Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

The 7th International Conference on
Computational Mechanics and Virtual Engineering
COMEC 2017
Brasov, ROMANIA, 16-17 November 2017

PROPERTIES OF SOME COMPOSITES MATERIALS REINFORCED WITH NATURAL FIBERS

Camelia Cerbu
University of Brașov, Brașov, ROMANIA, cerbu@unitbv.ro

Abstract: *First of all, the paper presents some particular aspects of composite materials reinforced with natural fibers used in structural applications: classification, advantages, disadvantages, applications etc. The paper synthesizes the main mechanical test methods and the corresponding standards used for such composite materials. Then, the article focuses on the comparison of the mechanical properties of composite materials based on epoxy resin, reinforced either only with textile fibers (flax, jute) or in combination with fibers providing from the agricultural waste (corn cob) or with glass fibers. The comparison of the properties is made in terms of the mechanical properties measured in bending test (flexural strength, modulus of elasticity).*

Keywords: *composite material, vegetable fibers, tensile, bending, impact.*

1. INTRODUCTION

Literature in the field of composite materials shows a great interest concerning the using of the biofiber reinforcements in composite materials in the last years [1-6]. The biofibers or the natural fibers are classified in the following classes: wood fibers from various wood species (fir, oak, beech etc.) [3, 7]; vegetable textile fibers (flax, jute, hemp, cotton, ramie, kenaf etc.) [1, 6]; agricultural wastes like seed husks, kernels, wastes from the grape bunches, corn cobs etc. [5-12].
Vegetable fibers cultures were expanded in the last years and the most cultivated plants are jute, flax, ramie, hemp and cotton [1, 2, 6]. India, China, Bangladesh and Thailand provide over 90% from jute word production [6]. The greatest flax harvested areas are in Canada, China, India [1].
The earliest evidence on the use of the vegetable fibers as reinforcement materials were found at Pyramid Dahshur located at 40 km apart Cairo where it was discovered flax yarns in the bricks used in constructions [1]. The first composite materials made of vegetable textile fibres were the panels made of wood fibres hot pressed having textile inserts (flax, jute, hemp, ramie etc.) in the purpose of the improving of the mechanical properties.
The main advantages of the using of the biofibers to reinforce the composite materials are the following: represents a rapidly renewable of raw material; are cheaper comparatively with the inorganic reinforcing fibers (glass, carbon, aramid, bor fibers); leads to the reducing of the weight of the composite materials due to the reduced density comparatively with the common fibers (glass, bor or even compared to carbon fibers); leads to the increasing of the absorption coefficient of the sound waves in case of soundproofing panels [10]; these can replace glass fibers in case of the thermal insulation panels [4]. A recent published paper shows low heat transfer coefficients measured in case of the panels composite materials based on epoxy resin reinforced with corn stalk particles (60 wt.%), manufactured by moulding under low pressure $0.007 \div 0.012$ N/mm^2 [9].
In compression testing of the biomass brick made of a mixture of corn stalk and poplare wood fibers and calcium hydroxide (1:4 is ratio of biofibers and binder) it was showed that $13.33 \div 18.18$ wt.% content of corn stalk fibers lead to 0.071 MPa average value of the compression strength [10].
But, there are some major desavantages of the vegetable fibers comparing with the inorganic fibers (glass fibers, carbon fibers, kevlar fibers): these absorb a greater quantity of humidity in wet environment and these degrade in such enviroments; their mechanical properties decrease under the action of the aging cycles (humidity , UV rays, thermal cycles) [3, 10, 13].
Regarding the testing of composite materials reinforced with biofibers, the following standards are used in case of the static mechanical tests: EN ISO 14125 (2000) for determination of flexural properties; EN ISO 527-4 (2000) for determination of tensile properties; EN ISO 179-1 (2001) for determination of the properties in Charpy test.

Scientific literature is lacking in the results concerning to the mechanical testing of the structures made of hybrid composite materials reinforced both with vegetable fibers and with glass fibers or with agricultural wastes.
The main objective of this paper is to compare the mechanical properties measured in bending test in case of three composites materials based on epoxy resin reinforced with: flax woven fabric and corn cob fibers; only with flax woven fabric; glass and jute woven fabric.
A recent publish paper shows that the mechanical properties corresponding to the corn plastic composites reinforced with corn cob fibers or corn stem fibers are better that the ones corresponding to the reinforcing with corn leaf fibers or corn husk fibers [12]. This is the reason of the using of the corn cob fibers to reinforce the core of one kind of composite material involved in this work, whose sheet layers are reinforced with flax woven fabric.

2. MATERIALS AND WORK METHOD

2.1. Materials tested

Three kinds of bidirectional woven fabrics are used to manufacture the composite materials tested: flax woven fabric whose density is 280 g/m^2; jute woven fabric whose density is 400 g/m^2; E-glass woven fabric whose density is 200 g/m^2 [14, 15]. E-glass and jute woven fabrics have the same kind of yarn on both warp and weft directions (Fig. 1). On the contrary, the flax yarn corresponding to weft direction flax is thicker than the yarn corresponding to the warp direction in case of the flax woven fabric (Fig. 2).

Figure 1: Photos aquired by digital microscope in case of the jute woven fabric used for reinforcing

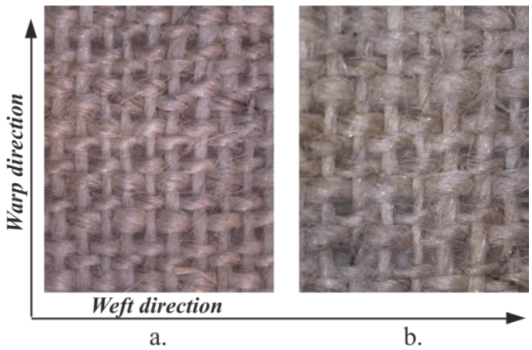

Figure 2: Photos aquired by digital microscope in case of the flax woven fabric used for reinforcing:
a.Zoom 100x; b. Zoom 150x

The Epolam 2015 epoxy resin whose physical and chemical characteristics are shown in Table 1, is used to manufacture the composite materials [16]. To initiate and to accelerate the polymerisation process, the hardener agent was certainly mixed with the epoxy resin before the impregnation of the fabrics or before the admixture of the corn cob fibers. Mechanical characteristics of the epoxy resin with hardener are shown in Table 2 [16].. Analyzing its properties, one may remark that this resin has: lower viscosity, good mechanical properties.
The epoxy resin is widely used for manufacturing of the laminated composite materials by handing lay-up technology, injection with low pressure and filament wrapping. This kind of resin has a good behaviour for impregnation of timber. It has also a good behaviour in wet environment [16].
A lower forming pressure was used to manufacture the plate by using hand lay-up technology.
Reinforcing combination for each layer of the composite materials tested and the abbreviation used for each type of composite materials are shown in Table 3.

One panel was manufactured for each kind of composite materials whose dimensions was 500x500 mm^2. The thickness of each panel was different: 4mm in case of the Composite 1; 5.5mm in case of the Composite 2; 3.5mm in case of the Composite 3.

In case of both Composite 1 and Composite 2, 20 flexural specimens were cut from each kind of panel, 10 specimens whose length is parallel to the weft direction of the flax fabric and other 10 specimens whose length is parallel to the warp direction. In case of Composite 3, all specimens were cut as their length was parallel with the same direction. The shape and dimensions of the flexural specimens were in accordance with standard [17].

Table 1: Physical and chemical characteristics of the epoxy resin, in liquid state [16]

Characteristic	Value	Unit of measure	Method
Density, 25 ^oC	1.15	g/cm^3	ISO 1675: 1985
Viscosity, 25 ^oC	1550	mPa·s	Brookfield LVT
Mixture ratio with hardener agent	32 (weight ratio) 38 (volume ratio)	%	-
Gel-time, at 23 ^oC (100 g resin + 32 g hardener)	2.5	Hours	-
Manipulation time (100 g resin + 32 g hardener)	60	Minutes	-
Glass transition temperature	80	^oC	ISO 11359: 2002°C9188

Table 2: Mechanical characteristics of the epoxy resin (with hardener) without reinforcing [16]

Characteristic	Value	Unit of measure	Method
Tensile stress in tension	70	MPa	ISO 527: 1993
Flexural stress	120	MPa	ISO 178: 2001
Modulus of elasticity E	3100	MPa	ISO 178 :2001
Impact strength - Charpy (unnotch specimen)	40	kJ/m^2	ISO 179
Elongation in tensile test	5	%	ISO 527: 1993
Toughness	83	Shore D15	ISO 868: 2003

Table 3: Abbreviation and structure of the composite materials tested

No.	Composite code	Composite name	Type of layers
1	Composite 1	Flax / corn cob fibers / Epolam 2015 epoxy	1 layer Flax / epoxy + 1 core layer Corn cob fibers / epoxy + 1 layer Flax / epoxy
2	Composite 2	Flax / epoxy	8 layers Flax / epoxy
3	Composite 3	Glass / Jute / epoxy	1 layer Glass / epoxy + 2 layers Jute / epoxy + 1 layer Glass / epoxy

2.2. Work method

The testing equipment (manufacturer Walter & Bai – Switzerland) used in bending test consists in vertical accuator with hydraulic power supply that may be used also in static test. The maximum force capacity is ±100kN. The speed of loading was equal to 1.5 mm/min during the bending test. The method of the three points was used for testing in bending (flexural test). The span between the simple supports of the flexural specimen was accorded with standard used [17].

Before each mechanical test of a specimen, the dimensions of the cross-section were accurately measured and then, they were considered as input data in the software program of the machine.

The testing equipment allowed us to record pairs of values in form of text files having 200-300 lines: bending force F and deflection v at midpoint of the flexural specimen. The experimental data were statistically processed in order to determine the mechanical properties. The modulus of elasticity E in bending test was determinate on the linear portion of the loading curve. Therefore, the average values of the following quantities could be accuracy computed for the bending test: Young's modulus E in bending test or flexural modulus; maximum normal stres σ_{max} recorded in bending test or flexural strength.

3. RESULTS

The comparisons of the average results concerning both the flexural strength $\sigma_{\max}$ and the flexural modulus E are shown in the figures 1 and 2, respectively. The corresponding standard deviation values are graphically shown in the figures 1 and 2 in case of each average value. The areas corresponding to the deviation standards show a low degree of scattering of the results.

In case of the Composite 1, the flexural strength $\sigma_{\max}$ corresponding to the weft direction of the flax layers is 24.14% greater than the average value corresponding to the warp direction of the flax layers. The flexural modulus E is 32.25% grater in the weft direction than in the warp direction of the flax layers of the Composite 1.

In the same manner, the flexural strength $\sigma_{\max}$ corresponding to the weft direction of the flax layers is 11.11% greater than the average value corresponding to the warp direction of the flax layers in case of the Composite 2. The flexural modulus E is 13.59% grater in the weft direction than in the warp direction of the flax layers in case of Composite 2.

We may remark that the average values recorded for the flexural modulus E are comparable in case of the Composite 1 and Composite 2 while in case of the Composite 3, the flexural strength $\sigma_{\max}$ is twice greater than the flexural strength $\sigma_{\max}$ corresponding to the weft direction of the flax layers of the Composite 1. The reason is the reinforcing with glass woven fabric of the sheet layers in case of the Composite 3.

The good values of the mechanical properties (flexural strength $\sigma_{\max} = 72\ MPa$; flexural modulus $E = 3678\ MPa$) recorded for weft direction corresponding to the flax layers in case of the Composite 3, show that corn cob fibers can be successfully used to reinforce the core of the Composite 2 whose sheets are reinforced with flax fabrics.

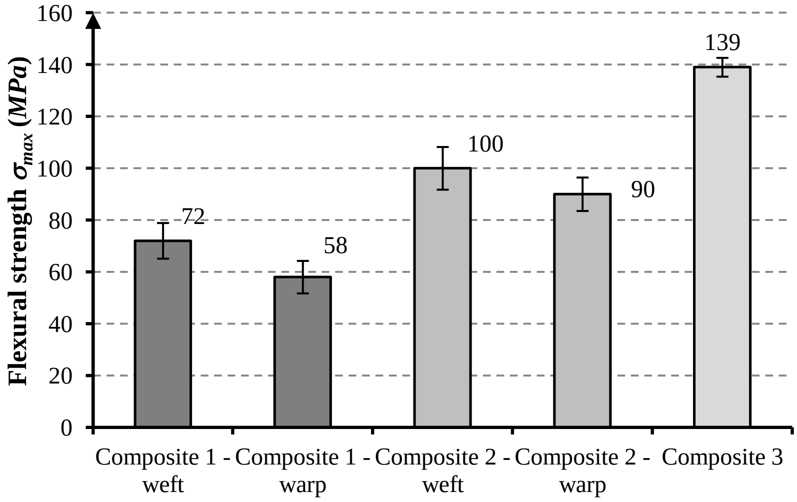

Figure 1: Comparison of the values of the flexural strength in case of the composite tested

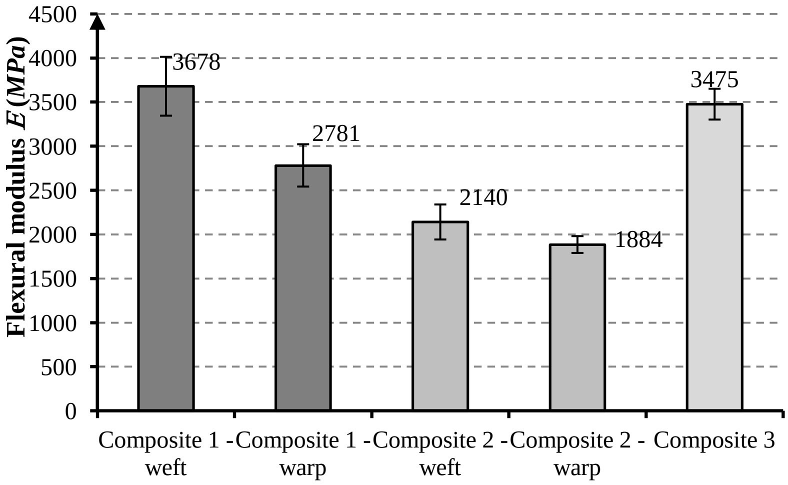

Figure 2: Comparison of the values of the flexural modulus E in case of the composite tested

4. CONCLUSION

The paper presents the modern trends in the field of composite materials with regard to the use of the biofibers as reinforcement materials for resin-based composites. In the same time, the paper shows the mechanical properties obtained in bending test in case of two hybride composite materials (Composite 1 and Composite 2) whose layers contain different reinforced materials. Comparing of the results concerning the flexural modulus E in case of these kinds of hybrid composites, it may recommend the using of the corn cob fibers to reinforce the core of the composite materials whose sheet layers are reinforced with woven fabrics made of vegetable textile fibers (like flax woven fabric in case of the Composite 1). Thus, the paper proposes a possible use of vegetable waste like is corn cob fibers, in order to reduce both the price and the weight of the composite materials.
Different results corresponding to the weft and warp directions of the flax fabric in case of both Composite 1 and Composite 2, shows the importance of the testing of such composites on both directions.

ACKNOWLEDGMENTS

The authors hereby acknowledge the structural founds project PRO-DD (POS-CCE, O.2.2.1., ID 123, SMIS 2637, ctr. No 11/2009) and Transilvania University of Brasov for providing the infrastructure used in this work.

REFERENCES

[1] Müssig J.; Haag K., Chapter 2: The use of flax fibres as reinforcements in composites, In: Biofiber Reinforcements in Composite Materials, Edited by: Omar Faruk and Mohini Sain, ISBN: 978-1-78242-122-1 (print), Woodhead Publishing, Elsevier, 2015, p. 35-85, DOI: 10.1533/9781782421276.1.35;
[2] Müssig, J. (editor), Industrial Applications of Natural Fibres: Structure, Properties and Technical Applications. Chichester, UK , John Wiley & Sons , 2010, p. 538;
[3] Klyosov, A. A., Composition of wood-plastic composites: cellulose and lignocellulose fillers, În: Wood-plastic composites, John Wiley & Sons Publishing, Hoboken, New Jersey, 2007, p. 75-122;
[4] Cantorski da Rosa L., Santor C. G., Lovato A., Severo da Rosa C., Güths S., Use of rice husk and sunflower stalk as a substitute for glass wool in thermal insulation of solar collector, Journal of Cleaner Production, vol. 104, 2015, pp. 90-97;
[5] Nourbakhsh A., Ashori A., Wood plastic composites from agro-waste materials: Analysis of mechanical properties, Bioresource Technology, vol. 101, 2010, pp. 2525–2528;
[6] Khan J. A., Chapter 1: The use of jute fibres as reinforcements in composites, In: Biofiber Reinforcements in Composite Materials, Edited by:Omar Faruk and Mohini Sain, ISBN: 978-1-78242-122-1 (print), Woodhead Publishing, Elsevier, 2015, p. 3-35, DOI : 10.1533/9781782421276.1.86.;
[7] Cerbu Camelia; Coșereanu Camelia, Moisture effects on the mechanical behavior of fir wood flour/glass reinforced epoxy composite, BioResources (BioRes.), ISSN: 1930-2126, 2016, vol. 11, no.4, pp. 8364-8385. DOI: 10.15376/biores.11.4.8364-8385;
[8] Papanicolaou, G. C.; Koutsomitopoulou, A. F.; Sfakianakis, A., Effect of thermal fatigue on the mechanical properties of epoxy matrix composites reinforced with olive pits powder, Journal of Applied Polymer Science 124(1), 2012, p. 67-76, DOI: 10.1002/app.35092;
[9] Binici H., Aksogan O., Demirhan Ceyda, Mechanical, thermal and acoustical characterizations of an insulation composite made of bio-based materials, Sustainable Cities and Society, vol. 20, 2016, pp. 17–26;
[10] Lu Z., Zhao Z., Wang M., Jia W., Effects of corn stalk fiber content on properties of biomass brick, Construction and Building Materials, vol. 127, 2016, pp. 11–17;
[11] Luo H., Xiong G., Ma C., Chang P., Yao F., Zhu Y., Zhang C., Wan Y., Mechanical and thermo-mechanical behaviors of sizing-treated corn fiber/polylactide composites, Polymer Testing, vol. 39, 2014, pp. 45-52;
[12] Luo Z., Li P., Cai D., Chen Q., Qin P., Tan T., Cao H., Comparison of performances of corn fiber plastic composites made from different parts of corn stalk, Industrial Crops and Products, Article in press, 2016, No. of pages 7;
[13] Yan L.; Chouw N.; Jayaraman K. (2015). Effect of UV and water spraying on the mechanical properties of flax fabric reinforced polymer composites used for civil engineering applications, Materials and Design, vol. 71, p. 17–25;
[14] *** Fișa tehnică a țesăturii de in;
[15] *** Fișa tehnică a țesăturii de sticlă de tip E, AeroGlass (Niederlenz, Switzerland), 2010.
[16] *** Fișa tehnică a rășinii de tipul Epolam 2015. Axson Technologies (U.S.A.), 2006;
[17] SR EN ISO 14125:2000. Fibre-reinforced plastic composites determination of flexural properties.