DIMENSIONAL STABILITY PERFORMANCE OF FIRE RETARDANT TREATED VENEER-ORIENTED STRANDBOARD COMPOSITES

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This study investigated dimensional stability properties of oriented strandboard (OSB) panels faced with fire retardant treated (FRT) veneers. The beech (*Fagus orientalis* Lipsky) veneers were treated with monoammonium phosphate (MAP), diammonium phosphate (DAP), lime water (LW), and a borax/boric acid (BX/BA) (1:1) mixture. Dimensional stability tests were performed according to ASTM D-1037. The results revealed that facing veneers impregnated with fire-retardant chemicals had significant effects on the linear expansion (LE) properties. The lowest LE value was obtained from the panels faced with MAP treated veneers, while the highest LE value was found in the panels faced with BX/BA treated veneers. The FRT treated veneer facing technique also affected the thickness swelling (TS) properties of the OSB panels. The panels faced with LW treated veneers had the highest TS, whereas the panels faced with MAP treated veneers had the lowest TS values.

Keywords: Dimensional stability; Fire retardant chemicals; Veneer; Oriented strand board; Wood composites

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INTRODUCTION

Oriented strandboard (OSB) is a structural wood composite product used as an alternative to plywood panels in building structures. However, OSB could be used in such areas as packing, flooring, underlayment, roofing, and sheathing (Haygreen and Bowyer 1996). When compared to plywood, OSB has still not overcome its main limitation, higher linear expansion and thickness swelling values. With respect to strength, OSB panels have lower strength values than plywood panels. For this reason, researchers previously have studied process development techniques to improve its physical, mechanical, and fire performance properties.

Among various process development techniques, veneer facing has been studied by various researchers to improve end-use properties of composite materials. Impacts of fire retardant treated (FRT) veneer facing on fire performance and mechanical properties of OSB panels were determined by Ayrilmis et al. (2007a). They indicated that while treatments had significant negative effects on the mechanical properties of OSB panels, the effects on the fire performance were positive. The mechanical properties of the veneer-OSB composites were comparable to FRT plywood, and the composites could be considered as an alternative to FRT plywood used in such areas as roofing, sheathing, packing, flooring, and underlayment. Facing with veneers could also be applied for cardboard panels as recycled composite to obtain enhanced mechanical properties (Ayrilmis et al. 2007b, 2008). Combustion performance of OSB and other wood composites is also an important issue in building construction. By using chemical treatments, combustion characteristics of wood composites can be significantly improved (Ayrilmis et al. 2007a; Candan et al. 2010; Kartal et al. 2007; Keskin 2009; Kol et al. 2010; Kurt and Mengeloglu 2008; Myers and Holmes 1975; Ozciftci and Okcu 2008; Ozkaya et al. 2007). Properties such as dimensional stability, combustion performance, and surface quality of laminated veneer lumber (LVL) panels made from FRT veneers were also studied by Ayrilmis et al. (2009), Candan et al. (2010), and Dundar et al. (2008, 2009). FRT wood products provide a viable alternative to traditional noncombustible materials in cases where a higher level of fire performance is desired. The most common fire retardant chemicals used for wood and wood based panels are inorganic salts, boron compounds (borax-BX and boric acid-BA), phosphoric acid (PA), monoammonium phosphate (MAP), diammonium phosphate (DAP), ammonium sulfate, nitrogen, and zinc chloride (ZnCl) (Forest Products Laboratory 1999; Levan and Tran 1990; Winandy 1997). Treated wood materials with inorganic salts are usually more hygroscopic than untreated wood, particularly at high relative humidity (RH) values. Boron compounds might have diverse effects on hygroscopicity (Alexiou et al. 1986; Hashim et al. 1994; Levan and Winandy 1990). Increases in the equilibrium moisture content (EMC) of such treated wood products will depend upon the type of chemical, the level of chemical retention, and the size and species of the wood involved (Forest Products Laboratory 1999). Typically, an increase in moisture content (MC) from 2% to 8% occurs in the treated wood, and MC further increases from 5% to 15% at 80% RH compared with untreated samples (Holmes 1977). Barnes et al. (2010) investigated relationships for fire retardant compounds between laboratory and field exposure conditions based on mechanical properties, relative humidity, temperature, and FRT chemicals. Morris et al. (2008) improved decay resistant wood composites such as glulam and LVL by borate treatment and transparent coatings. Kirkpatrick and Barnes (2006) investigated some properties of OSB in terms of engineered wood composites treated with copper naphthenate.

In solid wood and wood composites, dimensional properties such as linear expansion (LE) and thickness swelling (TS) are some of the most important performance criteria. These dimensional changes become important when large panel sizes are used or when the expansion is totally or partially restrained. The in-plane movements can cause high internal stresses due to restraint from fasteners such as screws and nails. These stresses may be sufficient to cause panels to buckle, pushed out nails, and separate from the structure (Wu and Suchsland 1996). Thus, LE properties of OSB panels could be important for suitable design applications.

There is limited data available in the literature describing the effects of the FRT veneer facing process on the LE and TS properties of OSB panels. The objective of this study was to investigate the effects of facing with veneers treated with different fire retardant chemicals on the dimensional stability performance of OSB panels. The LE and TS properties of the OSB panels faced with untreated and FRT veneers were investigated.

EXPERIMENTAL

Materials

Three commercial OSB panels with dimensions of 1220- by 2440- by 15-mm made from a mixture of pine and aspen strands were commercially supplied. First, both the upper and lower surfaces of the OSB panels were sanded with 60 grit paper in a sanding machine to obtain a smooth surface, allowing the OSB panels to be uniformly faced with the FRT veneers. The panel thickness was approximately 14.0 mm after sanding. The sanded panels were then cut into 500- by 500-mm square panel parts with a total of 20 pieces obtained from three OSB panels. All of the experimental panel pieces and the veneers were placed in a climate chamber adjusted 20±2°C and 65%±5 RH.

Rotary-cut beech (*Fagus orientalis* Lipsky) veneers were used to face commercial OSB panels. Beech rotary veneers were supplied by Kurogullari Plywood Industry and Trade Inc. in Kocaeli, Turkey. Its wood is convenient for veneer, plywood, and LVL panels manufacturing. Veneer sheets used in this study were 1.5 mm in thickness and nearly defect-free. The veneers were cut into 50- by 50-mm² pieces.

Five chemicals were used in the treatments: (1) a mixture (1:1) of boric acid-H_3BO_3 and borax (BX)-$Na_2B_4O_7.10H_2O$, monoammonium phosphate-$NH_4H_2PO_4$, diammonium phosphate-$(NH_4)_2HPO_4$, (supplied from Eti Mine Co. in Ankara, Turkey), and lime water (Eau de chaux) (Canakkale, Turkey). Lime water (LW) is a colourless and an odorless solution obtained naturally from limestone ($CaCO_3$) in Canakkale, Turkey. The chemical composition of boric acid:borax (1:1), MAP, DAP, and LW is given in Table 1.

Methods

Chemical treatment

The veneers were pressure impregnated with the above chemicals, using a full-cell pressure process. Samples were put under vacuum at 0.086 MPa for 30 min, the chemical of interest was added, and a pressure of 1.1 MPa was then applied for 60 min. Concentration of the chemical solutions were adjusted to provide an average retention of 58 $kg \cdot m^{-3}$. Table 2 shows average chemical retention and solution concentration in percentage of weight for each treatment.

FRT veneer facing process of OSB panels

Each panel was composed of two face layers with one OSB panel as the substrate. A commercial liquid phenol-formaldehyde (PF) was used to bond the treated and untreated face and back veneers to the panels. Before gluing, the sheets were conditioned until they reached approximately 7% moisture content. The PF adhesive (solids content 47%±1) was uniformly applied on one side of the face veneers at approximately 180 $g \cdot m^{-2}$. This study did not include the addition of any external wax or water repellent to the PF resin. All substrate materials were then sandwiched with the FRT veneer sheets and pressed at 1.5 MPa and 140 °C for 8 min in a laboratory type hot press at Wood Composite Panels Manufacturing Laboratory, Department of Forest Products Engineering in Istanbul University. The completed panel density was 0.649 to 0.661 $g \cdot cm^{-3}$. Except for treatment chemicals, process options such as tree species, resin type, percentage of PF resin, and press parameters, were unchanged in treated panels.

Table 1. Typical Composition of Borax, Boric Acid, Monoammonium Phosphate, Diammonium Phosphate, and Lime Water

Fire retardants	Component	Amount (%)
Borax (BX)	B_2O_3	36.4
	Na_2O	16.4
	Purity	99.9
Boric acid (BA)	B_2O_3	56.2
	Purity	99.9
Monoammonium phosphate (MAP)	P_2O_5	61.0
	N	12.0
	Purity	99.9
Diammonium phosphate (DAP)	P_2O_5	53.0
	NH_3	25.0
	N	20.8
	Purity	99.9
Lime water	Ba	0.368 mg/L
	Cd	< 1 µg/L
	Ni	0.012 mg/L
	Mg	4.25 mg/L
	Fe	< 5 µg/L
	Pb	< 5 µg/L
	Cu	< 1 µg/L
	Zn	< 10 µg/L
	Mn	< 1 µg/L
	Cr	< 2 µg/L
	Co	< 0.5 µg/L
	Hg	< 5 µg/L
	As	< 0.5 µg/L

Table 2. Chemical Contents of OSB Panels

Pan el numbers	Treatment of veneer	Solution concentration (percent wt)	Average chemical retention ($g \cdot cm^{-3}$)
4	Control	No chemical applied	-
4	BX/BA (1:1)	10	57.3
4	DAP	10	57.6
4	MAP	10	57.9
4	Lime water	10	58.1

Determination of dimensional stability properties

The linear and thickness variations of the OSB panels faced with FRT veneers were determined in conformity with ASTM standard D 1037 (ASTM 2006). Eight test specimens with dimensions of 76 mm by 152 mm by 15.5 mm were obtained from each group, giving a total of 40 specimens for conducting the LE and TS tests. The linear and thickness variations of the OSB panels, between two EMC, are calculated as a percentage of the initial specimen length and thickness at 20 ± 3 °C. The specimens were exposed to humidity until reaching equilibrium at one regime which represented the change among consecutive RH 50 ± 2 % and 90 ± 5 % at 20 ± 3 °C (68 ± 6 °F) temperature. The specimens were conditioned until constant weight and moisture content in a climate chamber for each treatment level.

Determination of linear expansion

Linear expansion was calculated on the basis of the specimen's initial length by using of dial gage comparator shown in Fig. 1 with an accuracy of ±0.01 mm. The LE was calculated from following equation (1),

$$LE_{50to90} = (L_{90\ final} - L_{50\ initial}) / L_{50\ initial} \times 100 \qquad (1)$$

Where LE_{50to90} is the linear expansion after RH change from 50% to 90%, based on the length measured at 50% RH (%), $L_{90\ final}$ is the final length of the specimen conditioned at 90% RH (mm), and $L_{50\ initial}$ is the initial length of the specimen conditioned at 50% RH (mm)

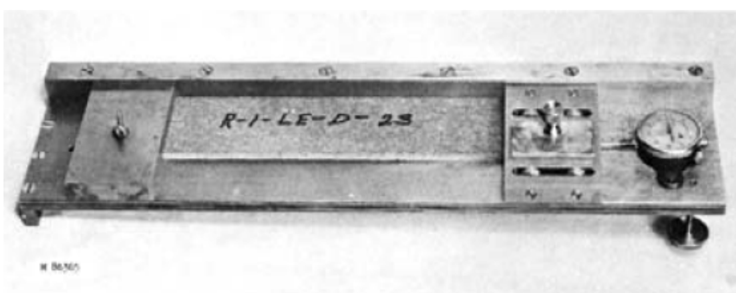

Fig.1. Dial gage comparator for measuring linear expansion of the specimens

Determination of thickness swelling

The thicknesses were taken at three points at the specimens' medium width with an accuracy of ±0.01 mm. TS properties were calculated as follows,

$$TS_{50to90} = (T_{90\ final} - T_{50\ initial}) / T_{50\ initial} \times 100 \qquad (2)$$

Where $TS_{50\ to\ 90}$ is the thickness swelling after RH change from 50% to 90%, based on the thickness measured at 50% RH (%), $T_{90\ final}$ is the final thickness of the specimen conditioned at 90% RH (mm), and $T_{50\ initial}$ is the initial thickness of the specimen conditioned at 50% RH (mm)

RESULTS AND DISCUSSION

The average linear expansion and thickness swelling values of the OSB panels faced with FRT veneers are shown in Table 3. For FRT veneered panels the lowest LE values were observed with MAP treated veneer sheets. The highest LE values were observed in BX/BA treated veneer sheets. LE values for control veneered panels were higher than all FRT veneered panels with the exception of panels with BX/BA treated veneers. The results acquired from this study showed that the LE performance of the OSB panels was positively affected by facing FRT veneers as having reduced LE percentage.

The FRT veneer facing technique had a positive effect on the TS properties of the OSB panels. TS values of OSB panels faced with LW treated veneers were highest but they were not significantly different from TS values obtained from control panels. The panels faced with MAP treated veneers had the lowest TS and LE values. Moreover, in the panels faced with DAP treated veneers, TS values were observed to be between those of panels faced with MAP treated and BX/BA treated veneers.

Table 3. Dimensional Stability Results of FRT Veneer Faced OSB Panels

Groups	Linear Expansion (%)	Thickness Swelling (%)
Control	0.509 (0.296)	8.050 (0.616)
MAP	0.290 (0.485)	5.758 (0.935)
DAP	0.302 (0.232)	5.849 (0.554)
BX/BA	0.552 (0.678)	7.719 (0.237)
LW	0.323 (0.457)	8.083 (0.584)

* Values in parentheses are standard deviation

The findings obtained from this study are supported by a study of Dundar et al. (2009). The authors carried out dimensional stability properties of LVL panels made from veneers treated with DAP, MAP, and BX/BA. It was reported that fire retardant chemicals have an effect on the hygroscopic behavior and dimensional stability of LVL panels. BX/BA treated LVL panels experienced the highest moisture intake at 13.8%. These treated panels also had significantly higher LE and thickness shrinkage values than panels treated with other fire retardant chemicals and control panels. Ayrilmis et al. (2007a) investigated thickness swelling and water absorption after 24 hours of water submersion in OSB panels faced with FRT veneers. It was reported that the highest TS was found for the specimens with BX/BA treated veneers having a value of 16.3%. The OSB panels with DAP and MAP treated veneers showed better performance than specimens with BX/BA treated veneers. Based on the thickness swelling investigations obtained from the present study, it was concluded that boron compounds, BX and BA, increased thickness swelling of the panels more than phosphorous compounds, MAP and DAP.

Previous works have demonstrated that wood materials treated with inorganic flame-retardant salts are usually more hygroscopic than is untreated wood, particularly at high relative humidity. Above 80% RH, MC reached equilibrium faster in the case of veneers treated with chemical salts (Kartal et al. 2007; Levan and Winandy 1990; Holmes 1977; Leao 1993; Lesar et al. 2009; Repellin and Guyonnet 2005). Increasing water sorption can be attributed to the new adsorption sites that were formed from treatments. However, structural and chemical modifications of cell-wall constituents may lead to the formation of additional hydrogen-bonding sites for water. Increases in the EMC of such treated wood products will depend upon the type of chemical, level of chemical retention, size, and species of the wood involved (Forest Products Laboratory 1999). A number of studies have verified the correlation between chemical treatment and water-intake properties of wood (Alexiou et al. 1986; Hashim et al. 1994; Levan and Winandy 1990; Lesar et al. 2009). Boron-based fire-retardant treatments have negatively affected the dimensional stability of wood and wood composite panels (Akbulut et al. 2004; Ayrilmis 2006; Ayrilmis et al. 2007a; Kartal et al. 2007; Yalinkilic et al. 1998).

CONCLUSIONS

The goal of this research was to determine the influence of facing with veneers treated with several fire retardant chemicals on the linear expansion and thickness swelling properties of OSB panels. The results obtained have shown the following:

- Facing veneer sheets impregnated with fire retardant chemicals had a significant effect on the linear expansion and thickness swelling properties of the OSB panels.
- The panels faced with MAP treated veneers had the least linear expansion and thickness swelling performance as dimensional stability characteristics.
- FRT veneer faced OSB composite is regarded as new biobased material with better dimensional stability.
- OSB panels faced with FRT veneers could be used as engineered wood composite in building constructions having stringent requirements for safety, due to their improved combustion performance and higher mechanical properties as well.

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