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Some physical and mechanical properties of impregnated chestnut wood with natural and chemical agent exposed to outdoor conditions

Açık hava koşullarına bırakılan doğal ve kimyasal maddelerle emprenye edilen kestane odununun bazı fiziksel ve mekanik özellikleri

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Some Physical and Mechanical Properties of Impregnated Chestnut Wood with Natural and Chemical Agent Exposed to Outdoor Conditions

Araştırma Makalesi / Research Article

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ABSTRACT

Wood preservatives have been widely used to extend the service life of wood. The most objectionable environment for wood is outdoor conditions. In this study, test specimens prepared from chestnut wood (Castanea sativa Mill) were impregnated with natural and chemical impregnation agent. It was aimed to determine the effect of outdoor conditions on physical and mechanical properties of wood material by keeping them under these conditions for one year.

As natural impregnation material pine tannin and acorn tannins, as chemical impregnation material imersol aqua and timbercare aqua were used. The retention amount, air-dried density, bending strength, modulus of elasticity, compression strength parallel to fibers, adhesion strength parallel to fibers, screw withdrawal strength were determined.

As a result, it can be said that the physical and mechanical test values can compare wood impregnated with natural impregnation materials to wood impregnated with chemical impregnation materials after one year exposed to outdoor conditions.

Anahtar Kelimeler: Outdoor conditions, chestnut, pine tannin, acorn tannin, mechanical tests.

Açık Koşullarına Bırakılan Doğal ve Kimyasal Maddelerle Emprenye Edilen Kestane Odununun Bazı Fiziksel ve Mekanik Özellikleri

ÖZ

Ahşap koruyucular, ahşabın kullanım ömrünü uzatmak için yaygın şekilde kullanılmaktadır. Ağaç için en sakıncalı ortam açık hava koşullarıdır. Bu çalışmada, kestane (Castanea sativa Mill) ağacından hazırlanan örnekler doğal ve kimyasal emprenye maddesi ile emprenye edilmiştir. Açık hava koşullarının ağaç malzemenin fiziksel ve mekanik özelliklerine etkisini, bir yıl boyunca bu koşullar altında tutarak belirlenmesi amaçlandı.

Doğal emprenye materyali olarak çam taneni ve meşe palamudu taneni, kimyasal emprenye maddesi olarak imersol aqua ve timbercare aqua kullanılmıştır. Retensiyon miktarı, hava kurusu yoğunluk, eğilme direnci, elastikiyet modülü, liflere paralel basınç direnci, liflere paralel yönde yapışma direnci, vida tutma direnci belirlenmiştir.

Sonuç olarak, doğal emprenye maddeleriyle emprenye edilen ahşap malzemelerin kimyasal emprenye maddeleri ile emprenye edilen ahşap malzemeler ile bir yıl süreyle açık hava koşulları altındaki değerlerin mukayese edilebilir düzeyde olduğu söylenebilir.

Keywords: Açık hava koşulları, kestane, çam taneni, meşe palamudu taneni, mekanik testler

1. INTRODUCTION

Wood is a natural, renewable, easily processable, economical and infrastructure is a less demanding material. As human population increases, so does demand for wood.

Wood is composed of cellulose, hemicellulose, lignin, and minor amounts of extraneous materials [1]. When wood used in outdoor conditions occurs chemical changes in the major constituents of wood, cellulose, hemicellulose and lignin, lead to changes of color, loss of luster, increased roughness and formation of cracks on the surface [2,3]. Therefore the wood material impregnated with some chemical substances when it used in outdoor environments [4,5]. Because of degradation in the outdoor exposure is slow and variable, it requires that the changes be examined under the same conditions for a given period [6]. Stamm, (1978) found that lignin was degraded and decayed in wood remaining for 20 years under outdoor conditions without impregnation and over-surface treatment, and that cellulose was little affected except for the nearby parts [7].

The length of the waiting period in the outside environment increases the degree of destruction in the

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materials used and therefore the economic losses are also increasing considerably [8].

The hardwood species such as chestnut, which are successfully used in engineering designs thanks to their natural structure, are a low cost raw material [9].

The service life of wood products exposed to outdoor conditions, can be increased by treating with various preservative materials [10,11]. But these materials must be recyclable and environmentally friendly at the end of used [12].

Tannin is a renewable and economical source widely use to produce heavy duty leather. Tannins sources are very varied. Tannin can be obtained from major are mimosa bark, quebracho wood, oak bark, chestnut wood, sumach, tara and bark of several species of pines. The main usage areas of tannin are leather manufacture, adhesives, wine, beer and fruit juices additives ore flotation agents, cement super plasticizers, medical and pharmaceutical applications [13].

The Oriental beech and scots pine samples impregnated with 10% and 20% w/w mimosa extract showed improvements of on average 20% on compression, bending, hardness and gluing tests [14].

It was investigated durability of the tannin-hexamine-treated wood samples for their resistance against outdoor agents in terms of dimensional stability, resistance to leaching and resistance to biological agents. The artificial and natural weathering provided comparable results in terms of changes in surface colour. Dimensional Stability of the 10% and 20% tannin-treated samples were very similarly [15]

Bending strength results was decreased by impregnated with solution of 5 % natural oak tannin [16]. Heat treatment parts screw withdrawal strength values were highest results in the tangential direction than transverse directions [17]. Density of wood may have a decisive importance for screw withdrawal resistance [18].

2. MATERIAL AND METHOD

2.1 Material

Wood specimens were cut from randomly selected smooth fibrous, knotless chestnut wood (*Castanea sativa* Mill) from Trabzon in Turkey. In selection of impregnation materials determined pine and acorn tannins as natural material, imersol aqua and timbercare aqua as water based chemical material. Imersol aqua and timbercare aqua were supplied by Hemel Timber Products Co. in Turkey.

In preparation of parallel adhesion resistance test specimens used double-component PVAc-D4 glue resistant to outdoor conditions. D4 glue recommended for the manufacture of joinery according to desmodur VTKA glue [19]. During the testing of the test samples; digital caliper, drying oven, desiccator, precision scale and universal tester (Zwick Z050-for mechanical test).

2.2. Method

2.2.1. Preparation of the test samples

Factors such as tree type, chemical materials and cutting direction affect the results of the experiments [20-22]. Therefore, the examples are arranged according to the principles set out in Table 1. Experiments were carried out in Universal Testing Machine (Zwick Z050) with a capacity of 5 tons in the material laboratory of Gumushane University, Gumushane Vocational School Furniture and Decoration Workshop.

2.2.2. Impregnation solution and process

For the impregnation process, pine and acorn tannins were first prepared in solution. Solution; based on weight, 5% mineral tannin was distilled (distilled and dissolved in water at 60 °C).

Solution and treatment temperature were applied at 20 ± 2 °C for all impregnates. After the impregnation, the specimens weighed and dimensioned at full age were conditioned until 60% ± 3% relative humidity and 20% ± 2% humidity at 20 ± 2 °C. Solution prepared with tannins and chemical impregnated materials were placed in a coarse array with dimensions of 20 * 50 * 50 cm, the test specimens were immersed in the solution and the wire mesh weight was placed. Dipping was carried out for 2 hours.

After the impregnation process was completed, samples were brought to equilibrium humidity and subjected to outdoor conditions.

2.2.3. Natural aging of test samples

Control and impregnated samples were hold on outdoor conditions between 01.09.2011 - 01.09.2012 dates for 12 mounts periods in Ankara, Turkey. Conditions was adjusted to according to the principles of ASTM G7-05 standard as to face to the south and 45° from ground in oblique position (Figure 1.) [29].

Table 1. Sample sizes and testing standards for wood properties

Properties	Test	Standard
Physical	Owen dried density	TS 2472 (1976), [23]
Mechanical	Bending strength	TS 2474 (1976), [24]
	Modulus of elasticity	TS 2478 (1976),[25]
	Compression strength parallel to fibers	TS 2595 (1976),[26]
	Adhesion strength parallel to fibers	TS-EN 205 (2004), [27]
	Screw withdrawal strength	TS-EN 13446 (2005), [28]

Figure 1. Inclined platform of test samples stored in the outdoor conditions

The height of the test samples at the lowest level is 50 cm, care has been taken that organic wastes will increase the proportion of water in the soil unnecessarily and that there will be no water-holding residues.

The meteorological data of Ankara province in which the test samples were left for outdoor conditions between 01.09.2011 - 01.09.2012 in Table 2.

Table 3. Retention amounts

Retention Amounts (g/cm^3)			
Impregnation Type	X_{ort}	S_x	V
Pine tannin	13.50	0.52	0.04
Acorn tannin	15.00	0.59	0.04
Imersol aqua	2.50	0.96	0.38
Timbercare aqua	2.33	0.76	0.33

Retention of samples were found to be between 2.33-15

Table 2. The meteorological data of Ankara province 01.09.2011 - 01.09.2012 [30].

Date	Average Temperature (°C)	Average Maximum Temperature (°C)	Average Minimum Temperature (°C)	Monthly Mean Relative Humidity (%)	Monthly Precipitation (mm)
September- 2011	20.1	30.8	7.6	42.4	0.6
October- 2011	10.9	25.8	0.2	65.1	62.4
November- 2011	3.3	15.2	-7.1	70.3	10.9
December- 2011	3.8	16.0	-6.8	74.9	39.3
January-2012	-0.9	12.2	-11.3	87.1	93.3
February-2012	-1.9	10.1	-15.9	83.7	47.7
March-2012	3.7	18.6	-5.4	67.2	43.0
April-2012	14.9	28.1	0.1	50.5	24.8
May-2012	17.5	28.2	9.0	56.8	65.1
June-2012	24.2	36.6	10.1	38.7	1.2
July-2012	27.0	41.0	13.5	35.8	4.6
August-2012	24.0	36.0	12.0	38.2	7.4

2.2.3. Analysis of The Data

Statistical evaluation of the results was analyzed with SPSS 22.0 (2013) statistical package software. In case of mutual interactions of sources of variance being significant according to ($P< 0.05$) for which factors are the differences important was identified by Duncan test.

3. RESULTS AND DISCUSSION

Retention amounts of impregnation materials is given in Table 3.

g/cm^3. Tannins showed upper retention value. In other study observed similar results in other studies [31]. Microscopic views of the specimens taken from the parts exposed to outdoor conditions for one year (impregnated material) are given in Figure 2.

The effects of the impregnation material used in the samples prepared with natural and chemical impregnation materials prepared from chestnut wood, variance analysis and Duncan tests were applied to determine whether the bending resistance, modulus of elasticity, compression strength parallel to fibers, adhesion strength parallel to fibers, screw withdrawal strength were statistically significant (Table 4. and Table 5.

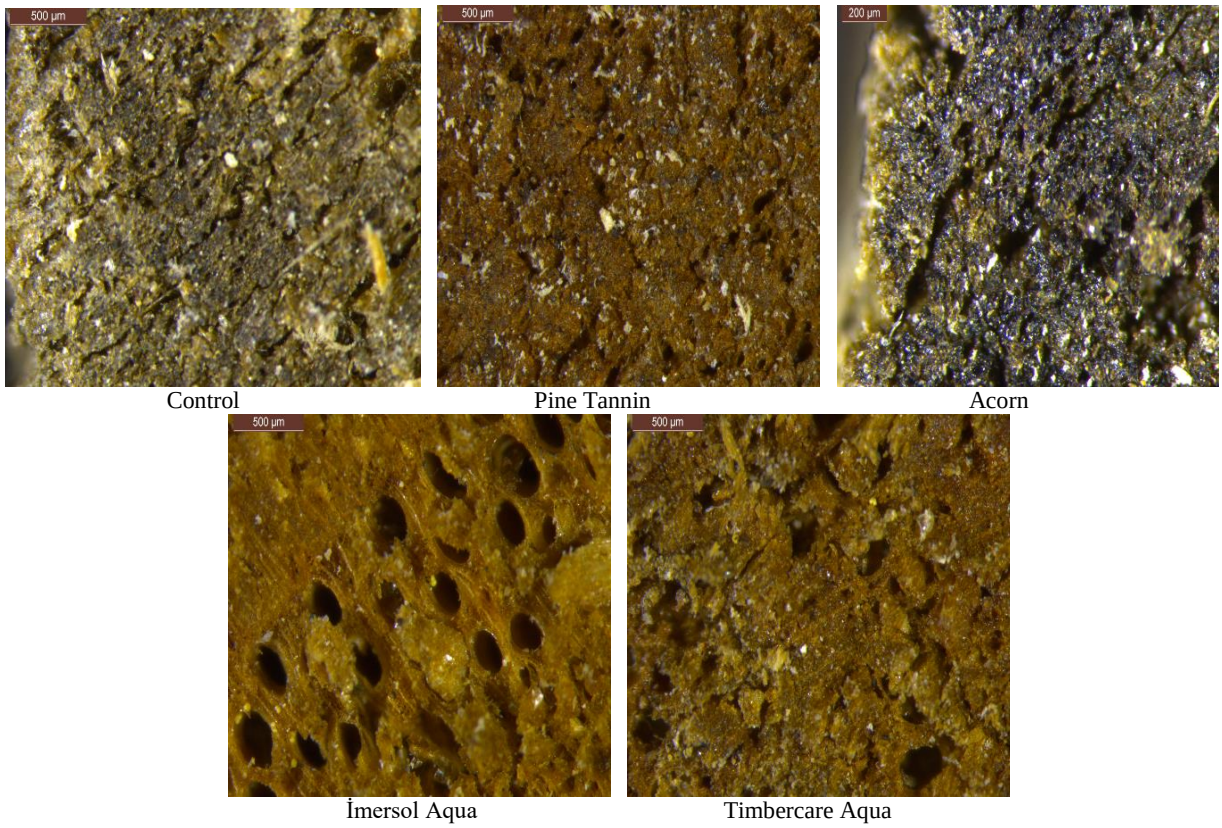

Figure 2. Microscopic views of the specimens after a year exposure outdoor conditions (control, pine tannin, acorn, imersol aqua, timbercare aqua)

Table 4. Variance analysis for physical and mechanical properties

Analysis of Variance						
Process	Variation Source	F.D.	S.S	S.M.	F value	Pr>F
Air-dried density	Between groups	2	0.001	0.001	0.352	0.705
	Within groups	46	0.068	0.001		
	Total	48	0.069			
Bending strength	Between groups	2	0.017	0.009	12.184	0.000*
	Within groups	46	0.032	0.001		
	Total	48	0.050			
Modulus of elasticity	Between groups	2	50.082	25.041	4.856	0.012*
	Within groups	46	237.186	5.156		
	Total	48	287.268			
Compression strength parallel to fibers	Between groups	2	49.842	24.921	1.909	0.160
	Within groups	46	600.580	13.056		
	Total	48	650.422			
Adhesion strength parallel to fibers	Between groups	2	49.842	24.921	1.909	0.160
	Within groups	46	600.580	13.056		
	Total	48	650.422			
Screw withdrawal strength	Between groups	2	11752.671	5876.335	3.218	0.049*
	Within groups	46	84010.230	1826.309		
	Total	48	95762.900			

Table 5. Duncan test results

Duncan Test					
Process	Impregnation Type	Mean Square	No	Subset for alpha=0.05	
				1	2
Air-dried density	Control	0.648	10	0.6367	
	Natural imp.	0.637	20	0.6400	
	Chemical imp.	0.641	20	0.6480	
	Sig.			0.464	
Bending strength	Control	78.730	10	0.4467	
	Natural imp.	80.616	20		0.4950
	Chemical imp.	82.020	20		0.4950
	Sig.			1	1
Modulus of elasticity	Control	7393.330	10	13.4590	
	Natural imp.	7723.160	20		15.2695
	Chemical imp.	7642.500	20		15.8989
	Sig.			1	0.464
Compression strength parallel to fibers	Control	25.66	10	6.7265	
	Natural imp.	27.395	20	8.7570	
	Chemical imp.	27.140	20	8.8244	
	Sig.			0.151	
Adhesion strength parallel to fibers	Control	4.881	10	25.6556	
	Natural imp.	4.77	20		27.1400
	Chemical imp.	5.779	20		27.5900
	Sig.			1	0.488
Screw withdrawal strength	Control	269.494	10	78.7333	
	Natural imp.	309.960	20	80.3800	
	Chemical imp.	305.314	20	82.0200	
	Sig.			0.516	

As a result of the analysis of variance made; it has been determined that there are significant differences between bending resistance, modulus of elasticity and screw withdrawal strength in the samples prepared from chestnut wood (natural impregnation - imersol aqua - timber care aqua - control) air-dry density, compression strength parallel to fibers and adhesion value perpendicular to the fibers were found to be negligible.

It has been determined that there is no significant difference in air-dried density, vertical pressure resistance and screw withdrawal strength in the samples treated with natural impregnation (pine tannin - acorn) - chemical impregnation (imersol aqua - timbercare aqua) prepared from chestnut wood according to Duncan test ($P \leq 0.05$).

Bending strength, modulus of elasticity, compression strength parallel to fibers, adhesion strength parallel to fibers, screw withdrawal strength tests results in Table 6. and are shown Figure 1.

Table 6. Physical and mechanical properties of chestnut wood

Process	Impregnation	X_{ort}	S_x	V
Air-dried density	Control	0.63	0.03	0.05
	Pine tannin	0.63	0.03	0.05
	Acorn tannin	0.66	0.04	0.06
	Imersol aqua	0.66	0.04	0.06
	Timbercare aqua	0.65	0.04	0.06
Bending strength	Control	78.66	10.53	0.13
	Pine tannin	79.44	9.30	0.18
	Acorn tannin	81.32	16.73	0.21
	Imersol aqua	81.91	14.19	0.17
	Timbercare aqua	82.13	11.17	0.14
Modulus of elasticity	Control	7413	707.75	0.10
	Pine tannin	7710	850.39	0.11
	Acorn tannin	7689	1358.02	0.18
	Imersol aqua	7537	1180.51	0.16
	Timbercare aqua	7748	996.97	0.13
Compression strength parallel to fibers	Control	25.86	1.39	0.05
	Pine tannin	26.99	1.39	0.05
	Acorn tannin	28.19	1.94	0.07
	Imersol aqua	27.62	1.94	0.07
	Timbercare aqua	26.66	1.66	0.06
Adhesion strength parallel to fibers	Control	4.90	1.62	0.33
	Pine tannin	5.87	1.32	0.23
	Acorn tannin	3.68	1.31	0.36
	Imersol aqua	5.49	1.30	0.24
	Timbercare aqua	6.11	1.87	0.31
Screw withdrawal strength	Control	268.79	13.53	0.05
	Pine tannin	291.52	36.38	0.12
	Acorn tannin	332.66	31.29	0.09
	Imersol aqua	310.14	53.06	0.17
	Timbercare aqua	300.49	55.20	0.18

The highest air-dried mean density was 0.66 g/cm^3 in the samples with acorn tannin and imersol aqua and lowest was 0.63 g/cm^3 in the samples impregnated with the control and pine tannin. Results is similar with another study [31].

The highest bending strength was 82.13 N/mm^2 in the samples with impregnated with timbercare aqua and lowest was 78.66 N/mm^2 in control samples.

The highest modulus of elasticity was 7748 N/mm^2 in the samples impregnated with timbercare aqua and lowest was 7413 N/mm^2 in the control samples.

The highest compression strength parallel to fibers was 28.19 N/mm^2 in the samples with acorn and lowest was 25.86 N/mm^2 in the control samples. These findings are consistent with earlier reports [32].

The highest adhesion strength parallel to fibers was 6.11 N/mm^2 in the samples impregnated with timbercare aqua and lowest was 3.68 N/mm^2 in the samples with acorn.

The highest screw withdrawal strength was 332.66 N/mm^2 in the samples with acorn and lowest was 268.79 N/mm^2 in the control samples.

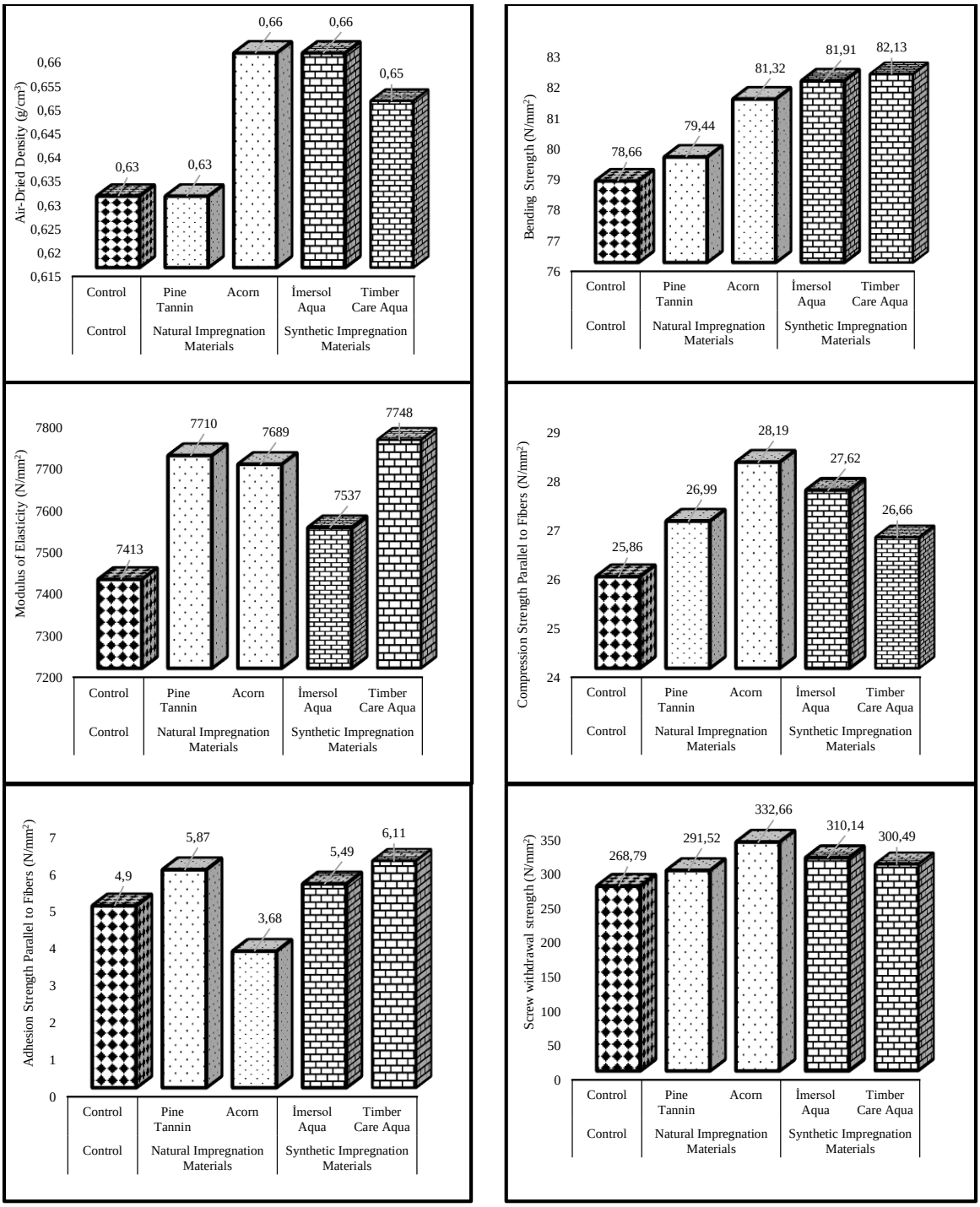

Figure 1. Graphical representation of physical and mechanical properties of chestnut wood

4. CONCLUSION

According to the experimental results, retention amount values of the samples impregnated with natural materials are higher than impregnated with chemical impregnation materials.

In air-dried density values obtained close results. Oak acorn gave similar results with chemical impregnation materials. Control samples and pine tannin samples showed lower results than the other samples.

Control samples was showed the lowest results in bending strength, modulus of elastic, compression strength parallel to fibers and screw withdrawal strength tests. Natural and chemical impregnation materials increased the values in these experiments.

The bending strength values were close to each other. The bending strength of the samples impregnated with chemical wood preservatives values were higher then tannins. The highest values were determined in samples impregnated with timber care aqua in bending strength,

modulus of elastic and adhesion strength parallel to fibers tests.

According to the control samples, chemical and natural impregnation materials increased the elasticity modulus values. The samples impregnated with acorn tannin showed the lowest values in adhesion strength parallel to fibers. The highest values in compression strength parallel to fibers and screw withdrawal strength were determined in samples impregnated with acorn tannin.

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