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BENDING & TENSILE PROPERTIES OF VAPOR BORON-TREATED COMPOSITES

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BENDING & 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 boards. The study was designed as 3 x 2 factorial with three treatment levels and two mill locations for each composite type. In general, mill location significantly affected most property values while treatment level caused significant reductions at the highest treatment level only. The significance of mill location was taken to mean a significant difference due to species as species varied between locations for each composite type.

INTRODUCTION

The past decade has seen a substantial increase in the production and consumption 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 our inability to successfully treat new generation composite materials with biocides without significant loss in properties. The importance of protecting wood-based composites was the theme of a recent international conference (Preston 1993). Failure to protect these materials, especially in exterior applications, could lead to the loss of markets to competitive materials such as masonry, vinyl, and aluminum.

Research in the UK and in New Zealand has led to the development of a vapor 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). Germane to composite treatments is the fact that there is no liquid water to excessively swell the material. 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. We have previously reported on ancillary board properties and tool wear for VBT-treated MDF and OSB (Jones, *et al*. 2001a, b). This research documents our experience with the mechanical properties of North American composite materials.

METHODS AND MATERIALS

<u>Materials</u>--Oriented strandboard (OSB) manufactured from mixed southern pine and southern hardwood furnish (SO) and from mixed northeastern conifer and hardwood furnish (NE), and laminated veneer lumber (LVL) were acquired from commercial producers. The SO-OSB was bonded with liquid

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phenol-formaldehyde resin and the NE-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 northern hardwood (NO) furnish were included in the study. The SO-MDF was a wet process board and the NO-MDF was a dry process board. Both were bonded with a phenol-formaldehyde resin. Nominal OSB and MDF board thickness was 12.5 mm (0.5 in). The LVL was produced from two species (southern pine, Douglas-fir). Nominal thickness was 44 mm (1.75 in) for Douglas-fir and 38 mm (1.5 in) 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. ASTM D143 procedures were used for testing LVL. 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 x 3 (MILL x TL) factorial arrangement of treatments within a completely random design for each composite type.

RESULTS AND DISCUSSION

Medium density fiberboard--Static bending results are given in Tables 1. 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. For MOE, mill location, treatment level, and their interaction were found to be significant variables. The significance of mill location was taken to mean that furnish species and/or processing differences significantly reduced these property values with values being higher for the southern mill. Recall that board from the NO 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 level for the SO board, so no deleterious effect of treatment on MOE is noted. In the case of the NO, 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 x TL interaction was significant for MOR so no conclusions could be drawn from the main effects, even though mill and treatment level were significant. 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 is 11%. The data for the NO 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 level were significant but not their interaction. 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, we conclude 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 retentions required for control of decay or insect attack.

A similar result is shown in Table 4 for tensile strength where only mill location was found to be significant.

Oriented strandboard--Results for the OSB boards are given in Tables 2 and 4. Specific gravity was a significant covariant in the analyses of MOE, fiber stress, and work. Once adjusted for specific gravity, then neither mill, treatment level nor their interaction was significant in the analyses of fiber stress and work. For MOE, only mill location was significant with board from the NE location being 19% stiffer than SO mill board. Treatment had no impact.

For MOR, both MOE and MC were significant covariants. 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 SO mill. While there was a significant impact of treatment level for the NE board, the data indicated no deleterious effect since the MOR for NE 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 4).

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 3 for LVL. Similar results for MDF and OSB, mill effects can be attributed to species difference (Douglas-fir vs. southern pine). 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 are evident in the analyses of both MOE and MOR where mill location was the only significant source of variation. 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. 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 difference being due to species.

SUMMARY

Data are presented as to 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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Table 1. Comparison of static bending least square means for medium density fiberboard.[1]

Modulus of Elasticity (psi) [MILL, TREATMENT LEVEL, M x TL] (G)					
MILL x TREATMENT LEVEL					
SO	LOW	490,132 A	NO	LOW	465,896 A
SO	CONTROL	489,345 A	NO	CONTROL	453,183 A
SO	HIGH	463,003 A	NO	HIGH	404,726 B
Modulus of Rupture (psi) [MILL, TREATMENT LEVEL, M x TL] (MOE, G)					
MILL x TREATMENT LEVEL					
SO	CONTROL	4,946 A	NO	CONTROL	2,721 A
SO	LOW	4,597 B	NO	HIGH	2,642 A
SO	HIGH	4,406 B	NO	LOW	2,609 A
Fiber Stress (psi) [MILL, TREATMENT LEVEL] (G)					
MILL			*TREATMENT LEVEL*		
SO	2,627 A		CONTROL		2,370 A
NO	1,915 B		LOW		2,337 A
			HIGH		2,106 B
Work-to-Proportional Limit (in-lbf/in^3) [MILL, TREATMENT LEVEL] (G)					
MILL			*TREATMENT LEVEL*		
SO	0.801 A		CONTROL		0.672 A
NO	0.463 B		LOW		0.647 A
			HIGH		0.577 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 2. Comparison of static bending least square means for oriented strandboard.[1]

Modulus of Elasticity (psi) [MILL] (G)					
MILL					
SO	605,951 A				
NE	749,609 B				
Modulus of Rupture (psi) [MILL, M x TL] (E, MC)					
MILL x TREATMENT LEVEL					
SO	HIGH	4,133 A	NE	HIGH	3,952 A
SO	LOW	4,038 A	NE	CONTROL	3,103 B
SO	CONTROL	3,913 A	NE	LOW	3,011 B
Fiber Stress (psi) [NO EFFECTS] (G)					
SO	CONTROL	2,459 A	NE	CONTROL	2,486 A
SO	LOW	2,406 A	NE	LOW	2,485 A
SO	HIGH	2,163 A	NE	HIGH	2,559 A
Work-to-Proportional Limit (in-lbf/in^3) [NO EFFECTS] (G)					
SO	CONTROL	0.492 A	NE	CONTROL	0.431 A
SO	LOW	0.562 A	NE	LOW	0.438 A
SO	HIGH	0.520 A	NE	HIGH	0.555 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.					

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

Modulus of Elasticity (psi) [MILL] (G)			Modulus of Rupture (psi) [MILL] (E)		
MILL			*MILL*		
SP	1,629,704 A		SP	10,151 A	
D-F	1,733,690 B		D-F	8,282 B	
Fiber Stress (psi) [TREATMENT LEVEL] (G)					
TREATMENT LEVEL					
LOW	5,976 A				
HIGH	5,822 AB				
CONTROL	5,557 B				
Work-to-Proportional Limit (in-lbf/in^3) [TREATMENT LEVEL, M x TL] (NONE)					
MILL x TREATMENT LEVEL					
SP	HIGH	1.189 A	D-F	LOW	1.199 A
SP	LOW	1.166 A	D-F	HIGH	1.020 AB
SP	CONTROL	1.157 A	D-F	CONTROL	0.938 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 (psi) [MILL] (NONE)		Tensile Strength (psi) [MILL] (NONE)	
MILL		*MILL*	
SO	2,838 A	SO	1,742 A
NO	1,583 B	NO	1,530 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.