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IMPACTS OF IMPREGNATION WITH SOME CHEMICALS ON THE SHEAR STRENGTH OF OAK (*QUERCUS PETRAEA SUBSP*. IBERICA) AND SCOTS PINE (*PINUS SYLVESTRIS* L.)

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Abstract

This study attempts to evaluate the performance of wood adhesives. Two wood species, Oak (Quercus petraea subsp. iberica) and Scots Pine (Pinus sylvestris L.) were treated with Borax, boric acid, borax+boric acid and di-ammonium phosphate, and then bonded with tree different wood adhesives such as ürea formaldehyde (UF) resin, phenol formaldehyde (PF) resin and melamine-urea-formaldehyde (MUF) resin. The shear strength test was performed according to the procedure defined in the BS EN 204 standard. The highest bonding strength 8.74N/ mm^2 was obtained from oak control samples. The lowest 1.80N/ mm^2 was obtained from pine wood treated by boric acid solution. In conclusion, the impregnation process negatively affected the bonding strength.

Key words: *borax; boric acid; diammonium phosphate; melamine-urea-formaldehyde; shear strength; phenol formaldehyde; urea formaldehyde.*

INTRODUCTİON

Wood has four major enemies: insects, marine borers, fungi and fire, and any of these can destroy the usefulness of wood. However, wood can be protected from all of them, to a large extent, by using protective chemicals (Ozcifici 2006). Fire-retardant and preservative treated wood products are commonly used in many applications (Yalinkilic *et al.* 1998). The use of woods treated with preservatives for the manufacture of the products requires assessment of the performance of wood adhesives. Exterior grade wood adhesives such as phenol–formaldehyde (PF) resin, resorcinol–formaldehyde (RF) resin, or melamine–formaldehyde (MF) resins are mainly used due to their high moisture resistance in outdoor environment (Lee et al. 2006). Many factors contribute to the development of insufficient adhesive strength of treated woods. The presence of contaminants such as waxy, oily, and inorganic materials hinders the development of cohesive adhesion bonds between wood substrate and adhesive (Pizzi 1994). The insoluble metallic components of wood preservatives, for example, impede the formation of interfacial adhesion between wood and adhesives leading to a poor adhesive strength in products (Vick 1997).

Örs et al. (2003) reported that the shear strength of the test samples prepared from Oriental beech (*Fagus orientalis* lipsky), oak (*Quercus petraea* liebl.), scotch pine (*Pinus sylvestris*lipsky) and Toros cedar (*Cedrus libani* A. Rich) and impregnated with Imersol-Aqua. It was noted that impregnation affected adhesive bonding strength negatively whilst bonding surface sanding after impregnation affected adhesive bonding strength positively (Ors et al. 2003).

Uysal (2006) conducted a study to determine the effects of wood pretreatment on the bonding strength of wood materials. Beech, Scotch pine, oak, and chestnut were impregnated with Tanalith-C, creosote, and Protim 230 WR-parafin and bonded with poly (vinyl acetate) (PVAc), Desmodur- VTKA, and Pattex fast. The highest shear strength was obtained in nonimpregnated (control) and PVAc glued oak (5.328N/mm^2), and the lowest shear strength was obtained in Protim 230 WR-paraffm and Pattex fast glued chestnut (0.169N/mm^2). The impregnation process negatively affected the adhesive bonding strength (Uysal 2006).

Özcifçi (2006), has studied to determine the bonding strength of phenol formaldehyde and melamine-formaldehyde adhesives to impregnated wood materials. For this purpose, black pine and elm woods were impregnated with boron compounds, Di-ammonium phosphate and Tanalith-C 3310. The effects of wood samples, impregnating material and type of adhesive on the bonding strength were determined. The highest shear strength (11.09N/mm^2) was obtained from elm wood control (i.e. without any impregnating materials) samples with melamine-formaldehyde; thus, the impregnation process negatively affected the adhesive bonding strength (Özcifçi 2006).

The purpose of this study was to determine the shear strength of Oak (*Quercus petraea subsp*. İberica) and Scotch Pine (*Pinus sylvestris* L.) woods, which were impregnated with boron compounds borax (BX), boric acid (BA), BX + BA and di-ammonium phosphate (DAP), glued by urea formaldehyde (UF), phenol formaldehyde (PF) and melamine-urea-formaldehyde (MUF) adhesives.

MATERIAL AND METHOD

Material

Wood Materials

Oak (*Quercus petraea subsp.* iberica) and Scots Pine (*Pinus sylvestris* L.) woods were selected as test materials because of wide usage of industry. Special emphasis is given for the selection of the wood material. Accordingly, non-deficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect mushroom damages).

Adhesive

The urea formaldehyde (UF), phenol formaldehyde (PF) and melamine-urea- formaldehyde (MUF) were used as adhesives. UF, PF and MUF adhesives were supplied by GENTAŞ, producer firm in Turkey and their characteristics are given in Table 1.

Table1

Characteristics of adhesives used

Adhesives	Density (20 ºC) (g/cm3)	pH (20 ºC)	Viscosity (20 ºC) (cPs)	Solid (2 h, 120 ºC) (%)
UF	1.290	8.5	400-600	65.00
PF	1.120	8.4	600	48.00
MUF	1.282	8.2	600	65.00

Impregnation Chemicals

Boron compounds borax ($Na_2B_4O_7.5H_2O$), boric acid (H_3BO_3), BX+BA mixed and di-ammonium phosphate ($(NH_4)2HPO_4$) were used as impregnation chemicals in this study. The chemicals are widely found in Turkey and effective against biotic and abiotic damage and have fire-retardant characteristic.

Method

Preparation of Test Samples

The samples(500mm long by 55mm wide by 5mm thickness), cut radially from sapwood region of the planks and acclimatized at 20 ± 2^{o}C and with 65 ± 3% relative humidity until their weights became constant. Before the bonding test samples, the impregnating process was carried out. In the impregnation process pressure - vacuum method has been applied. For that reason, a vacuum chamber, 31cm diameter and 55cm depth, was used. Before the impregnation process, the average moisture content of the samples was about 12%. The samples were weighed before impregnation and placed in a vacuum chamber. After vacuum period (710mm-Hg, 30min), the impregnating solution long by containing, BA, BX, BX+BA or DAP were filled into the vacuum chamber until the samples were covered. Pressure was increased to 3 bar and lasted for 1 h. After the internal pressure was decreased to atmospheric pressure, impregnation solution was unloaded and the final vacuum, 710mm-Hg, was applied for 10min. Then, the samples were removed and re-weighed. Net uptake of impregnation chemicals were calculated from the difference between the last weight and initial weight. The amount of retention (R, kg/m3) was calculated as follow:

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$$R = \frac{GxC}{V}10 \qquad (1)$$

Here;
G= M_2 -M_1 M_2= sample mass after impregnation [g]
M_1= sample mass before impregnation [g]
V= volume of sample [cm^3]
C= concentration of solution [%]

The oversized test samples were climatized until they were stable at 20 ± 2°C and with 65 ± 3% relative humidity in climate room. The adhesive was applied at the rate of about 180-200g/m2 on single bonding surface of the rows (single glue line) as recommended by the manufacturer. Glues were spread uniformly on the veneers by manually hand brushing. The press pressure, temperature and duration were applied as 2kg/cm2, 120 ºC and 15min for PF, MF and MUF adhesives. Finally the pressed panels were cut with the dimensions of 150x20x10 mm3 according to the procedure of BS EN 205. 10 samples were manufactured for each test sample 300, test samples were prepared in total (Fig. 1). The samples were tested after being conditioned for 10 weeks at 20±2 °C and 65±3 % relative humidity.

The measurement of shear strength was carried out in a Zwick/Roel Z50 universal testing machine, according to BS EN 205 (BS EN 205, 2003).

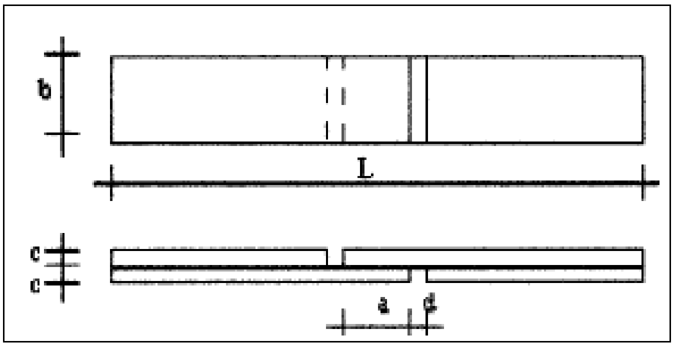

Fig. 1.
Shear strength test sample (a, 10 mm; b, 20 mm; c, 5 mm; d, 3 mm; L, 150 mm)

The loading speed was 10mm/min. The loading was carried out until a break or separation occurred on the surface of the test samples. The shear strength was calculated using the observed load (F_{max}) and bonding surface of sample (A, mm^2) according to the following formula (2):

$$\sigma_k = \frac{F_{max}}{A} = \frac{F_{max}}{ab}\left(N.mm^{-2}\right) \qquad (2)$$

where: a is the width of the glued surface (10mm) and b is the length of glued surface (20mm).

RESULTS AND DISCUSSION

The characteristics of the solutions used in impregnating test samples were given in Table 2.

Table 2.
Peculiarities of impregnation chemicals.

Impregnation Chemicals	Concentration of solution (%)	Temperature (ºC)	Solvent	pH		Density (g/cm3)	
				B.I.	A.I.	B.I.	A.I.
Borax	5	20	Pure water	9.19	9.21	1.040	1.043
Boric acid	5	20	Pure water	5.20	5.20	1.030	1.035
BX+BA	5(50:50)	20	Pure water	7.72	7.74	1.300	1.033
DAP	5	20		7.01	7.02	1.070	1.096

B.I.: before impregnation; A.I.: after impregnation

It can be seen that there is no change in the pH or density of the solutions after impregnation. This may be attributed to the fact that a fresh solution was used for each impregnation.

Table 3

Shear test results

Adhesive	Impreg. chemicals	Oak X.(N/mm^2)	Sd	Pine X.(N/mm^2)	Sd
UF	control	8.34	0.45	6.07	0.47
	BX	3.96	0.11	3.82	0.64
	BA	6.13	0.09	1.80 b	0.23
	BX+BA	7.09	0.37	4.91	0.51
	DAP	7.64	0.31	2.45	0.58
PF	control	6.99	0.15	5.50	0.34
	BX	3.35	0.47	3.80	0.44
	BA	3.50	0.68	2.25	0.42
	BX+BA	3.20	0.38	3.70	0.41
	DAP	5.01	0.13	2.96	0.47
MUF	control	8.74a	0.59	6.16	0.34
	BX	5.38	0.31	4.68	0.59
	BA	3.12	0.32	2.60	0.22
	BX+BA	3.80	0.12	2.99	0.52
	DAP	6.53	0.80	2.04	0.52

X: Average value Sd: standart devision . a The highest shear strength. b The lowest shear strength

According to test results wood material type, the highest shear strength value is obtained in Oak wood and the lowest shear strength in pine woods. According to wood adhesive type, the highest shear strength value is obtained in MUF and the lowest shear strength in UF adhesive. It can be said that the wood material type and adhesive type have affected the shear strength of the wood materials. The highest shear strength was obtained in control samples. The results indicated that the impregnating materials decreased the shear strength values. In accordance with the species of wood, the highest bonding strength was obtained in beech wood. If the beech wood cut with the proper tools, it gives good surface. Also, it has higher bonding strength due to its higher and its small tracheid (Cremonini et al. 1997).

Multivariance analyses were carried out for the shear strength of UF, PF and MF adhesives to impregnated wood materials, and these analyses indicated significant interactions between impregnating chemicals and adhesives. Based on the multivariance analysis for shear strength, the differences between the groups (wood material, adhesive and impregnating material) were statistically the same ($P < 0.05$). Then, the Duncan test was implemented to determine the importance of differences between the groups and the results are given in Table 4. Comparing the average values of shear strength in Table 5, the highest value (8.74N/mm^2) was obtained for control oak wood samples and MUF adhesive. The shear strength of samples treated with BA was lower (1.80N/mm^2) pine samples and UF adhesives. However, small differences were observed for different adhesives. The MUF adhesive gave higher value than the PF and MF adhesives for the same control samples.

CONCLUSION

The results of the tests carried out in this study revealed that the impregnation chemicals reduced the equilibrium moisture of shear strength of oak and pine wood bonded with PF, MF and MUF and adhesives. All the adhesives bonding performance was affected negatively by the impregnation chemicals.

The decreases in shear strength according to adhesives used were relatively similar. MUF adhesive gave the highest shear strength for the control samples oak and pine woods. PF adhesive gave the lowest shear strength for the boric acid impregnated oak and pine woods. In consequently, the impregnation process negatively affected the adhesive bonding strength.

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