December 2006 Volume 2 Issue 6

Materials Science

Trade Science Inc.

An Indian Journal

Full Paper

MSAIJ, 2(6), 2006 [197-206]

Impacts Of Impregnation With Imersol-Aqua On The Compression Strength Of Laminated Wood Materials

Corresponding Author

Hakan Keskin
Gazi University, Industrial Arts Education Faculty, 06500 Ankara, (TURKEY)
Fax: +90 312 2127763
E-Mail: khakan@gazi.edu.tr

Co-Author

Abdullah Togay
Gazi University, Industrial Arts Education Faculty, 06500 Ankara, (TURKEY)

Received: 31st October, 2006
Accepted: 15th November, 2006

Web Publication Date : 27th December, 2006

ABSTRACT

The aim of this study was to investigate the effects of impregnation with imersol-aqua on the compression strength of some laminated wood materials. For this aim, oriental beech (*Fagus orientalis Lipsky*), oak (*Quercus petrea Liebl.*), scotch pine (*Pinus sylvestris Lipsky*), uludag fir (*Abies Bornmülleriana Lipsky*) and oriental spruce (*Picea orientalis Lipsky*) wood materials impregnated with imersol-aqua according to ASTM D 1413-99 and producers' definition. Laminated wood samples were produced from impregnated wood materials according to TS EN 386 in the form of five ply (4 mm each) from oriental beech, oak, scotch pine, uludag fir and oriental spruce wood by using desmodur-VTKA adhesive. The test samples were prepared and compression strength was measured according to TS 2595. Consequently, impregnation and lamination process increased compression strength by 1.01 % in oriental beech (BI+L_W), 19.92 % in oak (OI+L_W), 21.37 % in scotch pine (PI+L_W), 0.39 % in oriental spruce (SI+L_W) and 0.16 % in Uludag fir (FI+L_W) as compared with massive (solid wood) control samples (S_W). In consequence, in the massive construction and furniture elements that the compression strength after the impregnation and lamination (I+L_W) is of great concern, oak and scotch pine wood materials could be recommended.

KEYWORDS

Compression strength;
Impregnation;
Imersol-Aqua;
Laminated wood materials;
Desmodur-VTKA.

INTRODUCTION

Wood has good insulating properties against heat and sound. It can be worked easily and it is available in many texture, color, sizes, and shapes. Due to its properties, wood is being used for variety of aims. In the forest products industry, raw materials should be used economically and reasonably to improve the utilization of timber. This is a vital issue for the future of the forest resources.

Long and curved forms may not be manufactured from solid wood due to production difficulties and economic reasons. The lamination technique has been used to produce variety of shapes (curved, tapered and ribbed) of wood members to suit architectural and structural aims. Also, short wood pieces can be used for this purpose and it is possible to eliminate strength reducing characteristics due to knots, shakes or drying, because the lamination need not be thick when seasoned before manufacturing. The properties can be improved by using dried and small thickness of wood without degrades. Laminae may be positioned due to strength criteria with respect to species, density, grades and defects. Laminated timber has less variability in strength and stiffness compared to solid sawn timber.

Laminated veneer lumber (LVL) has more superior values, technological properties, more aesthetic and economic than solid woods. It can be used for production of furniture, cupboard, desk, chair, table etc.[1].

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

Among the materials used for the impregnation of pine; sodium pentaclorfenet, cupper sulphate and sodium fluoride increased the compression strength respectively by 95%, 25% and 3% whereas zinc chloride decreased the compression strength by 9 %. sodium pentaclorfenet also increased the bending strength[4].

It was assessed that, salty impregnation materials increased the compression strength by 4.6-9.6 %, whereas decreased the bending strength by 2.9-16 %[5]. In another study, chromate copper arsenate (CCA) and arsenate copper arsenate (ACA) salts did not caused any significant impact on modulus of elasticity in bending[6].

Impregnation of alder (*Alnus glutinosa Lipsky*) with vinyl-monomers increased the compression strength[7]. In another study, impregnation of scotch pine and oriental spruce with zinc clor and sulphate did not cause to a decrease in the compression strength[8].

In this study, laminated oriental beech (*Fagus orientalis Lipsky*), oak (*Quercus petrea Liebl.*), scotch pine (*Pinus sylvestris Lipsky*), oriental spruce (*Picea orientalis Lipsky*) and uludag fir (*Abies Bornmülleriana Lipsky*) woods commonly being used in furniture manufacturing and construction were examined with respect to the impacts of impregnation with imersol-aqua on the compression strength..

EXPERIMENTAL

Wood materials

The woods to be used as test samples were randomly selected from the timber merchants of ankara. specific pains were taken for the selection of wood materials. Accordingly, non-deficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect mushroom damages) wood materials were selected.

Impregnation material

Imersol-aqua used as an impregnation material in this study was supplied from Hemel-Hickson Timber Products Ldt., Istanbul. Imersol-aqua 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. In the impregnation process, dipping duration was at least 6 minutes and the impregnation pool contained at least 15 litres of impregnation material for 1 m^{-3} of wood. The impregnated wood was left for drying at least 24 hours[9].

Adhesive

Desmodur-VTKA adhesive usually has been found preferable for the assembly process in the woodworking industry. It is a one compenented (without any solvent), polyurethane based and moisture cured adhesive. Bonding surface should be clean, dry, dust less and oil less. Dry surfaces should be moistured so as to increased hardening speed of the glue. Glue is directly applied to one of the surfaces and bonding process is conducted at 20±2°C and 65±5 % relative humidity conditions. Polyurethane glue has a pH of about 7 and a viscosity of 5500-7500 mPa s at 25±2ºC. Its density is 1.11±0.02 g cm^{-3}, the period of solidification at 20±2°C with 65±5 % relative humidity is 24 h. It is recommended that desmodur-VTKA adhesive be applied to both surfaces 150-200 g m^{-2}. It solidifies in 30 min. According to its producer[10].

Determination of density

The densities of laminated wood materials, used for the preparation of test samples were determined according to TS 2472[11]. 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 and 65±5 % relative humidity until they reached to a stable 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 formula;

$$\delta_{12} = \frac{M_{12}}{V_{12}} \, g\,cm^{-3} \qquad (1)$$

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

The samples were kept at a temperature of 103±2°C in the drying oven until they reached to a stable weight for the assessment of full-dry density. Afterwards, full-dried samples were cooled in the desiccators containing phosphorus pentoxide (P_2O_5). Then, they were weighted on a scale of ±0.01 g sensi tivity and their dimensions were measured with a compass of ±0.01 mm sensitivity. The volumes of the samples were determined by stereo metric method and the densities (δo) were calculated by the formula;

$$\delta_0 = \frac{M_0}{V_0} \, g\,cm^{-3} \qquad (2)$$

Where, M_0 is the full-dry weight (g), and V_0 is the full-dry volume of the wood material (cm^3).

Determination of humidity

The humidity of test samples before and after the impregnation process was determined according to TS 2471[12]. Thus, the samples with a dimension of 20×20×30 mm were weighed and then oven dried at 103±2°C till they reach to a constant weight. Then, the samples were cooled in desicator containing phosphorus pentoxide (P_2O_5) and weighed with an analytic scale of 0.01g sensitivity. The humidity of the samples (h) was calculated by the formula;

$$h = \frac{Mr - M_0}{M_0} \times 100\, g\, g^{1} \qquad (3)$$

Where, Mr is the initial weight of the samples (g) and M_0 is the final dry weight (full-dry) of the samples (g).

Preparation of test specimens

The test lumbers, for the preparation laminated wood, with a dimension of 25×30×500 mm were cut from the sapwood parts of solid woods and conditioned at a temperature of 20±2°C and 65±5 % relative humidity for three months until reaching an equilibrium in humidity distribution.

The lumbers were impregnated according to ASTM D 1413-99[13], TS 344[14] and TS 345[15] with imersol-aqua by dipping method. The lumbers were dipped in the impregnation pool immersing 1 cm below the upper surface for 2 hours for medium-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 the

Full Paper

formula;

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

where, G is the amount of impregnation solution absorbed by the sample (g), T_2 is the sample weight after the impregnation (g), T_1 is the sample weight before the impregnation (g), C is the concentration (%) of the impregnation solution, and V is the volume of the samples (cm^3).

Laminated lumbers, with a dimension of 20×30×500 mm were produced according to TS EN 386[16]. For this purpose, veneers with 4 mm thickness, were cut from air-density lumbers with a dimension of 25×30×500 mm by using circular saw machine. The glue was spread to one surface of veneer by using a roll. The spreading rate of glue was approximately 180 gm^{-2}. The spreading rate was calculated by weighting each veneer before and after gluing. The glue line pressure ranged between 0.7-1.2 N mm^{-2} depending on the species of wood, and solidified in ~30 min. Laminated lumbers were kept under a temperature of 20±2°C and 65±5 % relative humidity until reaching to a stable weight.

Test samples of compression strength, with a dimension of 20×20×30 mm, parallel to the fiber and glue line were cut from the drafts having an average humidity of 12 % according to TS 2595[17].

Application of experiment

The tests for compression strength of parallel to fiber and glue line of laminated wood materials were carried out with the universal testing equipment shown in figure 1, according to TS 2595.

The capacity of the universal testing equipment was 400 N. The speed of the test machine was adjusted to 5 mm/min. for crashing to occur in 1-2 minutes.

Compression strength was calculated by the formula;

$$\sigma = \frac{F_{max}}{a.b} N \cdot mm^{-2} \qquad (5)$$

Where F_{max} is the breaking load on the scale (N), α is the cross-sectional width of test sample (mm), b is the cross-sectional thickness of the test sample (mm).

Statistical evaluation

A total of 20 treatment groups were obtained with five different kinds of wood materials. Ten replications were made in each treatment group. Thus, a total of 200 samples (5×4×10) were prepared. When the differences between groups were found to be significant, duncan test was used to determine the differences between means at prescribed level of α=0.05. Statistical values (ANOVA, mean, deviation of standard, variance, minimum, maximum values) were calculated by the SPSS 13 for Windows computer software.

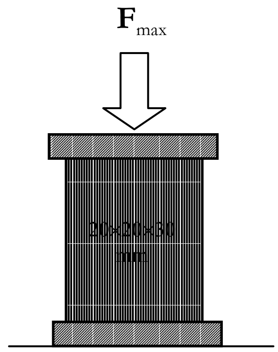


Figure 1: Test equipment for compression strength

RESULT AND DISCUSSION

Peculiarities of impregnation solutions

The pH value and density of imersol-aqua, 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.

Retention quantities

Results of retention test were summarized by using descriptive statistics such as the maximum, minimum, mean, standard deviation and variance. Descriptive statistical values of tested retention amounts of test samples were given in TABLE 1.

ANOVA of the impact of impregnation method on retention of impregnated and laminated wood materials is given in TABLE 2.

According to ANOVA, differences between groups were found to be significant ($F4;45=1202.550$, $P<0.05$). Duncan test was used to determine the differences between means at prescribed level of α = 0.05 and results of Duncan Test are given in TABLE 3.

TABLE 1: The quantities of retention of solid wood materials (kg m^{-3})

Impregnation method	Statistical values	Beech	Oak	Pine	Spruce	Fir
Medium-term Dipping (S_W)	X	213.599	62.590	71.363	96.941	80.901
	Ss	9.9374369	3.90152568	4.38988273	2.00093827	2.5564009
	v	109.72517	16.9132252	21.4123004	4.448615511	7.261317289
	Min	194.836	56.594	62.951	92.406	77.672
	Max	225.965	69.681	78.665	99.658	85.892

S_w : Solid wood, Min: Minimum, Max: Maximum, Ss: Standard deviation, v: Variance

TABLE 2: ANOVA indicating the impact of wood types and impregnation method on retention

Source	SS	DF	MS	F Value	SIG*
Between groups	153696.086	4	38424.022	1202.550	0.000
Within groups	1437.846	45	31.952		
Total	155133.932	49			

*P<0.05, SS: Sum of Squares, DF: Degrees of Freedom, MS: Mean Square, SIG: Significance

According to duncan test results, highest retention amount was obtained in oriental beech and the lowest was in oak wood samples. The highest retention amount obtained in oriental beech could be attributable to the

TABLE 3: Retention amounts as a result of duncan test

Wood material(S_W)	Subset for alpha = 0.05				
	1	2	3	4	5
Oak	62.590				
Scotch pine		71.362			
Uludag fir			80.901		
Oriental spruce				96.941	
Oriental beech					213.599
Sig.	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed. Uses harmonic mean sample size = 10

TABLE 4: Full-dry densities of wood materials (g cm^{-3})

Process	Statistical values	Beech	Oak	Pine	Spruce	Fir
S_W	x	0.658	0.636	0.539	0.404	0.387
	Ss	0.02222611	0.02597306	0.02015937	0.021156559	0.015119524
	v	0.00054889	0.00074956	0.00045156	0.000497333	0.000254
	Min	0.619	0.599	0.511	0.382	0.356
	Max	0.692	0.668	0.579	0.452	0.412
I+S_W	x	0.665	0.657	0.561	0.413	0.403
	Ss	0.01329662	0.02524678	0.01649848	0.011668762	0.023289483
	v	0.00019644	0.00070822	0.00030244	0.000151289	0.000602667
	Min	0.641	0.619	0.532	0.402	0.356
	Max	0.686	0.699	0.582	0.441	0.438
L_W	x	0.675	0.665	0.565	0.426	0.409
	Ss	0.01412799	0.02170253	0.01734935	0.014696938	0.025632011
	v	0.00022178	0.00052333	0.00033444	0.00024	0.00073
	Min	0.648	0.638	0.535	0.408	0.368
	Max	0.701	0.698	0.584	0.451	0.441
I+L_W	x	0.684	0.671	0.572	0.434	0.417
	Ss	0.01404279	0.01633401	0.01987687	0.011949895	0.021452273
	v	0.00021911	0.00029644	0.00043899	0.000158667	0.000511333
	Min	0.662	0.649	0.548	0.418	0.388
	Max	0.712	0.705	0.608	0.456	0.462

S_w: Solid wood, I+S_w: Impregnated solid wood, L_w: Laminated wood, I+L_w: Impregnated + laminated wood, x: Mean

Full Paper

impact of permeability.

Full-dry density

Statistical values for the full-dry density of test samples impregnated with imersol-aqua by using medium-term dipping (2 hours) method and laminated with desmodur-VTKA adhesive are given in TABLE 4.

ANOVA of the impact of impregnation method on full-dry densities of impregnated and laminated wood materials are given in TABLE 5.

According to ANOVA, differences between groups were found to be significant ($F_{19;180}$=335.703, P<0.05). Duncan test was used to determine the differences between means at prescribed level of $\alpha = 0.05$ and results of duncan test are given in TABLE 6.

TABLE 5: ANOVA indicating the impact of wood types and process on the full-dry density

SOURCE	SS	DF	MS	F Value	SIG*
Between groups	2.595	19	0.137	335.703	0.000
Within groups	0.073	180	0.000		
Total	2.668	199			

***P<0.05**

As seen from the TABLE 6, impregnated + laminated oriental beech wood (BI+L_W) specimens have the highest air dry density. In contrast, uludag fir solid wood (FS_W) specimens have the lowest air-dry density in all groups.

Air-dry density

Statistical values for the air-dry density of test samples impregnated with imersol-aqua by using medium-term dipping method (2 hours) and laminated with desmodur-VTKA adhesive are given in TABLE 7.

ANOVA of the impact of impregnation method on air-dry densities of impregnated and laminated wood materials is given in TABLE 8.

According to ANOVA, differences between groups were found to be significant ($F_{19;180}$ = 362.618, P<0.05). Duncan test was used to determine the differences between means at prescribed

TABLE 6: Full-dry densities as a result of duncan test

Process	1	2	3	4	5	6	7	8	9
FSw	0.387								
FI+Sw	0.403	0.403							
SSw	0.404	0.404							
FLw		0.409	0.409						
SI+Sw		0.413	0.413						
FI+Lw		0.417	0.417	0.417					
SLw			0.426	0.426					
SI+Lw				0.434					
PSw					0.539				
PI+Sw						0.561			
PLw						0.565			
PI+Lw						0.572			
OSw							0.636		
OI+Sw								0.657	
BSw								0.658	
BI+Sw								0.665	0.665
OLw								0.665	0.665
OI+Lw								0.671	0.671
BLw								0.675	0.675
BI+Lw									0.684
Sig.	0.076	0.172	0.087	0.076	1.000	0.249	1.000	0.082	0.061

Means for groups in homogeneous subsets are displayed. Uses Harmonic Mean Sample Size = 10
Subset for alpha = 0.05, B : Beech, O : Oak, P : Pine, S : Spruce, F : Fir

TABLE 7: Air-dry densities of wood materials (g cm^{-3})

Process	Statistical values	Beech	Oak	Pine	Spruce	Fir
S_W	x	0.682	0.666	0.568	0.422	0.405
	Ss	0.01831393	0.02263184	0.01638292	0.02131666	0.011331372
	v	0.00037267	0.00056911	0.00029822	0.000504889	0.000142667
	Min	0.652	0.625	0.539	0.399	0.392
	Max	0.709	0.688	0.597	0.464	0.432
$I+S_W$	x	0.693	0.679	0.591	0.435	0.414
	Ss	0.01551129	0.01793321	0.02179449	0.017623847	0.009022195
	v	0.00026733	0.00035733	0.00052778	0.000345111	9.04444E-05
	Min	0.668	0.646	0.541	0.409	0.404
	Max	0.716	0.701	0.617	0.471	0.43
L_W	x	0.697	0.682	0.607	0.449	0.428
	Ss	0.01692926	0.02167948	0.02483948	0.018681542	0.014456832
	v	0.00031844	0.00052222	0.00068556	0.000387778	0.000232222
	Min	0.664	0.651	0.566	0.422	0.411
	Max	0.719	0.712	0.639	0.478	0.454
$I+L_W$	x	0.712	0.688	0.616	0.456	0.437
	Ss	0.01451206	0.02092845	0.02709982	0.019879638	0.016679329
	v	0.000234	0.00048667	0.000816	0.000439111	0.000309111
	Min	0.691	0.652	0.571	0.431	0.416
	Max	0.734	0.716	0.662	0.492	0.472

TABLE 8: ANOVA indicating the impact of wood types and process on the air-dry density

Source	SS	DF	MS	F Value	SIG*
Between groups	2.724	19	0.143	362.618	0.000
Within groups	0.071	180	0.000		
Total	2.795	199			

*P<0.05

level of $\alpha = 0.05$ and results of duncan test are given in TABLE 9.

As seen from the TABLE 9, impregnated + laminated oriental beech wood ($BI+L_W$) specimens have the highest air dry density. In contrast, uludag fir solid wood (FS_W) specimens have the lowest air-dry density in all groups.

Compression strength

Test results of compression strength were summarized by using descriptive statistics such as the maximum, minimum, mean, standard deviation and variance. Descriptive statistical values of tested compression strength test samples were given in TABLE 10.

As well as that, average values of the interaction between the wood material type and process and the results of ANOVA and duncan test results regarding the impacts of wood type and process on the compre - ssion strength are given in TABLE 11 and TABLE 12, respectively.

As seen from the TABLE 11, differences between groups were found to be significant ($F19;180 = 116.107$, $P<0.05$). Duncan test was used to determine the differences between means at prescribed level of $\alpha = 0.05$ and results of Duncan test are given in TABLE 12.

According to duncan test results, impregnated and laminated oak wood ($OI+L_W$) specimens have the highest compression strength value. In contrast, impregnated uludag fir wood ($FI+S_W$) specimens have the lowest compression strength value in all groups.

The compression strength determined with regard to the wood types and process are given in figure 2.

Among the impregnated+laminated wood ($I+L_W$) materials, the highest compression strength value was obtained in oak ($OI+L_W$) and the lowest value in Uludag fir ($FI+L_W$).

Among the impregnated+solid wood ($I+S_W$) materials, the highest compression strength value was obtained in oriental beech ($BI+S_W$) and the lowest

TABLE 9: Air-dry density results of duncan test

Process	1	2	3	4	5	6	7	8	9	10	11
FSw	0.405										
FI+Sw	0.414	0.414									
SSw	0.422	0.422	0.422								
FLw		0.428	0.428								
SI+Sw			0.435	0.435							
FI+Lw			0.437	0.437							
SLw				0.449	0.449						
SI+Lw					0.456						
PSw						0.568					
PI+Sw							0.591				
PLw							0.607	0.607			
PI+Lw								0.616			
OSw									0.666		
OI+Sw									0.679	0.679	
OLw									0.682	0.682	
BSw									0.682	0.682	
OI+Lw										0.688	
BI+Sw										0.693	
BLw										0.697	0.697
BI+Lw											0.712
Sig.	0.072	0.139	0.127	0.139	0.432	1.000	0.074	0.313	0.102	0.078	0.093

Subset for alpha : 0.05

TABLE 10: Compression strength values of wood materials (N mm^{-2})

Process	Statistical values	Beech	Oak	Pine	Spruce	Fir
Sw	X	68.980	57.677	53.470	50.673	48.508
Sw	Ss	2.2429614	2.52022821	2.79035682	2.022304715	1.98041222
Sw	V	5.58986204	7.05727804	8.6512124	4.544129289	4.357813956
Sw	Min	63.524	53.624	49.525	47.625	45.954
Sw	Max	71.628	63.527	57.125	54.214	52.347
I+Sw	X	57.924	55.264	52.547	47.454	44.629
I+Sw	Ss	2.20847232	2.48030531	2.3025075	1.581591948	2.078217517
I+Sw	V	5.41927779	6.83546046	5.8906009	2.7793701	4.798875611
I+Sw	Min	53.625	50.289	49.628	43.527	41.365
I+Sw	Max	62.325	59.578	58.065	49.651	48.627
Lw	X	70.224	64.766	60.781	56.243	53.883
Lw	Ss	1.93259301	3.75372101	3.24191982	2.459428055	3.589909018
Lw	v	4.1499064	15.6560238	11.6778268	6.720873733	14.31938529
Lw	Min	67.523	59.532	57.003	51.325	47.356
Lw	Max	74.337	70.124	68.624	58.633	58.627
I+Lw	x	69.682	72.031	68.003	50.876	48.588
I+Lw	Ss	2.16387412	1.96247121	1.49469384	2.137968335	1.396668107
I+Lw	v	5.20261246	4.27921471	2.4823441	5.078787333	2.167424222
I+Lw	Min	65.312	69.627	65.339	48.627	46.223
I+Lw	Max	72.461	75.245	70.229	55.637	50.324

value in uludag fir ($FI+S_W$).

Among the laminated wood (L_W) materials, the highest compression strength value was obtained in oriental beech wood samples (BL_W) and the lowest value in uludag fir (FL_W).

Among the solid wood (S_W) materials, the highest compression strength value was obtained in oriental beech wood samples (BS_W) and the lowest value in uludag fir (FS_W).

TABLE 11: ANOVA indicating the impact of wood types and process on compression strength

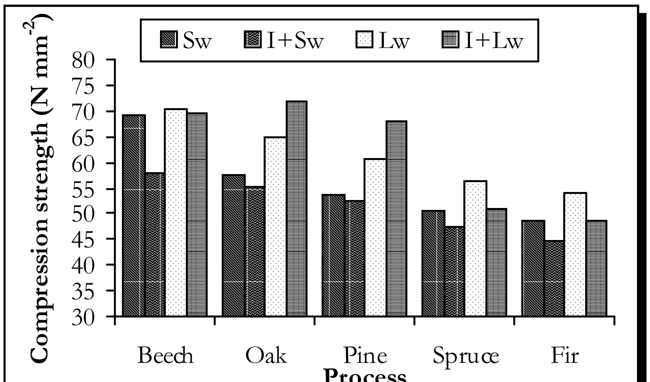
SOURCE	SS	DF	MS	F value	SIG*
Between groups	14055.862	19	739.782	116.107	0.000
Within groups	1146.876	180	6.372		
Total	15202.738	199			

*P<0.05

TABLE 12: Duncan test results

Process	1	2	3	4	5	6	7	8	9	10	11	12
FI+Sw	44.629											
SI+Sw		47.454										
FSw		48.508	48.508									
FI+Lw		48.588	48.588									
SSw			50.673	50.673								
SI+Lw			50.876	50.876								
PI+Sw				52.547	52.547							
PSw					53.515	53.515						
FLw					53.883	53.883						
OI+Sw						55.264	55.264					
SLw							56.243	56.243				
OSw								57.677				
BI+Sw								57.924				
PLw									60.781			
OLw										64.766		
PI+Lw											68.003	
BSw											69.028	
BI+Lw											69.682	
BLw											70.224	70.224
OI+Lw												72.031
Sig.	1.000	0.348	0.056	0.119	0.268	0.146	0.387	0.162	1.000	1.000	0.073	0.111

Subset for alpha : 0.05



S_W: Solid wood, $I+S_W$: Impregnated solid wood, L_W: Laminated wood, $I+L_W$: Impregnated + laminated wood

Figure 2: Compression strength determined with regard to the wood materials and process

CONCLUSION

The amount of retention was observed as sufficient in scotch pine as but higher than expected in oriental beech. The lowest retention amounts were found in scotch pine and oak. This may be due to resin in scotch pine and tyloses in oak.

The air-dry and full-dry densities of impregnated samples increased with respect to unimpregnated samples. Impregnated and laminated oriental beech wood ($BI+L_W$) specimens have the highest air-dry and full-dry density. In contrast, uludag fir solid wood (FS_W) specimens have the lowest air-dry density in all groups. This may be due to the impregnation and gluing process.

Compression strength was measured in massive (S_W), impregnated massive ($I+S_W$) and laminated massive (L_W) woods as highest in oriental beech and lowest in uludag fir. In impregnated and then laminated woods ($I+L_W$), compression strength was measured as highest in oak (72.031 N mm^{-2}) and lowest in uludag fir (48.588 N.mm^{-2}). According to this results, impregnation and lamination process increased the compression strength.

Impregnation and lamination process increased compression strength by 1.01 % in oriental beech ($BI+L_W$), 19.92 % in oak ($OI+L_W$), 21.37 % in scotch pine ($PI+L_W$), 0.39 % in oriental spruce ($SI+L_W$) and 0.16 % in uludag fir ($FI+L_W$) as compared with massive (solid wood) control samples (S_W).

It has been determined that the compression strength of impregnated+laminated ($I+L_W$) in softwoods (particularly scotch pine) have more superior values than the S_W, L_W and $I+S_W$ materials which were representing their kinds. This situation can be attributable to the higher resistance of scotch pine against the chemical substances. It was reported that the softwood woods, having less hemicelluloses are more resistant to chemical effects than hardwood woods[18].

In consequence, in the massive construction and furniture elements that the compression strength after the lamination and impregnation ($I+L_W$) is of great concern, oak and scotch pine wood materials could be recommended.

REFERENCES

[1] C.A.Eckelman; Forest Products Society J., **43**, 19-24 **(1993)**.
[2] B.A.Richardson; 'Wood Preservation', Construction Press, Lancaster, UK, **(1987)**.
[3] P.D.Evans, A.J.Michell, K.Schmalzl; Wood Science Technology, **26**, 151-163 **(1992)**.
[4] A.J.Vologdin; Novyje Dreviesinyje Materialy, Moskova, **(1976)**.
[5] J.Wazny; Dreviesiny Sreda, **3**, 181-185 **(1973)**.
[6] B.A.Bendtsen; USDA Forest Service, 434 **(1984)**.
[7] A.Temiz; Physical and Mechanical Properties of Wood-Polymer Composites Prepared from Alder Wood, 32nd Annual Meeting Nara, Japan, **(2001)**.
[8] L.Tetjamer; Material Prüfungsaf, Schweizerischen Polytechnikum, Paul Paray Verlac, Zurich, **(1986)**.
[9] Hickson's Timber Impregnation Co. (GB) Ltd., Into the 21st Century, Imersol-Aqua Brochure, Datassheet, 6214; **2**, 1-4, Hickson Timber Treatments, **(2000)**.
[10]. Y.Ors, M.Atar, H.Keskin; International Journal of Adhesion and Adhesives, **24(4)**, 287-294 **(2003)**.
[11] TS 2472, Assessment volume density for the mechanical and physical tests of woods, TSE, **(1976)**.
[12] TS 2471, Assessment of humidity for the mechanical and physical tests of woods, TSE, Ankara, **(1976)**.
[13] ASTM D 1413-76, Standard test method of testing wood preservatives by laboratory Soilblock Cultures, ASTM Standards, 452-460, **(1976)**.
[14] TS 344, General methods for the conservation of wood materials, TSE, Ankara, **(1981)**.
[15] TS 345, Test methods for determining the impacts of wood impregnation materials, TSE, Ankara, **(1974)**.
[16] TS EN 386, Glued laminated timber- performance requirements and minimum production requirements, TSE, Ankara, **(1999)**.
[17] TS 2595, The test methods for determining the compression strength of parallel to grains of wood materials, TSE, Ankara, **(1977)**.
[18] F.P.Kollman, A.Cote; 'Principles of Wood Science and Technology, Springler-Verlac, **1**, 66-70 **(1968)**.