August 2007 Volume 3 Issue 3

Trade Science Inc.

Materials Science

An Indian Journal

Full Paper

MSAIJ, 3(3), 2007 [159-166]

The Effects Of Impregnation With Imersol-Aqua On The Bending Strength Of Some Softwood And Hardwood Materials

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Received: 24th December, 2006 ; Accepted: 29th December, 2006

ABSTRACT

The aim of this study was to investigate the impacts of impregnation with imersol-aqua on the bending strength of some solid wood materials. For this aim, Oriental beech(*Fagus orientalis Lipsky*), oak(*Quercus petrea Liebl.*), Scotch pine(*Pinus sylvestris Lipsky*), Uludag fir(*Abies Bornmülleriana Lipsky*), Oriental spruce(*Picea orientalis Lipsky*) and poplar(*Populus nigra Lipsky*) wood samples were prepared according to TS EN 408 and impregnated with Imersol-aqua by the method of short, medium and long-term of dipping according to ASTM D 1413 and producers' definition. After the impregnation process, bending strength was measured according to TS EN 408. Consequently, among the non-impregnated wood samples, bending strength was found to be the highest in oriental beech, (138.617N.mm^{-2}) and the lowest in poplar (61.021N.mm^{-2}). As for the period of dipping, the highest bending strength was obtained in short-term dipping and the lowest in long-term dipping. Considering the interaction of wood type and period of impregnation, the highest bending strength was obtained in Oriental beech with short term dipping (118.404 N.mm^{-2}) whereas the lowest was in poplar with long-term dipping (53.510 N.mm^{-2}). In consequence, in the massive constructions and furniture elements that the bending strength after the impregnation is of great concern, short term impregnation of Oriental beech and Scotch pine wood materials could be recommended.

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KEYWORDS

Imersol-aqua;
Impregnation;
Bending strength;
Wood materials.

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].

It is reported that, in mines, as a result of the impregnation of the beech and spruce wood with water-soluble salts, the bending, tensile and impact strength decreased a little whereas compression strength increased[4]. In another research concerning the impregnation of pine, spruce, fir, beech and poplar woods with Antrasen, it was found that, the compression strength increased by 6-40% and bending strength increased by 10-22%[5].

In the impregnation of pine and beech wood with UA salts and tar oil, the tar oil increased compression strength by 10% and UA salts increased with a small rate. On the other hand, the tar oil increased the bending strength whereas the UA salts diminished the bending strength[6].

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[7]. In another study, pressure treatment caused to a decrease of 8-10% in the bending strength of different wood types[8].

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%[9]. 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[10].

After the impregnation of pine wood samples by hot-cold open tank method with eleven preventives, no significant difference was observed in the bending strength except the decreasing effects of fluotox containing acid florid[11].

In this study, Oriental beech(*Fagus orientalis Lipsky*), oak(*Quercus petrea Liebl.*), Scotch pine(*Pinus sylvestris Lipsky*), Uludag fir(*Abies Bornmülleriana Lipsky*), Oriental spruce(*Picea orientalis Lipsky*) and poplar(*Populus nigra Lipsky*)woods commonly being used in furniture manufacturing were examined with respect to the effects of impregnation with imersol-aqua on bending 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, Istanbul. Imersol-aqua is non-flammable, odourless, fluent, water based, completely soluble in water, noncorro sive material with a pH value of 7 and a density of 1.03gcm^{-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 should be at least 6 minute and the impreg nation pool must contain at least 15 litres of impreg nation material for 1m^3 of wood[12].

Determination of density

The densities of wood materials, used for the preparation of test samples were determined according to TS 2472[13]. For determining the air-dry density, the test samples with a dimension of 20×30×30mm were kept under the conditions of 20±2⁰C 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 ±0.01mm. The air-dried densities (δ_{12}) of the samples were calculated with the following equations

$$\delta_{12} = \frac{W_{12}}{V_{12}} gcm^{-3} \qquad (1)$$

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 a temperature of 103±2⁰C 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 desicator containing (phosphorus pentoxide) P_2O_5. Then, they were weighted on a scale of ±0.01g sensitivity and their dimensions were measured with a compass of ±0.01mm sensitivity. The volumes of the samples were determined by stereometric method and the densities(δo) were calculated with the following equations;

$$\delta_O = \frac{W_O}{V_O} gcm^{-3} \qquad (2)$$

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

Determination of humidity

The humidity of test samples before and after the impregnation process was determined according to TS 2471[14]. Thus, the samples with a dimension of 20×20×20 mm were weighed and then oven dried at 103±2⁰C 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 with the following equations

$$h = \frac{Wr - Wo}{Wo} \times 100 \qquad (3)$$

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 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±2⁰C 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 having an average humidity of 12% according to TSEN 408[15]. The densities and humidity values of all test samples were measured before the impregnation process.

The test samples were impregnated according to ASTM D 1413[16], TS 344[17] and TS 345[18]. The samples were dipped in the impregnation pool immersing 1cm below the upper surface for 10 minutes in short-term dipping, 2hours for medium-term dipping and 5days for long-term dipping[19]. The specifications of the impregnation solution were determined before and after the process.

The processes were carried out at 20±2⁰C[20]. Retention of impregnation material(R) was calculated by using with the following equations;

$$R = \frac{G.C}{V_1} 10^3 kgm^{-3} \qquad (4)$$
$$G = T_2 - T_1$$

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). Impregnated test samples were kept under a temperature of 20±2⁰C and 65±3% relative humidity until they reach to a stable weight.

APPLICATION OF EXPERIMENT

The tests for bending strength were carried out with the Universal testing equipment shown in figure 1, according to TS EN 408.

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

Bending strength was calculated with the following equations.

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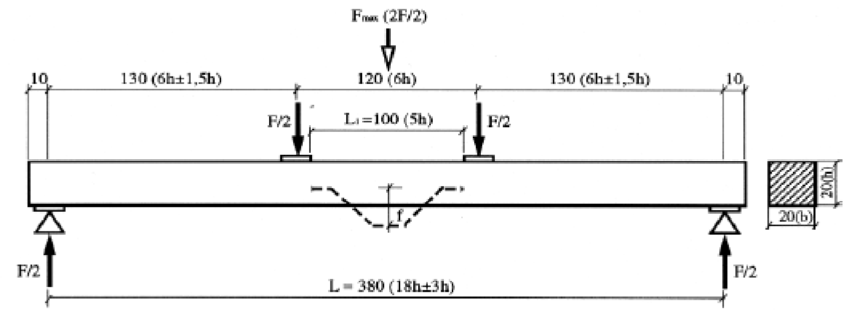

Figure 1 : Test equipment for bending strength (dimensions in mm)

TABLE 1 : Full-dry densities of wood materials(g.cm^{-3})

Impregnation methods	Statistics values	Oriental beech	Oak	Scotch pine	Uludag fir	Oriental spruce	poplar
Control	x	0.657	0.652	0.537	0.380	0.405	0.306
	Min	0.605	0.596	0.512	0.349	0.388	0.294
	Max	0.679	0.572	0.572	0.406	0.435	0.327
	Ss	0.0196471	0.0206274	0.016681	0.0192202	0.0154602	0.0104193
	v	0.0003862	0.0002782	0.000278	0.0003694	0.0002390	0.0001085
Short-term dipping	x	0.658	0.655	0.543	0.382	0.408	0.315
	Min	0.638	0.606	0.524	0.352	0.393	0.298
	Max	0.685	0.698	0.566	0.426	0.425	0.344
	Ss	0.0136902	0.0266076	0.011758	0.0228182	0.0105399	0.0114603
	v	0.0001871	0.0007081	0.000138	0.0005206	0.0001112	0.0002132
Middle-term dipping	x	0.661	0.659	0.561	0.389	0.409	0.320
	Min.	0.642	0.625	0.525	0.355	0.398	0.302
	Max.	0.692	0.705	0.582	0.431	0.427	0.355
	Ss	0.014393	0.0228728	0.017394	0.0214683	0.0091044	0.0156931
	v	0.000207	0.0005232	0.000302	0.0004608	0.0000828	0.0002462
Long-term dipping	x	0.666	0.665	0.568	0.396	0.414	0.325
	Min.	0.644	0.631	0.542	0.365	0.401	0.306
	Max.	0.698	0.708	0.596	0.444	0.438	0.368
	Ss	0.015125	0.0203608	0.014726	0.0223757	0.0111624	0.0169411
	v	0.000229	0.0004146	0.000216	0.0005006	0.0001246	0.0002870

x=Mean, Min=minumum, Max=maximum, Ss =Standard deviation, v =variance

$$\sigma_e = \frac{3F\max.(L-l_1)}{2bh^2}(Nmm^{-2}) \qquad (5)$$

Where, F_{max} is the breaking load on the scale(N), L is distance between the lower tension rods (mm), l_1 is distance between two loads(mm), b is the cross-sectional width of test sample(mm), h is the cross-sectional thickness of the test sample(mm).

Data analyses

A total of 24 treatment groups were obtained with six different kinds of wood materials, three different impregnation dipping method and one control sample. Eleven replications were made in each treatment group. Thus, a total of 264 samples (6×4×11) were prepared. The effects of wood material and impregnation method on the bending strength were analysed by Analysis of Variance (ANOVA). Duncan's multiple range test was also applied where appropriate.

RESULT AND DISCUSSION

Full-dry density

Statistical values for the full-dry densities of test samples impregnated with imersol-aqua are given in TABLE 1. As seen from the TABLE, full-dry density values vary due to the type of wood and impregnation period. The full-dry densities of Scotch pine, fir, spruce, and poplar increases as the impregnation period increases. In Oriental beech and oak, the densities of the control and other treatment groups(short, medium and long-term of impregnation samples) were found to be approximately similar.

TABLE 2 : Air-dry densities of wood materials ($g.cm^{-3}$)

Impregnation methods	Statistics values	Oriental beech	Oak	Scotch pine	Uludag fir	Oriental spruce	Poplar
Control	x	0.679	0.672	0.577	0.401	0.420	0.340
	Min	0.655	0.655	0.555	0.385	0.401	0.311
	Max	0.705	0.699	0.592	0.412	0.441	0.362
	Ss	0.01678101	0.01382290	0.0121909	0.00922841	0.01435143	0.01679935
	v	0.00028202	0.00014860	0.0001486	0.00008546	0.00020596	0.00028222
Short-term dipping	x	0.682	0.676	0.579	0.407	0.428	0.346
	Min	0.662	0.658	0.558	0.392	0.407	0.320
	Max	0.708	0.702	0.600	0.415	0.455	0.371
	Ss	0.01669811	0.01422672	0.0002416	0.00700391	0.01238621	0.01683935
	v	0.00027920	0.00020241	0.0002416	0.00004905	0.00012340	0.00028356
Middle-term dipping	x	0.689	0.678	0.592	0.410	0.437	0.349
	Min.	0.668	0.664	0.578	0.399	0.412	0.325
	Max.	0.716	0.704	0.605	0.422	0.460	0.380
	Ss	0.01648220	0.01297760	0.0076324	0.00607379	0.01568961	0.01558080
	v	0.00027200	0.00016840	0.0000582	0.00003689	0.00024616	0.00024240
Long-term dipping	x	0.695	0.683	0.597	0.419	0.440	0.352
	Min.	0.669	0.667	0.579	0.408	0.422	0.333
	Max.	0.722	0.709	0.612	0.444	0.462	0.384
	Ss	0.01485321	0.01312320	0.0098322	0.01106592	0.01436029	0.01461560
	v	0.00022120	0.00017221	0.0000966	0.00012245	0.00020621	0.00021360

TABLE 3 : Retention amounts of wood materials($kg.m^{-3}$)

Impregnation methods	Statistics values	Oriental beech	Oak	Scotch pine	Uludag fir	Oriental spruce	Poplar
Short-term dipping	x	120.178	22.484	43.289	45.950	58.704	48.083
	Min	109.462	19.022	36.231	32.124	54.321	44.445
	Max	130.226	26.546	47.012	50.214	62.358	52.234
	Ss	7.947587	2.689613	3.413306	4.020328	3.135393	2.634260
	v	63.164146	7.234019	11.65066	16.16304	9.830689	6.939328
Middle-term dipping	x	274.728	44.936	68.538	79.180	92.225	75.405
	Min.	268.256	42.521	65.321	75.021	88.452	69.032
	Max.	281.356	49.357	75.265	82.854	95.985	80.265
	Ss	4.870316	2.093756	3.260492	2.489244	2.365208	4.177241
	v	23.719986	4.383817	10.630811	6.196337	5.594210	17.44934
Long-term dipping	x	365.691	218.851	167.369	216.472	209.076	327.112
	Min.	355.654	212.854	159.654	205.213	203.568	319.256
	Max.	375.954	235.987	176.654	229.564	214.002	333.008
	Ss	7.433700	6.190976	6.165483	7.370773	3.435018	4.636656
	v	55.256903	38.32818	38.013184	54.32830	11.799354	21.49858

Air-dry density

Statistical values for the air-dry densities of samples impregnated with imersol-aqua are given in TABLE 2. As seen from TABLE 2, air-dry densities of wood species have increased with the increase in impregnation period. Oriental beech specimens have the highest air dry density both within the control and within the three impregnation period. In contrast, poplar specimens have the lowest air-dry density in all treatment groups.

Retention quantities

The quantities of retention due to wood species and impregnation period are shown in TABLE 3. The amount of retention changed due to the type of wood and period of impregnation. The highest retention amount was obtained in Oriental beech for long-term dipping and the lowest was in Oak for short-term dipping. The retention amounts were enhanced in all wood species due to the increase of dipping period. The amount of retention was found to be higher in broad-leaved wood than needle-leafed wood. As the impregnation period increases the amount of retention increases. The highest amount of retention was found in the long-term dipping for all wood species. The highest retention amount obtained in Oriental beech for each dipping period could be attributable to the impact of permeability.

Bending strength

The average values of bending strength due to the type of wood and impregnation period are given

TABLE 5 : Average bending strength for interaction of wood type and impregnation period

Impregnation Methods	Oriental Beech	Oak	Scotch Pine	Uludag Fir	Oriental Spruce	Poplar
C	138.617	103.627	92.755	78.168	88.235	61.021
S	118.404	97.788	105.846	76.073	81.324	56.204
M	109.695	96.856	109.231	74.687	79.624	54.164
L	107.108	94.060	111.323	66.472	77.433	53.510

C : Control, S : Short-term dipping, M : Medium-term dipping, L : Long-term dipping

TABLE 6 : The analysis of variance (ANOVA)

Source	Degrees of freedom	Sum of squares	Mean square	F value	Probably % 5(Sig)
Factor A	5	112508.752	22501.750	1857.427	0.0000
Factor B	3	2717.861	905.954	74.782	0.0000
AB	15	8805.425	587.028	48.456	0.0000
Error	240	2907.473	12.114		
Total	263	126939.511			

Factor A : Wood materials, Factor B : Impregnation period

TABLE 7 : Mean comparisons of bending strength (Duncan Test) (Nmm^{-2})

Treatments	Bending strength*	HG	Treatments	Bending strength*	HG
I+C	138.6	A	V+C	88.2	H
I+S	118.4	B	V+S	81.3	I
III+L	111.3	C	V+M	79.6	IJ
I+M	109.7	CD	IV+C	78.2	IJK
III+M	109.2	CD	V+L	77.4	IJK
I+L	107.1	CDE	IV+S	76.1	JK
III+S	105.8	DE	IV+M	74.7	K
II+C	103.6	E	IV+L	66.5	L
II+S	97.8	F	VI+C	61.0	M
II+M	96.9	FG	VI+S	56.2	N
II+L	94.1	FG	VI+M	54.2	N
III+C	92.8	G	VI+L	53.5	N

***Different letters in the columns refer to significant changes among wood types at 0.05 confidence level ($LSD_{0.5}$= 3.958), I:Oriental Beech, II:Oak, III:Scotch pine, IV: Uludag Fir, V:Oriental Spruce, VI:Poplar, C: Control, S: Short-term dipping, M: Medium-term dipping, L: Long-term dipping**

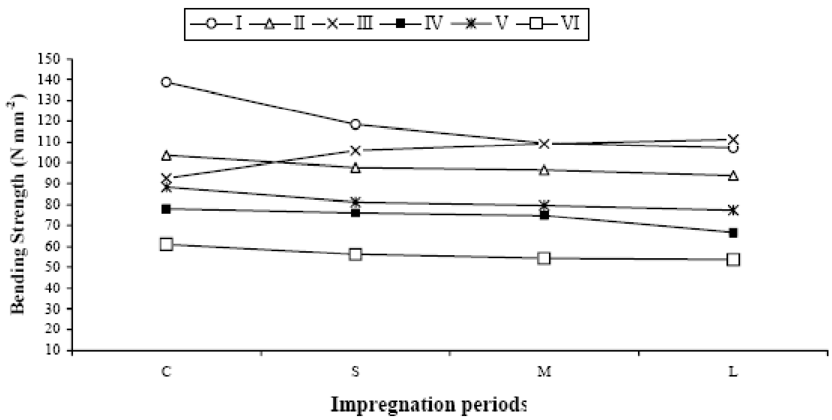

Figure 2 : Bending strength determined with regard to the wood materials and impregnation periods

in TABLE 4.

As well as that, average values of the interaction between the wood type and impregnation material and the results of variance analysis regarding the impacts of wood type and impregnation period on the bending strength are given in TABLE 5 and TABLE 6, respectively.

Generally, bending strength was found to be the highest in Oriental beech and the lowest in poplar. This may be due to the higher density of Oriental beech than the other tested wood materials. As to the impregnation period, bending strength was found to be the highest in short-term dipping and the lowest in long-term dipping. It can be derived from these results that, bending strength decreased with the increase in dipping period. The average values of bending strength concerning the interaction of wood material and impregnation period are given in TABLE 5.

In all wood materials excluding Scotch pine, bending strength decreased as the increase in impregnation period. This may be due to the less interaction between the wood fiber and impregnation material in Scotch pine. As a matter of fact, it is acknowledged that pine species are more resistant to chemical materials than other wood types[21]. The analysis of variance concerning the impacts of wood material and impregnation period on the bending strength is presented in TABLE 6.

As seen from TABLE 6, the effects of variance sources(wood material, impregnation method and their interaction) on the bending strength were found to be significant($P<0.05$). The comparisons of the mean values of 24 treatment groups as the result of Duncan's multiple range test are shown in TABLE 7.

According to Duncan's multiple range test results, within the non-impregnated wood materials, bending strength was found to be the highest in Oriental beech(138.617N.mm^{-2}) and the lowest in poplar (61.021 N.mm^{-2}). Among the impregnated wood materials, the highest bending strength was obtained in oriental beech samples(118.404 N.mm^{-2}) for short term dipping method whereas the lowest was obtained in poplar samples(53.510 N.mm^{-2}) for long term dipping method.

The bending strength determined with regard to the wood materials and impregnation periods are given in figure 2.

For the impregnation with imersol-aqua, the bending strength decreased in all wood species except Scotch pine with the increase in impregnation period. However, in Scotch pine, the bending strength increased with the increase in impregnation period.

CONCLUSION

The air-dry and full-dry densities of impregnated samples increased with respect to control samples. This may be due to more penetration of impregnation solution into the wood with the extension of time. As a matter of fact, it was observed that, the retention amount was higher in long-term dipping than short-term dipping. In a similar research, it was reported that in the impregnation of Scotch pine and Oriental beech the retention increased with the increase in impregnation period[22].

The amount of retention in the long-term dipping of Oriental beech, Oak, Scotch pine, Uludag fir, Oriental spruce and poplar were found to be higher than those in medium and short term dipping. On the other hand, the amount of retention was observed as sufficient in Scotch pine as but higher than expected in Oriental beech. The lowest retention amount was found in Scotch pine and Oak. This may be due to pit aspiration in Scotch pine and tyloses in Oak.

Among the non-impregnated wood materials, the highest bending strength was obtained in Oriental beech and control samples. Bending strength at this situation from the highest to lowest can be enumerated Oriental beech, oak, Scotch pine, Uludag fir, Oriental spruce and poplar. With regard to the impregnation period, the sequence form the highest to lowest was as short term, medium term and long term dipping.

Higher bending strength values were observed in the samples impregnated with imersol-aqua by short term dipping method. Accordingly, it can be pointed out that, except Scotch pine, the modulus of elasticity in bending increased with the increase in the retention amount of impregnation material. In the interaction of wood material and impregnation period, the highest bending strength values were found in the samples impregnated with short-term dipping method except Scotch pine whereas the lowest in the samples impregnated with long-term dipping method. These may be due to negative effects of imersol-aqua on the structure of the wood material. As a matter of fact, bending strength values decreased with the increase in impregnation period. The only exclusion for this approach was the samples of Scotch pine. For Scotch pine samples the bending strength increased with the increase in impregnation period. This situation can be attributable to the higher resistance of Scotch pine against the chemical substances. It was reported that the hardwood woods, having less hemicelilose are more resistant to chemical effects than softwood woods[23].

In consequence, in the massive constructions and furniture elements that bending strength after the impregnation is of great concern, short term impregnation of Oriental beech and Scotch pine materials could be recommended.

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