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SHORT NOTICE

THE EFFECT OF BORIC ACID / BORAX TREATMENT ON SELECTED MECHANICAL AND COMBUSTION PROPERTIES OF POPLAR LAMINATED VENEER LUMBER

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ABSTRACT

The effect of Boric acid/Borax (BA/BX) treatment by spraying method on selected mechanical and combustion properties of laminated veneer lumber (LVL) (15 ply, 2 mm veneer thickness) produced from hybrid poplar (Populus x Euramericana Canadensis) and phenol formaldehyde adhesive were investigated. The results showed that modulus of rupture (MOR) and selected combustion properties of LVLs increased with addition of BA/BX.

KEY WORDS: laminated veneer lumber, boric acid, borax, poplar, mechanical properties, combustion properties

INTRODUCTION

The main problem of the wood products industry is to develop products using forest resources efficiently since the availability and quality of timber are becoming worse. Up to 60% of tree can be used to produce solid sawn lumber but when engineered wood products (EWPs) are manufactured, the ratio is higher (depends on the end product) since any size of tree and tree parts that would otherwise be wasted or utilized as fuelwood, can be used for that purpose (Kurt et al. 2003).

Laminated veneer lumber (LVL) may be one of the important solutions concerning raw material economy. LVL was the first type of structural composite lumber (SCL) produced for the marketplace. LVL is being used in many areas, especially for structural uses because of its high strength, dimensional stability and consistency and treatability (Nelson 1997). LVL can be used for structural and non-structural purposes.

The wood material is one of the important factors in the production of LVL. Most commonly preferred species of wood are Douglas and Southern pine (Wang et al. 2003), but other species can be used including off-grade and fast growing species including poplar.

With the introduction of LVL, OSB and other composite products, the utilization of poplar will increase (Kurt and Mengeloglu 2002). Numerous investigations are being done to improve the utilization of poplar wood in engineered wood and wood composite panel products (Nelson 1997, Wu et al. 1998, Ozarska 1999, Bridaux et al. 2001, Wang and Ping 2005).

The borate chemicals offer fire resistance and protection against fungi and insects. There is growing interest in their low mammalian toxicity and environmental acceptability (Laks et al. 1994). Boric acid suppresses glowing but has little effect on flame spread. On the other hand, borax tends to reduce flame spread, but it can promote smoldering or glowing (Wang et. al. 2004) and also it can be included in the surface preparation to improve wood surface properties (Sernek 2002). Results showed that the incorporation of boron in the glue line may improve LVL durability (Bridaux et al. 2001). Also, the effects of boron compounds on selected mechanical and physical properties (Hashim et al. 1992, Laks and Manning 1995, Colakoglu et al. 2003) wood based materials were investigated.

To date, there is no evidence to suggest that engineered wood products like laminated veneer lumber will behave any differently in a fire than the sawn lumber and timbers that replace. Wood designers have been attempting to improve wood structures or assemblies' fire resistancy by brushing, spraying, dipping, immersing and pressure treating with a variety of different chemicals (Slifka 1997).

Fire performance of wood and wood based materials that were treated with boron compounds, determined by a number of researchers (Ors et al. 1999a and 1999b, Yalınkılıc et al. 1998, Baysal et al. 2003). However, research addressing the effect of chemical agents (Boric acid / Borax (BA/BX)) to improve selected mechanical and combustion properties of on poplar LVL is sparse.

The objectives of this study are to determine the effect BA/BX treatment by spraying method on selected mechanical and combustion properties of poplar LVLs.

MATERIAL AND METHODS

The LVLs used in this study were manufactured using hybrid poplar (Populus x Euramericana Canadensis). Logs were only debarked prior to peeling, they were not steamed. They were rotary peeled into 2 mm thick veneers at 110% moisture content. The veneer sheets were clipped into 70 x 70 cm veneer plies and dried to approximately 9% moisture content.

Veneer pieces (27 x 60 cm) were cut with the grain parallel in one direction. The veneer sheets were pre-selected for strength and appearance. They were without any stain, decay and fungi and they were also free of splits, knots and knot holes. They were conditioned to an equilibrium moisture content of 6% before manufacturing.

A commercial phenol formaldehyde adhesive (47±1 % solid) that cures at 150 °C was used (Polisan Chemical Corporation 2005). Its specification is given in Tab. 1. The spreading rate was 300 g/m^2.

Two different treatment types were used; these were untreated (U) and treated (T). For each type of treatment types 20 samples were used yielding a total of 40 samples for bending tests. Of the 40 LVLs, 20 were assembled with untreated veneers and 20 were assembled with treated veneers (by spraying method) with boric acid (H_3BO_3) / borax (disodium tetraborate, $Na_2B_4O_7$) (BA/BX) (5:1 ratio) water solution (6.5 gr/m^2).

Tab. 1: Specification of the PF adhesive

pH at 20°C	11.50
Viscosity at 20°C	400 cps
Specific Gravity at 20°C	1.21
Phenol Formaldehyde	47±1 %
Water Tolerance at 20°C	Unlimited
Appearance	Red

For the fabrication, PF adhesive was spread to veneers and they were immediately assembled into 15 ply LVL with the tight side facing out on each veneer. Billets were hot pressed for 35 minutes at a temperature of 150 °C and the pressure was 1.7 MPa. Squeeze outs were observed for a glue line quality on both sides. Billets were sized to length and width (25x56 cm) using a circular saw. A general view of LVL samples is shown in Fig. 1.

Bending specimens (4.65x56 cm) were cut from each panel. The samples were conditioned by 50±5 % and temperature of 23±2 °C until they reached the equilibrium moisture content of 11%. Average weights of untreated and treated bending samples are 410.41 g and 400.27 g respectively after the conditioning. Test specimens were centrally loaded and conducted over a 500 mm span with a crosshead speed of 0.25 mm/min using universal testing machine (100 kN capacity). The tests were conducted in accordance with ASTM D198 (1994). The modulus of rupture (MOR) and modulus of elasticity (MOE) were determined by these tests.

Combustible properties of LVLs were performed using ASTM E60 (1980). LVL specimens (13x27x76 mm) were cut for the fire testing. They were conditioned by 30±5 % and temperature of 27±2 °C until they reached the equilibrium moisture content of 7%. The testing was conducted with a flame source, without a flame source and at the glowing stage. The testing set-up is shown in Fig. 2.

The specific gravities and moisture contents of samples were determined in accordance with ASTM D2395 (2002) and ASTM D4442 (2003) respectively.

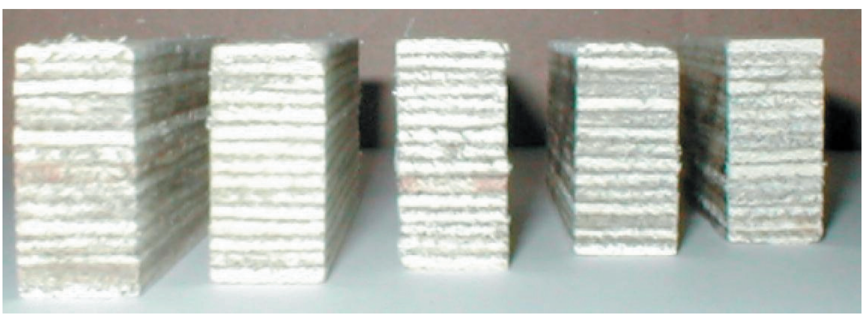

Fig. 1: A general view of LVL samples

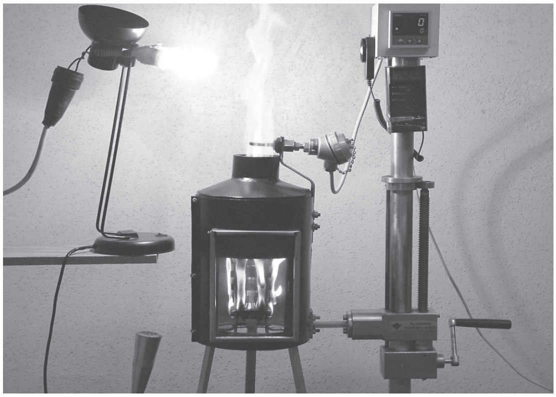

Fig. 2: Testing set-up for combustion properties

RESULTS AND DISCUSSION

The densities of untreated and treated LVLs were 0.53 g/cm^3 and 0.51 g/cm^3 respectively. LVLs densities' are higher considerably than that of hybrid poplar woods' (0.45 g/cm^3). The main reason can be attributed to the effect of hot-pressing and the glue lines. Also, the anatomical features of poplar might also contribute to that situation.

The descriptive statistical values of the LVLs including number of samples for each of the treatment method are presented in Tab. 2 and 3 for bending tests. All of the samples failed near the mid-span. The strength of two different treatment methods varied slightly. Treating the veneers with BA/BX increased both MOR and MOE of the samples. The T/U mean MOR ratio was 1.12 and mean MOE ratio is 1.09. The results showed that the BA/BX treatment has little effect on the bending properties of LVLs. MOR values are more affected than that of MOE values by the treatment process.

Tab. 2: Descriptive statistical values of MOR (N/mm^2)

TM	N	Mean	Minimum	Maximum	SD	CV (%)
Untreated	20	71.96	64.62	80.15	4.76	6.61
Treated	20	80.43	76.14	83.96	2.26	2.81

TM: Treatment method, N: Sample size, SD: Standard deviation and CV: Coefficient of variation

Tab. 3: Descriptive statistical values of MOE (N/mm^2)

TM	N	Mean	Minimum	Maximum	SD	CV (%)
Untreated	20	14018.32	11788.16	16885.84	2067.31	14.75
Treated	20	15229.05	12106.66	17204.44	1830.49	12.02

TM: Treatment method, N: Sample size, SD: Standard deviation and CV: Coefficient of variation

Statistical procedures were performed using the Statistical Analysis system (SAS) program. The analysis of variance (ANOVA) was used for statistical analyses to determine the effect of

BA/BX addition on MOR and MOE values. The resulting F value was compared to the tabular F value at the 95% probability level.

The statistical analysis results showed that mean MOR values were changed with different treatment methods (Tab. 4). There was a significant difference between MOR values due to BA/BX treatment at 0.05 level of probability among the samples. This suggests that the difference in average MOR values were observed when BA/BX treatment was used. On the other hand, no significant difference was found due to BA/BX treatment within MOE values (Tab. 5). Comparisons of mean MOR values as they were affected by the BA/BX treatment were made by Bonferroni (Dunn) t-test (Tab. 6 and 7).

Tab. 4: ANOVA table for MOR (N/mm²) values

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
Model	1	717.58	717.58	51.65	<.0001
Error	38	257.92	13.89		
Corrected Total	39	1245.50			
	R-square	0.58	Root MSE	3.73	
	CV	4.89	Mean	76.20	

Pr>F: Probability > F value and CV: Coefficient of variation, and Root MSE: Root mean square error

Tab. 5: ANOVA table for MOE (N/mm²) values

Source	Degree of Freedom	Sum of Squares	Mean Square	F Value	Pr>F
Model	1	14658622.90	14658622.90	3.85	0.0572
Error	38	144865205.60	3812242.30		
Corrected Total	39	159523828.50			
	R-square	0.09	Root MSE	1952.50	
	CV	13.35	Mean	14623.69	

Pr>F: Probability > F value and CV: Coefficient of variation, and Root MSE: Root mean square error

Tab. 6: Mean MOR value of different treatment methods

Treatment Method	MOR (N/mm²)
Untreated	71.96 B
Treated	80.43 A

[a] *Means with same letters are not statistically different*

Tab. 7: Mean MOE value of different treatment methods

Treatment Method	MOE (N/mm^2)
Untreated	14018.32 A
Treated	15229.05 A

[a] Means with same letters are not statistically different

Although, BA addition to the samples could have affected mechanical properties of LVLs negatively, its decreasing effect of BA was suppressed by the addition BX to the mixture similarly to the study of Yalinkilic et al. (1998). The addition was increased its mechanical properties of LVLs to some extent.

The results of combustion properties of LVLs are given in Tab. 8. Each result represents an average of 5 replicates. Treated LVLs has lower weight loss temperature records during flame combustion and significantly lower duration time of glowing stage. Boric acid was proved to be an effective glow retardant as reported by Day and Wiles (1978). The results showed that BA/BX treatment has increased the fire resistance of LVLs. The findings support the beneficial effects of incorporation of BA/BX on fire retardance of LVL.

Tab. 8: Combustion properties of LVLs

Treatment Method	W. Loss	TFC	TWFS	DGL
Untreated	83.2	462.6	305.2	22.8
Treated	76.3	450.9	332.7	6.4

W. Loss: Weight loss (%), TFC: Temperature records during flame combustion (°C), WFS: Temperature records without flame source, DGL: Duration time of glowing stage (min.)

CONCLUSIONS

The mechanical properties of poplar LVLs were evaluated in relation to treatment methods using the PF adhesive. BA/BX treatment process has significant influence over the MOR values of LVLs. The results showed that BA/BX treatment may be used to increase selected mechanical and combustion properties of LVLs.

Further research is necessary to investigate the effects of treatment process with BA/BX at different ratios, spreading rate, veneer grade and lay up and other manufacturing variables on LVLs bending and fire resistant properties. The method may be used to increase the use of poplar wood in engineered wood products (EWP) fabrication and other structural applications.

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