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Impact of heat treatment on weight loss during combustion of laminated veneer lumber (LVL)

Isıl işlemin lamine kaplama kerestenin (LVL) yanma esnasındaki ağırlık kaybına etkisi

***Yazar(lar) (Author(s))**: Osman PERÇİN[1], Mustafa ALTUNOK[2]*

ORCID[1]: 0000-0003-0033-0918

ORCID[2]: 0000-0002-2048-1994

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Impact Of Heat Treatment On Weight Loss During Combustion Of Laminated Veneer Lumber (LVL)

Araştırma Makalesi / Research Article

Osman PERÇİN[1*], Mustafa ALTUNOK[2]

[1]Necmettin Erbakan University, Faculty of Fine Arts, Department of Interior Architecture and Environmental Design, 42100, Konya-Turkey

[2]Gazi University, Faculty of Technology, Department of Wood Products Industry Engineering, 06500, Ankara-Turkey

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ABSTRACT

This study was performed to determine the effects of heat treatment on weight loss during combustion of the laminated wood materials produced from Oriental beech (*Fagus orientalis* L.), scotch pine (*Pinus sylvestris* L.), sessile oak (*Quercus petraea* L.), and poplar (*Populus nigra* L.) veneers bonded with PVAc-D_4, PUR and MF adhesives. For this aim, the weight loss during combustion of the test samples was determined according to ASTM E 160-50. The results of this study indicated that the weight loss percentage was the highest in poplar wood (89.17%), PVAc-D_4 adhesive (89.79%) and control samples (88.69%). In the interaction of the wood materials and type of adhesive, the highest value was measured in poplar+PUR (90.93%), interaction of the wood materials and heat treatment in poplar + control samples (90.87%), in the interaction of the type of adhesive and heat treatment in PVAc-D_4 + 185 °C (91.10%). In the interaction of the wood material, type of adhesive and heat treatment temperature, the highest value was determined in laminated control poplar samples with PUR adhesive (93%), while the lowest in laminated scotch pine samples with MF and heat-treated at 185 °C (81.83%). The use of laminated and heat-treated wood material in places where in high risk of fire, impregnation of wood material with fire-retardant compounds can be suggested.

Keywords: Heat treatment, weight loss, combustion, adhesive, wood material.

Isıl İşlemin Lamine Kaplama Kerestenin (LVL) Yanma Esnasındaki Ağırlık Kaybına Etkisi

ÖZ

Bu çalışma, ısıl işlemin Doğu kayını (*Fagus orientalis* L.), sarıçam (*Pinus sylvestris* L.), sapsız meşe (*Quercus petraea* L.), ve kavak (*Populus nigra* L.) kaplamalardan PVAc-D_4, PUR and MF tutkalları ile lamine edilmiş ağaç malzemelerin yanma esnasında ağırlık kaybına etkilerini belirlemek için yapılmıştır. Bu amaçla yanma esnasındaki ağırlık kayıpları ASTM E 160-50 standartına göre belirlenmiştir. Çalışma sonunda en yüksek ağırlık kaybı, kavak odununda (%89.17), PVAc-D_4 tutkalında (%89.79) ve kontrol (ısıl işlemsiz) örneklerde (%88.69) belirlenmiştir. Ağaç malzeme ve tutkal türü etkileşiminde en yüksek ağırlık kaybı kavak + PUR kombinasyonunda (%90.93), ağaç malzeme ve ısıl işlem etkileşiminde en yüksek ağırlık kaybı kavak + kontrol (ısıl işlemsiz) örneklerde (%90.87), tutkal türü ve ısıl işlem etkileşiminde en yüksek ağırlık kaybı PVAc-D_4 tutkalı + 185 °C'de (%91.10) belirlenmiştir. Ağaç malzeme, tutkal türü ve ısıl işlem etkileşiminde ise en yüksek ağırlık kaybı PUR tutkalı ile lamine edilmiş kontrol kavak örneklerde (%93), en düşük ise MF tutkalı ile lamine edilmiş ve 185 °C'de ısıl işlem uygulanmış sarıçam örneklerde (%81.83) belirlenmiştir. Yangın riskinin yüksek olan yerlerde lamine edilmiş ve ısıl işlem uygulanmış ağaç malzemenin kullanılması durumunda yangın geciktirici kimyasal maddelerle emprenye edilerek kullanılması önerilebilir.

Anahtar Kelimeler: Isıl işlem, ağırlık kaybı, yanma, tutkal, ağaç malzeme

1. INTRODUCTION

Wood is optimal construction material which one of the few renewable and sustainable natural sources. It has been used for many purposes by humans for thousands of years because of its excellent properties [1-3]. The demand for the use of wood materials for implementations in both interior and exterior construction has been raising in recent years and it is still most widely used as building and construction materials [4].

Chemically, wood material is composed mainly of carbon, hydrogen, and oxygen. Generally, the hydrogen concentration is extremely low 6%, the carbon content of wood is about 50% , whereas the oxygen is 44% [5]. For this reason, wood is combustible material [6]. Combustion properties of wood material has been extensively studied because of its use as a construction material in many wood and wood-based systems. The combustibility of the wood is requently contributed to undesired and unexpected potential fires, leading to numerous wounds and casualties [4]. Making wood incombustible is not posssible, howeveer, making wood fire retardant is feasible [7]. Treatment of wood materials

**Corresponding Author*
e-mail : opercin@konya.edu.tr

with some fire retardant chemicals is one of the most efficient ways to preserve it from fire and provide safety [8,9]. Some of these chemicals can be harmful to human health and to the environment. The some chemicals provide high protection, while others provide low protection. In addition, always impregnated wood material is not used in interior and exterior applications[4,9].

In a study, Uysal [10] it was found that, Diammonium phosphate chemicals was the most effiecient fire-retardant in LVL wood. Another study prepared by Ozcifci et al. [11] studied the combustion characteristics of LVL produced from beech (*Fagus orientalis* L.) wood impregnated with boric acid, borax, and diammonium phosphate. In the study, they reported the lowest values for combustion temperature were obtained in the specimens glued with MF and treated with diammonium phosphate and boron compounds mixture. Atar [12] conducted a study to specify the impacts of varnish process after impregnating with boron compounds on combustion features of oak *(Quercus petreae* L.). The test specimens were impregnated with boric acid and borax. Following impregnation, surfaces were varnished by some varnish systems. As a consequence, used varnish systems showed an enhancing impact but boron compounds displayed diminishing effect on combustion properties of oak. In an another study conducted by Said Fidan et al. [13] they examnined the impact of impregatnation and surface treatment materials combustion properties of wood. The results of study indicated that the combustion parameters were lower in the 1-year-old samples 89.12% of control values, in the samples impregnated with the use of Wolmanit-CB 89.18% of control values, and in samples treated using water-based varnish 88.43% of control. Ors et al. [14], studied that the effect of some fire retardant chemicals on combustion properties of scotch pine (*Pinus sylvestris* L.) wood. They reported that boron compounds have positive impact on combustion properties of wood material. Martinka et al. [15] investigated that the impact of heat treatment on the heat release rate and propensity for fire propagation in the flashover phase of Norway spruce (*Picea abies* (L.) Karst.) and English oak (*Quercus robur*) woods. As a result, test results proved that thermally-modified of spruce and oak wood has no impact on the propensity for fire propagation in the flashover phase. They also reported that applied heat treatment was a significant effect on the heat release rate of spruce and oak woods.

Both laminated wood and heat-treated wood materials have a growing market in indoor and outdoor applications for years. The effect of lamination process and heat treatment on physical, chemical and mechanical properties of wood has been extensively investigated. There have been relatively few studies describing their combustion properties evaluation. Knowledge about combustion properties of the laminated veneer lumbers subjected to heat treatment after the laminating process can be important for scientists in the same topic and woodworking industry. For this reason this study was performed to determine the effects of heat treatment on combustion properties of the laminated wood materials produced of beech *(Fagus orientalis* L.), scotch pine (*Pinus sylvestris* L.), sessile oak (*Quercus petraea* L.), and poplar (*Populus nigra* L.) veneers bonded with PVAc-D_4, PUR and MF adhesives.

2. MATERIAL and METHOD

2.1. Material

2.1.1. Wood material

As test materials, the veneers (2mm thickness) were obtained from sessile oak (*Quercus petreae* L.), Oriental beech (*Fagus orientalis* L), scotch pine (*Pinus sylvestris* L.) and poplar (*Populus nigra* L.) logs used. Woods were obtained from Ankara province timber management completely randomly. These tree species have been preferred due to their widespread use in the woodworking and furniture industries.

2.1.2. Adhesive

The following adhesives were used in this experiment because of they are widely used in the industry.

Polyvinylacetate-D_4 (PVAc-D_4) (Kleiberit) is an odorless and non-flammable adhesive. The density is 1.120 g/cm^3, the viscosity (at 20 °C) 13000±2.000 mPa.s, and pH value 7.5. The gel time is 6-10 min, and amount applied 200g/m^2. PVAc-D_4 adhesive was obtained from Kleiberit PVAc-303 adhesive with addition of 5% Kleiberit Turbo-hardener 303.5 [16].

Polyurethane Kleiberit 501 (PUR) is a single component adhesive that the bonds are extremely strong and temperature and water resistant. Specific gravity is (at 20 °C) 1.13 g/cm³, viscosity (at 20 °C) 8000 mPa.s, and curing time 2-3 h. The pH value is 7 and, amount applied 200g/m^2 [16].

Melamine formaldehyde (MF) resins are used widely as adhesives for interior and exterior applications, plywood and particleboard. Density of MF adhesive 1.200g/cm^3, pH value 9.3, viscosity (at 20°C) 60 cPs, and amount applied 200g/m^2 [17,18]. Adhesives were obtained from commercial firms in Turkey.

2.2. Method

2.2.1. Preparation of test samples

The veneers without defects were selected and resized in samples with 150 x 950 mm (width x length). Production of LVL was conducted in laboratory conditions. The adhesives were spread to one surface of veneer by using a roll. The spreading rate of adhesive was approximately 200 g/m^2. LVL panels were obtained by bonding ten veneers. The pressure applied by the hot press for the LVL boards were 1 N/mm^2 for poplar and scotch pine veneers and 1.2 N/mm^2 for oak and beech veneers. The duration of the press and the temperature were 20 min and 80 °C, respectively for MF and PVAc-D_4, and 20 min and 60 °C for PUR adhesive. Enough panels were produced for each of the test groups according to TS EN

386 [19] and they were stored for one week for exact curing.

Panels were heat treated at 185 °C and 212 °C in a heat treatment oven under a normal atmosphere controlled in ±1°C temperature sensitivity under hot steam. The used heat treatment process was divided into three continuous phases (Figure 1). In the first phase oven temperature was increased to 100 °C for 6 h, then temperature was increased to 130°C for 12 h, in the second phase temperature was increased from 130 °C to 185 °C and 212 °C for 6 h and these temperatures were kept constant for 2 h, in the final phase temperature of the oven was decreased to initial temperature for 12 h. At the end of the heat treatment process, 10 mm edges were cut off of the panels.

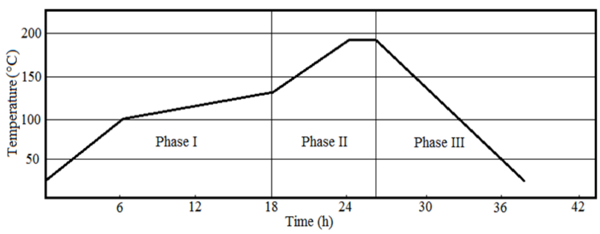

Figure 1. Example of a heat treatment process.

Combustion test samples were prepared from the panels with dimensions of 13 x 13 x 76 mm according to the ASTM E 160-50 [20] principles. In the combustion tests, each sample group was weighed before tests. The combustion test was carried out in three stages. Flame source was centered below sample pile and flame source combustion phase (FSC) was continued for 3 min. Then the flame source was extinguished and were carried out consecutive the other two combustion stages (without flame source (WFSC) combustion, ember combustion (E) stage). After combustion tests, the weights of test specimens were weighed and the weight loss (%) value was calculated by using following formula.

$$WL(\%) = [(Wb-Wa) / Wb] \times 100 \quad (1)$$

Here WL is weight loss (%) of test samples, Wb is weight of test sample before combustion (g), Wa is weight of test sample after combustion (g).

2.3. Statistical analyses

In the evaluation of the data, the MSTAT-C statistical software program was used. In this study, four types of wood, three types of adhesive, two types of temperature and one control samples, a total of 108 samples (4 x 3 x 3 x 3) were prepared with three samples for weight loss during combustion. The values of the factor effects of heat treatment temperature, wood type and adhesive type on weight loss were determined using the analysis of variance (ANOVA) procedure. When the variance among groups were determined to be significant, Duncan test was utilized to specify the variances between average values at the appointed level of α=0.05.

3. RESULTS AND DISCUSSION

Mean values of weight loss for different wood material, types of adhesive and heat treatment temperature are given in Table 1. Results of ANOVA, for effect of wood material, type of adhesive and heat treatment temperature on the weight loss rate of LVL samples are given in Table 2.

Table 1. Average of the weight loss of wood material, types of adhesive and heat treatment temperature

Type of material and treatment		Statistical Values	
		X(%)	HG
Wood material*	Poplar	89.17	A
	Scotch	88.30	B
	Oak	87.23	C
	Beech	86.08	D
Type of adhesive**	PVAc-D_4	89.79	A
	PUR	87.90	B
	MF	85.39	C
Heat treatment temperature***	Control	88.69	A
	185 ºC	88.00	B
	212 ºC	86.39	C

Different letters in the columns refer to significant changes in the weight loss at 0.05 confidence level (*LSD: 0.5756,** LSD: 0.4985, LSD: 0.3411), HG: Degree of Homogeny

According to the wood material the highest weight loss rate was determined in poplar wood, and the lowest was found in beech wood. This situation may be due to the different density values of wood materials. For type of adhesive, highest result was determined in PVAc-D_4, and the lowest was found in MF adhesive. For heat treatment temperature, the highest weight loss was obtained at 185 ºC, and the lowest was found at 212 ºC. However, the control samples have the highest rate. The difference in weight loss between the two heat treatment temperature was about 2%. Accordingly, in general it is possible to say that heat treatment decreased weight loss rate. The weight loss values were showed differences in all material and treatment.

Effects of wood material, type of adhesive, heat treatment temperature and all interactions on weight loss rate were found to be significant (α =0.05) (Table 2). Average temperature values according to wood material + type of adhesive, wood material + heat treatment temperature, and type of adhesive + heat treatment temperature combinations are given in Table 3. Duncan test was utilized to specify the variances between average values at the appointed level of α=0.05. Duncan Test results are given in Table 4.

Table 2. Results of variance analysis (ANOVA) on the eight loss rate of LVL samples

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Signature (P<0.05)
Factor A	3	144.609	48.203	42.3418	0.0000
Factor B	2	351.222	175.611	154.2579	0.0000
AB	6	87.967	14.661	12.8785	0.0000
Factor C	2	99.925	49.963	43.8875	0.0000
AC	6	40.911	6.819	5.9894	0.0000
BC	4	89.980	22.495	19.7598	0.0000
ABC	12	163.323	13.610	11.9553	0.0000
Error	72	81.967	1.138		
Total	107	1059.905			

Factor A = Wood material (Beech, Oak, Scotch pine, Poplar); Factor B = Adhesive (PVAc-D_4, PUR, MF)
Factor C = Heat treatment temperature (Control, 185 ºC, 212 ºC)

According to wood material + type of adhesive weight loss rate was measured as the highest in poplar+PUR, but the lowest in beech + MF adhesive (Table 3). This result may be due to the from difference of the used materials. Atar and Keskin [21] studied impacts of coating with various varnishes after impregnation with boron compounds on the combustion properties of Uludag fir(*Abies Bornmülleriana* Mattf.) wood. They reported that the tested varnishes showed an increasing impact but boron compounds (Ba and Bx) showed a decreasing impact on combustion properties of Uludag fir wood.

According to wood material + heat treatment, the highest weight loss was in poplar + control samples, but the lowest in beech + 212 °C. This situation may be derived from density differences of wood material and heat treatment temperature. Ćekovská et al. [22] studied the fire resistance of heat-treated Spruce (*Picea abies* L.) wood. They reported that applied heat treatment temperatures affected weight loss of wood material. It was the highest in PVAc-D_4 + 185°C, but the lowest in MF+185°C combination according to type of adhesive + heat treatment. This result may be originated from the properties of MF adhesive. Sadiye Yasar et al. [23] stated that better combustion properties for spruce (*Picea orientalis* L.) wood were obtained from the Wolmanit-CB impregnation material and synthetic varnish combination. Atar [24] declared that the varnnishes tested revealed an ascending effect, however, boron compounds displayed an diminishing effect on combustion properties of oak (*Quercus petreae* L) wood.).

Table 3. Average weight loss for the combination of type of material and treatment

Wood material + type of adhesive*	X(%)	HG
Poplar+PUR	90.93	A
Poplar+PVAc-D_4	90.89	A
Scotch pine+PVAc-D_4	90.70	A
Beech+PVAc-D_4	89.24	B
Oak+PVAc-D_4	88.33	BC
Oak+PUR	88.11	C
Scotch pine+PUR	87.54	CD
Scotch pine+MF	86.64	DE
Poplar+MF	85.68	EF
Oak+MF	85.26	F
Beech+PUR	85.01	F
Beech+MF	83.98	G
Wood material+heat treatment**	X(%)	HG
Poplar+Control	90.87	A
Poplar+185°C	90.06	AB
Scotch pine+Control	89.29	B
Oak+Control	88.14	C
Scotch pine+185°C	87.84	C
Scotch pine+212°C	87.76	C
Oak+185°C	87.76	C
Poplar+212°C	86.58	D
Beech+Control	86.44	DE
Beech+185°C	86.36	DE
Oak+212°C	85.80	DE
Beech+212 °C	85.43	E
Type of adhesive+heat treatment***	X(%)	HG
PVAc-D_4+185°C	91.10	A
PUR+Control	89.86	B
PVAc-D_4+Control	89.33	BC
PVAc-D_4+212°C	88.94	CD
PUR+185°C	88.36	D
MF+Control	86.87	E
PUR+212°C	85.48	F
MF+212°C	84.75	FG
MF+185°C	84.55	G

(*LSD: 0.9969,** LSD: 0.9969, LSD: 0.8633),

Table 4. Duncan Test Results

Wood material+ type of adhesive+	X	HG	Wood material+ type of adhesive+heat treatment	X	HG
Poplar+PUR+Control	93.00	A	Scotch pine+MF+Control	88.33	FGHIJ
Poplar+PVA$_c$-D$_4$+185°C	92.53	AB	Poplar+PUR+212°C	87.90	FGHIJK
Scotch pine+ PVA$_c$-D$_4$+185°C	92.37	ABC	Beech+ PVA$_c$-D$_4$+Control	87.73	GHIJK
Poplar+PUR+185°C	91.90	ABC	Beech+PUR+Control	87.67	HIJKL
Beech+ PVA$_c$-D$_4$+185°C	91.07	BCD	Oak+ PVA$_c$-D$_4$+212°C	87.43	IJKL
Poplar+ PVA$_c$-D$_4$+Control	90.50	CDE	Oak+PUR+212°C	86.60	JKL
Scotch pine+ PVA$_c$-D$_4$+Control	89.97	DEF	Oak+MF+185°C	86.30	KL
Scotch pine+ PVA$_c$-D$_4$+212°C	89.77	DEFG	Oak+MF+Control	86.10	KLM
Scotch pine+MF+212°C	89.77	DEFG	Poplar+MF+185°C	85.73	LMN
Poplar+ PVA$_c$-D$_4$+212°C	89.63	DEFGH	Beech+MF+185°C	84.33	MNO
Scotch pine+PUR+Control	89.57	DEFGH	Beech+MF+Control	83.93	NOP
Scotch pine+PUR+185°C	89.33	DEFGHI	Scotch pine+PUR+212°C	83.73	OPQ
Oak+PUR+Control	89.20	DEFGHI	Beech+PUR+212°C	83.70	OPQ
Oak+ PVA$_c$-D$_4$+Control	89.13	DEFGHI	Beech+PUR+185°C	83.67	OPQ
Poplar+MF+Control	89.10	DEFGHI	Beech+MF+212°C	83.67	OPQ
Beech+ PVA$_c$-D$_4$+212°C	88.93	EFGHI	Oak+MF+212°C	83.37	OPQ
Oak+PUR+185°C	88.53	EFGHIJ	Poplar+MF+212°C	82.20	PQ
Oak+ PVA$_c$-D$_4$+185°C	88.43	EFGHIJ	Scotch pine+MF+185°C	81.83	Q

According to the Table 4, the highest weight loss rate was determined in laminated control poplar with PUR adhesive, while the lowest in laminated with MF and heat-treated at 185°C scotch pine samples. In general, the lower weight loss was recorded in beech and oak samples more than scotch pine and poplar. MF also gave better results than PUR and PVAc-D$_4$ adhesives, while PUR adhesive was showed lowest thermal strength to the temperature. With increasing temperature PUR bondlines of veneer between deteriorated. Result shows that the weight loss rate decrease with an increase in heat temperature especially beech and oak woods. Osvaldová and Gaff [25] studied that different thermal modifications and the influence of fire retardant on combustion properties of thermally modified spruce (*Picea abies* L.) wood. They reported that the highest burning rate has been reached with heat-treated samples at 210°C. However, those treated with a fire retardant, had the lowest burning rate. The test results show that fire retardant treated and heat-treated spruce wood has lower weight losses than non-treated spruce wood. Also, Müllerová [26] reported thermally treated spruce wood reduce the smoke released when compared with untreated sample. Heat treated pine shows opposite effect. Thermally treated soft wood has decreased ignition time and heat release while burning. In another study was conducted by Wang and Cooper [27] declared that the heat treatment of wood in plant oils decreases its resistance to the spread of flame.

4. CONCLUSION

Heat treatment is one of the methods of protecting wood, which increases its resistance to biological degradation, improves its dimensional stability and color. Based on the findings obtained from the present study, it can be said that the heat treatment changes the natural properties na of the wood. The beech wood had a lower weight loss than the oak, poplar and scotch pine woods. The melamine-formaldehyde (MF) among adhesives give better results than other types of adhesive in the test samples. Weight loss rate of the wood samples which were laminated and then heat treated in a oven were a little lower than the control samples. The weigth loss ratio decreased by nearly 1% in the samples which heat-treated at 185 ºC and 2.6% at 212 ºC when compared with the control samples. For the wood material, adhesive type and heat treatment temperature was the highest weight loss value in poplar + PVAc-D$_4$ + 185°C as 92.53%, the lowest in scotch pine + MF + 185°C determined as 81.83%. Consequently, the use of heat-treated wood material in places where in high risk of fire, impregnation of wood material with fire-retardant compounds and extra measurements on combustion properties can be suggested.

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REFERENCES

[1] Ors Y., Keskin H., "Ağaç malzeme bilgisi", ***Atlas Yayın Dağıtım***, ISBN: 975-6574-01-1, İstanbul, (2001).

[2] Yorur H., Kurt S., and Uysal, B., ""Bonding strength of oak with different adhesives after humid-water-heat tests", ***Journal of Adhesion Science and Technology***, 28(7): 690–701, (2014).

[3] Yorur H., Kayahan K., Günay M. N., Altun S., and Şeker, B., "The effects of liquid nitrogen treatment on the some physical and mechanical properties of scots pine and oriental spruce wood", ***Turkish Journal of Forestry***, 18(4): 309-313, (2017).

[4] Lowden L. A., and Hull T. R., "Flammability behaviour of wood and a review of the methods for its reduction", ***Fire Science Reviews***, 2(4): 1-19, (2013).

[5] Roger C. P., "The chemical composition of wood", ***in The Chemistry of Solid Wood***, Edited by Rowell R., Advances in Chemistry Series 207, Chapter 2, 57-126, American Chemical Society, Washington, D.C. (1984).

[6] Keskin H., "Effects of Impregnation Solutions on weight loss during combustion of laminated veneer lumber", ***G.U. Journal of Science***, 22(3): 235-243, (2009).

[7] Baysal E., "Combustion properties of wood impregnated with commercial fertilizers", ***African Journal of Biotechnology***, 10(82): 19255-19260, (2011).

[8] He X., Li X., Zhong Z., Yan Y., Mou Q., Yao C., and Wang, W., "The fabrication and properties characterization of wood-based flame retardant composites", ***Journal of Nanomaterials***, Article ID 878357, 1-6, (2014).

[9] Keskin H., Atar M., and Izciler M., "Impacts of impregnation chemicals on combustion properties of the laminated wood materials produced combination of beech and poplar veneers", ***Construction and Building Materials***, 23: 634–643, (2009).

[10] Uysal B., "Combustion properties of laminated veneer lumbers bonded with polyvinyl acetate and phenol formaldehyde adhesives and impregnated with some chemicals", ***Combustion Science and Technology***, 177(7):1253–1271 (2005).

[11] Ozcifci A., Toker H., and Baysal, E., "Fire properties of laminated veneer lumber treated with some fire retardants", ***Wood Research***, 52(4): 37-46 (2007).

[12] Atar M., "Impacts of varnishes and impregnation chemicals on combustion properties of oak (*Quercus petreae* lipsky)", ***Journal of Applied Polymer Science***, 107(6): 3981–3986, (2008).

[13] Said Fidan M., Sadiye Yasar S., Yaşar M., Atar M., and Alkan, E., "Characterization of the combustion parameters of ımpregnated and varnished cedar wood (Cedrus libani)". ***Forest Products Journal***, 66 (5-6): 290-299, (2016).

[14] Ors Y., Atar M., and Peker H., "Sarıçam odununun yanma özelliklerinin bazı borlu bileşikler ve su itici maddelerin etkileri", ***Türk Tarım Ve Ormancılık Dergisi***, TÜBİTAK Yayınları, Ankara, s. 501 – 509, (1999).

[15] Martinka J., Kačíkova D., Rantuch P., and Balog, K., "Investigation of the influence of spruce and oak wood heat treatment upon heat release rate and propensity for fire propagation in the flashover phase", ***Acta Facultatis Xylologiae Zvolen***, 58(1): 5−14, (2016).

[16] Kleiberit product catalog, 2017: https://www.kleiberit.com/en/media-library/info-sheets.html (10.04.2017).

[17] Sahin Kol, H., Ozbay, G. and Altun, S. "Shear strength of heat-treated tali (*Erythrophleum Ivorense*) and ıroko (*Chlorophora Excelsa*) woods, bonded with various adhesives", ***BioResources***, 4(4): 1545-1554, (2009).

[18] Pizzi A., ""Melamine-formaldehyde resins", ***in Handbook of Adhesive Technology***, Pizzi A., and Mittal K. L. (Eds.), Marcel Dekker Inc, (2nd edition) New York, USA. (2002).

[19] TS EN 386 "Glued laminated timber- Performance requirements and minimum production requirements", Turkish Standards Institution, Ankara, Turkey, (1999).

[20] ASTM E 160-50 "Standard test method for combustible properties of treated wood by the cribe test", West Conshohocken, PA, USA: ASTM Standards (1975).

[21] Atar M., and Keskin H., ""Impacts of coating with various varnishes after ımpregnation with boron compounds on the combustion properties of Uludag fir", ***Journal of Applied Polymer Science***, 106: 4018–4023, (2007)..

[22] Ćekovská H., Gaff M., Osvald A., Kačík F., and Kubš J., "Fire resistance of thermally Modified Spruce Wood", ***BioResources,*** 12(1): 947-959, (2017).

[23] Sadiye Yasar S., Said Fidan M., Yasar M., Atar M., and Alkan, E., "Combustion properties of impregnated spruce (*Picea orientalis* L.) wood", ***Construction and Building Materials***, 143: 574-579, (2017).

[24] Atar M., "Impacts of Varnishes and Impregnation Chemicals on Combustion Properties of Oak (*Quercus petreae* Lipsky)", ***Journal of Applied Polymer Science***, 107: 3981–3986, (2008).

[25] Osvaldová L. M., and Gaff M., ""Retardation Effect On Thermally-Modified Spruce Wood", ***in Sustainable Development and Planning IX***, Etd. Brebbia C. A., Longhurst J., Marco E., Booth C., WIT Transactions on Ecology and The environment 226: 537-546, (2017).

[26] Müllerová J., "Fire Safety Properties of Heat Treated Wood", ***Research Journal of Recent Sciences***, 2(12): 80-82, (2013).

[27] Wang J., and Cooper P. A., "Fire, flame resistance and thermal properties of oil thermally-treated wood", ***The international research group on wood protection*** (IRG/WP) 07, Jackson, MS, USA. IRG/WP 07-40361, (2007).