WOOD RESEARCH
63 (6): 2018
1033-1044

DETERMINATION OF SOME PROPERTIES OF SCOTCH PINE (*PINUS SYLVESTRIS* L.) WOOD WHICH IS IMPREGNATED WITH BORON COMPOUNDS AND QUECHUA

Selim Sen
Gumushane University, Gumushane Vocational High School
Department of Forestry and Forest Products
Gumushane, Turkey

M. Said Fidan
Bursa Technical University, Faculty of Forestry, Department of Forest Industry Engineering
Bursa, Turkey

Elif Alkan
Gumushane University, Institute of Natural Applied Science
Department of Forestry and Environment Sciences
Gumushane, Turkey

S. Sadiye Yasar
Gumushane University, Gumushane Vocational High School
Department of Design
Gumushane
Turkey

(Received September 2017)

ABSTRACT

As the industrialisation and technological developments increase; the search for functional material which is environment-friendly, non-toxic, flame resistant, with a broad applicability and with high-temperature endurance also increases. Even though the wood material corresponds most of these features, its possession of an organic structure causes it to be affected negatively by damages occurring under proper conditions in the outdoor environment.

Due to this reason, this study is conducted to prevent damages (biotic, abiotic pests, fire, etc.) caused by the environment to the wooden material, and to determine some physical and mechanical properties of wooden material impregnated with quechua, borax and boric acid, which are used to extend the usage life. Those features are needed in an outdoor environment. The Scotch pine (*Pinus sylvestris* L.) test specimens are prepared with borax, boric acid, borax+boric acid, from borax compounds, which have a great potential in Turkey, and with quechua, one of the natural impregnation substances. Then these samples are impregnated with three different (1%, 3%, 5%) solution concentrations according to ASTM 1413-76 standards and some physical-mechanical property changes are investigated. After impregnation, samples are tested and compared with control samples.

According to the test results; the lowest oven dried density change is obtained in borax as 0.46 $g \cdot cm^{-3}$ in terms of boron compounds and the retention amount is determined to be highest with 3.83 $kg \cdot m^{-3}$ in the samples impregnated with boric acid. The bending strength and elastic modulus are found to be highest with 83.53 MPa and 10281 MPa in the samples impregnated with boric acid. When examined at the concentration level, it is determined to be highest with 81.89 MPa in samples with 3% concentration. There are statistical discrepancies with 55.77 MPa in the comprehensive strength parallel to grain in boric acid in terms of boron compounds.

KEYWORDS: Borax, boric acid, impregnation, quechua, Scotch pine.

INTRODUCTION

The wooden material has been an important construction material since ancient times. The most significant characteristics of wood can be listed as following; its light weight and its resistance to mechanical and physical impacts. In addition to these, its low heat and sound transmission, its easy processability, its aesthetic appearance, obtainment of the colour and design unity in terms of environment and health, its feasibility in interior and exterior building construction works make wooden material more appealing than other construction elements (Esen 2009, Qu et al 2011, Temiz et al. 2008).

The wooden material has some negative characteristics regarding other construction materials. The wooden material is combustive as it is an organic-based material containing carbon and hydrogen (Kolman and Cote 1968). On the one hand, cracks occur in the wooden material because of continuous soakage and colour drying fungi, and fungus grows in these areas. On the other hand, the sun rays demolish the wood layer, and the materials which can go away with the effect of rain and wind are formed (Bozkurt et al. 1993).

The impregnation of wood with preservative chemical substances is required to prevent damages and extend the usage time. Boron compounds have gained currency due to their high performance against biological pests, their wood diffusion ability, their easy applicability by dissolving in water, their low cost and easy supply, their low toxicity effects against mammals that can be ignored and the fact that they increase the wood resistance significantly against the combustion (Baysal 2003). Borax and boric acid, which have many usage areas, are also used as fire retardants in the wood preservation industry (Le Van and Tran 1990, Baysal 2002).

The structural changes are connected with various mechanical and physical features of damaged wood. They will be mentioned briefly now. The improvement of impregnability and permeability of wooden products from refractory species, which are poorly impregnable, can be achieved through their biological, chemical, physical or mechanical pre-treatment. The mechanical features of chemically degraded wood get worse in the prevailing majority of cases. Its physical features are shifted individually; for instance, alkali causes cell to collapse and to an increase in wood density. For instance, cell walls with a greater ratio of the S2 layer, therefore with cellulose, provide wood with a greater tensile strength along the fibres. The mechanical features of wood damaged by acids are not decreased only in its wet state, but also partly in its dry state (Reinprecht 2016).

The Scotch pine wood has a wide distribution in our country, and quechua is known to be harmless to the environment and to have preservative features against fungi and bugs. It is investigated whether they make any positive contribution to the utility in outdoor air conditions by identifying the relation of quechua with boron and by determining impregnation property of quechua in the wood type by means of using dual process both with boron derivatives and separately in this study.

MATERIALS AND METHODS

Materials

The test samples used in the study are prepared from the Scotch pine (*Pinus sylvestris* L.) wood. The Scotch pine logs, from which the experiment samples are prepared, have grown at altitude of 1400 meters in Alacadağ of Kürtün district in Gümüşhane province. The chosen logs are kept at a temperature of 20±2°C and a relative humidity of 65±3% until they reach an average moisture of 12% and a constant weight, and later rough cutting from the wooden material is performed according to the experiments.

For the impregnation process, the solution was first prepared by using quechua tannins. Solution was prepared through dissolving in water using 5% mineral quechua materials based on the weight amount. Aqueous solutions in concentrations with 1%, 3% and 5% of boron compounds: Borax (B) and Boric acid (BA) are used as impregnation material. The quechua which contains plenty of tannins is used as the natural impregnation material.

Methods

Preparation of the test samples

Test samples are prepared from sapwood parts which are knotless, crack-free, not affected by the damages of fungus and bugs. Those sapwood parts have smooth fibre, don't have tulle formation and growth defects, don't have colour and density difference, without reaction wood. Test samples are prepared according to TS 2470 standards at Gümüşhane University Gümüşhane Vocational School Furniture and Decoration Workshop. Mainly 15 samples for each test was prepared to utilise in this study.

Before applying the impregnation process, the test specimens are dried until they reach the constant weight at 20±2°C and relative humidity of 65±5%, then these samples are weighed on a scale measuring with a precision of 0.01 g.

Impregnation

The impregnation process is executed under the conditions stated in ASTM-D 1413-76. In each impregnation process, the prepared samples are subjected to impregnation under a pressure of 10 bars for 30 minutes after samples are implemented with a pre-vacuum in the impregnation apparatus equivalent to a pressure of 70 cm Hg for 30 minutes (ASTM-D 1413 76, 2007). The impregnated samples are conditioned at a temperature of 20±2 °C and relative humidity of 65±3% for one week and then are left to dry until 12% equilibrium humidity is reached (Atar et al. 2003).

Determination of the extent of retention

The retentions amount of impregnation material in the test samples are calculated as pre-impregnation and post-impregnation with the help of following Eq. 1 (TS 5724, 1988).

$$R = \left[\frac{G.C}{V}\right] \times 10^3 \qquad (kg \cdot m^{-3}) \qquad (1)$$

where: G - T2 -T1,
T1 - pre-impregnation weight (g),
T2 - post-impregnation weight (g),
V - sample size (cm3),
C - solution concentration.

Determination of physical and mechanical properties

The applied test methods and dimensions of wooden materials used in the determination of physical and mechanic features are given in Tab. 1.

Tab. 1: Dimensions and standards of test specimens used to the determine mechanical and physical properties.

Number	Name of test	Sample size (mm)	Standard
1	Oven dried density	20 x 20 x 30	TS 2472
2	Bending strength	20 x 20 x 360	TS 2474
3	Elastic modulus	20 x20 x 360	TS 2478
4	Compression strength parallel to grain	20 x 20 x 30	TS 2595

Statistical evaluation of the data

The data gathered as a result of tests performed are recorded in the Excel program. The arithmetic averages, standard deviations and coefficient of variation are calculated for each test and they are shown in related charts. Afterwards, the statistical analysis of the obtained findings is conducted. The variance analyses of findings are carried out according to randomised blocks factorial experimental design by using SAS program (SAS Inst. 1989).

RESULTS AND DISCUSSION

In this study, variance analysis results concerning the amounts of oven dried density, retention, bending strength, elastic modulus, compressive strength parallel to grain of Scotch pine subjected to impregnation process are given in Tab. 2. Mean values and least significant difference (LSD) test results are shown in Tab. 3.

Tab. 2: Results of variance analysis on oven dried density, retention, bending strength, elastic modulus and compression strength parallel to grain.

Source of variance	*Oven dried density*				*Amount of retention*			
	F.D.	S.S.	S.M.	F.D.	F.D.	S.S.	S.M.	F.D.
Boron compound (b)	2	103.46	51.73	1.99	2	460.52	230.26	18.16**
Solution concentr.(s)	2	24.31	12.15	0.47	2	1.07	0.54	0.04
Number of repeat (r)	14	326.14	23.30	0.90	14	216.04	15.43	1.22
Interaction (b*s)1	4	49.52	12.38	0.48	4	335.62	83.91	6.62**
Interaction (b*r)2	28	653.15	23.32	0.90	28	579.29	20.69	1.63
Interaction (s*r)3	28	723.14	25.85	1.00	28	336.83	12.02	0.95
Error	56	1453.02	25.95		56	710.15	12.68	
Total	134	3333.27			134	2639.53		
Source of variance	*Bending strength*				*Elastic modulus*			
	F.D.	S.S.	S.M.	F.D.	F.D.	S.S.	S.M.	F.D.
Boron compound (b)	2	514.28	257.142	2.13	2	13119752	6559876	3.20*
Solution concentr.(s)	2	129.28	64.64	0.54	2	704428	352214	0.17
Number of repeat (r)	14	2400.81	171.47	1.42	14	35985863	2570418	1.25
Interaction (b*s)1	4	266.67	66.67	0.55	4	1686620	421655	0.21
Interaction (b*r)2	28	3065.06	109.47	0.91	28	46750025	1669643	0.81
Interaction (s*r)3	28	3624.38	129.44	1.07	28	86230949	3079676	1.50
Error	56	6764.04	120.79		56	114969401	299447041	
Total	134	16764.52			134	299447041		
Source of variance	*Compression strength parallel to grain*							
	F.D.	S.S.	S.M.	F.D.				
Boron compound (b)	2	880.63	440.31	14.64**				
Solution concentr.(s)	2	317.01	158.51	15.27**				
Number of repeat (r)	14	312.80	22.35	0.74				
Interaction (b*s)1	4	353.52	88.38	2.94*				
Interaction (b*r)2	28	856.15	30.58	1.02				
Interaction (s*r)3	28	762.42	27.23	0.91				
Error	56	1683.96	30.07					
Total	134	5166.50						

F.D: Degrees of Freedom, S.S: Sum of Squares, S.M: Mean of Squares, F.D: F-Value, 1Boron compounds* Solution concentration, 2Boron compounds*Amount of Repeat, 3Solution concentration*Amount of Repeat*, **:1% and 5% significance level, respectively.

The Values of oven dried density

The oven dried density was statistically non-significant on the variation sources of scotch pine. Even though concentration and boron compounds values show numerical differences in the oven dried density, there is no statistically significant effect. In the variances with no statistical differences between them, the highest is 2.33 $g \cdot cm^{-3}$ in boric acid+borax in terms of the boron compounds and 1.39 $g \cdot cm^{-3}$ in the samples impregnated at 5% concentration with respect to solution concentration. The lowest oven dried density change is obtained in borax as 0.46 $g \cdot cm^{-3}$ in terms of boron compounds and as 0.48 $g \cdot cm^{-3}$ in samples impregnated with a 1% concentration (Tab. 3).

Tab. 3: The average values and the groups related to the least significant difference (LSD) test on oven dried density, retention, bending strength, elastic modulus and compression strength parallel to grain.

Factor	Physical properties		Mechanical properties		
	Oven dried density (g·cm^{-3})	Retention (kg·m^{-3})	Bending strength (MPa)	Elastic modulus (MPa)	Compression strength parallel to grain (MPa)
Boron compounds					
Boric Acid	0.47 a	3.83 b	83.53 a	10281 a	53.77 a
Borax	0.46 a	7.48 a	80.02 a	9723 ab	55.35 a
Boric A.+Borax	2.33 a	3.34 b	78.96 a	9550 b	49.32 b
Average	1.09	4.88	80.84	9851	52.81
Sx	1.08	2.26	2.39	381	3.13
LSD	2.15	1.50	4.64	605	2.32
Solution concentration					
1%	0.48 a	4.97 a	81.10 a	9899 a	51.33 b
3%	1.38 a	4.76 a	81.89 a	9906 a	54.92 a
5%	1.39 a	4.91 a	79.53 a	9750 a	51.33 b
Average	1.08	4.88	80.84	9852	52.53
Sx	0.52	0.11	1.20	88.12	2.07

In the literature, the oven dried densities of said solid wooden material are stated as following; 0.49 g·cm^{-3} in Scotch pine, 0.48 g·cm^{-3} in Taurus cedar, 0.59 g·cm^{-3} in *Castanea sativa* and 0.67 g·cm^{-3} in Sessile oak (Bozkurt 1982). The oven dried density findings we obtained come out close to the study results done by Bozkurt (1982).

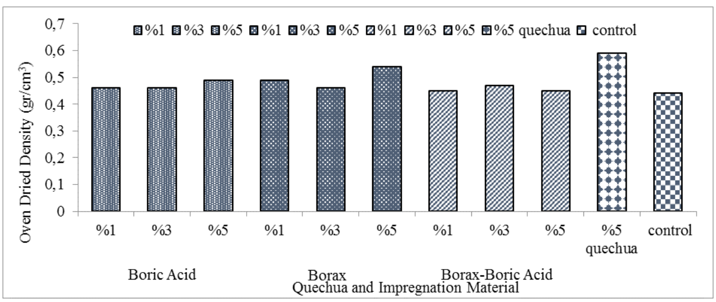

Fig. 1: The values of the average oven dried density of Scotch pine wood impregnated with the boron compounds.

It is observed that the values of the samples impregnated with the boron compound mixtures and the control samples come out close to each other regarding dry density values. The highest density value is obtained in samples treated with 5% quechua and the lowest oven dried density value is obtained in samples with a mixture of 5% boric acid+borax (Fig. 1).

The values for retention

The effect of the retention amount of Scotch pine impregnated with quechua and boron compounds on boron compounds and interaction is identified to be different at a significance level of 5%.

In the retention amount of the Scotch pine wood in Tab. 3; even though boric acid, borax+boric acid, 1%, 3% and 5% concentrations do differ numerically among themselves, they aren't statistically significant. The retention amount of the variations with no statistical difference between themselves is determined to be highest with 3.83 kg·m^{-3} in the samples impregnated with boric acid when analysed in terms of boron compounds. When examined at the concentration level, it is confirmed to be 4.97 kg·m^{-3} in the samples with 1% concentration. The samples impregnated with borax at a value of 7.48 kg·m^{-3} is found to be statistically different.

Özçifci and Batan (2009) have determined that the retention amount is highest in Scotch pine (19.39 kg·m^{-3} - 21.81%) and lowest in the oak (8.742 kg·m^{-3} - 9.15%). They have reported that the obtainment of the highest values in the Scotch pine samples may be due to the fact that the passage pairs are open leading to the fluid flow in the longitudinal direction of the coniferous trees and thus resulting in storing of excess impregnation material. The statistical values we have obtained show similarity to those in the literature. It is determined that the total retention amount increases as the solution concentration increases. This situation may have originated due to reasons like solution characteristics, wood type, anatomical structure, etc.

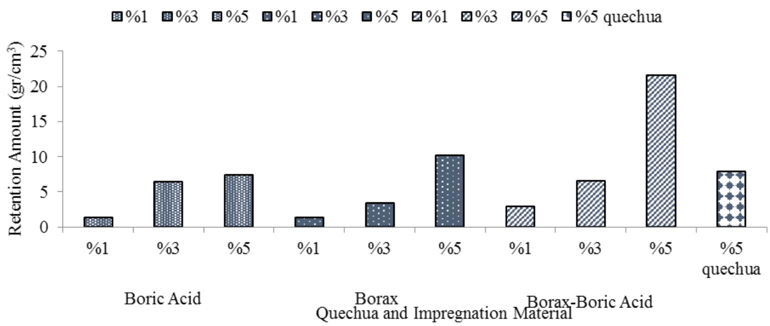

Fig. 2: The values for the average retention of Scotch pine wood.

As it is seen in Fig. 2, the retention amount and retention ratios of the test specimens are also recorded to increase with the increase in the impregnation substance concentration. Accordingly, the highest retention amount and retention rates are reached in the test samples impregnated with solutions of 5% and the lowest values are found in the samples impregnated with solutions of 1%.

The values for bending strength

The bending strength are statistically non-significant on the variation sources of scotch pine.

The bending strength amounts of the scotch pine wood in Tab. 3 in the variations without statistical difference between each other is found to be highest with 83.53 MPa in the samples impregnated with boric acid when examined in terms of boron compounds. When examined at the concentration level, it is determined to be highest with 81.89 MPa in samples with 3% concentration. Even though borax, boric acid, borax+boric acid, 1%, 3% and 5% concentrations are numerically different from each other, it is not statistically significant.

In the literature, the bending strength of Scotch pine is found to be highest with 104 MPa and lowest with 75 MPa in the study done by Efe and Çağatay concerning the determination of the bending strength of said solid wooden material (Efe and Çağatay 2011). It is determined that the findings we obtained for the identification of the bending strength parallel to grain are close to the work done by Efe and Çağatay (2011).

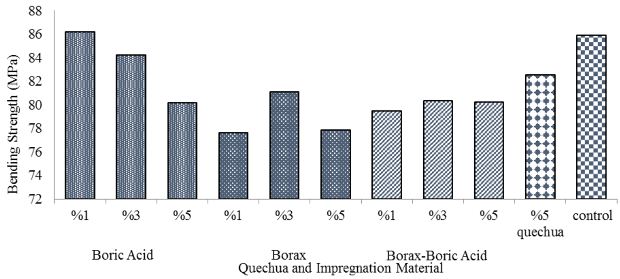

Fig. 3: The values of the average bending strength of scotch pine wood impregnated with the boron compounds.

As it can be seen in Fig. 3, the bending strength in the test samples impregnated with quechua and boron compounds is determined to be the highest in the borax+boric acid solutions with 3% concentration.

The values for elastic modulus

As a result of variance analysis conducted, the impact of the Scotch pine samples impregnated with quechua and boron compounds on the elastic modulus of boron compounds is found to be different at a 1% significance level (Tab. 2).

According to the findings in Tab. 3; the elastic modulus at the boron compounds level is determined to be highest with 10281 MPa in the samples impregnated with boric acid. When examined at solution concentration level, the highest value for the elastic modulus is obtained as 9906 MPa in samples impregnated with the concentration of 3%. According to these results; although borax, boric acid+borax, 1%, 3% and 5% concentrations of Scotch pine specimens differ numerically from themselves, this isn't statistically significant apart from samples impregnated with boric acid.

It is found as 11629.46 $N \cdot mm^{-2}$ in Oriental beech, 10055.83 $N \cdot mm^{-2}$ in Sessile oak, 10603.51 $N \cdot mm^{-2}$ in Eastern black walnut, 8319.13 $N \cdot mm^{-2}$ in Black poplar, 12093.65 $N \cdot mm^{-2}$ in ash tree and 9654.72 $N \cdot mm^{-2}$ in Scotch pine. The findings regarding the determination of the elasticity modulus values are confirmed to be close to values of the study done by Keskin and Dağlıoğlu in 2016.

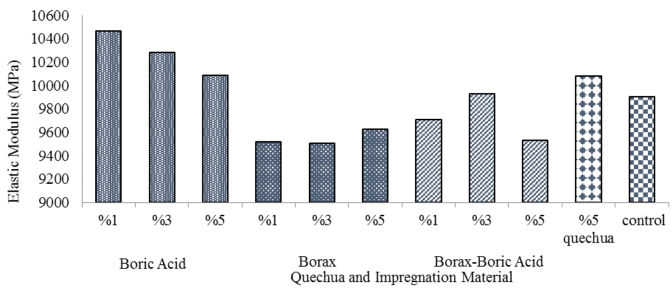

Fig. 4: The values of the average elastic modulus of scotch pine wood impregnated with the boron compounds.

As can be seen in Fig. 4, the elastic modulus of all Scotch pine samples impregnated with quechua and boron compounds is found to be generally higher than control samples.

The values for compressive strength parallel to grain

In the determination of compressive strength parallel to grain of scotch pine impregnated with quechua and boron compounds, its effect on the repetition numbers and interactions (b*r, s*r) isn't found statistically different. However, the impact of compressive strength of Scotch pine samples parallel to grain on boron compounds and solution concentration is determined to have differences at a 5% significance level and to have differences at a 1% significance level with the interaction (b*s) (Tab. 2).

According to the findings in Tab. 3; there are statistical discrepancies with 55.77 MPa in the comprehensive strength parallel to grain in boric acid in terms of boron compounds and with 54.92 MPa in samples impregnated with 3% concentration in respect to solution concentration. The aforesaid values in other variances don't have a significant difference with Scotch pine samples, the values are obtained as 49.32 MPa in borax+boric acid in terms of boron compounds and as 41.33 MPa in samples impregnated with 1% and 5% concentrations with regards to solution concentration. Accordingly, even though boric acid and 3% concentrations differ from each other, they are not statistically significant.

In the literature, the compressive strength of Scotch pine is found to be highest with 50.82 MPa and lowest with 39.20 MPa in the study conducted by Efe and Çağatay to determine the compressive strength of the solid wooden materials parallel to grain (Efe and Çağatay 2011). The values obtained towards the determination of compressive strength parallel to the grain share similarity with those of the previous study. This positive structure, which is also seen on the compressive strength, shows that this material can be used in many areas related to wood. Besides these, it will be needed in the determination of other physical and mechanical properties for other usage areas.

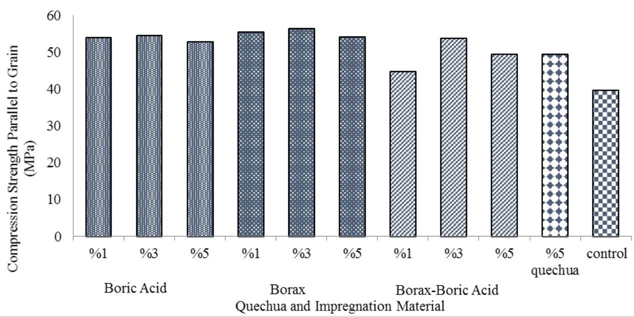

Fig. 5: The values for the average compressive strength parallel to grain of Scotch pine wood impregnated with the boron compounds.

In all the impregnated Scotch pine samples, compressive strength parallel to grain is detected to be higher than the control samples (Fig. 5). It is seen that the compressive strength parallel to grain of specimens impregnated with borax is in general higher than the other samples.

Boron compounds are not more toxic than common salt to animals and humans, and they are odourless and colourless. They don't have corrosive impacts. They are resistant to combustion. Nowadays, boron compounds are accepted to be one of the safest chemicals utilized as preservative impregnation substance. Since their negative effects on environment and humans are in minimum levels, their usage is gaining more and more importance. Because they have less toxic properties than other impregnation materials containing heavy metals, boron compounds are considered to be most significant impregnation materials of the future. Apart from their activities against pests like fungi and termite, usage areas of boron compounds are expanding through increasing the strength against combustion (Lloyd 1998).

CONCLUSIONS

In this study; the countless data concerning the physical and mechanical properties of the Scotch pine wood, which is frequently used in the wood products industry, are obtained. In the study in question, it will be enabled that environmental friendly preservatives become crucial in the wood protection sector through the use of both boron compounds and natural impregnation material.

The oven dried density value of samples impregnated with 5% quechua is identified to be higher. These results share similarity with the literature.

It is determined that the total retention amount also increases as the solution concentration goes up. The highest retention values are detected in solutions with 5% concentration and impregnated samples. Due to this situation, the density of the wooden materials also increases in parallel with the solution concentrations. Borax is used in many areas as an impregnation material. One of them is the protection of the wooden material. In this regard, boron compounds produce pretty good results and they do not affect human or animal health negatively. Because the boron compounds have a crystalized structure, they cause a decline in elastic modulus and the bending resistance perpendicular to grain after penetration into the wooden material, but this ratio is so small that it can be ignored. It has been observed that it causes a decline in compressive strength parallel to grain as in bending resistance, despite its benefits.

ACKNOWLEDGMENT

This article was derived from some of the parts of the master's thesis by Elif Alkan between the dates of 2013-2016. The thesis was prepared under the supervision of associate professor Dr. Selim Sen and assistant professor Dr. Muhammed Said Fidan at Gumushane University Institute of Science and Technology Department of Forestry and Environmental Sciences.

REFERENCES

1. ASTM D 1413-76-1976: Standart method of testing wood preservatives by laboratory soilblock cultura.
2. ASTM-D 1413-07-2007: Standard test method of testing wood preservatives by laboratory soilblock cultures..
3. Bozkurt, A. Y., Göker, Y., Erdin, N., 1993: Impregnate technique, Istanbul University Press, Istanbul, Turkey, Pp 106-107.
4. Baysal, E., 2002: Determination of oxygen index levels and thermal analysis of Scotch pine impregnated melamine formaldehyde-boron combinations, Journal of Fire Sciences 20(5): 373-389.
5. Baysal, E., 2003: Fire properties of Scots pine impregnated with borates and natural extractives, Erciyes University Journal of Science and Technology 19(1-2): 59-69.
6. Efe, H., Çağatay, K., 2011: Determination of some physical and mechanical properties of various wood and wood composite materials, Journal of Polytechnic 10(3): 55-61.

7. Esen, R., 2009: Determination of the effects on combustion strength of surface treatments applied on impregnated wood, MS Thesis, KBU Graduate School of Natural and Applied Science, Karabük, 111 pp.
8. Atar, H., Keskin, R., Kurt, M., 2003: Effects of impregnation and bleaching on the hardness of the varnish layer in Scotch pine (*Pinus sylvestris* L.) Wood, KSU Journal Science and Engineering 6(1): 85-95.
9. Keskin, H., Dağlıoğlu N., 2016: Effects of Tanalith-E impregnation substance on bending strengths and modulus of elasticity in bending of some wood types, Artvin Coruh University Journal of Forestry Faculty 17(1): 62-69.
10. Kolman, F., Cote, J. R., 1968: Principles of wood science and technology, I. Solid Wood Springer – Verlag, Pp 149-151.
11. Lebow, St.Laks, P. E., Palardy, R.D., 1990: The development of borate-containing flakeboard. Proceedings of 1st International Conference on Wood Protection With Diffusible Preservatives.
12. Lloyd, J.D., 1998. Borates and their biological applications. The International Research Group on Wood Preservation 29th Annual Meeting, 14-19 June 1998, IRG/WP/98-30178, 24 pp, Maastricht, Netherlands.
13. Özçifçi, A. Batan, F., 2009: Effect of some mechanical properties on wood materials impregnated with waste boron oil, Journal of Polytechnic 12(4): 287-292.
14. Temiz A., Gezer E.D., Yıldız U.C., Yıldız S., 2008: Combustion properties of alder (*Alnus glutinosa* L.) Gaertn. Subsp Barbata (CA Mey) Yalt.) and Southern pine (*Pinus sylvestris* L.) wood treated with boron compounds, Construction and Building Materials 22(11): 2165–2169.
15. TS 2472-1976: Determination of specific gravity for physical and mechanical testing in wood.
16. TS 2474-1976: Determination of the static bending strength of wood.
17. TS 2478-1976: Determination of elastic modululs in the static bending strength of wood.
17. TS 2595-1976: Compression strength parallel to grain of wood.
18. Qu, H., Wu, W., Wu, H., Xie, J., Xu, J., 2011: Study on the effects of flame retardants on the thermal decomposition of wood by TG–MS, Journal of Thermal Analysis and Calorimetry 103: 935-942.
19. Reinprecht, L. 2016: Wood Deterioration, protection and maintenance. John Wiley & Sons, Ltd, Chichester, 376 pp.

Selim Sen
Gumushane University
Gumushane Vocational High School
Department of Forestry and Forest Products
29100, Gumushane
Turkey

*M. Said Fidan
Bursa Technical University
Faculty of Forestry
Department of Forest Industry Engineering
16310, Bursa
Turkey.
Phone: +90 (224) 3003485
*Corresponding author: said.fidan@btu.edu.tr

Elif Alkan
Gumushane University
Institute of Natural Applied Science
Department of Forestry and Environment Sciences
29100, Gumushane
Turkey

S. Sadiye Yaşar
Gumushane University
Gumushane Vocational High School
Department of Design
29100, Gumushane
Turkey