December 2006 Volume 2 Issue 6

Trade Science Inc.

Materials Science

An Indian Journal

Full Paper

MSAIJ, 2(6), 2006 [207-214]

Technological Properties Of Limba (*Terminalia Superba*) Wood Impregnated With Imersol-Aqua

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Received: 11th November, 2006
Accepted: 26th 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 some technological properties of limba (*Terminalia superba*) wood. For this aim, limba wood samples were prepared according to TS 2472, TS 2595, TS EN 408 and impregnated with imersol-aqua by the method of short, medium and long-term dipping according to ASTM D 1413 and producers' definition. After the impregnation process, the densities, compression strength, bending strength and modulus of elasticity in bending (MOE) was measured according to TS 2472, TS 2595 and TS EN 408. Consequently, the retention amount of imersol-aqua increased by the period of impregnation and found the highest in the long-term dipping. Densities and strength values of impregnated samples increased with respect to control samples in the long-term dipping. Full-dry density increased 14%, air-dry density increased 9%, bending strength increased 16% and compression strength increased by 19% by long-term dipping method. Modulus of elasticity in bending decreases by short-term or medium-term dipping but remains the same in long-term dipping. So, impregnation by imersol-aqua affects the mentioned properties of wood positively. If the density, bending strength, compression strength and modulus of elasticity in bending is important factors in the limba wooden construction and furniture elements, impregnation by long-term dipping method is suggested.

KEYWORDS

Impregnation;
Imersol-AQUA;
Limba;
Compression strength;
Bending strength;
Modulus of elasticity in bending.

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INTRODUCTION

If the wood materials are used without processing by preservative 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. In the case of wood is not impregnated but only painted and varnished instead, the prevention on the surfaces is limited to a maximum of two years[2].

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[3]. 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 %[4].

In the impregnation of pine and beech wood with tar oil and UA salts, 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[5].

Vologdin declared that, 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 by 9%. sodium pentaclorfenet also increased the bending strength[6]. In another study, pressure treatment caused to a decrease of 8-10 % in the bending strength of different wood types[7].

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 %[8]. 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[9].

After the impregnation of scotch pine wood samples by hot-cold open tank method with eleven preservatives, no significant difference was observed in the bending strength except the decreasing effects of fluotox containing acid florid[10].

The full-dry density of limba wood is 0.490 g cm^{-3}. It is preferred in furniture, veneer, plywood, musical equipments production and interior design but sensitive to fungal stains, insect infestation and termites[11].

In this study, limba wood commonly being used in furniture manufacturing were examined with respect to the effects of impregnation with imersol-aqua on the densities, compression strength, bending strength and modulus of elasticity in bending.

MATERIALS AND METHODS

Materials

1. Wood materials

The limba wood (*Terminalia superba*) to be used as test sample was chosen randomly from the timber merchants in Ankara. Special emphasis is given for the selection of wood materials. Accordingly, non-deficient, proper, knotless, normally grown (without zone line, without reaction wood, without decay and insect mushroom damages) wood materials were selected.

2. Impregnation material

Imersol-aqua, used as an impregnation material in this study was supplied from hemel (Hemel-Hickson Timber Products Ltd.), Istanbul. Imersol-aqua is non-flammable, odorless, fluent, water-based, completely, soluble in water, non-corrosive material with a pH value of 7 and a density of 1.03g 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-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 minutes and the impregnation pool must contain at least 15 liters of impregnation material for 1m^3 of wood. The impregnated wood should be left for dry-

ing at least 24 hours[12].

Methods

1. 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 20×30×30 mm were kept under the conditions of 20±2°C temperature and 65±3 % 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 sensitivity. The air-dried densities (δ_{12}) of the samples were calculated by the formula;

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

Where W_{12} is the air-dry weight (g) and V_{12} is the air-dry volume (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 dessicator containing phosphorus pentoxide (P_2O_5). Then, they were weighted on a scale of ±0.01g sensitivity and their dimensions were measured with a digital compass of ± 0.01mm sensitivity. The volumes of the samples were determined by stereo metric method and the densities (δo) were calculated by the formula;

$$\delta_0 = \frac{W_0}{V_0} g\,cm^{-3} \quad (2)$$

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

2. 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±2°C till they reach to a constant weight. Then, the samples were cooled in dessicator containing phosphorus pentoxide (P_2O_5) and weighed with an analytic scale of 0.01 g sensitivity. The humidity of the samples (r) was calculated by the formula;

$$r = \frac{Mr - Mo}{Mo} \times 100 \quad (3)$$

Where Mr is the initial weight (g) and Mo is the full-dry weight (g).

3. Preparation of the test 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 for compression strength test, with a dimension of 20×20×30 mm were cut from the drafts having an average humidity of 12 % according to TS 2595[15]. The samples for bending strength and modulus of elasticity in bending test, with a dimension of 20×20×400 mm were cut from the drafts having an average humidity of 12 % according to TS EN 408[16]. 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[17], TS 344[18] and TS 345[19]. The samples were dipped in the impregnation pool immersing 1 cm below the upper surface for 10 minutes in short-term dipping, 2 hours 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 temperature. Retention of impregnation material (R) was calculated by the formula;

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

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).

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

4. Compression strength

The tests for compression strength parallel to

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grains of wood materials were carried out with universal testing machine shown in figure 1, according to TS 2595. The capacity of universal testing machine was 400 N. The speed of testing machine was adjusted to 5 mm/min. for crashing to occur in 1-2 minutes.

Compression strength was calculated by the formula;

$$\sigma_b = \frac{F_{max}}{ab} N.mm^{-2} \quad (5)$$

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

5. Bending strength

The tests for bending strength were carried out with the universal testing machine shown in figure 2, according to TS EN 408.

The capacity of the universal testing machine was 400 N. The speed of the testing machine was adjusted to 5 mm/min. For breakage to occur in 1-2 minutes. Bending strength was calculated by the formula.

$$\sigma_e = \frac{3F_{max}(L-L_1)}{2bh^2} (N\,mm^{-2}) \quad (6)$$

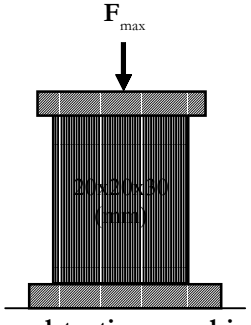

Figure 1: Universal testing machine for compression strength

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).

6. Modulus of elasticity in bending (MOE)

The tests for modulus of elasticity in bending were carried out with the universal testing machine shown in figure 2, according to TS EN 408.

The capacity of the universal testing machine was 400 N. Deformations on the test samples were measured in the middle of the sample within a zone of five times the width of the sample by comparator. The deformations by incrementally increasing the forces were assessed with a sensitivity of ±0.01mm.

In the elastic deformation zone, modulus of elasticity was calculated by the formula;

$$MOE = \frac{\Delta F.L^3}{4.b.h^3.\Delta f} N\,mm^{-2} \quad (7)$$

Where ΔF is the difference between the arithmetic average of the upper and lower limits of applied force in the elastic deformation zone (N), Δf is the net elastic deflection - difference between the measured elastic deflection in the upper and lower loading limits- (mm), L is the span (mm), b is the cross-sectional width of test sample (mm), h is the cross-sectional thickness of the test sample (mm).

Data analysis

The results were analyzed statistically by computer software, SPSS 13.0 for Windows. A total of 20 treatment groups were obtained with five different kinds of tests, three different impregnation dip-

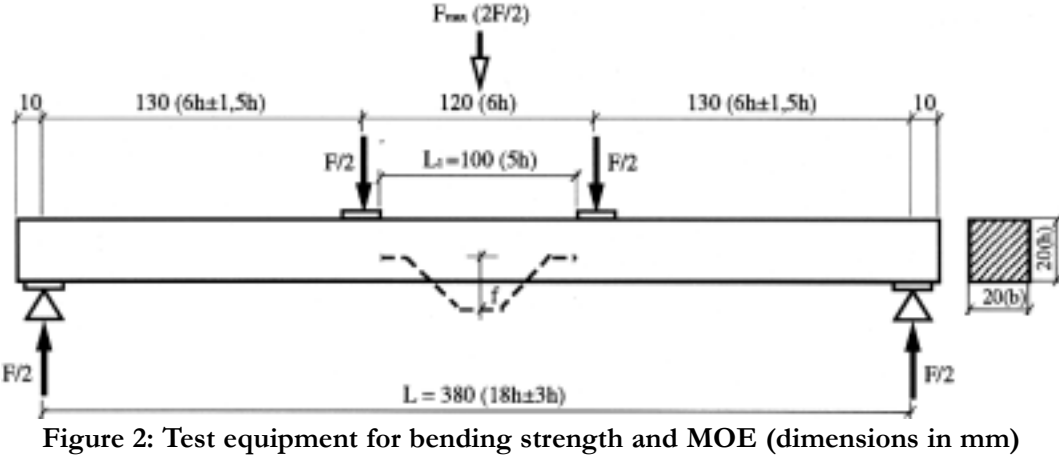

Figure 2: Test equipment for bending strength and MOE (dimensions in mm)

ping method and one control sample. Eleven replications were made in each test group. Thus, a total of 220 samples (5×4×11) were prepared. The effects of impregnation with imersol-aqua on the densities, compression strength, bending strength and MOE of limba wood were analyzed by ANOVA (Analysis of Variance). Duncan Test was also applied where appropriate.

RESULTS AND DISCUSSION

Peculiarities of impregnation solutions

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

Retention quantities

The amount of retention by limba wood according to the impregnation period is shown in TABLE 1.

Retention amount was found the highest in long-term dipping and the lowest in short-term dipping. As the period impregnation increases, the retention amount also increases. ANOVA of the impact of impregnation period on retention of impregnation material is given in TABLE 2.

Effect of impregnation period on retention amount was found statistically meaningful ($P<0.05$). Duncan test was applied to determine the importance of differences on groups and results are given in TABLE 3. The highest retention amount is in the long-term dipping.

Technological properties

Some of technical properties of limba wood impregnated with imersol-aqua are given in TABLE 4.

TABLE 1: Retention amounts of limba wood (kg m^{-3})

Statistics values	Short-term dipping	Medium-term dipping	Long-term dipping
x	33.587	47.693	148.400
Min	23.324	44.323	134.672
Max	45.834	55.721	196.420
Ss	6.54839	3.95435	17.94540
V	42.88140	15.6369	322.0371
N	11	11	11

x : Mean, Min: Minimum, Max: Maximum, Ss: Standard deviation, v: Variance, N: Number of samples

TABLE 2: ANOVA indicating the impact of impregnation period on the retention

SOURCE	SS	DF	MS	F value	SIG*
Between groups	86248.680	2	43124.340	341.750	0.000
Within groups	3785.604	30	126.187	-	-
Total	90034.284	32	-	-	-

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

TABLE 3: Results of duncan test

Impregnation methods	N	Retention amounts (kg m^{-3})	
		X	HG
Short-term dipping	11	33.542	C
Medium-term dipping	11	47.772	B
Long-term dipping	11	148.403	A

α = 0.05, Means for groups in homogeneous subsets are displayed x: Mean, HG: Homogeneous groups

Full-dry density, air-dry density and compression strength increases by the period of impregnation. Bending strength decreases in short-term and medium-term dipping but increases some amount in long-term dipping. The modulus of elasticity is less than the control sample in all of dipping period but the lowest in the short-term dipping. ANOVA of impact of impregnation on density, bending and compression strength, modulus of elasticity is given in TABLE 5.

There is differences between the groups of impregnation by the effect of impregnation on density, compression strength, bending strength and MOE ($P<0.05$). To determine the importance of differences between the groups, duncan test is applied and the results are given in TABLE 6. Imersol-aqua impregnation affects some technical properties of limba wood positively, especially in long-term dipping. Bending strength decreases in short-term and medium-term dipping but increases in long-term dipping. MOE was found less than the control samples in all of impregnation methods.

Effect of impregnation with imersol-aqua on density, compression and bending strength, MOE of limba wood is given in figures 3-6.

Retention increased by the period of impregnation. Retention amount in long-term dipping is 3 times more than medium-term dipping and 4 times in short-term dipping.

The densities of impregnated samples increased

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TABLE 4. Technological properties of limba wood impregnated with imersol-AQUA

Impregnation methods	Statistics values	Full-dry density (g cm^{-3})	Air-dry density (g cm^{-3})	Bending strength ($\perp$N mm^{-2})	Modulus of elasticity ($\perp$N mm^{-2})	Compression strength (//N mm^{-2})
Control groups	X	0.304	0.358	60.215	28205	33.036
	Min.	0.284	0.342	55.125	25725	31.250
	Max.	0.327	0.372	66.150	30830	34.629
	Ss	0.01630	0.008800	3.51574	1761.73	1761.73
	v	0.00030	0.000081	12.3604	3103682	3103682
	N	11	11	11	11	11
Short-term dipping	x	0.336	0.376	54.353	24213	34.211
	Min.	0.304	0.354	48.951	21466	32.564
	Max.	0.363	0.399	67.725	30100	35.652
	Ss	0.01676	0.01423	5.14810	2319.01	0.95951
	v	0.00028	0.00020	26.5030	5377822	0.92067
	N	11	11	11	11	11
Medium-term dipping	x	0.338	0.384	58.810	25656	37.417
	Min.	0.308	0.368	53.025	23095	35.566
	Max.	0.366	0.398	63.525	27668	39.256
	Ss	0.01510	0.00869	3.4145	1481.22	1.34515
	v	0.00019	0.000076	11.6580	2194000	1.80943
	N	11	11	11	11	11
Long-term dipping	x	0.353	0.392	71.348	27932	40.739
	Min.	0.329	0.383	63.525	23758	38.659
	Max.	0.369	0.405	86.235	29218	42.356
	Ss	0.01260	0.00682	6.92468	1573.7	1.03924
	v	0.00021	0.000046	47.9511	2000019	1.08003
	N	11	11	11	11	11

x: Mean, Min: Minumum, Max: Maximum, Ss: Standard deviation, v: Variance, N: Number of samples

with respect to control samples in the impregnation period. The increment in full-dry density is 10% in short-term dipping, 11% in medium-term dipping and 14% in long-term dipping. The air-dry density of samples increases 5% in short-term dipping, 7% in medium-term dipping and 9% in long-term dipping.

Bending strength of impregnated samples decreased 10% in short-term dipping and 3% in medium-term dipping but increased 16% in long-term dipping with respect to control samples.

Effect of impregnation with imersol-aqua on the compression strength of limba wood is positive. Compression strength of impregnated samples increased by 4.5% in short-term dipping 12% in medium-term dipping and 19% in long-term dipping with respect to control samples. Wood used under compression may gain an advantage if impregnated with imersol-aqua.

MOE of impregnated samples decreased 14% in short-term dipping, 10% in medium-term dipping and 1% in long-term dipping with respect to control samples. The lowest value in the decrease of MOE in long-term dipping can be a result of the highest amount of retention in that method of dipping.

In consequence, in the massive constructions and furniture elements that the compression and bending strength, MOE after the impregnation is of great concern, long-term impregnation of limba wood could be suggested.

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TABLE 5: ANOVA indicating the impacts of impregnation period on density, bending and compression strength, modulus of elasticity in bending

	SOURCE	SS	DF	MS	F Value	SIG*
Full-Dry density g cm^{-3}	Between groups	0.01408	3	0.004692		
	Within groups	0.009321	40	0.0002330	20.135	0.000
	Total	0.02340	43			
	SOURCE	**SS**	**DF**	**MS**	**F Value**	**SIG***
Air-Dry density g cm^{-3}	Between groups	0.006962	3	0.002321		
	Within groups	0.004028	40	0.0001007	23.043	0.000
	Total	0.01099	43			
	SOURCE	**SS**	**DF**	**MS**	**F Value**	**SIG***
Bending strength (⊥N mm^{-2})	Between groups	1722.153	3	574.051		
	Within groups	984.726	40	24.618	23.318	0.000
	Total	2706.879	43			
	SOURCE	**SS**	**DF**	**MS**	**F Value**	**SIG***
Modulus of elasticity (⊥N mm^{-2})	Between groups	1.20E+08	3	39965273.114		
	Within groups	1.32E+08	40	3288018.841	12.155	0.000
	Total	251E+08	43			
	SOURCE	**SS**	**DF**	**MS**	**F Value**	**SIG***
Compression strength (//N mm^{-2})	Between groups	395.597	3	131.866		
	Within groups	50.360	40	1.259	104.738	0.000
	Total	445.957	43			

***P<0,05 SD: Sum of square, DF: Degrees of freedom, MS: Mean square, SIG: Significance**

TABLE 6: The Result of DUNCAN test

Impregnation methods	N	Full-Dry density (g cm^{-3})		Air-Dry density (g cm^{-3})		Bending strength (⊥N mm^{-2})		Modulus of elasticity (⊥N mm^{-2})		Compression strength (//N mm^{-2})	
		x	HG	x	HG	x	HG	x	HG	x	HG
Control groups	11	0.304	D	0.358	D	60.215	BC	28204.64	B	33.036	D
Short-term dipping	11	0.336	BC	0.376	BC	54.353	D	24213.27	CD	34.211	C
Medium-term dipping	11	0.338	BC	0.384	BC	58.806	BC	25655.73	CD	37.417	B
Long-term dipping	11	0.353	A	0.392	A	71.347	A	27932.45	A	40.739	A

α = 0.05, Means for groups in homogeneous subsets are displayed., x: Mean, HG: Homogeneous groups

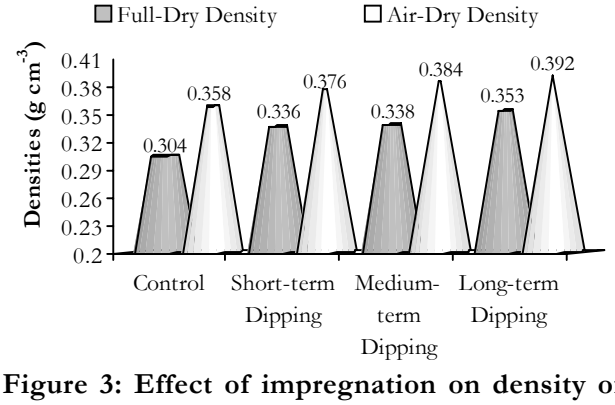

Figure 3: Effect of impregnation on density of limba wood

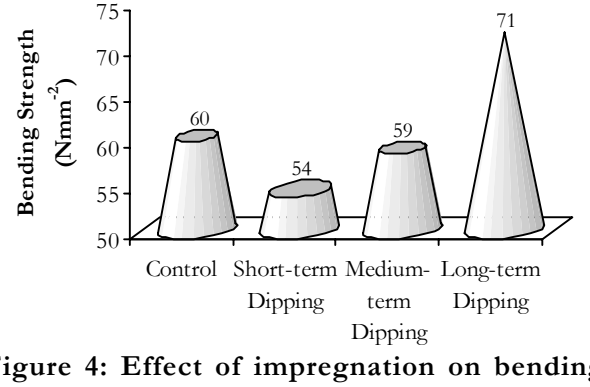

Figure 4: Effect of impregnation on bending strength of limba wood

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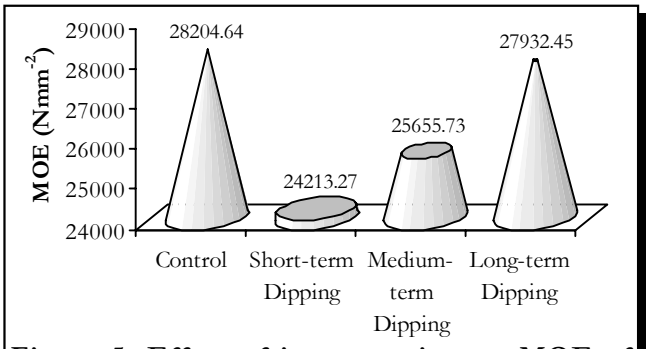

Figure 5: Effect of impregnation on MOE of limba wood

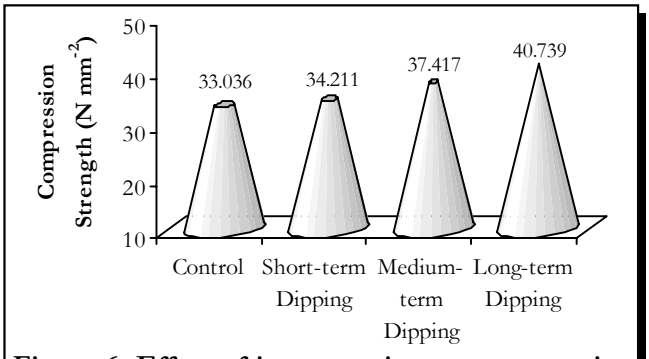

Figure 6: Effect of impregnation on compression strength of limba wood

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