

Compression Strength Perpendicular to Grain Characteristics of Impregnated Laminated Veneer Lumbers Exposed to Sea Water

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Abstract

The purpose of this study is to determine the compression strength perpendicular to grain of laminated veneer lumber exposed to sea water 3, 6, 9 and 12 months and obtained from Scots pine by using different adhesive and impregnating materials. While the highest compression strength perpendicular to grain is obtained from then unimpregnated samples, which are not exposed to sea water, with 39.56 N/mm² the lowest compression strength perpendicular to grain is obtained from the unimpregnated samples exposed to sea water for 12 months with 10.94 N/mm².

Keywords: pine, compression strength perpendicular to grain, LVL, biodegradation, preservation

Introduction

Wood is a hygroscopic material, and its mass, dimensions, and density, as well as its mechanical, elastic, electrical, thermal, and transport properties are affected by its moisture content. The moisture content of wood in the living tree is always above the fiber-saturation point. The cell walls in green wood are, therefore, in the fully saturated condition and no hygroscopic shrinking or swelling occurs, except that resulting from changes in fiber-saturation points already referred to, which are a function of temperature (Skaar 1983).

The use of composite products gained from wood increase day by day. One of these composite products is laminated veneer lumbers. In our country, an increase in the use of laminated veneer lumbers in specific fields is observed. With the use of laminated veneer lumbers, products in desired curve and shape can be produced. Naturally, there is a need for curved trees in the production of wooden boat and yacht, and in our country existence of these kinds of wood materials may not be continuous. As an alternative to these kinds of curved trees which can be used in the production of wooden boat and yacht, laminated veneer lumbers may be suggested.

The biodegradation of wood, whether it is above ground, by soil contact, or in marine applications, is

brought about by fungi, bacteria, insects, and marine borers (Becker 1974).

Toxic preservatives function by disrupting the cellular organisation of microorganisms so that the organism dies. Thus, numerous organic salts of copper, zinc, arsenic, and boron have been used as wood preservatives, generally with added chromium compounds, to reduce rapid leaching of the water-soluble compounds. Among organic compounds, coal-tar creosote and pentachlorophenol are important toxic preservatives in wide commercial use (Subramanian 1984).

Decomposition of wood is an important part of the carbon cycle of nature. Decomposition is caused by fungi, insects, and marine borers that use the wood as food or shelter, or both. Lignin in wood provides a physical barrier to enzymatic decomposition of cellulose and hemicelluloses. This barrier is breached mechanically by insects and marine borers, biochemically by white- and soft-rot fungi, and possibly by small nonenzyme catalysts in the case of brown-rot fungi. Rapid strength loss occurs with all decay fungi, but especially with brown-rot fungi. Strength loss due to insect attack is roughly proportional to the amount of wood removed (Kirk and Cowling 1984).

It should be appreciated that every application of wood in its natural or unprocessed state is affected potentially by the tendency to a relatively large cross-grain

dimensional change whenever significant moisture content changes in service is expected. For example, the performance of every structural connection in wood, with the possible exception of a glued joint, can be affected by different dimensional changes in the members. Even simple glued joints, including those in laminated wood members, show shrinkage or swelling stresses if the pieces put together do not have identical moisture response properties (Bozkurt 1986).

In focusing attention on wood bonding, we are dealing with nature's own unique material whose sophisticated structure and complexities are at the same time baffling and challenging. Thus there are several complicating factors in the study of wood as an adherend: the species; heartwood, sapwood, earlywood, latewood, surface planes in radial, tangential, longitudinal, or intermediate directions; pH, porosity, moisture content, and extractives are all capable of modifying the bonding properties of wood (Blomquist 1983, Adhesive Bonding of Wood 1975).

Today, synthetic resins are being produced according to the wood materials used on dry and damp conditions. They are also convenient for use in the workshops and straight manufacturing. To prevent material scraps and increase the quality, research studies have been carried on the development of glue and its new application areas (Örs et al. 1999).

The demand for engineered wood products such as oriented strand board, glulam and laminated veneer lumber, LVL, has increased due to a constant increase in the global population. The grain of each layer of veneer assembled into LVL runs parallel with each adjacent ply (Badwin 1985). Being a homogeneous and dimensionally stable building material, LVL can be used where strength and stability are required (Colak et al. 2004).

LVL panels, like plywood, are manufactured using different synthetic resins depending on where they are used. Phenol formaldehyde resins are generally used as a binder for exterior grade panel production (Pizzi 1993).

Main purpose of this research is to determine the resistance characteristics of laminated veneer lumbars both impregnated and bonded with different adhesives. For this purpose, Scots pine wood was used. For the impregnation process, the mixture of protim-paraffin, Tanalith-c (CCA) and creosote were used.

Materials

Wood Species

Scots pine (*Pinus sylvestris* L.) was chosen randomly from timber supplier of Ankara, Turkey. A special emphasis was put on the selection of the wood material. Accordingly, non-deficient, whole, knotless, normally grown (without zone line, reaction wood, decay, insect or fungal infection) wood materials are selected.

Adhesives

Polyvinylacetate (PVAc) adhesive is usually preferable for the assembly process in the furniture industry. According to the producer's recommendations, the adhesive was applied in the amount of 180-190 g/m² to the surfaces. Its viscosity was 16,000 ± 3,000 mPa·s at 25 °C, density 1.1 ± 0.02 g/ml at 20 °C, and 20 minutes for cold process is recommended at 6-15 % humidity. The TS 3891 standard procedure was used for applying PVAc adhesive that supplied by a company (TSE 1983).

Manufacturer's documentation describes Desmodur-VTKA as a polyurethane-based one-component solvent-free adhesive that is widely used for the assembly process in the furniture industry. It is used for gluing wood, metals, polyester, stone, glass, ceramic, PVC, and other plastic materials. Its application is specially recommended in locations subjected to high-level humidity. The gluing process was carried out at 20 °C and 65 % relative humidity. According to the producer's recommendations, the adhesive was applied in the amount of 180-190 g/m² to the surfaces. Its viscosity was 14,000 ± 3,000 mPa·s at 25 °C, the density was 1.11 ± 0.02 g/ml at 20 °C, and it showed resistance against the cold air (Polisan 1999).

The building blocks of PF are phenol and formaldehyde. Phenol is derived from crude oil. A principal feedstock of phenol is toluene and benzene. Toluene is converted into benzoic acid; benzene is combined with propylene into commune. Together with benzoic acid it forms phenol. Phenol and formaldehyde are combined in a reactor into PF resin. It is commonly shipped to engineered wood product plants as a colloidal aqueous solution with a solid content between 30 % (for LVL) and 50 % (for HB and OSB). This liquid is odourless, of dark-brownish colour, and, of course, not flammable.

Impregnation Chemicals

As impregnation chemicals; protim-paraffin, Tanalith-c (CCA) and creosote, were used. The mixture of protim and paraffin with the ratio equal 50 % concentrations were used at 60 °C as solution. Tanalith-c with 4 % concentration and creosote without being diluted were used for the impregnation process. Features related to impregnation materials have been shown in Table 1.

Table 1. Peculiarities of impregnation chemicals and test plan

Impregnation Chemicals	pH		Density, g/ml	
	BI	AI	BI	AI
Tanalith – C	2.36	2.58	1.62	1.68
Protim – Parafin	5	5.2	1.08	1.15
Creosote	5.88	5.78	1.12	1.15

Notes: BI: Before impregnation, AI: After impregnation

Methods

Determination of density

The dry densities of the wood materials used for the preparation of treatment samples were determined according to TS 2472(1976). Accordingly, air-dried samples were oven dried up at 103 ± 2 °C until they reached constant weights. Then, the samples were cooled in a desiccator containing calcium chloride and weighed in an analytic balance with ± 0.01 g sensitivity. Afterward, the dimensions of the wood materials were measured by a compass with ± 0.001 mm sensitivity and the volumes were determined by the stereo metric method. The oven dry density (δ_0) was calculated with the following equation:

$$\delta_0 = M_0/V_0 \text{ (g/cm}^3\text{)}, \tag{1}$$

where

M_0 is the oven dry weight (g), and

V_0 is the dry volume (cm³) of the wood material.

Preparation of experimental samples

The wood samples cut from sap wood were conditioned at 20 ± 2 °C and 65 ± 3 % relative humidity until they reached constant weight by holding them for 3 months in a climatization room. There were 1600 test samples with 12 % average moisture with dimensions of $20 \times 20 \times 30$ mm according to the procedure of TS 2473 for each wood species (1976).

The impregnation process was carried out according to the principles of ASTM D 1413-76 (1976). A vacuum, which was equal to 60 cmHg, was applied to the samples. They were then dipped for 60 min in a solution subject to open air pressure. Before the impregnation process all samples were weighed and then kiln dried at 103 ± 2 °C until they reached constant weight. Then, the samples were weighed in an analytic balance with a sensitivity of 0.01 g. After impregnation, all impregnated samples were held for 15 days in circulating air for evaporation of the solvent.

After this period the impregnated samples were kiln dried at 103 ± 2 °C until they reached constant weight. After cooling, all dried samples in the desiccator were weighed on the scale. The dry weights of the samples were determined and recorded. The amount of retention (R , kg/m³) and ratio of retention (R , %) were calculated as follows:

$$R = \frac{G \times C}{V} 10, \text{ kg/m}^3 \tag{2}$$

$$R(\%) = \frac{M_{di} - M_d}{M_d} 100, \tag{3}$$

where

G is the mass of the sample after impregnation (T2, kg) minus the mass of the sample before impregnation (T1, kg),

M_{di} is the dry mass after impregnation (kg),

M_d is the dry mass before impregnation, kg,

V is the volume of the sample, m³, and

C , % is the concentration of the solution.

The characteristic features of the impregnation chemicals were determined before and after impregnation processes. All processes were carried out at 20 ± 2 °C. Impregnated test samples were kept at 20 ± 2 °C and 65 ± 3 % relative humidity until they reached constant weight. Afterward, approximately 180 g/m² adhesive was applied to the bonding surfaces of samples, based on TS 5430 EN 204 (TSE 2003). Bonding was obtained with 0.5 N/mm² press pressure and 24-h pressing time. Press temperatures were applied as 110 °C for PF adhesive by taking the general curing temperatures recommended by their manufacturers into consideration.

Control samples and impregnated samples were exposed to water in Amasra district of Bartın for 3, 6, 9 and 12 months.

The wood samples taken from the sea were conditioned at 20 ± 2 °C and 65 ± 3 % relative humidity until they reached constant weight by holding them for 4-5 months in a climatization room. DensityS weights of the samples taken from the sea were also determined. Moreover, compression strength perpendicular to grain of samples, which were not exposed to water and which were exposed to water for 3, 6, 9 and 12 months, was defined.

Execution of the Test

In accordance with TS 2473, compression strength perpendicular to grain was determined on match basis. Universal test machine has been working quickly, within 1-2 minutes from sample installation time to sample being crushed coming up to 6 mm/min. Experiments on the physical action to the first cross section area of the sample allowed to measure compression force applied and then to calculate compression strength perpendicular to grain, (σ_b), from the equation below:

$$\sigma_b = F_{max} / A \text{ N/mm}^2, \tag{4}$$

where

F_{max} is the maximum force at crush;

A is the sample cross section area (mm²).

Data Analyses

By using three different types of adhesive substances and control, three impregnation chemicals and control and four exposure time intervals and control, a total of 1600 samples ($4 \times 4 \times 5 \times 20$) were prepared using 20 samples for each parameter. Multiple analysis of variance was used to determine the differences between the bonding strengths of the jointing surfaces of the prepared samples. The Duncan test was used to determine whether there was a significant difference between the groups.

Results

The averages of density are given in Table 2. The highest density (0.819 gr/cm³) was obtained in prepared Scots pine samples impregnated with Tanalith-C, bonded with PVAc adhesive.

The highest retention amounts are given in Table 3. The highest retention amounts (550.0 kg/m³) were found to be in samples impregnated with Protim-Paraffin. The lowest retention amounts (8.80 kg/m³) were found to be in samples impregnated with Tanalith - C.

The averages of compression strength perpendicular to grain are given in Table 4.

The highest compression strength perpendicular to grain (39.56 N/mm²) was obtained in samples not exposed

to sea, not processed with impregnation by LVL, but bonded with D-VTKA. The lowest compression strength perpendicular to grain (10.94 N/mm²) was obtained in unprocessed samples impregnated for 12 months and massive.

Table 2. Average values of density (gr/cm³)

Impregna- tion Materials	Exposed to time	PVAc-D4	Phenol Formal- dehyde	D-VTKA	Control
Protim- paraffin	Control	0.743	0.720	0.725	0.496
	3 month	0.725	0.716	0.716	0.490
	6 month	0.721	0.710	0.713	0.478
	9 month	0.716	0.669	0.707	0.466
	12 month	0.706	0.618	0.700	0.453
Creosote	Control	0.797	0.730	0.670	0.483
	3 month	0.785	0.728	0.661	0.474
	6 month	0.763	0.676	0.656	0.470
	9 month	0.697	0.655	0.636	0.465
	12 month	0.687	0.650	0.624	0.454
Tanalith-C	Control	0.819	0.712	0.701	0.497
	3 month	0.797	0.687	0.685	0.486
	6 month	0.793	0.680	0.682	0.481
	9 month	0.788	0.675	0.678	0.479
	12 month	0.681	0.670	0.670	0.477
Control	Control	0.553	0.547	0.519	0.463
	3 month	0.546	0.540	0.515	0.461
	6 month	0.540	0.535	0.508	0.454
	9 month	0.535	0.520	0.505	0.443
	12 month	0.530	0.508	0.500	0.437

Table 3. Amount of retention (kg/m³)

Impregna- tion Materials	Minimum value	Maximum value	Mean value	St. Devia- tion	Variance
Tanalith - C	8.60	9.00	8.80	0.108	0.012
Kreozot	408.0	416.0	412.0	2.309	5.333
Protim - Paraffin	540.0	560.0	550.0	5.374	28.889

Table 4. Average value of Compression strength vertical to grain (N/mm²)

Impreg- nation	Exposed to time	PVAc-D4	Phenol Formal- dehyde	D-VTKA	Control
Protim- paraffin	Control	32.06	34.52	36.62	25.85
	3 month	31.36	32.67	35.77	22.95
	6 month	17.35	30.52	35.33	16.67
	9 month	16.96	29.81	30.67	11.46
	12 month	16.85	28.76	30.06	11.82
Creosote	Control	24.10	19.80	22.93	25.00
	3 month	22.76	19.36	21.45	24.23
	6 month	21.20	18.17	25.19	23.42
	9 month	20.27	17.24	23.97	21.47
	12 month	18.46	16.54	23.07	11.37
Tanalith-C	Control	26.43	25.11	23.80	24.50
	3 month	24.56	24.80	22.56	25.24
	6 month	22.51	23.46	22.65	27.04
	9 month	19.16	21.70	22.23	19.76
	12 month	18.99	20.12	21.48	14.56
Control	Control	36.87	25.20	39.56	26.75
	3 month	29.90	22.96	26.84	22.03
	6 month	27.51	25.53	25.45	14.49
	9 month	26.29	23.62	24.38	11.80
	12 month	25.59	22.90	22.99	10.94

Table 5. Multiple variance analysis for evaluating the effect of adhesive substance type, impregnation materials, and exposure time on compression strength perpendicular to grain

Source	Type II Sum of Squares	df	Mean Square	F	Significance
Factor A	1634.553	3	544.851	49.315	0.000
Factor B	1002.737	3	334.246	30.253	0.000
Factor C	2149.748	4	537.437	48.643	0.000
A×B	2330.237	9	258.915	23.434	0.000
A×C	584.470	12	48.706	4.408	0.000
B×C	540.189	12	45.016	4.074	0.000
A×B×C	539.860	36	14.996	1.357	0.104

Notes:

Factor A =Adhesive substance type(PVAc-D4, D-VTKA, Phenol Formaldehyde),

Factor B = Impregnation materials (Tanalith- C, Creosote, Protim-paraffin, control)

Factor C = Exposure time (Control, 3, 6, 9 and 12 month)

The multivariate analysis applied on the data obtained from the compression strength perpendicular to grain in the following manner:

Factor A = Adhesive type (PVAc-D4, D-VTKA, Phenol Formaldehyde),

Factor B = Impregnate materials (Tanalith- C, Creosote, Protim-paraffin, control),

Factor C = Exposure time (Control, 3, 6, 9, 12 months)

According to the variance analysis, the effects of adhesive substance type, the effects of impregnation material, exposure time separately, the effects of impregnation

material and exposure time, exposure time and adhesive type at the same time were statistically significant. On the other hand, according to the variance analysis, exposure time, adhesive type and the effects of impregnation material interactions were not statistically significant. The results of the Duncan test of the compression strength perpendicular to grain (N/mm²) are given in Table 6.

As a result of the comparison of exposure time statistically, in the compression strength perpendicular to grain of Scots pine, the difference is observed statistically. No difference between sample groups, which were exposed

Table 6. Duncan test of Compression strength perpendicular to grain

Factors	Mean	Homogeneity Group	Factors	Mean	Homogeneity Group
12 Month Control – Control	10.94	a	6 Month PF - Tanalith-C	23.46	rstuv
12 Month Control - Creosote	11.37	a	9 Month PF - Control	23.62	stuvy
9 Month Control - Protim- Parafin	11.46	a	Control- D-VTKA - Tanalith-C	23.80	tuvy
12 Month Control - Protim- Parafin	11.82	a	9 Month D-VTKA - Creosote	23.97	tuvy
9 Month Control – Control	11.80	a	Control - PVAc-D4- Creosote	24.10	tuvyz
6 Month Control – Control	14.49	b	3 Month Control - Creosote	24.23	tuvzyA
12 Month Control - Tanalith-C	14.56	b	9 Month D-VTKA - Control	24.38	uvyzAB
12 Month PF – Creosote	16.54	c	Control - Control- Tanalith-C	24.50	vyzABC
6 Month Control - Protim- Parafin	16.67	c	3 Month PVAc-D4- Tanalith-C	24.56	vyzABC
12 month PVAc-D4- Protim- Parafin	16.85	c	3 Month PF - Tanalith-C	24.80	yzABCD
PVAc-D4- Protim- Parafin	16.69	c	Control - Control- Creosote	25.00	zABCDE
9 month - PF - Creosote	17.24	c	3 Month Control - Tanalith-C	25.04	zABCDE
PVAc-D4- Protim- Parafin	17.35	cd	Control -PF - Tanalith-C	25.11	ABCDE
6 month - PF - Creosote	18.17	de	6 Month D-VTKA – Creosote	25.19	BCDE
PVAc-D4- Creosote	18.46	ef	Control – PF- Control	25.20	BCDE
PVAc-D4- Tanalith-C	18.99	efg	Control- PF	25.45	CDEF
PVAc-D4- Tanalith-C	19.16	fgh	6 Month- PF- Control	25.53	DEFG
3 month-PF- Creosote	19.36	ghi	12 Month- PVAc-D4-Control	25.59	DEFG
Control - Tanalith-C	19.76	hi	Control- Control - Protim- Parafin	25.85	EFG
Control- PF - Creosote	19.80	hi	PVAc-D4- Control	26.29	FGH
12 Month PF - Tanalith-C	20.12	i	PVAc-D4- Tanalith-C	26.43	GH
9 Month PVAc-D4- Creosote	20.27	jk	Control- Control	26.75	HI
6 Month PVAc-D4- Creosote	21.20	k	3 Month D-VTKA – Control	26.84	HI
3 Month D-VTKA - Creosote	21.45	k	6 Month Control - Tanalith-C	27.04	HI
9 Month Control – Creosote	21.47	kl	6 Month PVAc-D4- Control	27.51	I
12 Month D-VTKA - Tanalith-C	21.48	klm	12 Month- PF- Protim- Parafin	28.76	J
9 Month PF - Tanalith-C	21.70	klmn	9 Month PF - Protim- Parafin	29.81	K
3 Month Control-Control	22.03	lmno	3 Month PVAc-D4- Control	29.90	K
9 Month D-VTKA - Tanalith-C	22.23	lmno	12 Month D-VTKA - Protim- Parafin	30.06	K
6 Month PVAc-D4- Tanalith-C	22.51	mnop	6 Month PF- Protim- Parafin	30.52	K
3 Month D-VTKA - Tanalith-C	22.56	mnop	9 Month D-VTKA - Protim- Parafin	30.67	K
6 Month D-VTKA - Tanalith-C	22.65	mnopr	3 Month PVAc-D4- Protim- Parafin	31.36	L
3 Month PVAc-D4- Creosote	22.76	mnopr	Control - PVAc-D4- Protim- Parafin	32.06	LM
12 Month PVAc-D4-Control	22.90	mnopr	3 Month PF- Protim- Parafin	32.67	M
Control- D-VTKA - Creosote	22.93	mnopr	Control- PF- Protim- Parafin	34.52	N
3 Month Control - Protim- Parafin	22.95	mnopr	6 Month D-VTKA - Protim- Parafin	35.53	NO
3 Month PF - Control	22.96	noprs	3 Month D-VTKA - Protim- Parafin	35.77	O
12 Month D-VTKA - Control	22.99	oprst	Control- D-VTKA - Protim- Parafin	36.62	P
12 Month D-VTKA - Creosote	23.07	oprstu	Control- PVAc-D4- Control	36.87	P
6 Month Control - Creosote	23.42	prstuv	Control- D-VTKA - Control	40.06	P

to sea water for 9 months and which were exposed to sea water for 12 months in the same way has been observed in interaction. No difference between sample groups, which were exposed to sea water for 6 months and which were exposed to sea water for 3 months in the same way, has been observed in interaction. However, statistical difference has been observed among other groups.

Discussion and Conclusions

The effect of impregnation materials and exposed time on perpendicular compression value is given Figure 1.

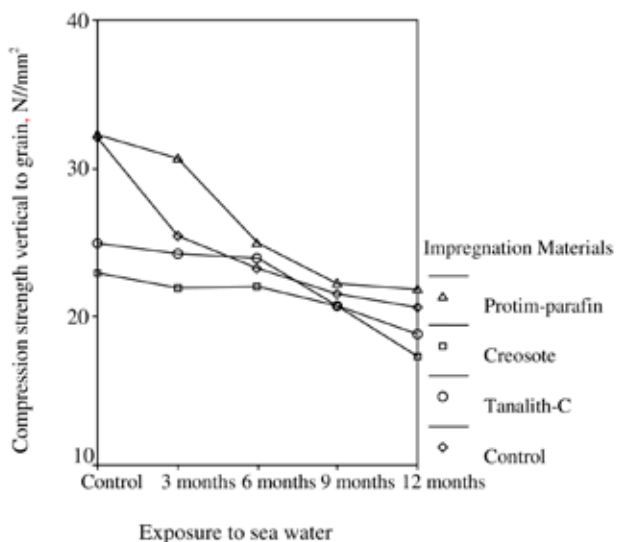


Figure 1. Effect of impregnation materials and exposure time on Compression strength perpendicular to grain

According to Figure 1, as to exposure time among the impregnated materials, the highest compression strength perpendicular to grain value was obtained in control samples. The lowest compression strength perpendicular to grain value was obtained in samples impregnated with creosote and exposed for 12 months.

According to Figure 1, when the effect of the duration of exposition to sea and impregnation material on the compression strength perpendicular to grain in samples is taken into consideration, it can be observed that if the material is exposed to sea for a longer period of time, there occurs a decrease in the compression strength perpendicular to grain gradually. The rate of decrease in the unimpregnated samples is 36 % in average, 32 % in the ones impregnated with protim-paraffin, 25 % in the ones impregnated with Tanalith-C, and 24 % in the ones impregnated with creosote. The highest decrease in compression strength perpendicular to grain values has been observed in the unimpregnated samples. When unimpregnated wood material is exposed to sea water, there may occur decomposition caused by bacteria and fungus.

The effect of adhesive type and exposure time on perpendicular compression value is given in Figure 2.

In Figure 2, the effect of adhesive type and the duration of the exposition of material to sea on the compression strength perpendicular to grain have been searched. Among the samples exposed to sea, the best result has been observed to be in D-VTKA adhesive.

Among the adhesive types, D-VTKA adhesive gave better results in Scots pine especially after being exposed to sea water (see Figure 2). D-VTKA showed high dry and wet strength; resistance to water and damp atmosphere; limited resistance to prolonged and repeated wet-

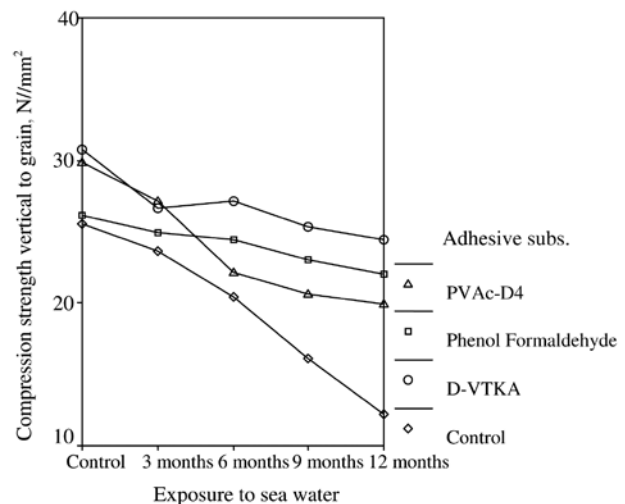


Figure 2. Effect of adhesive type and exposure time on compression strength perpendicular to grain

ting and drying; gap-filling (Vick 1994, Kurt 2006). At high temperatures, D-VTKA adhesives can be advised as the building material used for long term use (Uysal et al. 2008). Lay and Cranley (2003) stated that polyurethane adhesives have higher bonding strength and higher tolerance against humidity.

According to Figure 2, when adhesive type and the duration of the exposition of the material on the compression strength perpendicular to grain is taken into consideration, it can be observed that the longer the material is exposed to sea, the better the compression strength of LVL compared to massive samples is. The rate of decrease in massive samples is 52 % in average, 33 % in samples laminated with PVAc, 21 % in samples laminated with D-VTKA, and 16 % in samples laminated with phenol formaldehyde. The highest decrease in compression strength perpendicular to grain values has been observed in unimpregnated samples. When unimpregnated samples are exposed to sea water, there may occur decomposition caused by bacteria and fungus.

Phenolic resins are used as binders for exterior in grade plywood and particleboard, which need the superi-

or water resistance provided by these resins (Pizzi 2003). Phenolic resins (PF) show complete resistance to hydrolysis of the C-C bond between the aromatic nucleus and the methylene bridge and, therefore, are used for water and weather resistant glue lines and boards such as water and weatherproof particleboards, OSB, MDF, or plywood intended for use under weather conditions (Dunky 2003).

In addition; Amasra is the area known for wood material is most commonly destroyed by mussels *Teredo navalis* L. In the first 6 months of life these organisms do damage more quickly in the perpendicular direction than in the next period of their life, when their damage is more observed in the direction parallel to grain, and data on the compression strength perpendicular to grain shows more resistance in a horizontal course. Consequently, it is said that the use of impregnated LVLs increases their resistance against the marine fungus.

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