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Effect of Impregnation with Timbercare Aqua on the Properties of Some Woods

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Abstract: The aim of this study was to investigate the effect of impregnation with timbercare aqua on the Modulus of Elasticity (MOE) in bending of some woods. According to Duncan test results, for non-impregnated woods MOE were found the highest in Oriental beech (12,490 N mm^{-2}), the lowest in Oriental spruce (8,165 N mm^{-2}). For impregnated woods, Modulus of Elasticity (MOE) were found the highest in Oriental beech once impregnated (14,360 N mm^{-2}) and the lowest in Scotch Pine thrice impregnated (7,246 N mm^{-2}). The results show that except for oak samples, one times impregnation with timbercare aqua due to the increasing MOE and impregnation with timbercare aqua can be useful for the wood material subject to bending stress, which needs high elasticity.

Key words: Modulus of elasticity, bending strength, wood materials, coating, chemical resistance

INTRODUCTION

Impregnation is the most effective condition for protecting wood against destructive effects (Miclasevics, 2004; Hazir *et al*., 2003). If the wood materials are used without processing by preventive chemicals, fungal stains, insect infestation, humidity, fire etc., damages the wood with respect to the usage area. As a result of these damages, the wood needs to be cared, maintained or replaced before its economic life ends (Örs and Keskin, 2008; Arsenal, 1978). If the wood is not impregnated but painted and varnished only, the prevention on the surfaces is maximum for two years (Evans *et al*., 1992).

Many different chemicals are used for impregnation. Some of them can also reduce the strength of lumber or plywood and effect related to the nature of the chemicals and to the drying temperatures used in the treating process (Terziev and Daniel, 2002; Winandy *et al*., 1988). Hemicellulose content was significantly reduced depending on the type of chemical, the exposure temperature and the specific hemicellulose residue examined. The degradation of hemicelluloses plays an important role in the reduction of strength properties (Susan *et al*., 1990).

Modulus of Elasticity (MOE) of treated jack pine samples treated in a two-step process that involved first a copper chloride or a copper chloride-sodium borate mixture and then a phenol-formaldehyde resin was not found to be statistically different from that of the untreated wood (Daniel *et al*., 2008). The specimens impregnated with a mixture of boric acid and T-C 3310 showed a decreasing effect, specially, bonding strength of 26% for beech and 21.9% for pine (Özçiftçi and Uysal, 2004).

In the impregnation of pine and beech wood with UA salts and tar oil, the tar oil increases compression strength by 10% and UA salts increase by some amount. The tar oil increases the bending strength but the UA salts decrease (Gillwald, 1961). Salty impregnation materials increases the compression strength by 4.6-9.6%, but decreases the bending strength by 2.9-16% (Wazny, 1973). In all wood materials excluding Scotch pine, modulus of elasticity in bending decreased as the impregnation period increased. It can be a result of less interaction between the wood fiber and the impregnation material in Scotch pine. As a matter of fact, it is acknowledged that pine species are more resistant to chemical materials than are other wood types (Bozkurt and Erdin, 1997).

In this research, Oriental spruce (*Picea orientalis* Lipsky), Scotch pine (*Pinus sylvestris* Lipsky), oak (*Quercus petrea* Liebl.) and Oriental beech (*Fagus orientalis* Lipsky) woods being used in furniture manufacturing were searched for the effects of impregnation with timbercare aqua on the Modulus of Elasticity in bending.

MATERIALS AND METHODS

Wood materials: The woods for the preparation of test samples are obtained from the timber sellers in Ankara by chance and woods with no defect that are knotless, not doty, have no reactionary part, that are normally grown and not damaged by fungus and insects were selected.

Impregnation material: Waterborne timbercare aqua used as an impregnation material in this study was supplied by Hickson Timber Products Ltd., Istanbul. Timbercare aqua is for using on door/window framing, wooden casings for metallic window frames, shutters, flooring blocks. roof caging systems, surface covers, eave-vault-balcony timbers and bearing components. Timbercare aqua is a non-flammable, odorless, fluent, water borne, completely soluble in water, non-corrosive material with a pH value of 4 and a density of 1.02 g cm^{-3}. It is available as a ready-made solution. It contains 0.5% w/w tebuconazole, 0.5% w/w propiconazole, 1% w/w 3-iodo-2-propynyl-butyl carbamate and 0.5% w/w cypermethrin. Before the application of timbercare 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. Timbercare aqua should be applied by the brush, 1 L of impregnation material for 4-5 m^2 of wood. Before the application of timbercare 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 should be left for drying for at least 24 h. The wood material can be painted, varnished or glued after it is fully dried (Hickson, 2000).

Determination of density: The density of wood material, used for the preparation of test samples was determined according to TS 2472 (TS 2472, 1976). For determining the air-dry density, the test samples with a dimension of 20×30×30 mm were kept under the conditions of 20±2°C temperature and percentage 65±5 relative humidity up to reaching a stable weight at the conditioned climatology room. The weights were measured with an analytic scale of ±0.01 g precision and dimensions were measured with a digital compass. The air-dry density (δ_{12}) of samples were calculated by using the following formula:

$$\delta_{12} = M_{12}/V_{12}$$

where, M_{12} is the air-dry weight and V_{12} is the volume at air-dry conditions.

The samples were kept at a temperature of 103±2°C in the drying oven up to reaching a stable weight for the determination of full-dry density. Full-dried samples are cooled in the desiccator containing $CaCl_2$ and then weighted at the scale having a precision of 0.01 g and the dimensions were measured with a compass having a precision of ±0.01 mm. After the volumes were determined by stereometric method, the density (δ_o) was calculated by the following equation:

$$\delta_0 = M_0/V_0$$

where, M_0 is the full-dry weight and V_0 is the volume of the wood material.

Determination of humidity: The humidity of test samples was determined before and after the impregnation process according to TS 2471 (TS 2471, 1976). For this purpose, the samples with a dimension of 2×2×2 cm are weighted and then oven dried at 103±2°C till they reach constant weight. Then, samples were cooled in desiccator containing calcium chloride ($CaCl_2$) and weighed in an analytic balance of 0,01 g sensitivity. The humidity of the sample (r) was calculated by the following formula:

$$r = ((M_r - M_0)/M_0)\times 100$$

where, M_r is the moist weight of the samples and M_0 is the dry weight of samples.

Preparation of experimental samples: The rough drafts for the preparation test and control samples were cut from the sapwood parts of massive woods and conditioned at a temperature of 20±2°C and 65±3% relative humidity for three months until reaching an equilibrium in humidity distribution. The samples, with a dimension of 20×20×400 mm were cut from the drafts according to TS EN 408 having 12% average value of humidity (TS EN 408, 1997).The densities and humidity ratios of all test samples were measured before the impregnation process.

The test samples were impregnated according to ASTM D 1413-99 (ASTM D 1413-99, 1976), TS 344 (TS 344, 1981) and TS 345 (TS 345, 1974). The test samples are dipped in the impregnation pool immersing 1 cm below the upper surface for 10 min in short-term dipping, 2 h for medium-term dipping and 5 days for long-term dipping. The specifications of the impregnation solution were determined before and after the process.

The processes were carried out at 20±2°C. Retention of impregnation material (R) was calculated by using the following formula:

$$R = GC/V\times 10^3 \quad (1)$$

$$G = T_2 - T_1 \quad (2)$$

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

Impregnated test samples were kept at a temperature of 20±2°C and 65±5% relative humidity until their weights became stable.

Application of experiment: The test of MOE was carried out according to TS EN 408 by using the following test equipment (Fig. 1).

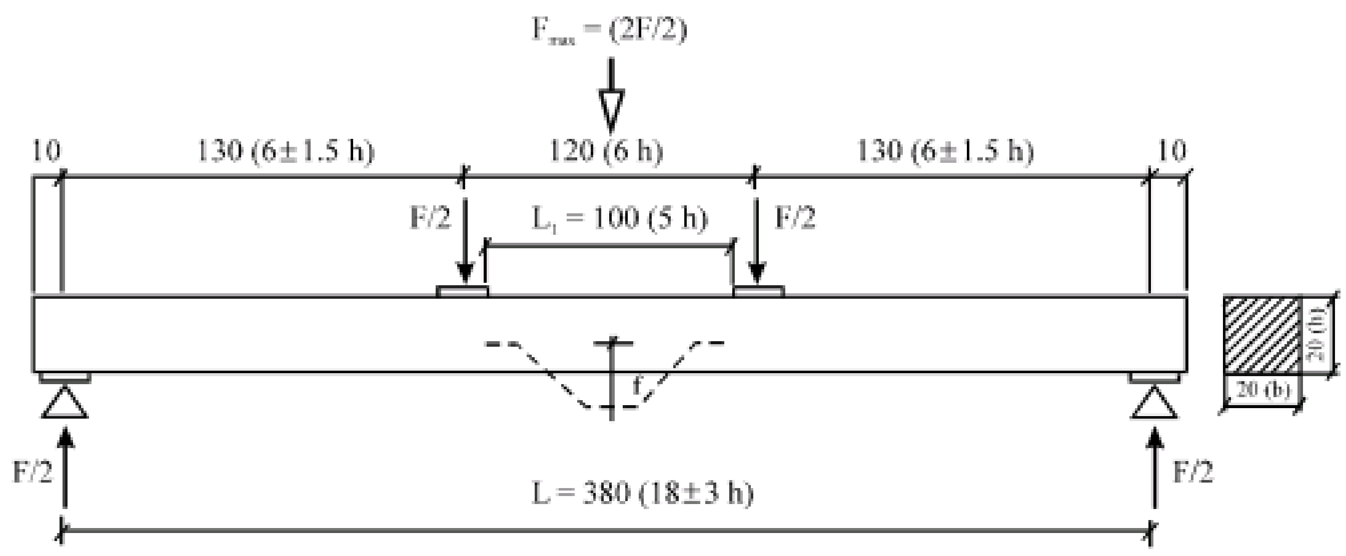

Fig. 1: Test equipment for modulus of elasticity in bending (mm)

The capacity of the universal testing equipment is 4.000 kP. Deformation at test samples was measured in a region five times the width of the sample by a tensionmeter. The deformations caused by incrementally increasing the forces were measured with a precision of 0.01 mm.

In the region of elastic deformation, MOE were calculated by the following formula:

$$E = (\Delta F L^3)/(4bh^3\Delta f)$$

where, ΔF is the difference between the arithmetic average of upper and lower limits of applied force in the elastic deformation region, Δf is the difference between the net rate of bending and the arithmetic average of the upper and lower limits of bending, L is the span, b is the width of test sample at cross section, h is the thickness at cross section.

Data analysis: By using four different kinds of wood and three different impregnation methods and control samples, a total of 160 samples (4×4×10) were prepared. Multiple Variance Analysis (MANOVA) technique was used to determine the differences between bending MOE of that samples. It was determined by the Duncan test whether the differences between the groups were meaningful or not.

RESULTS AND DISCUSSION

Density: Statistical values for the air–dry densities of samples impregnated with timbercare aqua are shown in Table 1.

Air-dry densities have been found different according to the methods of impregnation. Air-dry densities increased by the once and twice applications of impregnation.

Peculiarities of impregnation solutions: The pH value and density of timbercare aqua, used in the impregnation process did not change as pH value of 4 and a density of 1.02 g cm^{-3}, due to the use of fresh solution in each impregnation process.

Retention quantities: The amount of retention for the different kinds of wood and impregnation method interactions are shown in Table 2.

Table 1: Air-dry densities of wood materials (g cm^{-3})

Impregnation methods	Statistics values	Oriental spruce	Scotch pine	Oak	Oriental beech
Control	x	0.524	0.531	0.784	0.583
	Min	0.511	0.521	0.729	0.576
	Max	0.534	0.539	0.807	0.592
	S	0.0093256	0.0090983	0.0316054	0.0074006
	v	0.0000870	0.0000828	0.0009989	0.0000548
One times impregnation	x	0.529	0.539	0.789	0.585
	Min	0.521	0.523	0.731	0.556
	Max	0.535	0.552	0.812	0.603
	S	0.0060475	0.0115245	0.0356908	0.0176931
	v	0.0000366	0.0001328	0.0012738	0.0003130
Two times impregnation	x	0.532	0.542	0.786	0.593
	Min	0.521	0.530	0.739	0.588
	Max	0.541	0.552	0.802	0.605
	S	0.0083150	0.0096106	0.0268686	0.0077990
	v	0.0000691	0.0000924	0.0007219	0.0000608
Three times impregnation	x	0.530	0.535	0.790	0.590
	Min	0.516	0.530	0.781	0.584
	Max	0.539	0.545	0.794	0.598
	S	0.0091155	0.0062136	0.0055786	0.0068976
	v	0.0000831	0.0000386	0.0000311	0.0000476

Table 2: Retention amounts of wood materials (kg m^{-3})

Impregnation methods	Statistics values	Oriental spruce	Scotch pine	Oak	Oriental beech
One times impregnation	x	15.864	19.486	13.300	17.881
	Min	14.416	9.361	12.890	15.535
	Max	17.250	23.646	13.587	20.388
	S	1.2281532	5.8099018	0.2964027	2.1934112
	v	1.5083603	33.7549592	0.0878546	4.8110528
Two times impregnation	x	21.491	29.657	18.337	27.309
	Min	18.074	22.585	17.268	21.121
	Max	25.116	33.859	19.034	32.920
	S	2.7148407	4.5128813	0.7415812	4.8916688
	v	7.3703602	20.3660976	0.5499427	23.9284240
Three times impregnation	x	22.906	29.031	22.331	26.624
	Min	20.576	20.319	20.293	22.293
	Max	26.927	33.098	23.122	30.469
	S	2.4211722	5.0344697	1.1831597	3.4184792
	v	5.8620750	25.3458847	1.3998668	11.6859997

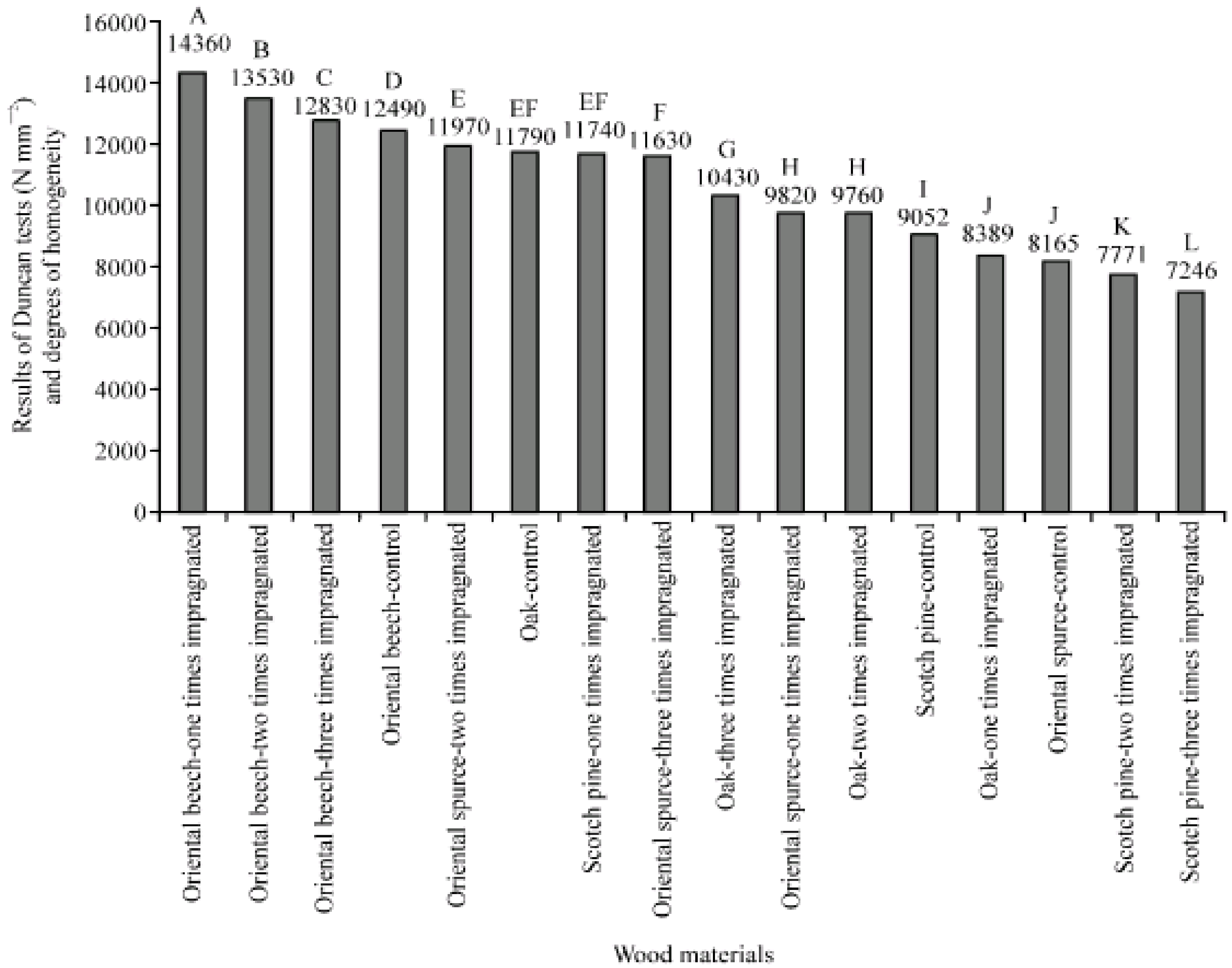

Fig. 2: Results of Duncan tests (N mm^{-2}) (*LSD = 224.0, **LSD = 70,85)

The amount of retention changes with the kind of wood and method of impregnation and it was found the highest in Scotch pine and the lowest in oak. As the impregnation repetition increases from once to twice the amount of retention increases. But it was not continuous from two to three times applications of impregnation.

Modulus of elasticity in bending: The average values of MOE in bending according to the type of wood and impregnation period are shown in Table 3.

Modulus of elasticity in bending was found the highest in Oriental beech. This may be due to the highest density of Oriental beech. MOE in bending was found the highest in one times application of impregnation material timbercare aqua and the lowest in three times application. The repetition of impregnation causes a decrease in MOE. So impregnation method and repetition were found effective on the MOE. The results of multiple variance analysis of wood material and impregnation method in bending modulus of elasticity are shown in Table 4.

As a result of the Duncan test for the effects of variance sources on the bending MOE, the difference between the groups ($\alpha = 0.05$) was meaningful as shown in Fig. 2.

According to Duncan test results, for non-impregnated woods MOE were found the highest in Oriental beech (12,490 N mm^{-2}), the lowest in Oriental spruce (8,165 N mm^{-2}) and for impregnated woods, the highest in Oriental beech once impregnated (14,360 N mm^{-2}) and the lowest in Scotch pine thrice impregnated (7,246 N mm^{-2}). MOE according to wood materials and impregnation periods are shown in Fig. 3. At the similar studies, MOE were less in spruce than

Table 3: Average MOE in bending according to the type of materials and impregnation period

Types of material	σ_k (N mm^{-2})	HG
Wood of species*		
Oriental spruce	10396.00	B
Scotch pine	8951.44	D
Oak	10091.60	C
Oriental beech	13303.50	A
Method**		
Control	10373.20	D
One times application of impregnation	11076.30	A
Two times application of impregnation	10757.90	B
Three times application of impregnation	10535.00	C

*LSD = 224.0, **LSD = 70,85, HG = Degrees of Homogeneity

Table 4: Results of multiple variance analyses of wood material and impregnation period in bending modulus of elasticity

Source	Sum of squares	df	Mean square	F-value	Probably % (Sig.)
Int.-A	411894564.365	3	137298188.122	5390.659	000
Int.-B	11127771.523	3	3709257.174	145.634	000
A×B	283113698.766	9	31457077.641	1235.081	000
Error	3667629.646	144	25469.650		
Corrected total	709803664.300	159			

Int.-A : Wood materials, Int.-B: Impregnation methods

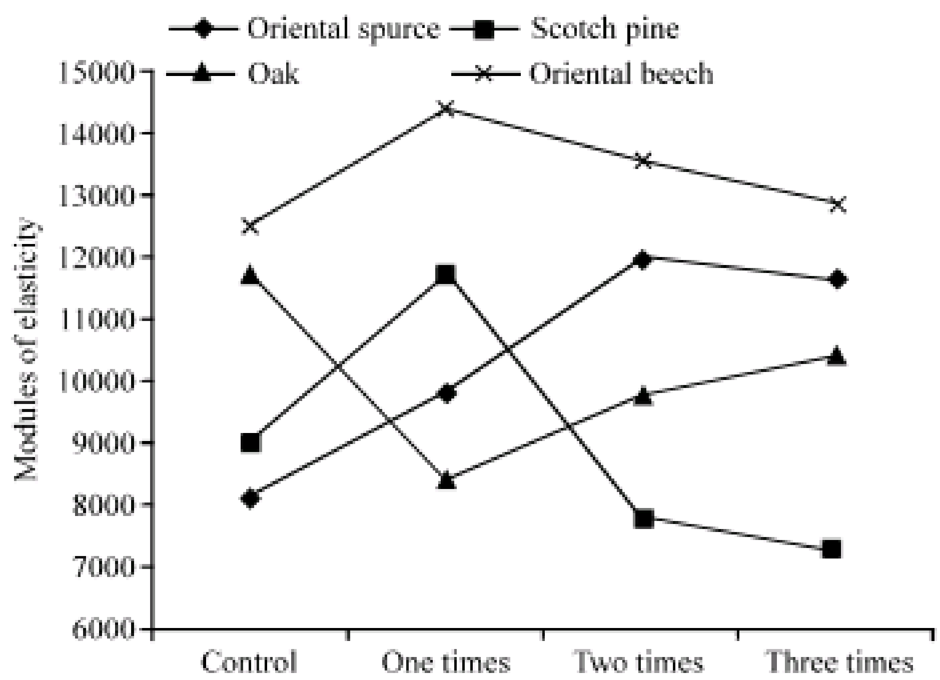

Fig. 3: Modulus of elasticity (N mm^{-2}) according to wood species and repetition of impregnation

Scotch pine and oak (Örs *et al*., 2006). But after the impregnation by the timbercare aqua this value was measured as higher.

MOE in bending decreases as the impregnation period increases in wood material except Scotch pine. This may be due to the interaction between the wood fiber and impregnation material. It is known that pine woods are chemically more resistant than other woods.

CONCLUSION

In the impregnation with timbercare aqua, type of wood, impregnation method and combination of both were found effective on the bending modulus of elasticity ($\alpha = 0.05$).

The highest MOE as mean values was measured in Oriental beech (13,303 N mm^{-2}). This result is similar with the literature and may be due to the highest density of Oriental beech. In the literature, mean values of MOE were less in spruce than Scotch pine and oak but it was measured as higher by the effect of timbercare aqua.

For the combination of impregnation material and wood type, MOE was measured highest in single impregnated Oriental beech and lowest in triple impregnated Scotch pine. Needle type of woods are more resistant to chemical substances than leave woods. In this study, timbercare aqua effected Scotch pine and Oriental beech similarly but oak and Oriental spruce differently.

MOE of impregnated samples except oak were measured higher than control samples. MOE was measured highest in single impregnation (11,076 N mm^{-2}) and decreased by the double and triple impregnation. According to this result, it can be said that timbercare aqua increases MOE of all wood except oak. A decrease in the MOE of oak wood in single impregnation and in other woods by the double and triple impregnation may be due to a decrease on the bond between the wood leafs by the oxidation effect of timbercare aqua.

As a result, the effect of timbercare aqua on MOE for the tested woods is found important. MOE of oak is decreased by impregnation with timbercare aqua but increased in the other woods. So, single impregnation of Oriental beech, Scotch pine and Oriental spruce is sufficient but for oak, using place is important for decision making in impregnation.

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