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Determination of The Physical And Mechanical Properties of Scotch Pine By Impregnating With OAK Tannin And Timber Care Impregnation Materials

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ABSTRACT

In this study, it is aimed to test the preservative impregnation characteristics of the scotch pine wood type as a consequence of impregnation with natural and chemical impregnation materials. The impregnated materials have been kept in outdoor conditions for one year and it is aimed to reveal which one of the impregnated materials is more advantageous by analysing the physical and mechanical properties of materials impregnated under these circumstances. The scotch pine (*Pinus sylvetsris* L.) is used as the wood material. The acorn has been used as the natural impregnation substance and timber care aqua as the chemical impregnation material. Physical and mechanical tests regarding air-dried density, full dried density, moisture content, retention amount, bending strength, elastic modulus, bonding strength parallel to the fibers, compressive strength parallel to the fibers, and the screw holding strength have been carried out. According to the results regarding the physical properties; full dried density and retention amount of the scotch pines have been confirmed to be higher than control samples in terms of the material, and the air-dried density, moisture content and retention amount of acorn specimens have been found to be higher than the timber care aqua samples in terms of impregnation materials. As for mechanical properties, the scotch pine's elastic modulus and compressive strength parallel to the fibers have been stated to be higher than the control samples in terms of material and bending strength and bonding strength parallel to fibers of acorn samples have been detected to be higher than timber care samples in terms of impregnation materials. As a result, it is determined that the wood materials impregnated with natural impregnation materials are in a state in which they can be compared with the wood material impregnated with a chemical substances.

Keywords: Scotch pine, Impregnation, Wood, Oak Tannin, Timber Care Aqua.

1. Introduction

The wood material which is used in a great variety of areas is the only natural raw material that is harmless to the environment and renewable. The chemical structure of wood material with its anatomic structure, physical and mechanical properties enables it to be used in the form of many different products (Bozkurt & Göker, 1987). As a result of being a decreasing forest entity in our day, the productive usage and the utilisation for a longer period of the wooden material, which has been an essential raw material source in human life throughout the history, has become compulsory.

Nowadays, there are about 10,000 usage areas of the wood material. For instance, it is used in building construction, furniture and decoration works, parquetry, musical instrument, wire pole, railway sleepers, coated sheet, plywood, flakeboard, fibreboard, paper and cardboard. The reason for so many usage areas of the wood material originates from its anatomical structure, its physical and mechanical properties and its chemical components (Bozkurt & Erdin, 2000).

When compared with building materials like iron and steel, the wood material has emerged as a preferred material in furniture and decoration, particularly in joinery industry due to reasons such as its easy portability, its high strength against various loadings in despite of being a light material, its easy processing, its low energy consumption during processing, having different colours and designs, its low transmission of sound, electric and heat, being less affected from chemical substances, getting appealing by applying surface treatments like colouring and varnishing, and getting an intense colour and a nice appearance as it wears off. In addition to the favourable features of wood material, which are mentioned above, its combustion property stemming from being an organic material, its possibility to be destroyed by insects, its tendency to be decayed by fungi, formation of changes in its dimensions based on equilibrium humidity which changes depending temperature and relative humidity of weather, fading of its colour with the effects of sun rays are accepted as its unfavourable characteristics (Kurtoğlu, 2000).

Even though the wood material possesses the natural endurance to show the strength and the adequate durability against some external effects because of its anatomic and chemical structure, it won't endure outdoor air effects for a long time. Therefore, the wood material is impregnated with a variety of chemical substances, upper surface treatments with various protective and layering materials, which are suitable for use of place, are done or wood is preserved with constructive precautions which are not chemical (natural, biological and alternative wood protection) (Kurtoğlu, 1984).
It is usually achieved by impregnating or coating with the preservatives when the wood material is desired to be long lasting (Uysal, 2005).

In this study, it is aimed to increase the use of natural preservatives which do not harm the environment and human health instead of chemical impregnation materials by applying natural impregnation materials, which holds a great potential in our country, to wooden materials.

2. Material and Methods

2.1.Materials

The scotch pine (*Pinus sylvetsris* L.) wood which is one of coniferous tree commonly preferred in woodworking industry is used in this study. The oak tannin is used as natural impregnation material, timber care aqua is used as chemical impregatnion material. PVA-D4 glue resistant to outdoor conditions is used in the preparation of bonding strength parallel to the fibers test samples.

2.2.Methods

The scotch pine wood types were converted into dimensions appropriate to standards of TS (Turkish Standards) in Gümüşhane University Gümüşhane Vocational School Furniture and Decoration Workshop (TS 53, 1981; TS 2470, 1976). For each test 10 test samples so as to be kept under open air conditions for one year were prepared from Scotch pine types to be used in the study. While preparing the test samples, test specimens were prepared from the sections without wood defects by paying attention to the fiber directions, and drying of samples till the proper moisture gradient were ensured. First of all, the solution has been prepared by using oak tannins for the impregnation process. The solution has been prepared by dissolving %5 mineral tannin in distillate (distilled and at a temperature of 60 ° C) water based on the amount of weight. The solution and processing temperature have been implemented as 20 ± 2 ˚C for all impregnates. Samples, whose full dried weight and dimensions has been identified after the impregnation, has been conditioned until it reaches equilibrium humidity of %12 in the conditioning chamber at relative humidity of 60% ± 3% and at 20 ± 2 ° C. The solution and chemical impregnation materials prepared with acorn tannins have been placed with a rough alignment of 20 * 50 * 50 cm dimensions, the test samples have been immersed in the solution and the wire cage weight has been positioned. Immersion process has been executed for 2 hours. After the impregnation process has been completed, the samples which will be brought to equilibrium humidity has been exposed to open air conditions (Yaşar, 2014).

Control and impregnated samples have been kept in open air conditions within the Gazi University Technical Education Facility area in Ankara for 1 year according to the principles stated in ASTM G7 (ASTM G7-05, 2005). The test specimens have been stated at an angle of 45° to the ground floor in a way that their surfaces facing south. The height of the test samples at the lowest level is 50 cm and non-existence of residues, which will unnecessarily increase water ratio in the soil and retain water, and organic wastes, like grass, around the stand has been taken care (Yaşar, 2014).

The test samples which will be used in the determination of physical properties, tests which will be conducted on natural and chemical impregnated wood materials, the dimensions and standards of test samples are given in Table 1. 10 test samples for each test have been prepared and test specimens have been tested.

Table 1. The dimensions and standards of test samples used in the determination of physical properties

No	Test	Dimensions (mm)	Standards
1	Air-Dried Density	20 X 20 X 30	TS 2472 (TS 2472, 1976)
2	Full-Dried Density	20 X 20 X 30	TS 2472 (TS 2472, 1976)
3	Moisture Content	20 X 20 X 30	TS 2471 (TS 2471, 1976)
4	Retention Amount	20 X 20 X 30	ASTM D 1413–07 (ASTM-D 1413-07, 2007)

The test samples used in the determination of mechanical properties, tests which will be performed on natural and chemical impregnated wood materials, the dimensions and standards of test samples are indicated in Table 2. For each test, 10 test samples have been prepared by paying attention to tree species, impregnation materials and control samples and test specimens are examined.

Table 2. The dimensions and standards of test samples used in the determination of mechanic properties

No	Test	Dimensions (mm)	Standards
1	Bending Strength	20 X 20 X 300	TS 2474 (TS 2474, 1976)
2	Elastic Modulus	20 X 20 X 300	TS 2478 (TS 2478, 1976)
3	Bonding Strength Parallel to the Fibers	20 X 20 X 60	TS 2595 (TS 2595, 1976)
4	Compressive Strength Parallel to the Fibers	20 X 15 X 150	TS EN 205 (TS EN 205, 2004)
5	Screw Holding Strength	50 X 50 X 20	TS EN 13444 (TS EN 13446, 2005)

3.Results and Discussion

As a result of the research conducted, the variance analysis results regarding the physical and mechanical strength values of the impregnated scotch pine wood are shown in Table 3; mean values and results of the Duncan test are given in Table 4.
At the end of the variance analysis; the effect of scotch pine and control materials, and acorn and timber care impregnation materials on the moisture content, retention amount, and bonding strength parallel to fibers is found statistically as different at %1 significance level (Table 3).

Table 3. The variance analysis results regarding the physical and mechanical strength values

				Properties of Physical				
Source of Variance	Air-Dried Density				Full-Dried Density			
	F.D.	S.S.	S.M.	F.V.	F.D.	S.S.	S.M.	F.V.
Material	1	0.0001	0.0001	0.01	1	0.0003	0.0003	0.13
Material of Impregnite	1	0.0002	0.0002	0.05	1	0.0002	0.0002	0.07
Error	27	0.0982	0.0036		27	0.1110	0.0041	
Total	29	0.0984			29	0.1794		
	Moisture Content				Retention Amount			
	F.D.	S.S.	S.M.	F.V.	F.D.	S.S.	S.M.	F.V.
Material	1	12.1410	12.1410	8.96*	1	391.48	391.48	21.25*
Material of Impregnite	1	17.6367	17.6367	13.01*	1	137.41	137.41	7.46**
Error	27	36.5982	1.3555		27	497.32	18.42	
Total	29	37.3759			29	1026.21		
				Properties of Mechanic				
Source of Variance	Bending Strength				Elastic Modulus			
	F.D.	S.S.	S.M.	F.V.	F.D.	S.S.	S.M.	F.V.
Material	1	6.2727	6.2727	0.02	1	1922460	1922460	0.59
Material of Impregnite	1	36.6602	36.6602	0.13	1	100860	100860	0.03
Error	27	7799.9418	288.8867		27	87771310	3250789	
Total	29	7842.8747			29	89794630		
	Bonding Strength Parallel to the Fibers				Compressive Strength Parallel to the Fibers			
	F.D.	S.S.	S.M.	F.V.	F.D.	S.S.	S.M.	F.V.
Material	1	27.8665	27.8665	21.13*	1	0.3527	0.3527	0.04
Material of Impregnite	1	49.3045	49.3045	37.39*	1	35.4202	35.4202	3.60
Error	27	35.5996	1.3585		27	265.6168	9.8376	
Total	29	112.7706			29	301.3897		
	The Screw Holding Strength							
	F.D.	S.S.	S.M.	F.V.				
Material	1	508.9011	508.9011	0.96				
Material of Impregnite	1	174.8992	174.8992	0.33				
Error	27	14344.5989	531.2814					
Total	29	15028.3993						

F.D: Degrees of Freedom, S.S: Sum of Squares, S.M: Mean of Squares, F.V: F-Value, *, **:1% and 5% significance level, respectively.

According to the findings belonging to physical properties in Table 4; air dried density has been determined in terms of the material as 0.707 g/cm^3 in the scotch pine and as 0.709 g/cm^3 in the control sample, and it has been stated as 0.709 g/cm^3 in acorn and as 0.704 g/cm^3 in the timber care aqua in respect to impregnation materials. The full dry density has been identified as 0.619 g/cm^3 in the scotch pine and as 0.612 g/cm^3 in the control sample with regard to the material, and it has been found as 0.615 g/cm^3 in the acorn and as d 0.620 g/cm^3 in the timber care aqua in terms of impregnation material. The moisture content has been obtained as %14.15 in the Scotch pine and as %15.50 in the control sample with respect to the material, and it is found as %15.15 in the acorn and as %13.52 in the timber care aqua in terms of impregnation materials. The retention amount has been determined as 12.58 kg/m^3 in the scotch pine, and as 6.62 kg/m^3 in the acorn and 2.08 kg/m^3 in the timber care aqua in terms of impregnation materials.

In the literature, the full dry densities of the said solid wood materials is stated to be obtained as 0.49 g/cm^3 in the scotch pine (Bozkurt & Kurtoğlu, 1982). The air-dried density findings we have obtained are close to the results of the study conducted by Bozkurt. In addition, it has been confirmed that the full dry density values of the control sample get higher results at a certain level. It can be said that variation in the full dry density values of the impregnated wood materials may be originated from the air gap ratio depending on the anatomical structure of the wood materials, the annual ring width and the impregnation material type.

In a study made in reference (Özçiftçi & Batan, 2009), they have determined that the retention amount is highest in Scotch pine (19.39 kg/m³-%21.81). It has been stated that the obtainment of the highest values in the scotch pine samples may have stemmed from gate pairs, which enable the fluid flow in the longitudinal direction of the coniferous trees, being open and thus storing the excess impregnation material. The statistical values we have obtained share similarities with values in the literature. The retention amount of timber care aqua impregnation material has been identified to be higher than that of acorn impregnation material. This situation may have resulted from reasons like solution property, wood type, anatomical structure, etc.

According to the findings regarding mechanical properties; the bending strength has been found as 117.43 N/mm^2 in scotch pine and as 118.40 N/mm^2 in the control sample in terms of the material, and it has been determined as 118.54 N/mm^2 in the acorn and as 116.19 N/mm^2 in the timber care aqua with regard to impregnation materials. The elastic modulus is identified as 10866 MPa in scotch pine and as 10149 MPa in control sample in terms of the material and it is found as 10466 MPa in acorn and as 10589 MPa in timber care aqua in respect to impregnation materials. The bonding strength parallel to fibers is identified as 4.19 N/mm^2 in the scotch pine and as 6.24 N/mm^2 in the control sample in regard to material, and it is detected as 5.78 N/mm^2 in the acorn and as 3.06 N/mm^2 in the timber care aqua with respect to impregnation material. The compressive strength parallel to fibers is determined as 32.98 N/mm^2 in the scotch pine and as 32.75 N/mm^2 in the control sample in terms of material, and it is stated as 32.13 N/mm^2 in the acorn and as 34.44 N/mm^2 in the timber care aqua with regard to impregnation materials. The screw holding strength value is found as 373 N/mm^2 in the scotch pine and as 382 N/mm^2 in the control sample n respect to the material, and it is confirmed as 374 N/mm^2 in the acorn and as 379 N/mm^2 in timber care aqua in regard to impregnation material (Table 4).

Table 4. The test results mean value and Duncan regarding the physical and mechanical strength values

Properties of Physical				
Factor	Air-Dried Density (g/cm^3)	Full-Dried Density (g/cm^3)	Moisture Content (%)	Retention Amount (kg/m^3)
Material				
Scotch pine wood	0.707 a	0.619 a	14.15 b	7.66 a
Control	0.709 a	0.612 a	15.50 a	0.00 b
Materials of Impregnation				
Acorn	0.709 a	0.615 a	15.15 a	6.62 b
Timber Care Aqua	0.704 a	0.620 a	13.52 b	2.08 a

Properties of Mechanic					
Factor	Bending Strength (N/mm^2)	Elastic Modulus (MPa)	Bonding Strength Parallel to the Fibers (N/mm^2)	Compressive Strength Parallel to the Fibers (N/mm^2)	The Screw Holding Strength (N/mm^2)
Material					
Scotch pine wood	117.43 a	10686 a	4.19 b	32.98 a	373 a
Control	118.40 a	10149 a	6.24 a	32.75 a	382 a
Materials of Impregnation					
Acorn	118.54 a	10466 a	5.78 a	32.13 a	374 a
Timber Care Aqua	116.19 a	10589 a	3.06 b	34.44 a	379 a

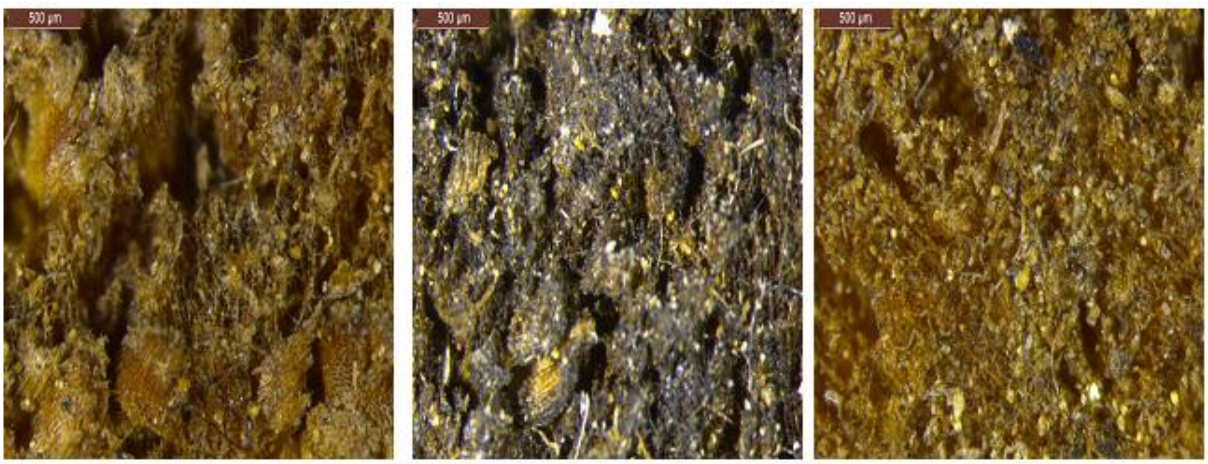
In the literature, the bending strength of scotch pine is determined as highest of 104 N/mm² and the lowest of 75 N/mm² in the study conducted by Efe and Çağatay on the determination of bending strength of said solid wood materials (Efe & Çağatay, 2011). It is identified that the findings concerning the determination of the bending strength to fibers we obtained come out close to values of the study done by Efe and Çağatay in 2011.

In the study done in the reference (Peker *et al.* 1999), the elastic modulus values of the control samples are obtained within values of 864 - 1847 MPa and the average is calculated as 1141 MPa. There has been no significant change in the elastic modulus values in the implementation after WR materials (apart from ISO). The borax and boric acid approached to neutrality with boric acid + borax at a pH value of 7:3 (weight: weight) – hasn't affected the bending strength of the scotch pine wood, but has led to a little reduction in the individual use. WR materials have a significant strength increase when they are applied after boric acid + borax impregnation. The findings we obtained on the determination of the elastic modulus obtained have been identified to be close to those of the previous study findings. The differentiation of non-impregnated scotch pine specimens from others may have originated from the impregnation type used.

The specimens prepared from oak, beech and scotch pine trees are impregnated with different impregnation materials and their screw holding strengths is measured by

Açıkel. If the screw holding strength of the screw is sorted from large to small according to the impregnation material type, it is determined that especially boric acid, borax, acid + borax mixtures have more effect on the screw holding strength than other impregnating agents. With regard to the test results, the impregnation process has increased the screw threading strength (Açıkel, 2007). In this study, it is observed that the screw holding strength of the impregnated scotch pine samples is lower than non-impregnated control samples.

In the literature, the compressive strength parallel to fibers of scotch pine is determined as highest of 50.82 N/mm² and the lowest of 39.20 N/mm² in the study conducted by Efe and Çağatay on the determination of the compressive strength parallel to fibers of said solid wood materials (Efe & Çağatay, 2011). It is identified that the findings concerning the determination of the compressive strength parallel to fibers we obtained come out close to values of the study done by Efe and Çağatay in 2011.



Control Oak Tannin Timber Care Aqua

Picture 1. Microscopic views of the specimens after a year exposure outdoor conditions (control, oak tannin, timber care aqua).

4.Conclusions

In the samples impregnated with impregnation materials, the density value of control sample in air-dried state (%12) is determined to be higher than the scotch pine and the density value of acorn impregnation material in air-dried state is higher than timber care aqua impregnation material. It is understood that the density value of scotch pine in the full dry state is higher than the control sample and that the density value of timber care aqua impregnation material in the full dry state is higher than acorn impregnation material. It has been identified the moisture content value of the control sample is higher than scotch pine and the moisture content value of acorn impregnation material is higher than the timber care aqua impregnation material. The retention amount of the acorn impregnation material has been confirmed to be higher than that of timber care aqua impregnation material.

From the mechanical properties of the impregnated test samples, the bending strength value of control specimens has been determined to have higher values than scotch pine and the bending strength value of the acorn impregnation material is higher than the timber care aqua impregnation material. The elastic modulus value of scotch pine has been found to have higher than the control sample and of the elastic modulus value of timber care aqua impregnated material is higher than the acorn impregnation material. The bonding strength parallel to fibers value of control samples is higher than scotch pine and the bonding strength parallel to fibers value of acorn impregnation material is higher than timber care aqua impregnation material. The comprehensive strength parallel to fibers value of scotch pine is higher than control sample and the comprehensive strength parallel to fibers value of the timber care aqua impregnation material is higher than the acorn impregnation material. The screw holding strength value of control sample is higher than in the scotch pine and the screw holding strength value of the timber care aqua impregnation material is higher than the acorn impregnation material.

As a conclusion, a comprehensive inventory analysis should be executed to utilise the potential of tanning substances and forest asset in our country, and the possibilities of sufficient utilisation at domestic and foreign markets should be explored. In this subject, it is inevitable for concerned firms to cooperate with public institutions and universities.

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