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MECHANICAL TESTING OF BEECH VENEER SANDWICH COMPOSITES

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Abstract: *The present paper investigates the mechanical characteristics of some sandwich composites made of beech veneers (3 and 5 layers) and textiles glued together with natural bone glue instead of conventional adhesives for veneers. The research work followed the influence of the textiles insertion (natural fibers and mixed fibres) into the beech veneer sandwich composites from the mechanical characteristics point of view. The products are intended to be made only of natural components, provided to replace classical structures of moulded plywood in some applications for furniture, buildings and cars. The beech veneer sandwich composite panels with and without textile insertion were compared. The final conclusion is that the textile insertion improves the mechanical properties of this type of sandwich structures.*
Key words: composites, wood, textiles, bone glue.

1. INTRODUCTION

Wood is a renewable, recyclable and biodegradable material. Engineered wood products (EWP) result by binding together the fibres, particles or veneers of wood, in order to form composite materials. The disadvantages of EWP are the additional primary energy necessary for their manufacturing compared with wood and the toxic adhesive often used in their structure. Green products, ecological, biodegradable composites from renewable resources are a higher level of thinking the structures of the new raw materials. The properties of the composites need to be improved to increase the range of applications so that, ideally, the composites exhibit high modulus and strength and have good thermal and dimensional stability [1]. Using the natural fibers in the composites structures bring the advantages of low costs, renewability and biodegrability characteristics. A variety of natural fibers were used in research of the biocomposites with good results, as in case of reinforced coconut fibers [2], where the tensile strength increased by about 33.3% compared to composites without fiber and improved values for tensile modulus by ca. 75% compared to blends without fibers. Improvement of strength occured in case of using Manila Hemp fiber [3] where the tensile and flexural strengths of the composites increased with increasing fiber content up to 70%. The use of reinforced ramie fibre [4] also proved an increasing of the tensile strength and impact test of the obtained composites, for a certain length and content of the fiber. Previous research have shown that the reinforcement of natural fiber as jute [5] in the structure of veneered based composites increses MOE by 25% and the shear strength by 50%, whilst the synthetic fibers will not increase them. The properties of the composites with insertion of natural or artificial fiber depends on the proportion and the volume of the fibers and the matrix, the density of the resulted structure, the thickness of the fiber, the position of the insertion into the structure, elasticity and stiffness of the components and the strength of materials [6]. The paper presents the further results of the research on the laminated wood-textile composites, with regards to mechanical properties as bending strength, tensile strength, MOE and shearing strength of adhesive bond, for several structures made of three and five layers of veneer, using natural and mixed woven fabric as insertion, determining the structures with improved strength and elasticity [7], given by the results of the investigations.

2. APPLIED METHODS

2.1 Bending strength

The bending test [9] was performed for seven (minim six recommended) samples resulted from each board. The samples have the length 20 times bigger than the thickness plus 100 mm for placing them on the fulcrums, in the range of 150 mm and 1050 mm, the width of 50 mm and the same thickness as the board has.
The testing principle is shown in Fig. 1. The test was set up to last for 1 ± 0.5 min. The samples were cut longitudinally and the final bending strength was calculated as the average value for all determinations (for six samples).
The bending strength was calculated with equation 1.

$$\sigma_i = \frac{3}{2} \cdot \frac{P_{max} \cdot l}{b \cdot g^2} \quad [MPa] \qquad (1)$$

where P_{max} is the maximum breaking force, in N;
l – distance between fulcrums, in mm;
b – width of the sample, in mm;
g – thickness of the sample, in mm.

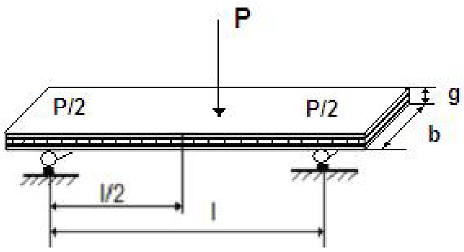

Fig. 1. The principle of determining the bending strength of the laminated composites

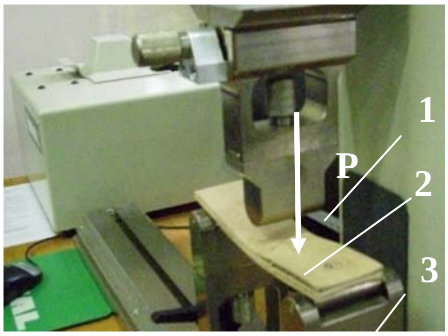

Fig. 2. IMAL universal testing machine; P-force, 1- bending device, 2-sample, 3-fulcrum

2.2 Modulus of elasticity (MOE)

MOE was determined during the bending test, as shown in Fig. 2, by measuring the elastic deformation and it was calculated with equation (2). The speed of applying the force was as high as necessary to complete the test in 1 ±0.5 min.

$$E_i = \frac{l^3 \cdot \Delta F}{4 \cdot b \cdot g^3 \cdot \Delta f} \quad [MPa] \qquad (2)$$

where l is the distance between fulcrums, in mm;
ΔF – difference between forces F_2 and F_1, the first one being 10 % and the second 40% of the breaking force, in N;
b – width of the sample, in mm;
g – thickness of the sample, in mm;
Δf – subtraction of the deformations of the two forces, in mm.
The final value of MOE was calculated as the average of the values determined for all samples.

2.3 Shearing strength of adhesive bond

The test [10] was applied on the samples shown in Fig. 3.

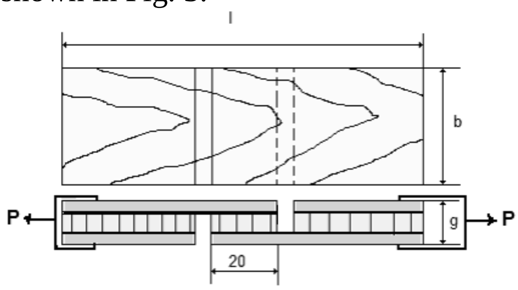

Fig. 3. Sample and test principle for the shearing strength of adhesive bond test

The samples have a length of 100 mm, width of 25 mm. The channels provided on the two faces of the sample produce the shear of the bond area when applying the tensile force. Seven samples (minim six indicated) were cut from each sandwich composite panel and subjected to a tensile load according to technical specification.
The shearing strength of adhesive bond is calculated with equation 3:

$$\tau_f = \frac{P_{max}}{A_r} \quad [MPa] \tag{3}$$

where P_{max} is the maximum breaking force, in N;
A_r – shearing area (20 x 20), in mm^2.
The final value of the shearing strength for each tested structure was calculated as the average of the six determinations for the six samples. The speed of applying the force was set up so the test to last for 30 seconds. This investigation gives data about the quality of the bond in case of gluing both wood and textile insertion with natural bone glue.

2.4 Internal bond (tensile strength)

This test [8], consists of measuring the delaminating maximum force into the bond area of the components. Samples of 50 x 50 mm are used for this test, cut from the tested panels. Hardwood or metal prisms are glued on the samples during the test. Special devices are provided for the testing machine in order to fix the prisms together with the samples, as seen in Fig. 4. The tensile strength resulted for the entire panel is the average value of the six determinations, for six samples cut from the panel. The following structures were tested: beech veneer sandwich composites made of 3 layers of veneer inserted with 2 layers of different fabrics (natural jute fabric and mixed woven fabric) and the other one made of 5 layers of veneer inserted with 2 layers of sackcloth (natural jute fabric). In the first case the specific consumption of the bone glue was of 155 g/m^2 and in the second case of 180 g/m^2.

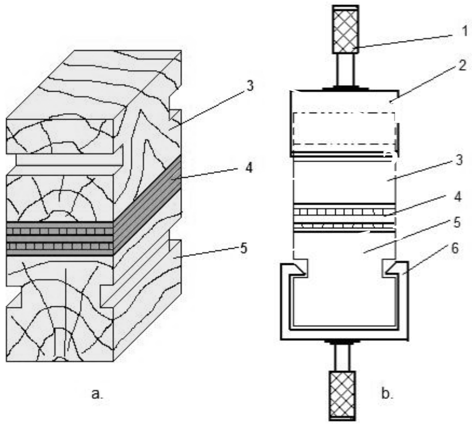

Fig 4. Sample (a) and device necessary to fix the sample (b) for the internal bond test

The thickness of the veneer used in the sandwich structure was of 1.1 mm for the faces and 2.4 mm for the core layers. Same beech veneer sandwich structures were made without inserted textiles, tested in the same conditions, in order to compare the results. The specific consumption of the bone glue for the last structures (named herein as standard panels) was of 200 g/m^2. The characteristics of the bone glue used to glue the layers of veneer and fabric are as follows: moisture content of 17%, ash content reported to the dry adhesive of 30%, viscosity of the solution (17.75% at 30ºc) of 13 MPa s, viability of the solution of 17.75% at 25ºC: more than 72 h, pH of the solution of 1%: 5.5-6.5. The shearing strength of adhesive bond, according to technical specifications is more than 7.5 MPa for bone glue and min. 8 MPa for the conventional adhesive of veneers (urea-formaldehyde).

Characteristics	Warp	Weft
Fineness	Nm 4	
Warp - Sett	43 yarns/ 10 cm	
Number of rounds		47 yarns/ 10 cm
Composition	100% jute	100% jute
Breaking force, N	1009	750
Extension, in %	5.08	6.65

Table 1. Characteristics of sackcloth fabric

Characteristics	Warp	Weft
Fineness	Nm 40/2	
Warp - Sett	95 yarns/ 10 cm	-
Number of rounds	-	100 yarns/ 10 cm
Composition	33% cotton, 67% mixed fibers	50% polyester 50% flax
Breaking force, N	446.2	1048
Extension, in %	15.7	22.7

Table 2. Characteristics of mixed fabric

The properties of the textiles used in the structure of the beech veneer sandwich composites presented in this paper are shown in Table 1 for natural fabric and in Table 2 for the mixed woven fabric.

3. RESULTS AND DISCUSSIONS

Seven specimens were cut from each tested sandwich composite panel.

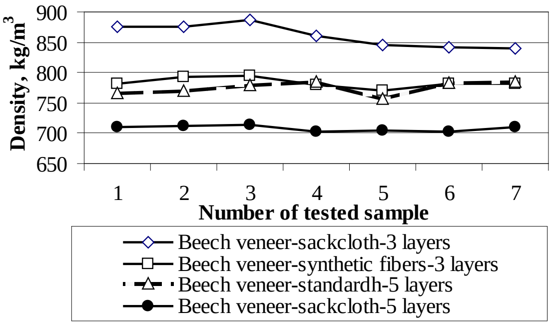

Fig 5. Distribution of the density for the tested samples of the four sandwich structures

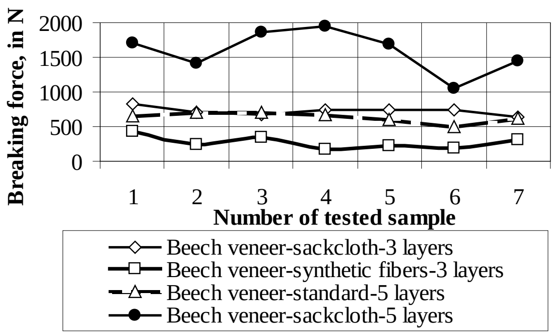

Fig 6. Distribution of the breaking forces for the tested samples

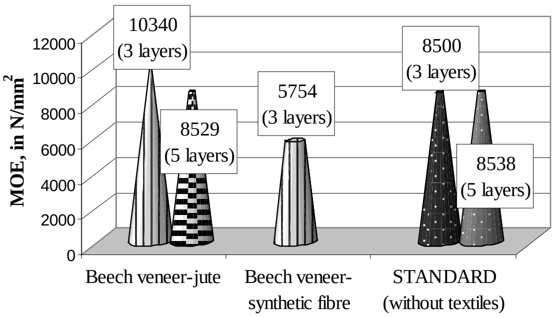

Fig 7. Values of MOE experimentally determined for beech veneer sandwich composite panels (with 3 and 5 layers of veneer)

The densities of the tested samples were determined. Distribution of the densities is shown in Fig. 5 and the distribution of the breaking forces during the bending test is shown in Fig. 6. The composites were manufactured in the same conditions of temperature (20ºC), and pressure (5 N/mm^2). The distribution of the forces appears quiet homogeneous for all the cases. The higher density values belongs to composites made of three layers of veneer inserted with sackcloth, whilst the breaking force has mean values. Interesting results registered for composites with five layers of veneer inserted with jute natural fabric (sackcloth), having low densities and high values of breaking forces. When using insertion of mixed woven fabric, low densities and low breaking forces were registered. Thus, no relation between density and breaking force found so far, but the preliminary conclusion is that the mixed fabric (both natural and synthetic fibers) does not improve the values of the breaking forces during the bending test.

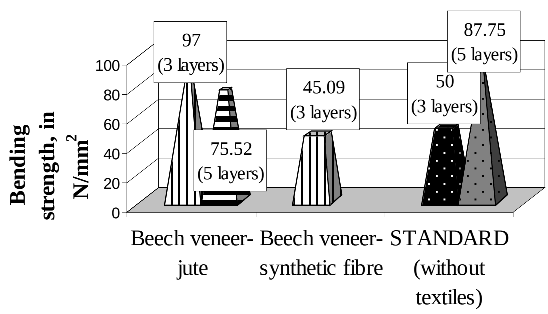

Fig 8. Values of bending strength experimentally determined

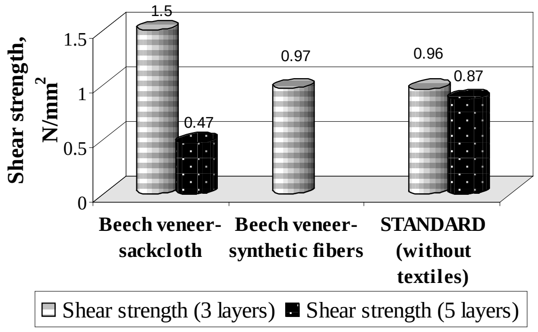

Fig 9. Shearing strength of the adhesive bond compared with standard values

The experimental values of MOE are shown in Fig. 7 and the bending strength results are shown in Fig. 8. The results are compared with those of the standard structures (without textile insertion) made of three and five layers of beech veneer. When the insertion of sackcloth was replaced in the composite panel by the mixed woven fabric, the results were not as satisfactory as expected, being a half of the values recorded for the same structure with jute fiber (sackcloth). From this reason, tensile strength and shearing strength of the adhesive bond were determined only for the structures that obtained acceptable results at the bending test (structures with jute – three and five layers of veneer). As seen in Fig. 9, best results were experimentally obtained for the shearing strength of the adhesive bond in case of composites with three layers of veneer and insertion of jute fabric and also for the tensile strength of the same structure, as seen in Fig. 10. An overview on the experimental results of the tested structures can be seen in Table 3.

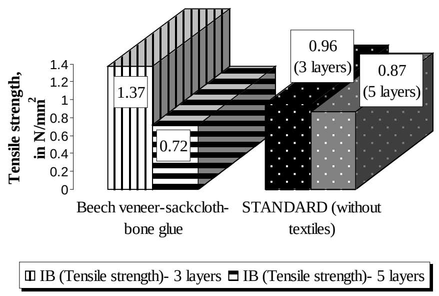

Fig 10. Internal bond (tensile strength) values for composites with 3 and 5 layers of veneer, compared with standard samples

Results, in N/mm	Type of sandwich composite				
	3 layers with:			5 layers with:	
	Jute	Mixed fabric	No textile	Jute	No text.
MOE	10340	5754	8500	8529	8538
Bend. strength	97	45.09	50	75.5	87.7
Shear strength	1.5	0.97	0.96	0.47	0.87
Tens. strength	1.37	-	0.96	0.72	0.87

Table 3. Experimental results on the mechanical tests of studied composites

4. CONCLUSION

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 moulded for applications in furniture, buildings and automotive industry. 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 the standard one (without textile insertion) and an increasing of approx. 50% of the shearing strength of adhesive bond compared with the values of the panel without textile insertion. The same structure of beech veneer and sackcloth glued together with bone glue, but in the variant of using five layers of veneer did not succeed to exceed the performance obtained by that with three layers. 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 mechanical properties of wooden composites. Thus, the best results were obtained for the composites made of three layers of veneers and two layers of sackcloth, the five layers structure bringing also the disadvantages of long conditioning time and higher costs.

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