES OF VAPOR BORON-TREATED COMPOSITES

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ABSTRACT

North American composites, including laminated veneer lumber, oriented strandboard, and medium density fiberboard, were treated by vapor boron technology and subsequently tested in static bending. Tensile properties were also determined for the two composite board products. The study was designed as a 2 x 3 factorial with two mill locations and three treatment levels for each composite type. In general, mill location significantly affected most property values, while treatment level caused only significant reductions at the highest treatment level. The significance of mill location was attributed mainly to species differences since species varied between locations for each composite type.

Keywords: OSB, MDF, LVL, vapor boron, tensile strength, bending properties.

INTRODUCTION

The past decade has seen a substantial increase in the production and utilization of treated products. The application of innovative technology to problems of wood treatment is a requisite for improved utilization of wood in areas where hazards from agents of biotic deterioration are present. Of particular importance has been the inability to successfully treat new generation composite materials with biocides without significant loss in properties. The importance of protecting wood-based composites from a variety of causal agents (decay, insects, fire) was the theme of a recent international conference (Preston 1993). One conclusion of this conference was that failure to protect composite materials, especially in exterior applications, could lead to the loss of markets to competitive materials such as masonry, vinyl, and aluminum.

Research in the United Kingdom and in New Zealand has led to the development of a vapor

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boron treatment (VBT) which could have a tremendous impact in North America (Bergervoet et al. 1992; Burton et al. 1990; Dickinson and Murphy 1989; Murphy and Turner 1989; Turner and Murphy 1987). Vapor-phase treatments offer several advantages to conventional liquid treatments (Schuerch 1968). There is no liquid water to excessively swell the material, a factor important in treating wood-based composites. Impregnation problems arising from liquid tension and other interfacial considerations are eliminated. Since treatment comes after mat consolidation, potential bonding properties arising from chemical treatment are eliminated. Hashim et al. (1992, 1994) found little negative effect of treatment on UK-produced boards. Ancillary board properties and tool wear for VBT-treated medium density fiberboard (MDF) and oriented strandboard (OSB) have been reported (Barnes et al. 2004; Jones et al. 2001). This research documents the mechanical properties of vapor boron-treated North American composite materials.

MATERIALS AND METHODS

Materials

Oriented strandboard (OSB) manufactured from mixed southern pine and southern hardwood furnish (designated MS) and from mixed northeastern conifer and hardwood furnish (designated ME), and laminated veneer lumber (LVL) were acquired from commercial producers. The MS-OSB was bonded with liquid phenol-formaldehyde resin and the ME-OSB was bonded with a powdered phenol-formaldehyde resin. Commercial medium density fiberboard (MDF) intended for the siding market and manufactured from southern hardwood furnish (SO) or mid-Atlantic hardwood (MA) furnish were included in the study. The SO-MDF was a wet process board and the MA-MDF was a dry process board. Both were bonded with a phenol-formaldehyde resin. Nominal OSB and MDF board thickness was 12.5 mm. The LVL was produced from two species (southern pine, Douglas-fir). Nominal thickness was 44 mm for Douglas-fir and 38 mm for southern pine.

Treatment

The composites were shipped to the Imperial College of Science, Technology and Medicine in London, England where they were vapor phase-treated with trimethyl borate as has been described elsewhere (Hashim, et al. 1992, 1994). Each type of composite was treated to different retention levels [nominally 1% (LOW) or 5% (HIGH) BAE (w/w)] in a 0.8-m^3 treatment vessel. Samples were separated by 3-mm stickers and loaded into the vessel. The vessel was evacuated to 5 mbar and a metered amount of trimethyl borate sufficient to achieve the target retentions was admitted. Gas contact time was 8 h for the high retention and 40 min for the low retention level. Comparison was with untreated controls.

Testing methods

Standard ASTM (1997) D1037 testing procedures were followed for testing MDF and OSB in bending and tension. ASTM D143 procedures were used for testing LVL in static bending. Thirty replicates for each combination of treatment level (TL) and mill location (MILL) were tested for each composite type. Data were analyzed using analysis of variance and mean separation techniques. The study was designed as a 2 × 3 (MILL × TL) factorial arrangement of treatments within a completely random design for each composite type.

RESULTS AND DISCUSSION

Medium density fiberboard

Specific gravity (G) and moisture content (MC) were treated as covariants in all analyses. Additionally, MOE was considered as a covariant for the MOR analysis. For all bending properties, specific gravity was found to be a significant covariant (Table 1). For MOE, mill location, treatment level, and their interaction were found to be significant variables (Table 1). The significance of mill location was taken to mean that furnish species and/or processing differences significantly reduced these property val-

TABLE 1. *Comparison of static bending least square means for medum density fiberboard.*[1]

Modulus of elasticity (MPa) [mill, treatment level, M × TL] (G)					
Mill × treatment level					
SO	Low	3,379 S	MA	Low	3,312 A
SO	Control	3,374 A	MA	Control	3,125 A
SO	High	3,192 A	MA	High	2,790 B
Modulus of rupture (kPa) [mill, treatment level, M × TL] (MOE, G)					
Mill × treatment level					
SO	Control	34,101 A	MA	Control	18,761 A
SO	Low	31,695 B	MA	High	18,216 A
SO	High	30,378 B	MA	Low	17,988 A
Fiber stress (kPa) [mill, treatment level] (G)					
Mill			*Treatment level*		
SO		18,113 A	Control		16,341 A
MA		13,203 B	Low		16,113 A
			High		14,520 B
Work-to-proportional limit (kJ/m^3) [mill, treatment level] (G)					
Mill			*Treatment level*		
SO		5.52 A	Control		4.63 A
MA		3.19 B	Low		4.46 A
			High		3.98 B

[1] Means not followed by a common letter are significantly different one from another at p = 0.05 or higher; significant sources of variation are shown in brackets; significant covariants are in parentheses.

ues with values being higher for the southern mill. Recall that board from the MA mill was a dry process board while the SO mill produced a wet-process board. In analyzing the interaction, no significant differences were found across treatment levels for the SO board, so no deleterious effect of treatment on MOE is noted. In the case of the MA, treatment at the high level resulted in a significant lowering of 11% when compared to the control value for MOE

In addition to specific gravity, MOE was a significant covariant in the MOR analysis. The MILL × TL interaction was significant for MOR so no conclusions could be drawn from the main effects, even though mill and treatment level were significant (Table 1). Analysis of the data by mill indicated a slight effect of treatment on the SO board as compared to the control. While statistically significant, the actual change in MOR due to treatment level is 11%. The data for the MA board showed no significant difference among retentions. In either case, the practical significance would seem to indicate little effect of treatment level.

For fiber stress and work values, both mill and treatment levels were significant but not their interaction (Table 1). Specific gravity was a significant covariant in both analyses. For both properties, a reduction was shown for the highest treatment level only. Across all property values in static bending, it can be concluded that effect of treatment was of practical significance only at the highest retentions. Other than the effect of process or furnish species, the mechanical properties from static bending testing were unaffected at the lower retentions required for control of decay or insect attack. A similar result is shown in Table 2 for tensile strength where only mill location was found to be significant.

Oriented strandboard

Specific gravity was a significant covariant in the analyses of MOE, fiber stress, and work for OSB (Table 3). Once adjusted for specific gravity, then neither mill, treatment level nor their interaction was significant in the analyses of fi-

TABLE 2. *Comparison of static bending least square means for oriented strandboard.*[1]

Modulus of elasticity (MPa) [mill] (G)					
Mill					
MS		4,178 A			
ME		5,168 B			
Modulus of rupture (kPa) [mill, M × TL] (E, MC)					
Mill × treatment level					
MS	High	28,496 A	ME	High	27,248 A
MS	Low	27,841 A	ME	Control	21,394 B
MS	Control	26,979 A	ME	Low	20,760 B
Fiber stress (kPa) [no effects] (G)					
MS	Control	16,954 A	ME	Control	17,140 A
MS	Low	16,589 A	ME	Low	17,133 A
MS	High	14,913 A	ME	High	17,644 A
Work-to-proportional limit (kJ/m^3) [no effects] (G)					
MS	Control	3.39 A	ME	Control	2.97 A
MS	Low	3.87 A	ME	Low	3.02 A
MS	High	3.59 A	ME	High	3.82 A

[1] Means not followed by a common letter are significantly different one from another at p = 0.05 or higher; significant sources of variation are shown in brackets; significant covariants are in parentheses.

ber stress and work. For MOE, only mill location was significant with board from the ME location being 19% stiffer than MS mill board. Treatment had no impact.

For MOR, both MOE and MC were significant covariants for OSB (Table 3). Analysis of these data showed both mill and the mill-treatment level interaction to be significant sources of variation. No impact of treatment level was noted for the MS mill. While there was a significant impact of treatment level for the ME board, the data indicated no deleterious effect since the MOR for ME board treated to the highest level was significantly greater than that for controls or low level treatment. As with MDF, only mill location was significant in the analysis of tensile strength (Table 2).

Treatment seems to have even a lesser effect on OSB compared to MDF. Differences can be attributed to the different furnish types in the two OSBs.

Laminated veneer lumber

Static bending property values are shown in Table 4 for LVL. Specific gravity was a significant covariant in the analysis of MOE and fiber stress. MOE was a significant covariant in the analysis of MOR, while the analysis of work values showed no significant covariants.

Species differences in LVL are evident in the analyses of both MOE and MOR where mill location was the only significant source of variation (Table 4). Similar to the results for MDF and OSB, the mill effect can be attributed to the species difference (Douglas-fir vs. southern pine). Treatment appeared to have no effect whatsoever. In the case of fiber stress, treatment level was significant but not deleterious since both treatments yielded fiber stress values greater than the controls. For work, both treatment level and the mill-treatment level interaction were significant. For the southern pine LVL, no differences among treatments were noted (Table 4). Differences among treatments did exist for the Douglas-fir LVL, but both treatments yielded higher work values than the controls. As with the other composite types, no real deleterious effect of treatment was shown with most differences being due to species.

TABLE 3. *Comparison of static bending least square means for laminated veneer lumber.*[1]

Modulus of elasticity (MPa) [mill] (G)			Modulus of rupture (kPa) [mill] (E)		
Mill			*Mill*		
SO		11,236 A	SP		69,989 A
D-F		11,953 B	D-F		57,102 B
Fiber stress (kPa) [treatment level] (G)					
Treatment level					
Low		41,203 A			
High		40,141 AB			
Control		38,314 B			
Work-to-proportional limit (kJ/m³) [treatment level, M × TL] (none)					
Mill × treatment level					
SP	High	8.20 A	D-F	Low	8.27 A
SP	Low	8.04 A	D-F	High	7.03 AB
SP	Control	7.98 A	D-F	Control	6.47 B

[1] Means not followed by a common letter are significantly different one from another at p = 0.05 or higher; significant sources of variation are shown in brackets; significant covariants are in parentheses.

TABLE 4. *Comparison of tensile strength least square means for medium density fiberboard and oriented strandboard.*[1]

Medium density fiberboard		Oriented strandboard	
Tensile strength (kPa) [mill] (none)		Tensile strength (kPa) [mill] (none)	
Mill		*Mill*	
SO	19,567 A	MS	12,011 A
MA	10,914 B	ME	10,549 B

[1] Means not followed by a common letter are significantly different one from another at p = 0.05 or higher; significant sources of variation are shown in brackets; significant covariants are in parentheses.

SUMMARY AND CONCLUSIONS

Data are presented as the effects of VBT-treatment on the bending properties of MDF, OSB, and LVL made from North American furnish. For most composite types, differences in property values can be attributed to differences in furnish, species, or processing. Deleterious effects due to treating, when found, were only for the highest treatment level. Treatments for protection in terrestrial applications (~1% BAE) had no negative effects on composite bending and tensile properties.

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