Influence of Synthetic and Natural Fibers on the Characteristics of Wood-Textile Composites

CAMELIA COSEREANU[1], IOAN CURTU[2]*, AUREL LUNGULEASA[1], DUMITRU LICA[1], MIHAELA POROJAN[1], LUMINITA MARIA BRENCI[1], IVAN CISMARU[1], IOAN IACOB[3]

[1]Transilvania University of Braşov, Wood Industry Faculty, Department of Wood Technology, 29 Eroilor Blv., 500039, Braşov, Romania

[2]Transilvania University of Braşov, Faculty of Mechanics, Department of Strength of Materials and Vibrations, 29 Eroilor Blv., 500039, Braşov, Romania

[3]"Gheorghe Asachi" Technical University of Iaşi, Faculty of Textiles, Leather and Industrial Management, Department of Technology and Design of the Textiles Products, 53 D. Mangeron, 700050, Iaşi, Romania

The paper presents the results of the research work on the evaluation of the mechanical properties (bending strength, MOE, shearing strength of the adhesive bond) of the laminated wood-textiles composite materials made of wood veneer (beech and poplar wood) and textiles: natural fabric made of jute (sackcloth) and woven fabric with synthetic fiber insertions (MTR-polyester, cotton, staple rayon). The layers of veneer and textiles were glued together by two types of adhesives, successively: a natural one (bone glue) and a polyvinyl adhesive (Jowacoll 107.10). Four types of wood-textile composite samples have resulted, as follows: beech veneer – sackcloth glued with bone glue, beech veneer – sackcloth glued with polyvinyl adhesive, poplar veneer – sackcloth glued with bone glue and beech veneer – woven fabric with MTR glued with bone glue. The samples resulted were loaded to the bending strain and the bending strength and MOE were calculated with the value of breaking force obtained for each tested sample. The shearing strength of adhesive bond has been also experimentally determined in order to establish which adhesive is more appropriate to be used both with wood and textile materials into the composites. The influence of the flexibility of the synthetic fibers on the elastic properties of the resulted composites has been also investigated by determining MOE of the corresponding composites. Based on the results obtained, it is concluded that the synthetic fibers (67%) contained by woven fabric with MTR does not increase MOE of the composites, whilst the natural jute fabric behaviour into the wood-textile composites gives unexpected results in strength and elasticity of the new product.

Keywords: *synthetic fibers, MOE, bending strength, shearing strength, composite, elasticity*

Wooden composites are classified in agglomerated boards (particleboard, hard fiberboard, MDF, etc.), laminated products (plywood, blockboard, panelled board) and wooden-plastic composites, obtained by extrusion method. The wooden laminated composite materials may have a structure developed on a horizontal direction, as the finger-jointed and edge-jointed panels are [1] and a structure developed on the vertical direction, as the sandwich composite panels are, case when the mechanical properties as bending strength and stiffness are improved [2]. Plywood is an example of the wooden sandwich composites and its properties depend on the adhesive used (durability), ply stacking, quality of veneer and wood species [3]. On plywood structure often subjected to bending strains there were developed sandwich structures made of glued beech veneer that can be molded with small curved shapes radius and applied in industry as components in furniture and automotive industry, for that purpose requiring a high elasticity (fig.1).

As regards to the textile composites, in the past 50 years, great progress has been made in developing artificial fiber-reinforced composite materials, generally using filaments with microscopic diameters, resulting thus flexible textile composites in the construction of different products for industry and building.

Unlike rigid composites, used for applications requiring extreme strength and high modulus, flexible textile composites find use in innumerable industrial and consumer applications where flexibility is a necessary requirement. Fibers, as basic component of textiles are characterized by flexibility and fineness. Fabrics retain more or less completely the strength, flexibility and other properties of their original fibrous nature [4].

Composites are used for high strength, stiffness or flexibility and heat resistant applications as automotive and aerospace components, maritime structures, materials for construction and industrial purpose [5-7], medical implants [8, 9] and

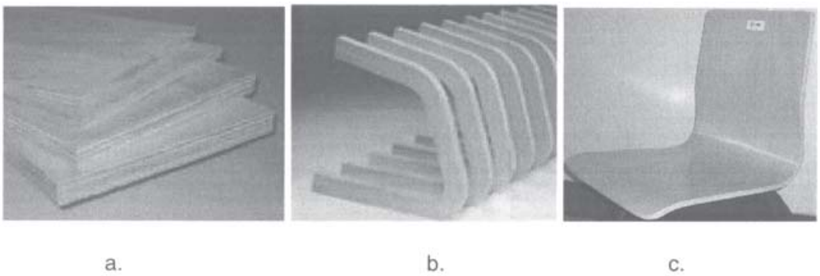


Fig.1. Plywood as laminated sandwich wooden composite (a.) and molded components (b. and c.)

* Tel.: (+40) 0268412921

recreational items starting with canoes and ending with fishing rods.

In design and manufacture of textile composites the term is used to describe the broad range of polymer composite materials with textile reinforcements, from woven and non-crimp fabrics to three dimensional textiles [10].

No data about wood – textile composites were found in the literature so far. The question this paper intends to answer is if the woven fabric inserted in the structure of the sandwich wooden composite (plywood) succeeds to improve the elastic properties of the new composite and its plastic deformation. The second question is if the flexibility of the synthetic fibers in the structure of the woven fabric will improve the elastic properties of the new wood-textile composite.

The structure of the composite materials studied in this paper is a sandwich one, similar to plywood structure, being obtained by gluing layers of veneer and sackcloth, using two types of adhesives: a natural one (bone glue) and a polyvinyl one (Jowacoll 107.10) The natural woven fabric of jute, namely sackcloth is investigated first in the structure of the wooden-textile composites, where two types of veneer are used: beech and poplar wood. The natural adhesive (bone glue) will give the product a high ecological grade and also a biodegradable property. Afterwards, the same structure of the composite except the bone glue which is replaced by Jowacoll 107.10 will be tested in the same conditions. The third structure of wood-textile composite, by replacing the sackcloth with woven fabric having synthetic fibers (rayon and polyester) will be then investigated in the same conditions. For this structure the adhesive with best test results will be used, and conclusions about the influence of the synthetic fibers to the elasticity of the new product are obtained.

Experimental part

Two species of wood were used for the layers of veneer: poplar and beech wood. Poplar is one of the fastest growing species of wood, having a reduced strength [11] and beech wood is one of the most common species of wood met in industrial fields, having a plastic deformation and being used for molding applications. When constructed the wooden-textile composites, the beech (Fagus Sylvatica) veneers had an initial moisture content of 10% and thicknesses of 1.1 mm and 1.5 mm. The poplar veneers had the same initial moisture content of 10% and thicknesses of 2.5 and 3.5 mm.

The samples were obtained in the laboratory conditions. The sizes of the experimental panels were 400 x 400 [mm] and 400 x 200 [mm] respectively, adapted to the dimensions of the press plane used in the laboratory.

The sackcloth used for the samples was made of jute (100%). The measured thickness of the sackcloth was 0.9 mm.

The characteristics of the adhesives used to glue the layers of veneer and fabric are as follows.

For bone glue they are according to STAS 88-73 and [12], as follows:

-moisture content of 17%,

-ash content reported to the dry adhesive of 30%,

-viscosity of the solution (17.75% at 30°c) of 13 MPa s,

-viability of the solution of 17.75% at 25°C: more than 72 h,

-pH of the solution of 1%: 5.5-6.5,

-shearing strength: more than 7.5 MPa.

The granules of bone glue were solved in warm water (60°C) in a rate of 1:2 (adhesive-water). The specific consumption when applying it on the veneer surface was of 150 g/m^2 as solution, meaning 50 g/m^2 of dried adhesive. It was applied after warming it on a steam bath.

The parameters used for the second adhesive, a polyvinyl one, named JOWACOLL 107 10 are as follows:

- specific consumption: 200g/ m^2;
- clamping pressure: 0.5 N/ mm^2;
- clamping time: 20 min;
- conditioning: 7 days at 20°C.

The technical characteristics of JOWACOLL 107 10 adhesive are as follows:

-D4 mono-component,

-ash content reported to the dry adhesive: 49%,

-viscosity of the solution (Brookfield): 6000 MPa s,

-*p*H: 3,

The structure and the shape of the experimental wood-textile composite panels are shown in figure 2. The sandwich structure formed this way was introduced between two aluminum plates into the press and a pressure of 2.5 MPa was applied at a temperature of 20°C for 2.5 h long. The panels were conditioned than at a temperature of 20°C for two days in a compact stack conditions.

After completing the panels conditioning, two types of specimens were cut from the panels: specimens for bending strength test, according to SR EN 310 and specimens for shearing strength test, according to SR EN

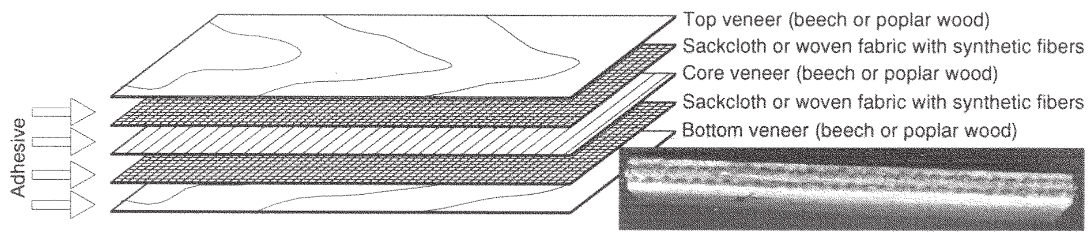


Fig. 2. Structure of the wood-textile composites

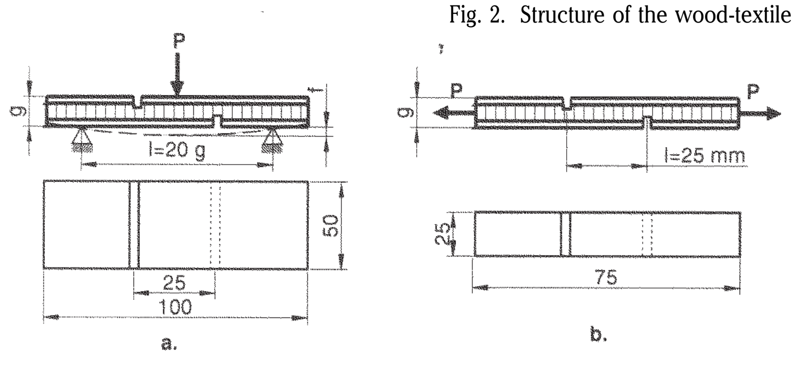


Fig. 3. Samples and testing principles for determining the MOE and bending strength(a.) and the shearing strength of adhesive bond (b)

Table 1
CHARACTERISTICS OF THE TEXTILES USED IN THE STRUCTURE OF WOOD-TEXTILE COMPOSITES

Characteristics on:	Natural fabric (sackcloth)		Woven fabric with synthetic fibers	
	Warp	Weft	Warp	Weft
Fineness	Nm 4		Nm 40/2	Nm 20
Warp - Sett	43 yarns/10cm	-	95 yarns/10cm	-
Number of rounds	-	47yarns/10cm,	-	100 yarns/10cm
Composition	100% jute		33% cotton (natural fibers) and 67% MTR (synthetic fibers+natural fibers)	50% synthetic fibers (polyester) + 50% flax
Breaking force (average), in N	1009	750	446,2	1048
Extension, in %	5,08	6,65	15,7	22,7

Fig. 4. IMAL 23600 testing equipment and the microscope EPI-FL B5

314-1. The shape and sizes of samples and the principles of the two tests are shown by drawings in figure 3.

The sample in figure 3a. was used for the determination both of MOE and bending strength after subjected it to bending load. The test lasted for 30 s and the bending strength (σ_i) was calculated with equation (1):

$$\sigma_i = \frac{3}{2} \cdot \frac{Pl}{bg^2}, \text{ MPa} \qquad (1)$$

in which:

P is the breaking force, in N;

l – distance between the fulcrums (20 x g), in mm;

b – sample width (50mm);

g – sample thickness, in mm.

MOE was calculated with equation (2):

$$E_i = \frac{l^3 \cdot (P_2 - P_1)}{4bg^3(f_2 - f_1)}, \text{ MPa} \qquad (2)$$

in which:

P_1, P_2 are the limit forces of the elasticity in case of bending strain, in N (P_1 = 10%P_{max}; P_2 = 40%P_{max});

l – distance between the fulcrums, (20 x g), in mm;

f_1, f_2 – bending deflection for P_1, P_2 forces, in mm;

b – sample width of 50 mm;

g – sample thickness, in mm.

The shearing strength of adhesive bond was calculated with equation (3), and the samples used for this test are those presented in figure 3b.

$$\tau_s = \frac{P}{A}, \text{ MPa} \qquad (3)$$

in which:

P is the breaking force, in N;

A– breaking area, in mm^2;

A = b . 1, where b is the width of the sample, in mm and l is the length of breaking area (b = 25 mm, l = 25 mm).

The third variant of wood-textile composites had the following structure: beech veneer and woven fabric with synthetic fibers (rayon and polyester fibers) and cotton. The properties of the textiles used in the structure of the wood-textile composites studied in this paper are presented in table 1.

The values of breaking forces and extensions were experimentally determined using an electronic dynamometer.

The equipment used for the experimental part is presented in figure 4. Bending tests was performed on IMAL 23600 testing machine provided with PC and the microscopic research at the interface wood-textile-adhesive was performed with Epi-fluorescence Microscope mod. EPI-FL B5.

Results and discussion

Distribution of the breaking forces and densities of the tested samples of each case are shown in figure 5. For the tests were used 12…24 specimens obtained from different panels made of the same materials and in the same environmental and technological conditions. It can be seen that the distribution of the forces is homogeneous for the case of composites made of poplar veneer glued with bone glue, but the resulted breaking forces have low values, meaning a low bending strength. When composites are made of beech veneer, the higher density values belong to the case when they are glued with bone glue and also the values of forces are higher in that case.

The maximum forces were registered for the composites made of beech veneer and glued with bone glue. The load curve in this case is shown in figure 6 (1) in comparison with the load curve (2) for the case when the wood-textile composite is made of beech wood glued with polyvinilic adhesive and the load curve (3) for the case when beech veneer and woven fabric with synthetic fibers are glued with bone glue.

The load curves show the behaviour of the samples during the bending test: a better resistance of the sample to the bending strain when the beech veneers are glued with bone glue having a higher elongation until the sample's breaking and a constant increasing of force, whilst the sample where the polyvinyl adhesive was used was broken more rapidly, indicating the frail characteristic of this

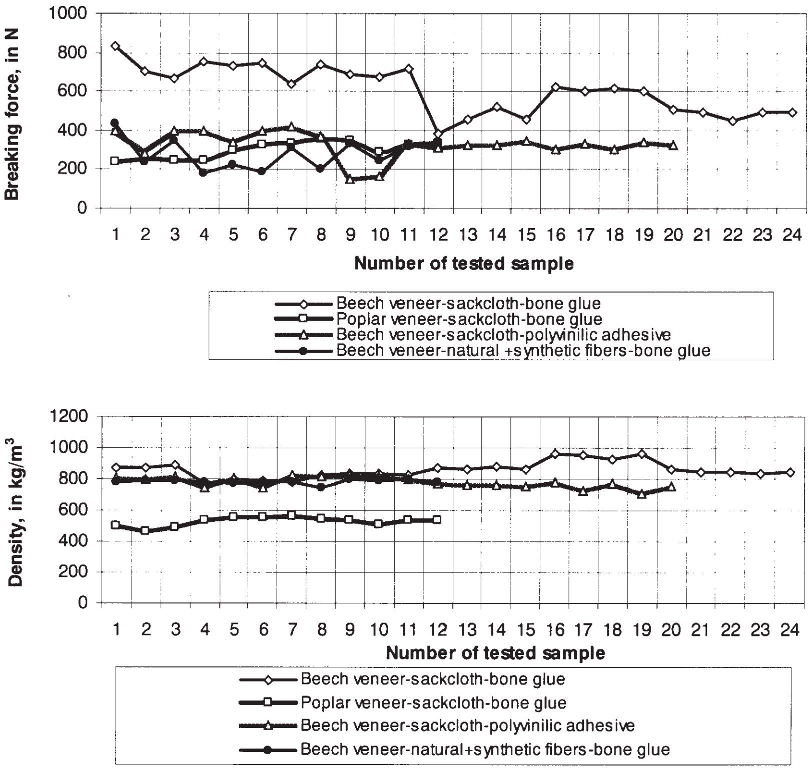


Fig. 5. Distribution of breaking force and density for the tested samples

samples. A better behaviour than the latest one was registered for the composites where the synthetic fibers were used, but not as good as the behavior of the samples with the insertion of sackcloth.

The values of MOE and of the bending strength and the comparison between the four cases are shown in figure 7. The results are also compared with the corresponding values of the plywood according to the literature in the field [13].

When the sackcloth was replaced in the composite panel by the woven fabric with synthetic fibers (MTR) the bending test was repeated for the new structure and the shearing strength test was done for the two cases in order to be compared (fig. 8). The values of the shearing strength

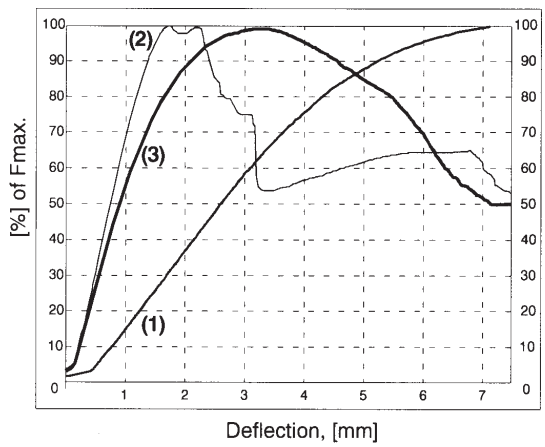
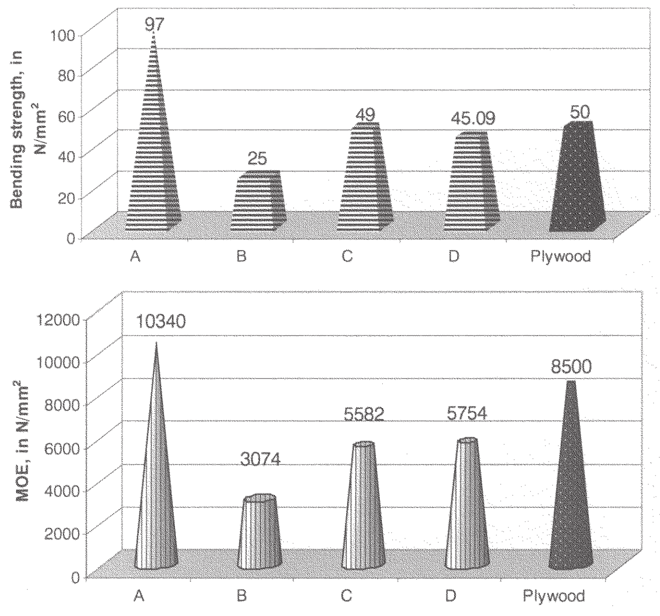


Fig. 6. Load curves for wood-textile composites made of beech veneer - sackcloth glued with bone glue (1), beech veneer – sackcloth glued with polyvinilic adhesive (2) and beech veneer-woven fabric with synthetic fibers glued with bone glue (3)



A Beech veneer-sackcloth-bone glue
B Poplar veneer-sackcloth-bone glue
C Beech veneer-sackcloth-polyvinilic adhesive
D Beech veneer-woven fabric with synthetic fibers-bone glue

Fig. 7. Bending strength and MOE for the tested samples

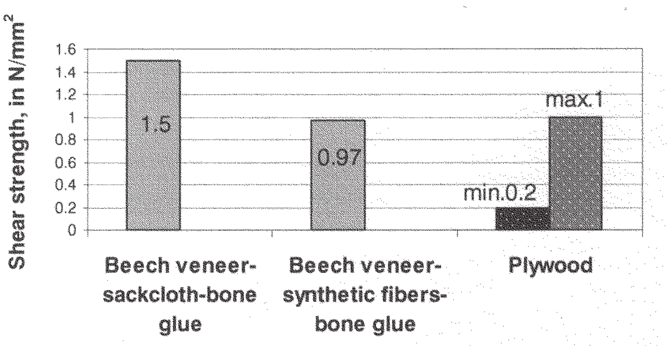


Fig. 8. Shearing strength of the adhesive bond when using bone glue and two types of fabric compared with plywood values

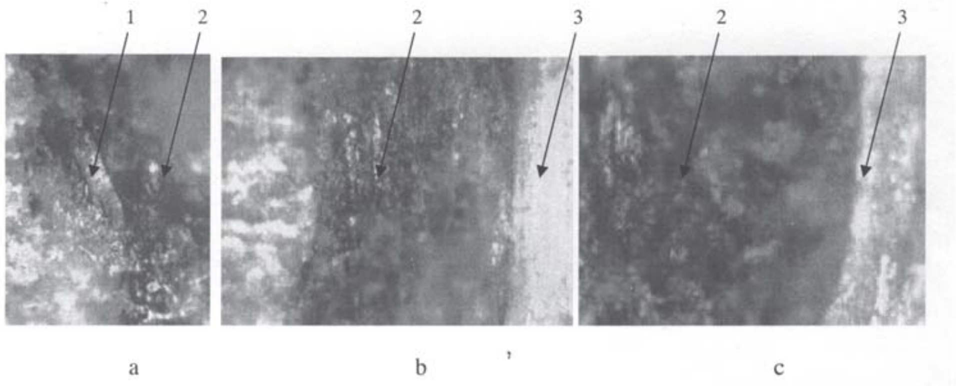


Fig. 9. Microscopic view on the interface wood – sackcloth – bone glue; 1-textile fiber, 2-bone glue, 3-beech wood veneer

of the adhesive bond in the technical specification SR EN 314-1 and in the literature [14] is between 0.2-1.0 N/mm^2 for the plywood, so a better value was obtained when using sackcloth, but a value in the admitted range of plywood was obtained when using woven fabric with synthetic fiber and cotton.

A microscopic research at the interface wood-sackcloth-glue bone (fig. 9) show the good adhesion of the bone glue with the sackcloth (a) and also a crystalline shape of the adhesive with a unitary appearance (b). The adhesion bone glue – wood is materialized through a visible continue line with no color edging (c).

Conclusions

The wood-textile composites proposed in this paper are new products designed to improve the elastic properties of the laminated composites having the structure of plywood in order to be molded for applications as components in furniture and automotive industry. The increased flexibility of the synthetic fibers which are the main components of the woven fabric with rayon and polyester fibers, unfortunately did not concluded to the expected results, of spectacular increasing the elastic properties and strength of the corresponding wood-textile composites. On the other hand the sackcloth insertion into the beech veneer - textile composites concluded to an increasing with 25 % of the elastic properties of the new material compared with those of the plywood and an increasing of 50% of the shearing strength of adhesive bond compared with the values of the plywood found in the literature. As seen in the microscopic view of the interface wood-textile-adhesive, the jute fiber is not entirely absorbed by the glue mass, allowing transferring its elastic properties to the final composite material. Due to its fineness, the woven fabric with synthetic fibers may be completely integrated in the compact mass of adhesive, so the flexibility of the synthetic fibers could not participated in this case to the elastic properties of the resulted composite. The final conclusion is that the wooden- textile composites composed of beech veneer and sackcloth fabric glued with bone glue are a variant of improving the elastic properties of wooden composites as plywood is.

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