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Experimental Study of Mechanical Behavior of HPL Composites

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Abstract. The paper provides experimental results of tensile and flexural tests of HPL composites. Mechanical properties of HPL laminates from four worldwide producers (Fundermax, Polyrey, Abet and Rexin) are compared. Composites are compared due to their stiffness and strength, both tensile and flexural. The exterior environment effect on mechanical behaviour of composites in service load conditions is presented, too.

Introduction

The HPL laminate consist of kraft paper layers made of natural fibers (about 65 % weight ratio) and polymer resin (mainly phenolic), which are under big pressure (100 bar) and high temperature (150 ºC) compressed and cured. The time of curing is normally set between 30-90 minutes depending on thickness of pressured material. The bearing core consists of phenolic resin and protective layers made of melamine resin. This material is non-conducting, heat resistant, corrosion resistant, vapor resistant and cold resistant. The material does not contain organics halogenide (chlorine, bromine, fluorine and etc.) and substances which occur in PVC. It does not contain asbestos and protector herbicide (fungicides, pesticides) or any sulphur, mercury, cadmium and other heavy metals. HPL laminate is highly resistant to abrasion, it is hygienic and can be used with food contact. HPL laminates are used in facing applications, such as doors of furniture or other interior parts. They are also used as face sheets of sandwich structures. [1, 2]

Chips created during machining (cutting or milling) of HPL laminate are not deleterious. During thermal destruction of this material the poisons for human or environment (muriatic acid, organic chlorine compound or dioxins) are not created. The laminate sheet is decomposed on carbon dioxide, nitrogen and dust at high temperature and present of the oxygen. The energy obtained from this process can be effectively utilized. Handling on industrial dumping places is trouble-free, too. [1]

This paper gives experimental results from tensile and flexural tests of HPL composites. Stiffness and strength are reviewed. Mechanical properties are compared for four worldwide producers of HPL laminates (Fundermax, Polyrey, Abet and Rexin). The exterior environment impact (water-1500hr and 3000hr, 20ºC) on mechanical behavior of HPL composites in service load conditions are presented. An effect of chemical resistance have been also analyzed (coefficient β, EN 978).

Materials and Methods

Researched HPL laminates were obtained from four different producers. Individual samples were divided by its producers. First, sample A was produced by Polyrey, sample B by Abet, the third one was obtained from Fundermax company and last, sample D was produced by Rexin.

The stability of all HPL laminates was observed in static tests, namely by tensile test (EN ISO 527) [3], and flexural test (EN ISO 178, EN ISO 14125) [4,5]. Supports in flexural test were distant from each other by 60mm. Measurements were conducted on the universal testing machine Zwick 1456. Elastic modulus and strength limit were determinate. Elastic modulus E is observed for a significant influence on the stability and deformation behavior of the product, while yield strength σ_M describes maximal load applicable on laminate. The test specimens were made by machining from plane sheet in direction L (longitudinal) and T (transversal). Structure and dimensions (100x20x5 mm) of all tested HPL laminates was similar and can be seen in Fig 1.

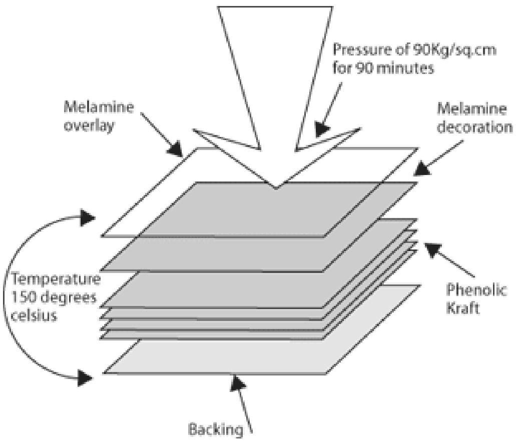

Fig. 1. The structure of HPL composite.

Static mechanical testes were focused on a comparison of short-term and long-term properties of material such as elastic modulus and strength limit. [6] The impact of pure water at 20 °C which acts on the material for 1500 hrs (flexural tests) and 3000 hrs (tensile tests) was investigated. The tests simulate the normal operation of the material in contact with water.

Results

Tensile properties of tested HPL laminates measured at room temperature and after exposure in water bath for 3000 hrs are shown in Fig 2. As it can be seen, the highest value of tensile strength was measured for sample B cut in L-direction from a sheet, while for T-direction samples A and B showed almost same value of this parameter. The lowest value of σ_{ML} equal 68% of sample B strength was measured for sample C and in case of σ_{MT} equal 75% of sample B strength for sample C and D. The same trend was also obvious for samples after exposure in bath.

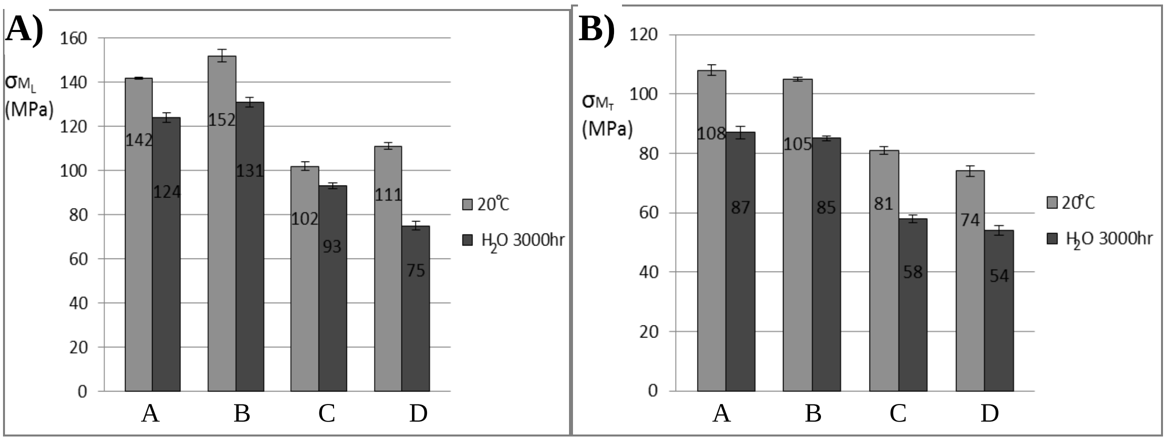

Fig. 2. Tensile strength σ_M without deposition (20°C, air) and after exposure (H_2O-3000hr), (A) Strength limit in L-direction, B) Strength limit in T-direction).

Data for elastic modulus (E) are depicted in Fig. 3. This parameter is almost the same for all samples at room temperature. However, sample D showed the greatest decrease of 44 % after exposure in water, where other samples showed almost similar decrease equaling almost 20 %.

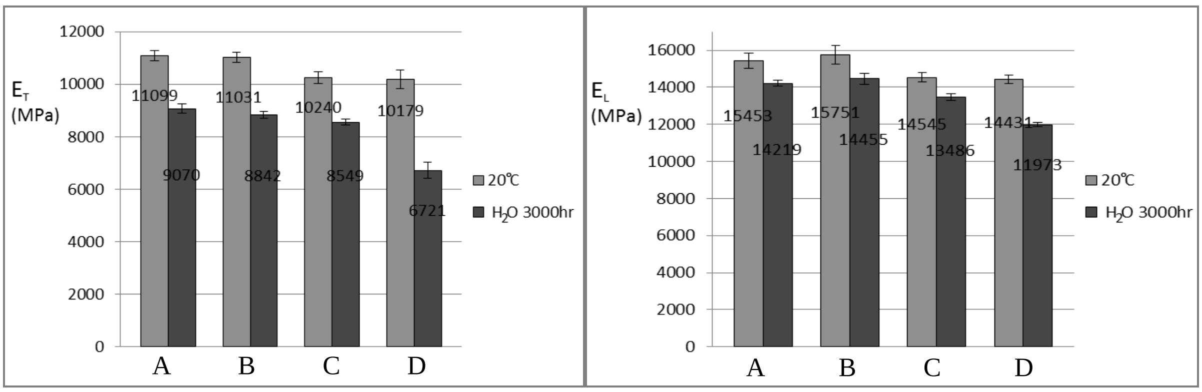

Fig. 3. Tensile elastic modulus E without deposition (20°C, air) and after exposure (H_2O-3000hr),
(A) Elastic modulus in L-direction, B) Elastic modulus in T-direction).

The results of flexural properties are depicted in Figs. 4 and 5. Decrease of flexural strength for both sample series (cut in L- and T- direction) in case of samples C and D is not as marginal as in case of tensile strength. The highest values were measured again for samples A and B. Exposure in water caused decline of flexural properties. Namely, decrease was in range of 6 to 20 %.

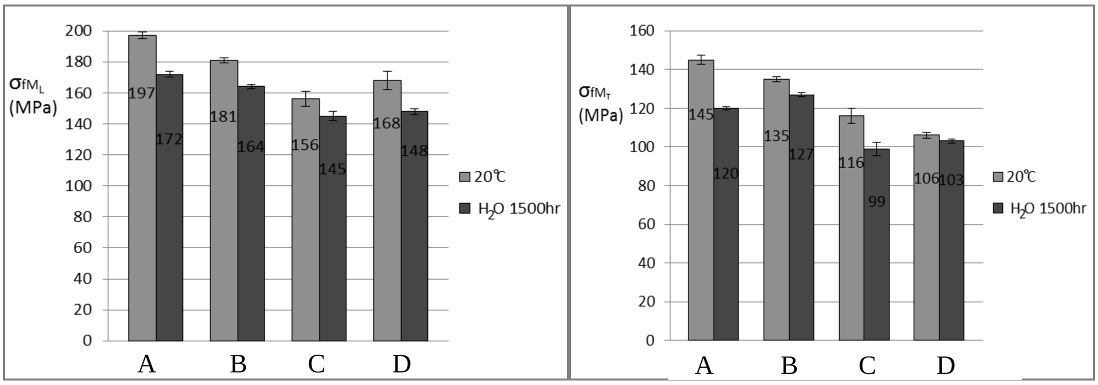

Fig. 4. Flexural strength σ_{fM} without deposition (20°C, air) and after exposure in H_2O-1500hr, (A) Elastic modulus in L-direction, B) Elastic modulus in T-direction).

Flexural modulus (Ef) of HPL laminates is provided in Fig. 5. As it can be seen, all samples have almost similar elastic modulus. The greatest decrease of this parameter (about 20 %) was measured for sample D. Modulus of samples cut in L-direction is almost by 25 % greater than in T-direction.

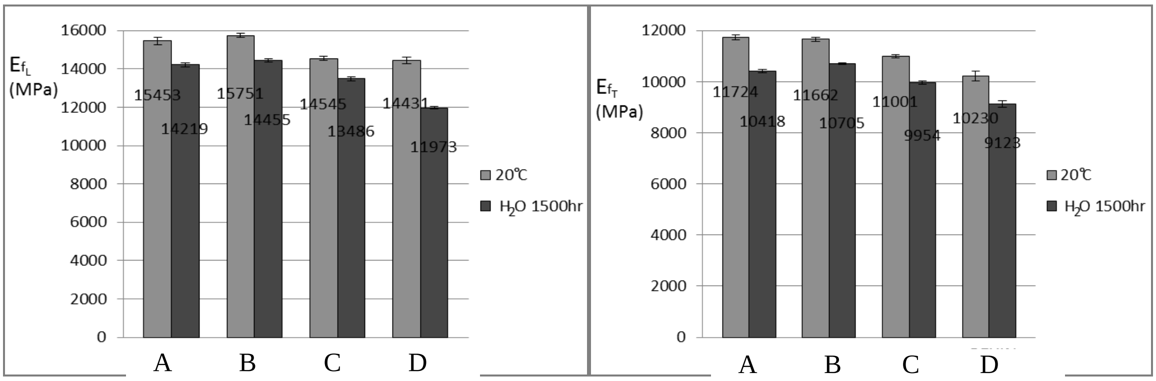

Fig. 5. Flexural elastic modulus E_f without deposition (20°C, air) and after exposure in H_2O-1500hr,
(A) Elastic modulus in L-direction, B) Elastic modulus in T-direction).

Long-term tensile and flexural properties of HPL laminates were described using coefficient β, which is defined as relationship between stiffness after storage in liquid and initial stiffness given in dry conditions at 20 °C [7, 8].

In a specific standard (ČSN EN 978 [8]) modifying coefficient β* is determined as:

$$\beta^* = E_2/E_1 \,, \quad (1)$$

where E_1 is elastic modulus at air 20 °C, E_2 is elastic modulus in H_2O (20 °C) for 1500 or 3000 hrs.

Calculated data of coefficient β are given in the following table (Table 1). As it can be seen, the highest value was obtained for sample C (FUNDERMAX) in L-direction. On the other hand, the lowest value was measured for sample D (REXIN) in T-direction in tensile. However, values for all other samples differ only in the range of 2 to 15 %.

Table 1. Determination of coefficient β*.

	POLYREY		ABET		FUNDERMAX		REXIN	
	L	T	L	T	L	T	L	T
$\beta^*_{Tensile}/H_2O$ 3000hr	0,92	0,82	0,92	0,8	0,93	0,83	0,83	0,66
$\beta^*_{Flexural}/H_2O$ 1500hr	0,92	0,89	0,92	0,92	0,93	0,91	0,83	0,89

Conclusion

The research has evaluated tensile and flexural tests of HPL composites obtained from four worldwide producers. Material of producer Abet showed the best tensile properties in a longitudinal direction, in a transversal direction Abet and Polyrey materials were the best ones. The bending test showed that the highest flexural strength had Polyrey material in both directions. On the other hand, results of elastic modulus were similar for Abet and Polyrey in both directions. As can be evaluated, mechanical properties of individual HPL laminates significantly differ and same cheaper material from different producer does not have to replace the old one properly.

From all above mentioned results it is also apparent that the effect of water caused changes of elastic modulus and tensile and flexural strength.

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