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Impacts of boron compounds, imersol-aqua and timbercare-aqua on the screw withdrawal strength of some woods

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ABSTRACT

The aim of this study was to investigate the effects of impregnation with Boron compounds (Borax (Bx), Boric acid (Ba), Bx+Ba (wt:wt 50:50%)), Imersol-Aqua (Ia) and Timbercare-Aqua (Ta) on the screw (S) withdrawal strength of some solid wood materials. For this aim, Oriental beech (*Fagus orientalis* Lipsky), European oak (*Quercus petrea* Liebl.) and Scotch pine (*Pinus sylvestris* Lipsky) wood samples were prepared according to TS EN 13446 and impregnated with Boron compounds, Imersol-Aqua and Timbercare-Aqua according to ASTM D 1413, TS 344, TS 345 and directions of the manufacturer. After the impregnation process the screw withdrawal strength was measured according to TS EN 13446. Consequently, among the wood types, withdrawal strength was found to be the highest in European oak (4.049 Nmm^{-2}) and the lowest in Scotch pine (2.583 $N.mm^{-2}$). As for the screw diameter, the withdrawal strength was obtained the highest in S_1 (3.5 mm) (3.564 $N.mm^{-2}$) and the lowest in S_2 (4 mm) (3.480 $N.mm^{-2}$). Considering the interaction of wood types, impregnation chemicals and screw diameters, the withdrawal strength were obtained in European oak + Bx + S_1 (4.481 $N.mm^{-2}$) whereas the lowest was in Scotch pine + Ta + S_1 (2.369 $N.mm^{-2}$). In consequence, it was seen that the impregnation process increased the screw withdrawal strength. It can be said that, in the applications, the pieces that are impregnated with Bx and connected with S_1 at the surface shall display the highest strength.

KEYWORDS

Screw withdrawal strength;
Boron compounds;
Imersol-aqua;
Timbercare-aqua;
Solid woods.

INTRODUCTION

If the wood materials are used without processing by preventive chemicals (with regard to the area of usage), fungal stains, insect infestation, humidity, fire etc. damage the wood. As a result of these damages, the woods require to be repaired, maintained or replaced before its economic life ends[1]. For this reason, in most places the wood materials should be impregnated with some chemicals[2]. In case wood is not impregnated but only painted and varnished instead, the prevention on the surfaces is limited to a maximum of two years[3].

The screwing withdrawal strength is a function of the screw diameter. Length of engagement of the threaded portion into the member containing the point and specific gravity of the species of wood[4].

Determination of screw withdrawal strength in the edge or face of wood-based materials is held to be of particular importance because the fasteners are inserted in the middle layer of panels where the holding strength of the boards is presumably the lowest and the most variable[5].

A kind of linear relationship was determined between screw diameter and the withdrawal strength in various investigations. Within this context, it was found that increments in screw diameters yielded increases in the resultant withdrawal strengths. In addition, it was also found that there was no relationship between screw length and withdrawal strength while the diameter of screw had a linear relationship[6], [7] and[8].

The screw withdrawal strength of various through-bolt and dowel-nut having different diameter and longitudinal on the oriented strand board (OSB), medium density fiberboard (MDF) and particleboard (Pb) for modular furniture was studied. Results showed that the dept of insertion for screw is more important than the diameter of screw[9]. The withdrawal strengths of screws and nails on wafer board, European oak and Oriental beech woods were determined. The highest withdrawal strength was obtained in oriental beech wood perpendicular to face for glued screw 20x35 as 17.67 $N.mm^{-2}$[10].

Örs et al. studied the withdrawal strength of screws that some glue was applied to pilot holes before inserting the glue for some wood and composite materials. At the result of the test, oriental beech wood gave the highest strength following by fiberboard. They also stated that glue applied in pilot hole increased the holding strength for screws[11].

In this study, Oriental beech, European oak and Scotch pine woods commonly being used in furniture manufacturing were examined with respect to the impacts of impregnation chemicals on the screw withdrawal strength.

MATERIAL AND METHOD

Materials

Wood materials

Oriental beech (*Fagus orientalis* Lipsky), European oak (*Quercus petrea* Liebl.) and Scotch pine (*Pinus sylvestris* Lipsky) woods were selected as test the materials because of wide usage of industry. Special emphasis was given for the selection of wood materials which are non-deficient, proper, knotless, normally grown (without reaction wood, decay and mushroom damages) according to TS 2476[12].

Impregnation materials

Boron compounds

Boric acid and borax are obtained from Etibank - Bandýrma (Turkey) Borax Factory. Properties of Boric acid (H_3BO_3) is 56.30 ½ % B_2O_3 43.70% H_2O with a molecular weight 61.8, density 1.435 $g.cm^{-3}$ and melting point 171 ^{0}C. Borax ($Na_2B_4O_7$ $5H_2O$) content is 21.28 % Na_2O 47.80% B_2O_3, 30.92% H_2O with a molecular weight 291.3, density 1.82 $g.cm^{-3}$, melting point 741 ^{0}C[13].

Imersol-aqua

Imersol-Aqua was supplied from Hemel-

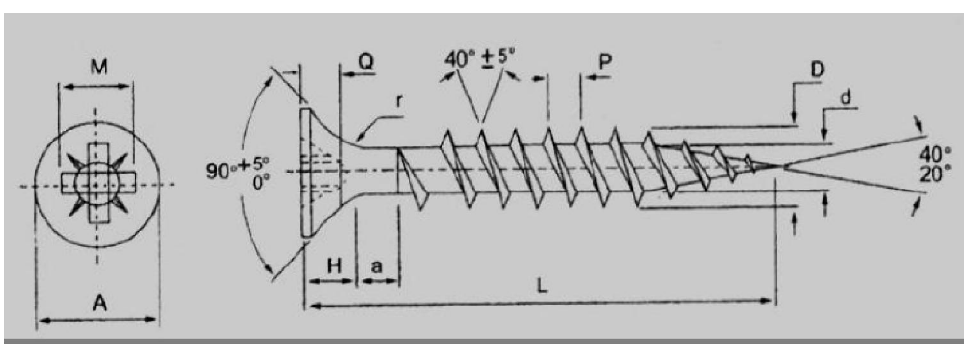

Figure 1 : Wood screw

TABLE 1 : Technical properties of screws (S_1 and S_2)

TYPE OF SCREW		S_1	S_2
Screw called diameter		**3.5**	**4**
Shank diameter	D	3.55	4.05
	min.	3.20	3.70
Root diameter	D	2.20	2.55
	min.	1.60	2.15
Head diameter	A	7.50	8.05
	min.	6.64	7.64
Head load	H	2.00	2.35
Width of combination drive	M	4.00	4.40
Screwdriver	PH	2.00	2.00
Torque	min.	20.00	30.00
Drive depth	Q	2.16	2.51
	min.	1.76	2.50
Thread step	P	1.60	1.80
	r	1.80	2.00
	a	2.60	2.80
Materials		C1018-C1022	
Core hardness		240–450 HV	
Surface hardness		min. 450 HV	
Surface hardness the thickness (depth)		0.05-0.18 mm	0.10-0.23 mm

Hickson Timber Products Co., Istanbul. It is non-flammable, odourless, fluent, water based, completely soluble in water, no corrosive material with a pH value of 7 and a density of 1.03 g cm^{-3}. It is available as ready-made solution. It contains 0.5 % w/w tebuconazole, 0.5 % w/w propiconazole, 1 % w/w 3-Iodo-2-propynl-butyl carbonate and 0.5 % w/w cypermethrin. Before the application of Imersol-aqua on the wood material, all kinds of drilling, cutting, turning and milling operations should be completed and the relative humidity should be in equilibrium with the test environment. The impregnated wood was left for drying at least 24 hours. The wood material can be painted, varnished or glued after it is fully dried[14].

Timbercare-aqua

Timbercare-Aqua was also supplied from Hemel-Hickson Timber Products Ldt., Istanbul. It is non-flammable, odorless, fluent, water-based and completely soluble in water, no corrosive material with a pH value of 7. It is available as ready-made solution. After the application of Timbercare-Aqua, surface should be painted by a UV resistant coating. Before painting, it should be waited for 24 hours and be sure the timber is dried. Before the application of Timbercare-Aqua on the wood material, all kinds of manufacturing operations should be completed and the relative humidity should be in equilibrium with the test environment[14].

Screws

Two type screws S_1 (3.5x50 mm) and S_2 (4x50 mm) were used in this study (Figure 1). These screws were selected not only they are standard low-cost fasteners that are readily available to the woodworking industry, but also they have excellent holding strength in wood and wood-based materials[15].

Technical properties of screws are given in TABLE 1.

Method

Determination of density

The densities of wood samples were determined according to TS 2472[16]. For gathering the air-dry density, the test samples with a dimension of

TABLE 2 : Oven-dry and air-dry densities of wood materials (g.cm^{-3})

Densities	Impregnation Process	Statistics Values	Oriental Beech	European Oak	Scotch Pine
Oven-dry	Control Samples	x	0.657	0.652	0.537
		Min	0.605	0.596	0.512
		Max	0.679	0.572	0.572
		Sd	0.0196471	0.0206274	0.016681
		v	0.0003862	0.0002782	0.000278
	Impregnated Samples	x	0.666	0.665	0.568
		Min	0.644	0.631	0.542
		Max	0.698	0.708	0.596
		Sd	0.015125	0.0203608	0.014726
		v	0.000229	0.0004146	0.000216
Air-dry	Control Samples	x	0.679	0.672	0.577
		Min	0.655	0.655	0.555
		Max	0.705	0.699	0.592
		Sd	0.01678101	0.01382290	0.0121909
		v	0.00028202	0.00014860	0.0001486
	Impregnated Samples	x	0.695	0.683	0.597
		Min.	0.669	0.667	0.579
		Max.	0.722	0.709	0.612
		Sd	0.01485321	0.01312320	0.0098322
		v	0.00022120	0.00017221	0.0000966

x: Mean, Min: Minimum, Max: Maximum, Sd: Standard deviation, v: Variance

TABLE 3 : Retention quantities and rates of wood materials (kg.m^{-3},%)

Impregnation Chemicals	Oriental Beech		European Oak		Scotch Pine	
	R	R %	R	R %	R	R %
Ba	20.23	114.40	2.94	13.68	3.72	19.87
Bx	19.20	107.47	3.19	15.76	4.22	22.96
Ba+Bx	19.67	109.89	3.24	15.67	4.32	24.87
IaS	170.87	28.52	56.11	7.41	53.30	8.93
IaL	487.54	82.91	383.66	55.01	326.30	52.44
Ta	160.17	26.54	61.75	8.65	58.19	10.28

Ba: Boric acid, Bx: Borax, IaS: Imersol-Aqua + Short term, IaL: Imersol-Aqua + Long term, Ta: Timbercare-Aqua

20x30x30 mm were kept under the conditions of 20±2 ^{0}C and 65±5 % relative humidity until they reached to a constant weight. The weights were measured with an analytic scale of ±0.01g sensitivity. Afterwards, the dimensions were measured with a digital compass of ±0.01 mm sensitivity. The air-dried densities (δ_{12}) of the samples were calculated by the following formula 1:

$$\delta_{12} = \frac{W_{12}}{V_{12}} \ g.cm^{-3} \quad (1)$$

Where W_{12} is the air-dry weight (g) and V_{12} is the volume (cm^3) at air-dry conditions.

The samples were kept at the temperature of 103±2 °C in the drying oven until they reached to a stable weight of oven-dry density. Afterwards, oven-dried samples were cooled in the desiccators containing Calcium Chloride (CaCl). Then, they were weighted on a scale of ±0.01 g sensitivity balance and their dimensions were measured with a digital compass of ±0.01 mm. The volumes of the samples were determined by stereo metric method and the densities (δo) were calculated by the following formula 2:

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$$\delta o = \frac{Wo}{Vo} \ g.cm^{-3} \qquad (2)$$

Where *Wo* is the oven-dry weight (g) and *Vo* is the oven-dry volume (cm^3) of the woods.

Determination of moisture content

The moisture content of test samples before and after the impregnation process was determined according to TS 2471[17]. Thus, the samples with a dimension of 20x20x20 mm were weighted and then dried at 103±2 °C in an oven till they reach to a constant weight. Then, the samples were cooled in desicator containing Calcium Chloride (CaCl) and weighted with an analytic scale of 0.01g sensitivity. The moisture content of the samples (h) was calculated by the following formula 3:

$$h = \frac{Wr - Wo}{Wo} \ x \ 100 \ g.g^{-1} \qquad (3)$$

Where *Wr* is the initial weight of the samples (g) and *Wo* is the final dry weight (oven-dry) of the samples (g).

Preparation of test samples

The rough drafts for the preparation test samples were cut from the sapwood parts of solid woods and conditioned at a temperature of 20±2°C and 65±3 % moisture content for three months until reaching an equilibrium in moisture distribution. The samples, with a dimension of 50x50x15 mm were cut from the drafts having an average moisture of 12 % according to TS EN 326-1[18] and TS EN 13446[19]. The densities and moisture content of all test samples were measured before the impregnation process.

The test samples were impregnated according to ASTM D 1413[20], TS 344[21], TS 345[22] and directions of the manufacturer. Accordingly, for boron compounds (Borax (Bx), Boric acid (Ba), Bx+Ba (wt:wt 50:50%)), the samples were exposed to 700 mm/Hg^{-1} prevacuum for 60 min. and then they were held in a solution under normal atmospheric pressure for 60 min. to allow the diffusion of the impregnation chemical. For Imersol-Aqua, the samples were dipped in the impregnation pool immersing 1 cm below the upper surface for 10 minutes in short-term dipping and 5 days for long-term dipping. The specifications of the impregnation solution were determined before and after the process. For Timbercare-Aqua, the samples were brushed the impregnation chemicals with a brush according to the producers' definition. Brushing process was performed twice with a period of 3-4 hours[23]. The processes were carried out at 20±2 °C. Retention of impregnation chemical (R) was calculated by the following formula 4:

TABLE 4 : Average withdrawal strength due to impregnation chemical, wood and screw type

TYPES OF MATERIAL	STATISTICAL VALUES	
Wood materials	**x**	**HG***
Oriental beech (I)	3.935	B
European oak (II)	4.049	A
Scotch pine (III)	2. 583	C
Screws	**X**	**HG****
Screw (3.5 mm) (S_1)	3.564	A
Screw (4 mm) (S_2)	3.480	B
Impregnation Chemicals	**x**	**HG*****
Control (C)	3.551	AB
Boric acid (Ba)	3.527	AB
Borax (Bx)	3.609	A
Boric acid + Borax (Ba+Bx)	3.470	BC
Imersol-Aqua + Short term (IaS)	3.609	A
Imersol-Aqua + Long term (IaL)	3.497	ABC
Timbercare-Aqua (Ta)	3.393	C

***$LSD_{0.5}$= 0.078, ** $LSD_{0.5}$ = 0.063, *** $LSD_{0.5}$ = 0.119, HG = Degree of Homogeny, x: Mean**

TABLE 5 : Average withdrawal strengths for the interaction of impregnation chemical,wood and screw type($N.mm^{-2}$)

Types of material	Statistical values	
***Woods + Screws**	**x**	**HG**
I+S_1	3.947	B
I+S_2	3.923	B
II+S_1	4.157	A
II+ S_2	3.940	b
III+S_1	2.589	c
III+S_2	2.577	c
****Impregnation chemicals + Screws type**		
S_1	3.470	bcde
Ba+S_1	3.633	ab
Bx+S_1	3.626	ab
Ba+Bx+S_1	3.429	cdef
IaS+S_1	3.718	a
IaL +S_1	3.500	bcd
Ta+S_1	3.629	ab
V_2	3.310	ef
Ba+S_2	3.589	abc
Bx+S_2	3.628	ab
Ba+Bx+S_2	3.652	ab
IaS+S_2	3.342	def
IaL+S_2	3.268	f
*****Woods + Impregnation chemicals**		
Ta+S_2	3.517	bcd
I	3.817	cd
I+Ba	3.871	cd
I+Bx	4.280	a
I+Ba+Bx	3.904	cd
I+IaS	4.026	bc
I+IaL	3.887	cd
I+Ta	3.757	d
II	4.176	ab
II+Ba	4.216	ab
II+Bx	4.034	bc
II+Ba+Bx	3.872	cd
II+IaS	4.014	bc
II+IaL	4.028	bc
II+Ta	4.002	bc
III	2.661	ef
III+Ba	2.495	fg
III+Bx	2.514	fg
III+Ba+Bx	2.632	efg
III+IaS	2.786	e
III+IaL	2.576	efg
III+Ta	2.419	g

***$LSD_{0.5}$= 0.110, **$LSD_{0.5}$= 0.168, ***$LSD_{0.5}$= 0.206**

$$R = \frac{G.C}{V} 10^3 \ kg.\ m^{-3} \ (G = T_2 - T_1) \qquad (4)$$

Where, G is the amount of impregnation solution absorbed by the sample, T_2 is sample weight after the impregnation, T_1 sample weight before the impregnation, C concentration (%) of the impregnation solution and V the volume of the samples.

Impregnated test samples were kept under a temperature of 20±2 °C and 65±3 % moisture content until they reach to a stable weight.

Screw withdrawal strength

Screw withdrawal strength test was carried out according to ASTM D 1037-91[24] with the testing speed was 15 mm/min. All test were carried out on a universal testing machine having 400 Newton capacity and equipped with jigs to hold the samples.

The loading was continued until separation occurred on the surface of the test samples; meanwhile, maximum load (F_{max}), bonding area (A) and withdrawal strength (σ_k) were calculated by the following formula 5:

$$\sigma_k = \frac{F\max}{A} = \frac{F\max}{h(2\pi r)} \ N.mm^{-2} \qquad (5)$$

Where, σ_k is screw holding strength, h is depth of screw embedded in the face member (mm).

Data analyses

By using three type of wood, six types of impregnation material and one control samples, two screw types, a total of 294 samples (3x7x2x7) were prepared with seven samples for each parameter. Multiple variance analysis (MANOVA) was used to determine the effects of impregnation chemicals on the screw withdrawal strength of some solid wood materials. DUNCAN test was applied to determine the significant difference between the groups.

RESULT AND DISCUSSION

The pH value and density of impregnation chemicals, used for the impregnation process did not change either prior or after the impregnation. This may be due to the use of fresh solution in each impregnation process.

Statistical values for the oven-dry and air-dry

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TABLE 6 : MANOVA concerning the impacts of impregnation chemical, wood and screw type on the withdrawal strength ($N.mm^{-2}$)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Significance (0.05)
Factor A[a]	2	130.256	65.128	842.0859	0.0000
Factor B[b]	1	1.516	0.253	3.2672	0.0041
AB	2	3.367	0.281	3.6281	0.0001
Factor C[c]	6	0.522	0.522	6.7436	0.0100
AC	12	0.645	0.322	4.1696	0.0165
BC	6	3.398	0.566	7.3225	0.0000
ABC	12	3.471	0.289	3.7397	0.0000
Error	252	19.490	0.077		
Total	293	162.664			

a: Wood materials (I = Beech, II = Oak, III =Pine, b: Screw types, (S_1: Screw (3.5 mm), S_2: Screw (4 mm)), c: Impregnation materials and control (C= Control, Ba: Boric acid, Bx: Borax, Ba+Bx: Boric acid+Borax, IaS: Imersol-Aqua + Short term, IaL: Imersol-Aqua + Long term, Ta: Timbercare Aqua)

TABLE 7 : Duncan's multiple range test results

Process type	X	HG[a]	Process type	x	HG[a]	Process type	x	HG[a]
II+Bx+S_1	4.481	a	II+Ba+Bx+S_1	3.950	defghı	III+Bx+S_2	2.940	j
I+IaS+S_1	4.403	ab	I+Ta+S_1	3.907	efghı	III+Ta+S_1	2.840	jk
II+Ba+Bx+S_2	4.349	abc	I+V_2	3.901	efghı	III+Ba+S_1	2.807	jkl
II+Ta+S_2	4.297	abcd	II+IaL+S_1	3.894	efghı	III+Ba+S_2	2.631	jklm
II+S_1	4.283	abcd	I+Ta+S_2	3.886	efghı	III+Ba+Bx+S_2	2.580	klm
II+IaS+S_1	4.173	abcde	I+Bx+S_2	3.884	efghı	III+IaS+S_1	2.577	klm
I+Ba+S_2	4.169	abcde	I+Bx+S_1	3.884	efghı	III+IaS+S_2	2.571	klm
I+IaL+S_1	4.157	abcde	I+Ba+Bx+S_1	3.859	efghı	III+S_1	2.516	klm
II+Ta+S_1	4.139	abcde	I+IaS+S_2	3.747	fghı	III+Bx+S_1	2.511	klm
II+Ba+S_1	4.069	bcdef	II+IaL+ S_2	3.707	ghı	III+Ba+Bx+S_1	2.479	lm
II+Bx+S_2	4.060	bcdefg	II+IaS+S_2	3.707	ghı	III+IaL+S_2	2.469	lm
I+Ba+Bx+S_2	4.026	cdefg	I+IaL+S_2	3.629	hı	III+IaL+S_1	2.450	m
I+Ba+S_1	4.024	cdefg	I+S_1	3.610	ı	III+S_2	2.424	m
II+Ba+S_2	3.967	defgh	II+S_2	3.606	ı	III+Ta+S_2	2.369	m

a: Different letters in a column refers to significant differences among the different interactions of wood material, screws and impregnation materials at 0.05 confidence level ($LSD_{0.5}$: *LSD= 0.291), I: Oriental beech, II: European oak, III : Scotch pine, S_1 : Screw (3.5 mm), S_2 : Screw (4 mm), C= Control, Ba: Boric acid, Bx: Borax, Ba+Bx: Boric acid+Borax, IaS: Imersol-Aqua+Short term, IaL: Imersol-Aqua+Long term, Ta: Timbercare Aqua

densities of test samples are given in TABLE 1. As seen from the Table, the densities vary due to the type of wood. The densities of impregnated samples increased with respect to control (un-impregnated) samples.

The quantities and rates of retention due to wood species are shown in TABLE 3. Quantities and rates of retention were obtained different depending on wood species and impregnation materials. The highest retention quantity and rate were obtained in beech and the lowest in oak. This may be due to tyloses in oak wood samples. In a similar research, it was reported that in the impregnation of Oriental beech and Scotch pine woods the retention quantities and rates increased with the increase in impregnation period[25].

In the interaction of wood types and impregnation chemicals, the highest retention quantity was obtained in Oriental beech + IaL (487.54 $kg.m^{-3}$) and lowest in European oak + Ba (2.94 $kg.m^{-3}$). The highest retention rate was obtained in Oriental beech + Ba (114.4 %) and lowest in European oak + IaS (7.41 %). The highest retention quantity and rate was

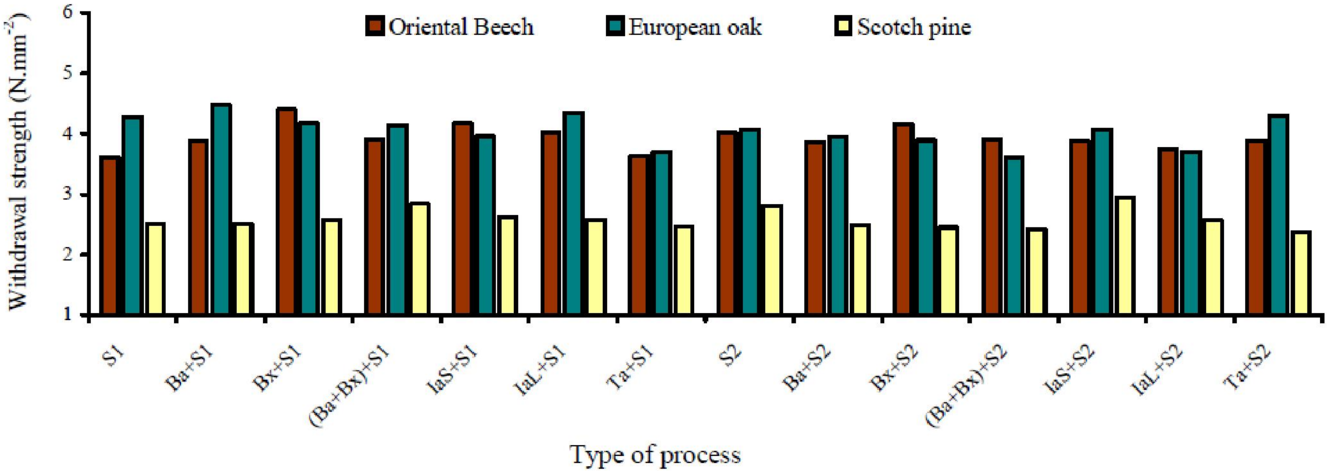

Figure 2 : Change of screw withdrawal strength according to impregnation chemical, wood and screw type

obtained in Oriental beech. This result may be due to the more penetration of impregnation solution into the wood with the extension of time. Withdrawal strength average values according to impregnation chemical, wood and screw type are given in TABLE 4.

According to impact of wood type, screw withdrawal strength was the highest in European oak (4.049 $N.mm^{-2}$) whereas the lowest in Scotch pine (2.589 N mm^{-2}). According to impact of impregnation chemical, it was the highest in Bx (3.609 $N.mm^{-2}$) whereas the lowest in Ta (3.393 $N.mm^{-2}$). According to screw diameter, it was the highest in S_1 (3.564 $N.mm^{-2}$).

The average values of the withdrawal strength concerning the interaction of impregnation chemical, wood and screw type are given in TABLE 5.

In the interaction of wood and screw type, screw withdrawal strength was obtained the highest in European oak + S_1 (4.157 $N.mm^{-2}$) whereas the lowest in Scotch pine + S_2 (2.577 $N.mm^{-2}$). Considering the interaction of impregnation chemical and screw type, it was found to be the highest in IaS + S_1 (3.718 $N.mm^{-2}$) whereas the lowest in IaL+ S_2 (2.419 $N.mm^{-2}$). With regard to the wood type and impregnation chemicals interaction, it was obtained the highest in Oriental beech + Bx (4.280 $N.mm^{-2}$) whereas the lowest in Scotch pine + Ta (2.419 $N.mm^{-2}$).

Average screw withdrawal strength for the interaction of impregnation chemical, wood and screw type and the results of variance analysis regarding the impacts of impregnation chemical, wood and screw type on the screw withdrawal strength are given in TABLE 6.

As seen from TABLE 6, the effects of variance sources (impregnation chemicals, wood species, screw types and their interaction) on the withdrawal strength were found to be significant (*$P<0.05$). The comparisons of the mean values of sample groups as the Duncan's multiple range test result is given in TABLE 7.

According to Duncan's multiple range test results, within the non-impregnated wood materials, withdrawal strength was found to be the highest in European oak + S_1 (4.283 $N.mm^{-2}$), and the lowest Scotch pine +S_2 (2.424 $N.mm^{-2}$). In the impregnated woods, withdrawal strength was obtained to be the highest in European oak + Bx + S_1 (4.481 $N.mm^{-2}$) whereas the lowest Scotch pine + Ta + S_1 (2.369 $N.mm^{-2}$). The change of withdrawal strength according to impregnation chemical, wood and screw type are shown in Figure 2.

CONCLUSION

Screw withdrawal strength was the highest in European oak (4.049 $N.mm^{-2}$) whereas the lowest in Scotch pine (2.589 N mm^{-2}) according to impact of wood type. Screw withdrawal strength according to pine samples; 64% higher in oak, 3% in beech samples. This may be due to positive effects of impregnation chemicals on the structure of the oak wood.

According to impact of impregnation materials, screw withdrawal strength was the highest in Bx (3.609 $N.mm^{-2}$) whereas the lowest in Ta (3.393 $N.mm^{-2}$). According to screw diameter was the highest in S_1 (3.564 $N.mm^{-2}$). It was 64% higher in oak, 3% in beech than control samples. Withdrawal strength of impregnated with Ba, Ba+Bx and IaL samples decreased with respect to control (without impregnated) samples.

Screw withdrawal strength increased impregnated with Boric acid wood samples. These may be due to positive effects of Boric acid on the structure of the wood material. This may be due to the expansion of wood by the fulfillments of lumen and capillary spaces with Boric acid.

According to screw diameter, withdrawal strength was the highest in S_1 (3.564 $N.mm^{-2}$) whereas the lowest in S_2 (3.480 ($N.mm^{-2}$). It was 3% higher in S_1 than S_2.

Considering the interaction of wood and screw type, screw withdrawal strength was obtained the highest in European oak + S_1 (4.157 $N.mm^{-2}$) whereas the lowest in Scotch pine + V_2 (2.577 $N.mm^{-2}$). In the interaction of impregnation chemical and screw type, it was found to be the highest in IaS + S_1 (3.718 $N.mm^{-2}$) whereas the lowest in IaL+ S_2 (2.419 $N.mm^{-2}$). With regard to the wood type and impregnation chemicals interaction, it was obtained the highest in Oriental beech + Bx (4.280 $N.mm^{-2}$) whereas the lowest in Scotch pine + Ta (2.419 $N.mm^{-2}$).

Considering the interaction of impregnation chemical, wood and screw type, screw withdrawal strength was fount to be the highest in European oak + Bx + S_1 (4.481 $N.mm^{-2}$) whereas the lowest Scotch pine + Ta + S_1 (2.369 $N.mm^{-2}$). This may be due to the higher density, celluloses and hemicelluloses of beech and oak wood than pine wood. It was reported that the hardwoods have more cellulose and hemicelluloses than softwoods[26, 27]. Cellulose and hemicelluloses increased the bending and withdrawal strength of wood materials[28]. Sequence, it was seen that the impregnation process increased the screw withdrawal strength.

In consequence, in the massive construction and furniture elements that the screw withdrawal strength after the impregnation is of great concern, impregnation with Bx and screwing with S_1 at the surface could be recommended.

REFERENCES

[1] M.Atar; The effects of varnish and impregnation processes on combustion properties of oak, Journal of Applied Polymer Science, **107/6**, 3981-3986 **(2008)**.

[2] P.D.Evans, A.J.Michell, K.Schmalzl; Studies of the degradation and protection of wood surfaces, Wood Science Technology, **22**, 151-163 **(1992)**.

[3] T.L.Higley, T.K.Kink; Biological degradation of wood, Phytopathology, **69**, 1151-1157 **(1990)**.

[4] B.A.Richardson; Wood preservation, The construction, Lancaster, England, **186**, **(1987)**.

[5] C.A.Eckelman, Z.A.Rajak; Edge and face withdrawal strength of large screws in particleboard and medium density fiberboard, Forest Product Journal, **43/4**, 25 **(1993)**.

[6] C.A.Eckelman; Predicting withdrawal strength of sheet-metal-type screws in selected hardwoods, Forest Product Journal, **28/8**, 25–28 **(1978)**.

[7] G.Kjucukov, E.Encev; The effect of screw dimensions on the withdrawal resistance in fir wood, Holztechnologie, **18/1**, 26-28 **(1977)**.

[8] Y.Ors, R.Ozen, S.Doganay; Screw holding ability of wood materials used in furniture manufacture, Turkish Journal of Agriculture and Forestry, **22/4**, 30 **(1998)**.

[9] D.L.Cassens, C.A.Eckelman; Face holding strength of treated metal insert in reconstituted wood products, Forest Product Journal, **35/3**, 18-22 **(1985)**.

[10] A.Ozcifci, S.Doðanay; Withdrawal strength of some screws and nails in waferboard and some solid woods, Turkish Journal of Agriculture and Forestry, **23/5**, 1207-1214 **(1999)**.

[11] Y.Ors, R.Özen, S.Doðanay; Mobilya üretiminde kullanilan aðaç malzemenin vida tutma dirençleri, Turkish Journal of Agriculture and Forestry, **22/3**, 807-815 **(1998)**.

[12] TS 2476, Odunda Fiziksel ve Mekaniksel Deneyler için Numune Elde Etme Metotlarý ve Genel Özellikler, **(1976)**.

[13] Y.Ors, M.Atar, H.Keskin, H.M.Colakoglu; Impacts of impregnation with boron compounds on the surface roughness of some woods and varnished surfaces, Journal of Applied Polymer Science (JAPS), **102/5**, 4952-4957 **(2006)**.

[14] Hickson's Timber Impregnation CO. (GB) Ltd., Into the 21st. Century, Imersol-Aqua brochure, Hickson

Timber Treatments Datasheet, **2**, 1-4 **(2000)**.

[15] TS 61-1, Baðlama Elemanlarý - Vidalar - Kýsým: 1-Terimler ve Tarifler, **(1994)**.

[16] TS 2472, Odunda Fiziksel ve Mekanik Deneyler için Hacim Yoðunluk Deðerinin Tayini, **(1976)**.

[17] TS 2471, Odunda Fiziksel ve Mekanik Deneyler için Rutubet Tayini, **(1976)**.

[18] TS EN 326-1, Ahºap esasli levhalar-numune alma kesme ve muayene bölüm 1: Deney numunelerinin seçimi, Kesimi ve Deney Sonuçlarýnýn Gösterilmesi, **(1999)**.

[19] TS EN 13446, Ahºap esaslý levhalar - Baðlayýcýlarýn geri çýkma kapasitesinin tayini, **(2005)**.

[20] ASTM D 1413-76, Standard Test Method of Testing Wood Preservatives by Laboratory Soilblock Cultures, **(1976)**.

[21] TS 344, Ahºap Koruma Genel Kurallarý, **(1981)**.

[22] TS 345, Ahºap emprenye maddeleri etkilerinin muayene metotlari, Türk Standartlarý Enstitüsü, **(1981)**.

[23] H.Keskin; Effects of impregnation materials on combustion properties of laminated veneer lumber (LVL) obtained from european oak (Quercus petraea Liebl.) and lombardy poplar (Populus nigra Lipsky), Journal of Applied Polymer Science (JAPS), **105/4**, 1766-1773 **(2007)**.

[24] ASTM D 1037, Standard Test Methods For Evaluating Properties of Woodbase Fiber and Particle Panel Materials, **(2006)**.

[25] Y.Ors, M.Atar, H.Keskin; Bonding strength of some adhesives in wood materials impregnated with Imersol-Aqua, International Journal of Adhesion & Adhesives (IJAA), **24/4**, 287-294 **(2003)**.

[26] D.Hon; Functional natural polymers: A new dimensional creativity in lignocellulosic chemistry, In chemical modification of lingocellulosic materials, Marcel Decker Inc., New York, **(1996)**.

[27] Y.Ors, H.Keskin, M.Atar, M.H.Colakoglu; Effects of impregnation with imersol aqua on the modulus of elasticity in bending of laminated wood materials, Construction & Building Materials (JCBM), **21/6**, 1647-1655 **(2007)**.

[28] Y.Ors, H.Keskin; Aðaç malzeme teknolojisi (wood material science), textbook, gazi university, Gazi Publication Company, Ankara, **2000/352, (2008)**.