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INVESTIGATION OF PHYSICAL PROPERTIES OF PLYWOOD TREATED WITH FIRE RETARDANT CHEMICALS

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Abstract

The treatment with fire retardant chemicals is the most effective process to protect wood and wood based products from fire. Therefore, the usage of fire retardant chemicals has been increasing. However, the fire retardant chemicals have an effect on other physical, mechanical and some technological properties of the materials treated with them. In this study, it was examined that the effect of fire retardant on physical properties of plywood. Alder (*Alnus glutinosa* subsp. *barbata*) and Scots pine (*Pinus sylvestris* L.) were used as wood species; zinc borate, monoammonium phosphate and ammonium sulphate were used as fire retardant chemicals and UF resin was used as adhesive. The veneer sheets were treated with immersion method. Physical properties of the plywood panels such as thickness swelling and water absorption, density and equilibrium moisture content of the panels were determined according to TS EN 317, TS EN 323-1 and TS EN 322, respectively. Thickness swelling and water absorption values of panels produced with the veneers treated with fire retardant chemicals were less than those of control panels for 2 h. However, there is no statistical difference in these results for 24 h. In addition, it was found that the density values of panels treated zinc borate was the highest in the all groups for Scots pine.

Keywords: Alder, Fire retardant, Physical properties, Plywood, Scots pine

1. Introduction

Plywood is preferred as constructional material and has conventionally played an important role in light frame construction. Plywood and other wood-based materials are extensively used in the production of furniture, engineered flooring, housing, and other industrial materials (Bohm et al. 2012). However, the usage and application areas of plywood are limited since the plywood is a flammable material. Therefore, there has been much interest in the fire-retardant-treatment of wood-based panels (Cheng and Wang 2011). The plywood panels treated with fire retardant chemicals are extensively used in usage. Especially, they are generally preferred in furniture industry and construction applications (Tanritanir and Akbulut 1999; Winandy 2001; Ayrilmis et al. 2006).

The wooden materials treated with fire retardant chemicals enable an applicable alternative to conventional non-combustible products where a higher level of fire safety is necessary or desirable (White and Mitchell 1992). Boron compounds are known one of the best fire retardant chemicals due to their beneficial effects like neutral pH, protective efficiency, and less effect on mechanical strength than the others (Levan and Tran 1990). Also, phosphorus-containing compounds like mono- and di-ammonium phosphates are considered very effective fire retardant chemicals, so they have been preferred for wooden and wood-based products for quite a long time (Grexa et al. 1999).

The fire retardant chemicals are harmless to human, animals and plants, there is also a less release of smoke and less toxic gases when burned and these are important parameters for consumers to select one of such products. It was also shown the fire retardant chemicals influence the physical, mechanical and some technological properties of the materials treated with them (He et al. 2014; Yao et al. 2012).

In this study, it was examined that the effect of fire retardant on physical properties of plywood. For this purpose, the panels produced as three ply-plywood and it was determined thickness swelling and water absorption, density and equilibrium moisture content as physical properties.

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2. Materials and Methods

In this experimental study, 2 mm-thick rotary cut veneers with the dimensions of 500 mm by 500 mm were obtained from alder (*Alnus glutinosa* subsp. *barbata*) and Scots pine (*Pinus sylvestris* L) logs. While the alder veneers were manufactured from freshly cut logs, Scots pine logs were steamed for 12 h before veneer production. The horizontal opening between knife and nosebar was 85% of the veneer thickness, and the vertical opening was of about 0.5 mm in the rotary cutting process. The veneers were then dried to 6–8% moisture content with a veneer dryer. After drying, veneer sheets were treated with some fire retardant chemicals. For this aim, 5% aqueous solutions of zinc borate (ZB), monoammonium phosphate (MAP) and ammonium sulphate (AS) were used. The veneers were subjected to re-drying process at 110°C after their immersion in fire retardant solutions for 20 min.

Three-ply-plywood panels having 6 mm thickness were manufactured by using urea formaldehyde resin. The formulations of adhesive mixture used for plywood manufacturing are given in Table 1. Veneer sheets were conditioned to approximately 5–7% moisture content in a climatization chamber before gluing. The glue mixture was applied at a rate of 160 g/m^2 to the single surface of veneer by using a four-roller glue spreader. Hot press pressure was 12 kg/cm^2 for alder and 8 kg/cm^2 for Scots pine while the hot pressing time and temperature were of about 6 min and 110ºC, respectively. Two replicate panels were manufactured for each test groups.

Table 1. The formulations of UF glue mixture used for the manufacturing of plywood

Glue Type	Ingredients of Glue Mixture	Parts by weight
UF	UF resin (with 55% solid content)	100
	Wheat flour	30
	Hardener - NH_4Cl (with 15% concentration)	10

Physical properties of the plywood panels such as thickness swelling and water absorption at 2 and 24 hours, density and equilibrium moisture content of the panels were determined according to TS EN 317 (1999), TS EN 323-1 (1999) and TS EN 322 (1999), respectively. The obtained data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean separation tests.

3. Results and Discussion

The density and equilibrium moisture content mean values and Duncan's test results of plywood panels according to the wood species and fire retardant chemicals were shown in Table 2. In addition, the thickness swelling and water absorption values at 2 and 24 hours and Duncan's test results were given in Table 3.

Table 2. Density and equilibrium moisture content means and Duncan's test results of plywood panels (P < 0.05)

Wood Species	Fire Retardants Chemicals	Density (g/cm^3)		Equilibrium Moisture Content (%)	
Alder	Control	0,639	a*	8,63	b
	ZB	0,646	a	8,39	a
	MAP	0,640	a	8,57	ab
	AS	0,626	a	8,55	ab
Scots Pine	Control	0,575	a	8,89	a
	ZB	0,649	b	8,62	a
	MAP	0,600	a	8,70	a
	AS	0,599	a	8,33	a

* The mean values marked with the same symbol are statistically identical.

Table 3. Thickness swelling and water absorption means and Duncan's test results of plywood panels (P < 0.05)

Wood Species	Fire Retardants Chemicals	Thickness Swelling (%)				Water Absorption (%)			
		2 h		24 h		2 h		24 h	
Alder	Control	3,70	b*	9,71	a	33,71	b	48,41	a
	ZB	3,27	ab	9,40	a	32,06	a	48,10	a
	MAP	2,43	a	8,93	a	31,74	a	47,96	a
	AS	2,29	a	8,75	a	31,34	a	47,80	a
Scots Pine	Control	3,70	a	8,15	a	32,47	b	39,33	a
	ZB	3,46	a	8,72	a	28,02	a	40,80	a
	MAP	3,30	a	8,45	a	27,49	a	40,59	a
	AS	3,38	a	8,53	a	27,60	a	40,67	a

* The mean values marked with the same symbol are statistically identical.

As can be seen from Table 2, there was no statistical difference in the density values were obtained for the all groups of alder plywood. However, the mean obtained from panel treated zinc borate was statistically the highest in the all groups of Scots pine plywood. It was seen that there was generally a slight increase in the density values. The spaces in the control groups are filled with air, but the spaces of the specimens were impregnated are filled with impregnated materials. Increasing of density is expected result due to less air space (Aytaskin 2009; Demir 2014). There was no difference in the equilibrium moisture content means for the groups of Scots pine plywood. The mean of the control group of alder plywood was higher than the other groups of alder plywood.

As can be seen from Table 3, the thickness swelling and water absorption values of panels produced with the veneers treated with fire retardant chemicals were less than those of control panels for 2 h. Waterborne inorganic salts, such as boron compounds and phosphates, adversely affect swelling and expansion properties of wood and wood composites because of their hygroscopic characteristics and possible interaction between the deposition of boron and phosphate crystals and the monomer in the cell wall (Dundar et al. 2009). This explains some changes in the groups especially the thickness swelling and water absorption values of Scots pine for 24 h. However, there is no statistical difference in these results for 24 h. In literature, phosphate and the boron compounds did not have a significant negative effect on the dimensional stability of sandwich and LVL panels (Rosero-Alvarado et al. 2018; Dundar et al. 2009).

4. Conclusions

In this study, it was aimed to investigation of the effect of fire retardant on physical properties of plywood. As a result of this study, thickness swelling and water absorption values of panels produced with the veneers treated with fire retardant chemicals were less than those of control panels for 2 h. However, there is no statistical difference in these results for 24 h. In addition, it was found that the density values of panels treated zinc borate was the highest in the all groups for Scots pine.

It has been determined that the impregnation process generally improves the physical properties of wood materials. It was affected differently especially the swelling and water absorption of the wood materials depending on the wood species. Therefore, these changes in the strength values and the probability of moisture exchange in the usage must be taken into attention, depending on the wood species used before impregnation.

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References

Ayrilmis, N., Korkut. S., Tanritanir, E., Winandy, J. E. and Hiziroglu, S. (2006). Effect of various fire retardants on surface roughness of plywood. Building and Environment, 41(7), 887–892.

Aytaskin, A. (2009). Some technological properties of wood ımptegnated with various chemical substances, Master Thesis, Karabük University Natural Science Institute, Karabük.

Bohm, M., Salem. M. Z. M. and Srba, J. (2012). Formaldehyde emission monitoring from a variety of solid wood, plywood, blockboard and flooring products manufactured for building and furnishing materials. Journal of Hazardous Materials, 221-222, 68-79.

Cheng, R. X. and Wang, Q. W. (2011). The influence of FRW-1 fire retardant treatment on the bonding of plywood. Journal of Adhesion Science and Technology, 25, 1715–1724.

Demir, A. (2014). The effects of fire retardant chemicals on thermal conductivity of plywood produced from different wood species. Master Thesis, Karadeniz Technical University, Natural Science Instute, Trabzon.

Dundar, T., Ayrilmis, N., Candan, Z. and Sahin, H. T. (2009). Dimensional stability of fire-retardant-treated laminated veneer lumber. Forest Products Journal, 59(11), 18-23.

Grexa, O., Horvathova, E., Besinova, O. and Lehocky, P. (1999). Flame retardant plywood. Polymer Degradation and Stability, 64, 529–33.

He, X., Li, X., Zhong, Z., Yan, Y., Mou, Q., Yao, C. and Wang, C. (2014). The fabrication and properties characterization of wood-based flame retardant composites. *Journal of Nanomaterials,* 1-6.

Levan, S. L., Tran, H. C. (1990). The role of boron in flame-retardant treatments. In: Hamel M, editor. First international conference on wood protection with diffusible Preservatives. Proceedings 47355, Nashville, TN, November 28–30, p. 39–41.

Rosero-Alvarado, J., Hernández, R. E. and Riedl, B. (2018). Effects of fire-retardant treatment and wood grain on three-dimensional changes of sandwich panels made from bubinga decorative veneer. Wood Material Science and Engineering, 1-10. https://doi.org/10.1080/17480272.2018.1465464.

Tanritanir, E. and Akbulut, T. (1999). Plywood industry and general situation of plywood trade. Laminart-Furniture and Decoration Journal, 9, 122–32 (In Turkish).

TS EN 317, 1999. Particleboards and fibreboards- Determination of swelling in thickness after immersion in water. Turkish Standards Institute, Ankara.

TS EN 322, 1999. Wood-based panels-Determination of moisture content. Turkish Standards Institute, Ankara.

TS EN 323-1, 1999. Wood- Based panels- Determination of density. Turkish Standards Institute, Ankara.

White, R. H. and Mitchell, S. S. (1992). *Flame retardancy of wood: present status, recent problems, and future fields*. In: Lewin M, editor. Recent advances in flame retardancy of polymeric materials. Proceedings of the third annual BCC conference on flame retardance, Stamford, CT: p. 250–7.

Winandy, J. E. (2001). Thermal degradation of fire-retardant-treated wood: predicting residual service life. Forest Product Journal, 51(2), 47–54.

Yao, C. H., Wu, Y. Q. and Hu, Y. C. (2012). Flame-retardation characteristics and mechanisms of three inorganic magnesium compounds as fire-retardant for wood. Journal of Central South University of Forestry and Technology, 32(1), 18–23.