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Article

Effect of Boron and Phosphorus Compounds on Fire and Technological Properties of Oriented Strandboard

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Abstract: Effects of various fire retardant chemicals on fire and technological properties of laboratory made oriented strandboards (OSBs) were investigated. Aspen chips were used in the production of OSB panels. An exterior liquid phenol formaldehyde resin with 47 percent solid content was used as adhesive. There was no addition of any hardener and filling materials into resin in the OSB manufacturing. Boron compounds such as borax and boric acid, and phospate compounds such as monoammonium phosphate and diammonium phospahate were used as fire retardant chemicals in the OSB panels. An exterior liquid phenol formaldehyde resin was used as adhesive. The chemicals in powder form were added into the resin blender at contents of 2%, 4%, and 6% based on oven-dry wood weight. The OSB panels containing borax had the highest thickness swelling, followed by the panels containing boric acid, monoammonium phospahate, and diammonium phosphate, respectively. Increasing the content of these chemicals in the OSB resulted in greater thickness swelling. For the mechanical properties, the chemicals can be used up to oven dry particle weight of 6% in the panels at humid and dry conditions because of the fact that they met the standard values of mechanical properties given in TS EN 300 for types of OSB/3 (exterior type. Fire resistance of the panels was improved with increased chemical content in the panels.

Keywords: Wood-Based Panels; Fire-Retardants; Boron Compounds; Technological Properties.

1. Introduction

Oriented strandboard (OSB) is a wood-based panel that is widely used in construction industry. OSB has virtually replaced plywood in new residential construction in many areas of North America. Wood products are important materials in both residential and non-residential building construction. They do not need to be made flame retardant for most applications. It is well known that one can significantly improve the fire performance of wood-based composites by chemical treatment and thereby widen the options for their utilization.

Boron compounds such as borax and boric acid are considered to be effective flame retardants that exert less impact on mechanical properties of wood as compared to some other flame retardant chemicals [1-3]. Phosphates such as mono- and di-ammonium phosphates, and ammonium

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polyphosphate are another group of fire retardants [4]. These phosphates are among the oldest known fire-retardant systems. They are usually included in proprietary systems used for wood. For example, mono-ammonium phosphates (MAP) have been used in extinguishers for a long time. In this study, the effect of the loading level of boron and phosphate compounds on the physical, mechanical, and fire properties of OSB panels were investigated.

2. Materials and Methods

2.1. Wood material

Aspen (*Populus spp.*) strands for OSB manufacture were obtained from a SFC Integrated Wood Company in Kastamonu, Turkey. The thickness, width, and length of the strands were 0.8 mm, 20-30 mm, and 90-110 mm, respectively. The strands were dried to 2 to 3% moisture content before the OSB production.

2.2. Resin

Phenol-formaldehyde (PF) (product code: Polifen 47) resin was supplied from Polisan The Chemical Company in Dilovası, Turkey (Table 1).

Table 1. Technical specifications of phenol-formaldehyde (Polifen 47®) resin.

Technical specifications of PF resin	Method	Result
Density (20 °C, g/cm³)	TS 1724 ISO 675:1997/T1	1.195-1.205
Solids content (% weight)	TS EN 480-8	47±1
Viscosity (20 °C, cps)	TS 6126 ISO 2555:1998/T1	250-500
pH (20 °C)	TS EN ISO 10523	10.5-13
Free formaldehyde (% weight)	TS EN 1243	max. 1.0

2.3. Fire-Retardant Chemicals

Four powder chemicals were used in the treatments: borax, boric acid, monoammonium phosphate, and diammonium phosphate. The technical grades of the chemicals were supplied from local market in Istanbul, Turkey.

2.4. The Production of OSB Panels

First the strands were put into the blender and then mixed with PF resin (6 wt% based on oven-dry solid-wood). Then the dry powder of the fire-retardants was added to the drum type blender at the contents of 2, 4, and 6 wt.% based on oven-dry weight of wood strands. The fire retardants and strands with resin were uniformy mixed for 5 min in the blender. The OSB mats were hot pressed at 3.5 N/mm² and 180 °C for 8 min. Three OSB panels with dimensions of 500 mm x 500 mm x 10 mm were produced. The OSB panels were conditioned in a climate room having 65% relative humidity and 20 °C. In the OSB production each OSB panel was composed of two face layers and one core layer (Fig. 1). The strands in the outer layers were aligned parallel to the panel length; the strands in the middle layer were randomly oriented. Each face layer constituted one-quarter of the total panel weight. The density values of the OSB panels were varied from 0.67 to 0.69 g/cm³.

Figure 1. OSB panel produced at laboratory.

2.5. Test Methods

Physical and mechanical tests such as density, thickness swell, bending strenght, modulus of elasticity, internal bond, and bond quality of the specimens were carried out according to EN (European Norm) standards. Fire properties such as flame height, and char area of the specimens were evaluated according to DIN (Deutsches Institut für Normung) standard (Figs. 2 and 3). Analysis of variance (ANOVA) ($p<0.05$) and Duncan's multiple-comparison tests were conducted to compare and evaluate differences among the average physical, mechanical, and fire properties of the treated specimens for each test method. Homogeneity groups were determined indivudually for each property by Duncan's multiple-comparison tests.

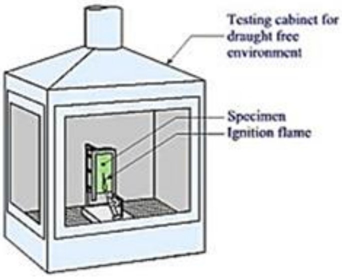


Figure 2. Fire test according to DIN 4102-1 standard.

The experimental design is given in Table 2.

Table 2. Experimental design

OSB code	Fire retardant content*	OSB size	The number of panels produced
Control	-	500 mm x 500 mm x 10 mm	3
Borax	%2		3
	%4		3
	%6		3
Boric acid	%2		3
	%4		3
	%6		3
Diammonium phosphate	%2		3
	%4		3
	%6		3
Mono ammonium phosphate	%2		3
	%4		3
	%6		3

*The addition of the chemical was based on the oven dry weight of strand.

The details regarding the sample size and test methods are given in Table 3. The number of specimens was 30 for the density, thickness swelling, and internal bond strength tests, and 36 specimens (18 specimens for parallel to the panel surface and 18 specimens perpendicular to the panel surface) for the bending strength.

Table 3. Test methods, the number of specimens and their size.

Test method	Standard no	Size (mm)
Density	TS EN 323	50 x 50
Thickness swelling (24-h)	TS EN 317	50 x 50
Bending strength	TS EN 310	250 x 50
Bending modulus	TS EN 310	250 x 50
Internal bond strength	TS EN 319	50 x 50
Fire resistance	DIN 4102-1	90 x 190

Figure 3. The fire test at the laboratory according to DIN 4102-1 standard.

3. Results and Discussion

3.1. Thickness Swelling

The thickness swelling values of the OSB specimens are presented in Figure 4. The OSB panels containing borax had the highest thickness swelling, followed by the panels containing boric acid, monoammonium phospahate, and diammonium phosphate, respectively. Increasing content of these chemicals in the OSB resulted in greater thickness swelling. Because the borax and boric acid cause more thickness swell on wood-based panels, they should not be used over oven dry fiber weight of 2% at humid place and 4% at dry conditions. The monoammonium phosphate and diammonium phosphate showed better performance than borax and boric acid. As the amount of BX was increased from 2 to 6 wt% in the OSB, the thickness swelling increased from 15.48 to 18.82%. This range was found to be 14.89 to 17.84% for BA, 14.30 to 17.27% for MAP, 13.86 to 16.37% for DAP, and 13.23% for the control group.

3.2. Mechanical Properties

The internal bond strength of the OSB specimens was found to be lower than that of the control group. It decreased with increasing content of the fire retardants (Fig. 5). The highest reduction in the internal bond strength was determined for the OSB specimens containing the boric acid while the lowest reduction was found in the OSB specimens containing the borax. The bending strength values of the OSB specimens parallel and perpendicular to the panel surface are presented in Figure 6. The OSB panels treated with fire-retardants can be used up to oven dry particle weight of 6% in the panels at humid and dry conditions because of the fact that they met the standard values of mechanical properties given in TS EN 300 for OSB/3 and OSB/1. Increasing the content of these chemicals in the panels depending on chemical type decreased the mechanical properties of the OSB panels. The panels treated with borax had highest bending strength, followed by di-ammonium phosphate, mono-ammonimum phosphate, and, boric acid, respectively. As the amount of BX was increased from 2 to 6 wt% in the OSB, the bending strength decreased from 51.82 to 47.52. This range was found to be 50.34 to 45.49% for DAP, 49.24 to 42.78% for MAP, 84.81 to 39.75% for BA, and 52.50 for the control group. A similar trend was determined for the bending modulus (Fig. 7). All the treated panel groups showed lower performance related to mechanical properties when compared to control panels group).

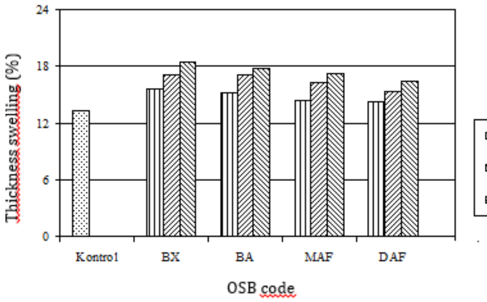


Figure 4. Thickness swelling of OSB panels depending on the content of the fire-retardants (from 2 to 6 wt%).

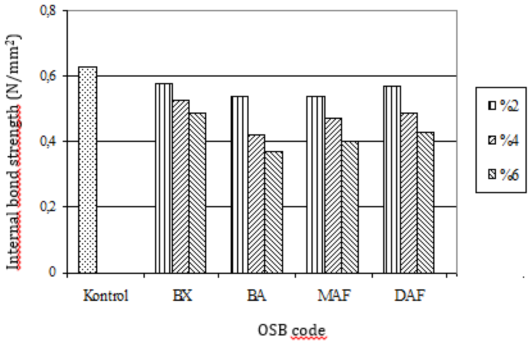
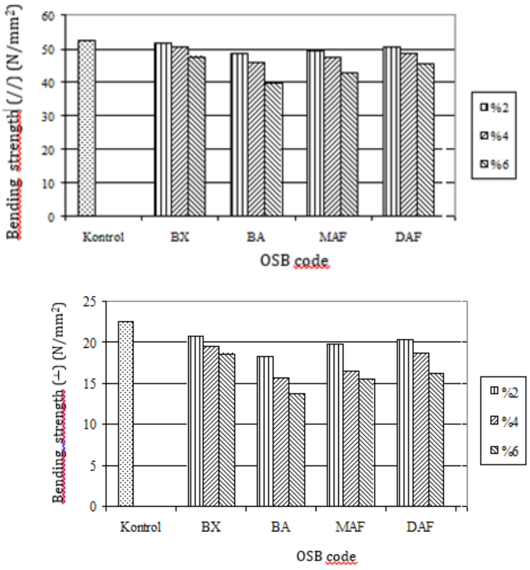


Figure 5. Internal bond strength of OSB panels depending on the content of the fire-retardants (from 2 to 6 wt%).

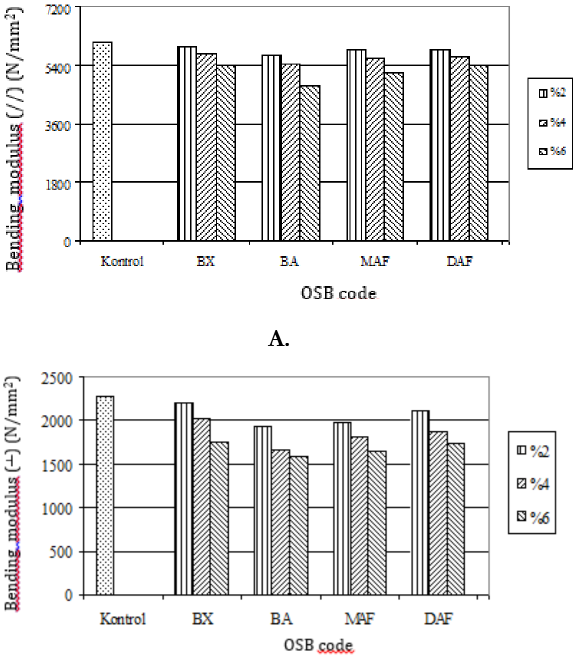


A.

B.

Figure 6. Bending strength (A: parallel and B: perpendicular to the panel surface) of OSB panels depending on the content of the fire-retardants (from 2 to 6 wt%).

The addition of borate to the strands with the PF resin may prevent the curing of PF resin [5]. The use of borate as a fire retardant in wood-based composite panels may cause several problems. The most critical one is related to its adverse effect on the mechanical properties of wood composites bonded with PF resin [8,9]. The main problem could be related to the functional methanol groups of the PF resin molecules and their interaction with borate ions. Schaeffer et al. [4] reported that acidic ammonium salts in both phosphate decreased the pH of the resin to a level much lower than the alkaline sodium salts. Obviously, the reduction in the mechanical properties of the OSB specimens containing the acidic fire retardants mainly caused by a combination of accelerated resin curing and thermal decomposition of the OSB strands [5]. For example, when the OSB mat was hot-pressed at 180 °C in the hot-press, the acid hydrolysis reactions, dehydration of glucose units and depolymerization of cellulose with a combined effect of chemical and high temperature, and thus the mechanical properties of the OSB panel decreased [6,7].



A.

B.

Figure 7. Bending modulus (A: parallel and B: perpendicular to the panel surface) of OSB panels depending on the content of the fire-retardants (from 2 to 6 wt%).

3.3. Fire resistance

Based on the fire resistance test results of the panels, the fire resistance of the OSB panels was significantly increased by the increased amount of chemicals. The chemicals showed individually different effects related to improvement of fire resistance of the panels. The OSB panels treated with borax had the shortest flame length after burner was turn off, followed by diammonium phosphate, boric acid, and monoammonium phosphate treated OSB panels, respectively (Fig. 8). The OSB panels treated with diammonium phosphate had the smallest char area among all treated panels, followed by borax, boric acid, and monoammonium phosphate treated OSB panels (Fig. 9).

Fire retardant chemicals contribute to the prolongation of the time required to spread non-flammable gases and retard the ignition of the wood by heat-absorption. Chemicals with acidic character such as inorganic phosphates increase the degradation rate of wood at lower temperatures, which causes the higher char yield [10].

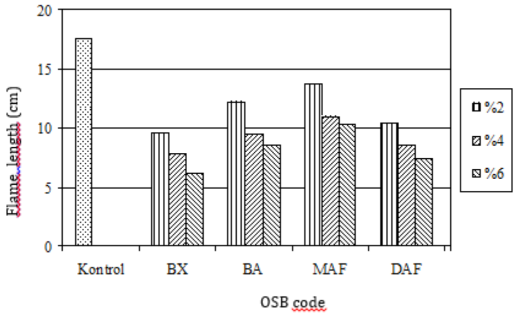


Figure 8. Flame length of OSB panels depending on the content of the fire-retardants (from 2 to 6 wt%).

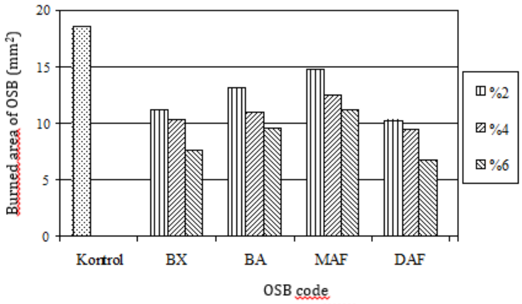


Figure 9. Burned area of OSB panels depending on the content of the fire-retardants (from 2 to 6 wt%).

4. Conclusions

The effect of boron and phospate compounds on the properties of OSB panels was investigated in this study. As compared to the boric acid and monoammonium phosphate, borax and diammonium phosphate could be used to improve the fire resistance of the OSB panels because of their relatively little effects on the mechanical properties of the panels. The boric acid and monoammonium phosphate decreased the mechanical properties of the OSB panels more than borax and diammonium phosphate. Thickness swelling and mechanical properties of the OSB panels were worse than the control group while the fire resistance was better.

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Conflicts of Interest

The authors declare no conflict of interest.

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