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EMPRENYE VE ISIL İŞLEMİN KAYIN AĞACININ BAZI MEKANİK ÖZELLİKLERİNE ETKİSİ

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Özet-Bu çalışmanın amacı doğal emprenye maddesi ile emrenye edilmiş ve ısıl işlem uygulanmış Doğu kayını (*Fagus orientalis* L.) ağacının hava kurusu yoğunluk değeri, eğilme direnci ve liflere paralel basınç direncinin belirlenmesidir. Emprenye maddesi olarak meşe palamudu taneni tercih edilmiştir. Deney örnekleri ASTM D1413-76 standardına göre %3, %5 ve %7 emprenye çözeltisinde emprenye edilmiştir. Emprenye işleminden sonra deney örneklerine 150, 170, 190 ve 210°C'de 2 saat ısıl işlem uygulanmıştır. Deney sonuçlarına göre, emprenye ve ısıl işlem genellikle Doğu kayını ağacının yoğunluk değerleri ile eğilme ve liflere paralel basınç direncini düşürdüğü belirlenmiştir. Eğilme ve liflere paralel basınç dirençleri için en yüksek direnç kaybı %7 emprenyeli ve 210°C'de ısıl işlem uygulanmış örneklerde tespit edilmiştir. Ayrıca eğilme ve liflere paralel basınç direnci düşük sıcaklıklarda bir miktar artarken, daha yüksek sıcaklıklarda bu dirençler azalmıştır.

Anahtar Kelimeler- Emprenye, tanen, ısıl işlem, ağaç malzeme.

THE EFFECT OF IMPREGNATION AND HEAT TREATMENT ON SOME MECHANICAL PROPERTIES OFBEECH WOOD

Abstract- The main purpose of this study was to investigate air-dry density değeri, bending strength (MOR) and compression strength parallelto grain (CS) of impregnated with natural impregnation material and heat-treated Oriental beech (*Fagusorientalis* L.) wood. Acorn tannin is preferred as the natural impregnation material. Test specimens were impregnated with 3%, 5% and 7% aqueous solutionof the impregnation material according to ASTM D 1413-76 standard. After impregnation process, the heat treatment was performed at the temperatures of 150, 170, 190 and 210°C for 2 hours. Test results showed that impregnation and heat treatment generally decreased the density and bending strength and the compressive strength parallel to grain of Oriental beech wood. The highest strength reduction for bending and compression strength were observed in impregnated with 7% and heat-treatedsamples at 210 °C. It was also found that the bending and compressive strength parallel to grain increased slightly at the lower heat treatment temperatures, however these strengths decreased at the higher temperatures.

Bu makale, 4. Uluslararası Mobilya ve Dekorasyon Kongresi'nde sunulmuş ve İleri Teknoloji Bilimleri Dergisi'nde yayınlanmak üzere seçilmiştir.

Key Words- Impregnation, tannin, heat treatment, wood material.

1. INTRODUCTION

Wood material has long been used effectively in many structural applications thanks to having some characteristics. There are many superior properties of wood material (high tensile strength, high elastic modulus, low density, renewability, easy processability etc.) However together with these positive featuresit can undergo physical and chemical damage when used outdoors and more easily degraded by fire and biotic and abiotic factors [1-2]. For this reason the wood material impregnated with some chemical substances whenit used in outdoor environments. Some of these chemicals can be harmful to human health or to the environment. Environmentally friendly chemicals and wood protection medhods have been used for over the past few decades.

Heat treatment of wood is one of the environmentally friendly wood protection method that it has been known as a process enhancing wood propertiesby reducing moisture absorption, improving dimensional stability and biological durability also, heat-treated wood has been subjected to increasing interest duringin recently years [3-6].

Sen and Hafizoglu (2008) investigated that wood preservative effects of plant extracts (*Pinus brutia* barks, Quercusithaburensis valonia extract, gallnut powders and sumac leaves) in open area conditions with impregnated *Picea orientalis, Pinus sylvestris, Fagus orientalis, Alnus glutinosa* samples. Test results showed that the damages of insect and fungus on *Fagus orientalis* and *Alnus glutinosa* wood samples were higher than *Picea orientalis* and *Pinus sylvestris* wood samples in some extent [7]. Sen et al. (2017) **s**tudied that the larvicidal activities of plant extracts and tannins against wood-damaging insects. Scots pine (*Pinus sylvestris*), beech (*Fagus orientalis*), and poplar wood (*Populus tremula*) were subjected to larvae of *Spondylis buprestoides* (Coleoptera: Cerambycidae) by impregnating them with mimosa (*Acacia mollissima*), quebracho (*Schinopsis lorentzii*) and redpine bark (*Pinus brutia*) extracts. As result, the lowest larva resistance was observed in Scots pine wood, while the highest larva resistance was achieved by beech wood. The lowest mass losses and the highest dead termite rates in all tree species were observed when the concentration of mimosa and quebracho extracts was 12%. Also, the pine bark extract showed a lower larvicide effect than the other two extracts [8]. Kartal et al. (2006) studied the effect of essential oil compounds and extracts from plants on decay and termite resistance of treated wood. Test results showed that the wood specimens treated with the formulations used in termite resistance tests were more resistant against the termites when compared to specimens treated with the formulations in decay resistance tests. Results suggest that essential oils and plant extracts might be important to develop new wood preservatives that are less harmful to the environment and humans than recently available ones [9]. Yasar et al. (2017) analyzed the changes on some physical and mechanical characteristics of sessile oakwood under the effects of open door conditions for one year by impregnating with natural and artificial substances. Pine and acorn tannins are preferred as the natural impregnation material, imersol aqua and Timber aqua are chosen as the synthetic impregnation material. The test results showed that bending resistance and elastic modulus of the samples impregnated with acorn gave better results in comparison with samples impregnated with other substances [10].

This study evaluated the effects of acorn tannin impregnation and heat treatment on air-dry density, bending and compression strength parallel to grain of Oriental beech (*Fagus orientalis* Lipsky) wood.

2. MATERIAL AND METHOD

In this study, Oriental beech (*Fagus orientalis* L.) wood was used as test material. The study material was obtained from a local sawmill in Siteler, Ankara, Turkey. Test samples were prepared in accordance with TS 2470 (1976) [11]. Small clear samples were obtained for air-dry density and compression strength parallel to grain (20 x 20 x 30 mm) according to TS 2472 (1976) [12] and TS 2595 (1977) [13], bending strength (20 x 20 x 360 mm) according to TS 2474 (1976) [14]. The first part of beech wood samples was impregnated with acorn tannin solution before heat treatment whereas the other part of wood sample was heat treated without any acorn tannin impregnation. The solution has been prepared by dissolving 3%, 5% and 7% mineral tannin in distilled and heated water at 60 °C based on the amount of weight. The test specimens were impregnated with aqueous solutions of tannin by a vacuum-pressure method according to ASTM D 1413-76 (1976) [15] before heat treatment. Accordingly the test samples were exposed to vacuum method 760 mm/Hg^{-1} pre-vacuum for 30 min and then they were held in a solution under atmospheric pressure for 30 min. Then samples were subjected to heat treatment at 150°C, 170°C, 190°C and 210°C for 2 hours (Fig.1).

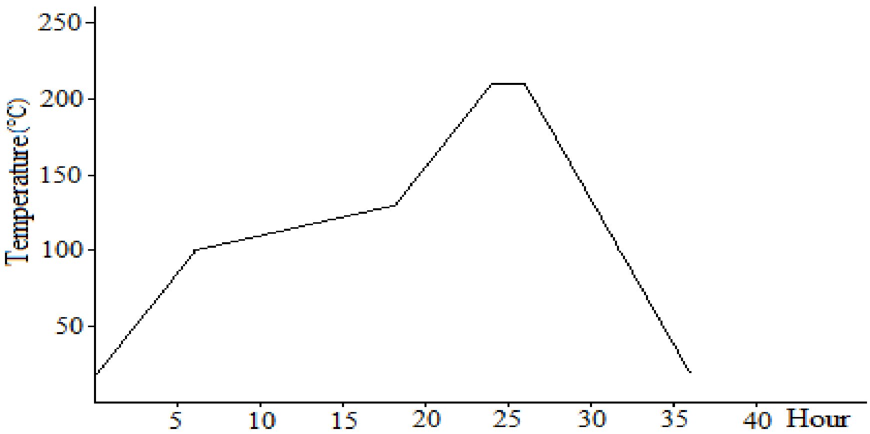

Figure 1. The applied heat treatment program

The samples were subjected to heat treatment under atmospheric pressure using water vapor. The oven temperature was raised to 100 °C for 6 h and then 130°C for 12 h under the protection hot water vapor. After this phase temperature was increased from 130°C to 150°C, 170°C, 190°C and 210°C for 6h. The test samples were kept at these temperature for 2 h. In the conditioning stage temperature was reduced for 10 h. Prior to the test, the dimensions of samples were measured and their weights were recorded. Thereafter they were conditioned in relative humidity of 65±5% and 20±2 °C temperature until they reached the equilibrium moisture content.

In this study, the MSTAT-C statistic package software program was used for the evaluation of the data. The values of the factor effects (heat treatment temperature and solution concentration) were determined using the analysis of variance (ANOVA). When the difference between groups werefound to be significant, Duncan test was used todetermine the difference between means at prescribedlevel of α=0.05.

3. RESULTS AND DISCUSSION

ANOVA tests results show that all the differences between groups were found to be significant ($P < 0.05$). Duncan test was used to determine the differences between means at prescribed level of a = 0.05 and results of Duncan test are given in Table1.

Table 1 shows the air-dry density, bending strength, and compression strength parallel to grain data for the impregnated and heat-treated samples for four temperatures. It is evident from Table 1 that the air-dry density values decrease with increasing heat treatment temperature. Heat treated wood samples at a temperature of 210°C gave the lowest air-dry density values when compared with other samples.

Density loss of heat-treated wood can be explained with material loses in the cell wall, degradation of hemiceluloses and the evaporation of extractives due to applied high heat treatment temperature. Korkut et al. (2008) explained that the reason for density loss is the losses in the cell wall, extractive substances and hemicellulose degradation due to the high temperature applied [16]. In addition, Esteves and Pereira (2009) reported that the degradation of hemiceluloses into volatile products and the evaporation of extractives are the main reasons for the density losses of heat-treated wood [17].

According to the Table 1, in general, as the concentration of impregnation material increases, density values of control samples increase, however values of heat-treated wood samples decrease with increasing heat treatment temperature. For example, samples exposed to a temperature of 210°C had 11.8% reduction in their density value compared to that of the control samples in unimpregnated samples. This reduction increased to13.3%, 13.0 and 14.4% for samples exposed to a temperature of 210°C for 3%, 5% and 7% concentration, respectively. Acorn tannin generally increased density losses. Gunduz et al. (2011) studied the effect of tannin and heat treatment on density value of Anatolian chestnut (*Castanea sativa* Mill.) wood. They reported that air-dry density were found to be higher in samples containing tannins and not exposed to heat treatment [18].

According to the Table 1, impregnation with tannin and heat treatment affected bending and compression strength parallel to grain of beech wood. The percentage decrease of bending strength compared to the control samples in beech wood given in Table 2.

Table 1. The effect of heat treatment on some physical and mechanical properties of impregnated Oriental beech (*Fagus orientalis* L.) wood

Concentration	Heat treatment	Statistical values	Air-dry density (g/cm^3)	Bending strength (N/mm^2)	Compression strength (N/mm^2)
Unimpregnated	Control	X	0.711d	119.4abc	70.46cde
		±s	0.013	3.08	1.79
	150°C	X	0.688g	121.2a	72.11b
		±s	0.011	3.01	1.31
	170°C	X	0.661k	115.6f	71.23bcd
		±s	0.009	1.08	1.28
	190°C	X	0.646m	105.6ı	65.66ı
		±s	0.008	1.55	1.15
	210°C	X	0.627q	91.42m	60.46k
		±s	0.012	2.43	1.62
3%	Control	X	0.721c	118.6bcd	71.68bc
		±s	0.010	2.16	1.27
	150°C	X	0.691f	120.5ab	73.71a
		±s	0.013	2.29	2.16
	170°C	X	0.662j	117.9cde	70.33cdef
		±s	0.006	2.89	2.02
	190°C	X	0.645n	103.5j	65.52ı
		±s	0.009	1.65	1.36
	210°C	X	0.625r	97.11l	60.94k
		±s	0.011	2.55	1.57
5%	Control	X	0.725b	116.5ef	69.98def
		±s	0.012	1.97	2.68
	150°C	X	0.689e	117.1def	69.17ef
		±s	0.015	1.41	1.94
	170°C	X	0.664ı	111.6h	67.51gh
		±s	0.008	1.37	2.03
	190°C	X	0.649l	101.4k	61.17jk
		±s	0.010	1.60	1.21
	210°C	X	0.631p	85.47n	56.89l
		±s	0.005	3.26	1.06
7%	Control	X	0.729a	115.4fg	68.90fg
		±s	0.013	2.37	2.05
	150°C	X	0.694e	113.6g	66.34hı
		±s	0.012	1.76	1.37
	170°C	X	0.679h	104.7ıj	62.43j
		±s	0.010	2.01	1.20
	190°C	X	0.643o	91.22m	55.84l
		±s	0.010	1.46	1.37
	210°C	X	0.624s	78.14o	50.88m
		±s	0.007	2.78	2.01

X: Average, ±s: Standard deviation.

Homogeneity groups: Same letters in each column indicate that there is no statistical difference between the samples according to the Duncan's multiply range test at $p<0.05$. All data in variance and one-way ANOVA tests were done at a confidence level of $p <0.05$ (95%).

Table 2: Percentage decrease of bending strength in beech wood.

Heat treatment temperature	Concentration level			
	Unimpregnated	3% (%)	5% (%)	7% (%)
150°C	-1.5	-1.6	-0.5	1.6
170°C	3.2	0.6	4.2	9.3
190°C	11.6	12.7	12.9	26.5
210°C	23.4	18.1	26.6	32.3

As seen in Table 1 and Table 2, bending strength values showed a small increase after heat treatment at 150 ºC with an exception of 7%. The bending strength values of wood samples were decreased with increasing treatment temperature. The maximum reduction in bending strengths (23.4%, 18.1%, 26.6%, and 32.3%) were obtained for the treatment at 210°C for unimpregnated samples, 3%, 5%, and 7% concentration, respectively. It can be derived from these results that the bending strength decreased with the increasing concentration level. Many studies have shown decrease in the bending strength of wood treated at high temperature [16-19]. Yasar et al. (2017) studied the effect of acorn tannin and timber care impregnation material on mechanical strength of scotch pine (*Pinus sylvetsris* L.) wood. They reported the bending resistance of acorn samples have been detected to be higher than timber care samples in terms of impregnation materials [20]. In another study, Adanur (2015) studied the boron compound (borax and boric acid), kebrako and tara tannin impregnation on physical and mechanical properties of beech (*Fagus orientalis* L.) wood. He found that all impregnation treatments decreased bending strength of beech wood [21]. The percentage decrease of compossion strength parallel to grain compared to the control samples in beech wood given in Table 3.

Table 3: Percentage decrease of compossion strength in beech wood

Heat treatment temperature	Concentration level			
	Unimpregnated	3% (%)	5% (%)	7% (%)
150°C	-2.3	-2.8	1.2	3.7
170°C	-1.1	1.9	6.1	9.4
190°C	6.8	8.6	12.6	23.4
210°C	14.2	14.9	18.8	26.2

As seen from the Table 1 and Table 3, the compossion strength was increased 2.3% at 150°C and 1.1% at 170°C for unimpregnated samples, and 2.8% at 150°C for impregnated samples with 3% acorn tannin solution. According to the Table 3, the compression strength progressively decreased with increasing heat treatment temperature. This decrease continued to the temperature of 210°C. In the literature, Boonstra et al. (2007) reported the compressive strength parallel to the grain increased (28%) after heat treatment [22]. According to Duncan test results, the highest compressive strength was obtained in impregnated samples with 3% acorn tannin solution and heat treated at 150°C (73.71 N/mm^2), whereas the lowest was in impregnated samples with 7% acorn tannin solution and heat treated at 210°C (50.88 N/mm^2). In another study, Sahin Kol et al. (2015) indicated that due to the increasing of heat treatment temperature, the compression strength parallel to the grain increased [23]. According to the these results compression strength decreased with the increasing concentration level and heat treatment temperature. The concentration level negatively affected the compression strength parallel to the grain. This situation may occur due to weakening cohesion strength between fibres of wood by tannin solution. Tondi et al. (2012) studied tannin-boron preservatives for mechanical properties of wood. They reported the impregnated samples which underwent compression and bending tests showed improvements of on average 20% [24]. In another study, wood particle impregnated with the mimosa bark extracts and as result decreases the bending strength of particleboard material [25].

4. CONCULUSION

The concentration level of acorn tannin and heat treatment temperature negatively affected strength properties and density value. The results of this study indicated that the compressive and bending strength increased at lower temperature, however these strengths decreased with increasing temperature. Impregnation and then heat treatment caused a greater decrease in bending strength than in the compressive strength of Oriental beech wood. The impregnation with acorn tannin before heat treatment is recommended only where a relatively mild heat treatment is involved.

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