BIO COMPOSITE MATERIALS AS A SUSTAINABLE SOLUTION FOR MODERN INDUSTRIES

George Răzvan BUICAN, Alexandrina IVASCU, Andrei BENCZE

"Transilvania" University of Brașov, Romania (buican.george@unitbv.ro, alexandrina.ivascu@student.unitbv.ro, andrei.bencze@unitbv.ro)

DOI: 10.19062/1842-9238.2025.23.1.3

***Abstract**: In the global effort to develop circular economy solutions, bio composite materials have emerged as viable, less toxic, and environmentally friendly alternatives to traditional materials. Due to their advantageous physical and mechanical properties, hemp, flax, jute, and bamboo represent renewable resources with significant potential in industries such as aerospace, construction, transportation, and energy. This article investigates the manufacturing processes and tensile strength characteristics of roving's produced from these materials.*

***Keywords**: Aerospace, bio composite materials, environmental, jute, bio epoxy resin.*

1. INTRODUCTION

In the context of increasing technological impact on the environment and growing demands for sustainable development, industry is facing the need to transition to environmentally oriented technologies and materials. One of the most promising directions in this context is the development and implementation of bio composite materials - multicomponent systems that include natural fibers and biopolymers as a base. Unlike traditional polymer and carbon composites, bio composites have several significant environmental advantages: renewability of raw materials, reduced energy intensity of production, biocompatibility and biodegradability.

Modern research in the field of bio composites is aimed at optimizing their mechanical and operational properties, expanding the raw material range and increasing competitiveness compared to traditional materials. Bio composites combining natural fillers (linen, jute, hemp fiber, etc.) with biopolymers (PLA, PHA, TPS, etc.) provide a solution that simultaneously reduces carbon footprint and improves the efficiency of manufacturing processes. The lower weight and relatively lower cost of natural fibers are the main reasons for their use in composites in these applications. The relevance of the topic is determined not only by the desire to reduce the negative impact on the environment, but also by the needs of high-tech industries in lightweight, durable and multifunctional materials.

In hybrid composite, the physical and mechanical properties are governed by the fiber content, fiber length, fiber orientation, and arrangement of individual fibers, extend of intermingling of the fibers and the interfacial adhesion between the fiber and matrix. [1]

Based on official dictionary of oxford dictionary, jute is a thin thread from a plant, used for making rope and rough cloth. [2]

Table 1- Mechanical Properties of jute [3]

Density (g/cm^3)	Length (mm)	Failure strain (%)	Tensile strength (MPa)	Stiffness GPa	Specific tensile strength (MPa/gcm^3)	Specific Young's Modulus (GPa/gcm^3)
1.3-1.5	1.5-120	1.5-1.8	393-800	10-55	300-610	7.1-39

Its low density makes it ideal for lightweight structures. Besides, its 2-3 times cheaper than fiberglass and fully biodegradable and renewable. As for the getting the material, is quite easy, as it grows quickly and does not require large amounts of pesticides or fertilizers.

2. FABRICATION AND METHOD

In our case, we used a 30x300mm, jute fabric which is a wear and abrasion resistant material.

FIG. 1 Jute fabric [4]

This material was hand-laid up with **LB2 Epoxy Laminating Bio Resin.** LB2 is a high-performance bio epoxy resin suitable for use with a wide range of reinforcements including glass, carbon and aramid fibers as well as natural reinforcements such as flax and jute fiber. This one is a medium viscosity clear two-component epoxy resin system with ~35% resin plant derived content, this offers a lower environmental impact without compromising on performance. [5; 6]

Table 2 - Mechanical Properties of LB2 [5]

Max Service Temp	90	°C
Impact Resistance	25	kJ/m^2
Flexibility	Hard / Rigid	
Tensile Strength	78	MPa
Tensile Modulus	3.23	GPa
Elongation at Break	5.8	%
Flexural Modulus	3.2	GPa
Flexural Strength	127	MPa
Interlaminar Shear Strength	52	MPa
Compressive Strength	107	MPa
Tg Onset (DMA)	90	°C

FIG. 2 LB2 Epoxy Laminating Bio Resin [5]

As a first step, was created an improvised matrix. As the resin has low viscosity, a wooden board was taken and glued with aluminium tape, as to create a smooth surface for the hand-laying the material.

FIG. 3 The layer of aluminium tape

FIG. 4 GLOBALWAX 200/S [6]

The next step was to create a surface that is not sticking to the material itself. It was used GLOBALWAX 200S, which is a release agent that forms a wax layer on the surfaces of molds and models. This product is characterized by a strong non-stick coating with high temperature resistance (GLOBALWAX 200/S up to 180 °C). GLOBALWAX 200/S is spray-applied and does not blur the fine details of the pattern. [6]

The jute fabric was cut into rectangles of size 20x25 cm at 90 degrees and 45 degrees. This resulted in 4 rectangles.

a). b).

FIG. 5 Rectangles of jute fabric

From the instructions of the LB2, the resin and the hardener were mixed with proportion of 101/28 to create the paste itself. Then layer by layer, with a classic brush, the resin was inserted into the fabric.

a). b). c).

FIG. 6 Layering the material

After definitive drying of the material, the result was a stiff plate with 3.9 mm thickness. The board was cut in 6 test tubes for bending and tensile experiment.

FIG. 7 Test tubes cut from material

Although the strength is lower than that of glass fiber or carbon fiber reinforced plastic, with proper fiber orientation and the proper curing technique, the composite can withstand moderate loads. The low density of jute makes the composite lightweight, which is especially important in the transport industry and structures where weight is critical.

3. MECHANICAL CHARACTERISTICS

For the bending experiment, 5 of the test tubes were placed into the bending machine, WDW-150. This is one of the common mechanical bending test methods used to determine the mechanical properties of composite or polymer materials such as flexural modulus or flexural strength, as well as fragility and ductility. The testing machine consists of a load rod (top) that applies a downward force, two supports (bottom) on which the specimen rests and a central loading blade/punch element that applies pressure to the center of the specimen.

This is a bio composite that is being tested for its mechanical properties for possible applications in aerospace engineering.

a).

b).

c).

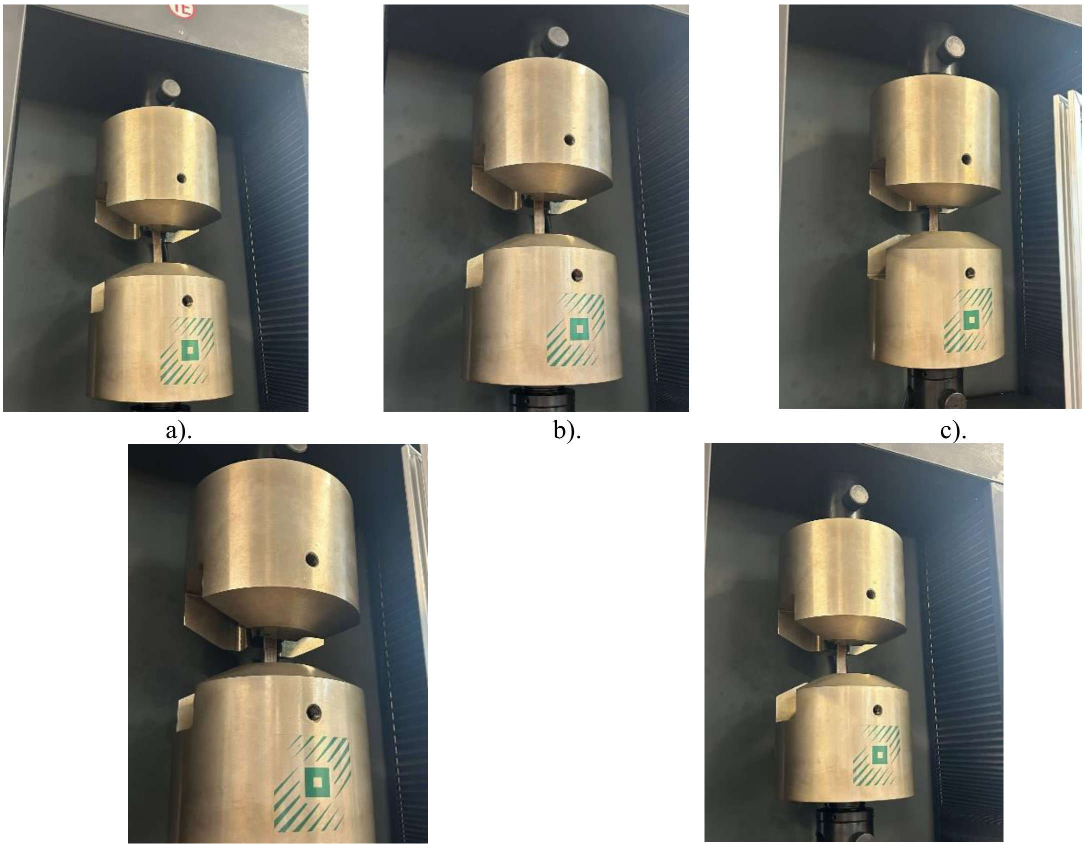
d).

e).

FIG. 8 - Test tubes tested on the bending machine

The test tubes are placed on two supports (bottom part). A force is applied from above at one point in the centre, the load is gradually increased and the machine records the value of the force and deflection. This allows the load-deflection diagram to be plotted and calculated.

As for the tensile testing, the purpose is to determine how the material behaves under an axial tensile force, the material is clamped between two grips, one upper and one lower. The machine begins to pull the sample by applying a load at a constant rate until failure occurs.



a). b). c).

d) e)

FIG. 9 - Test tubes tested for tensile strength

Upper and lower grips (grippers) are used to clamp the test piece for uniform load transfer. The cylindrical housings protect the mechanisms and transfer force with uniform distribution. The purpose of testing is to determine how resilient the composite is to stress under actual operating conditions.

Table 3 - The comparison between Jute composite and Hemp composite for the bending test [7]

Test tubes	Maximum Tensile Strength for Jute [MPa]	Maximum Tensile Strength for hemp [MPa] (7)
I 1	70	181
I 2	63	174
I 3	77	147
I 4	66	188
I 5	77	100

Table 4 - The comparison between Jute composite and Hemp composite for the tensile strength test [7]

Test tubes	Maximum Tensile Strength for jute [MPa]	Maximum Tensile Strength for hemp [MPa] (7)
I I	32	6
I II	31	10
I III	31	6
I IV	17	6
I V	33	14

As we can see, the difference between these 2 materials is quite noticeable. In bending, the hemp-based composite exhibits significantly higher strength, indicating good resistance of this fiber to bending stresses. This makes hemp promising for applications where flexural performance is important, such as panels and enclosures.

In tension, the jute composite performs significantly better, making it preferable for elements that work under tensile loads - for example, in load-bearing joints or reinforcing elements. Both materials confirm the potential of bio composites, but show differences in mechanical behavior, which underlines the need for individual selection of the reinforcing filler depending on the construction tasks.

CONCLUSION

The use of bio epoxy resin enhances the environmental sustainability of the material without adversely affecting the tensile strength characteristics. This confirms the potential of bio epoxy resins as full-fledged substitutes for traditional synthetic matrices in the production of bio composites. The combination of natural fibers with biodegradable epoxy resin shows high potential as an alternative to synthetic composites, especially in the context of sustainable development and environmentally friendly production. However, the mechanical performance requires the selection of the fiber type for the specific operating conditions.

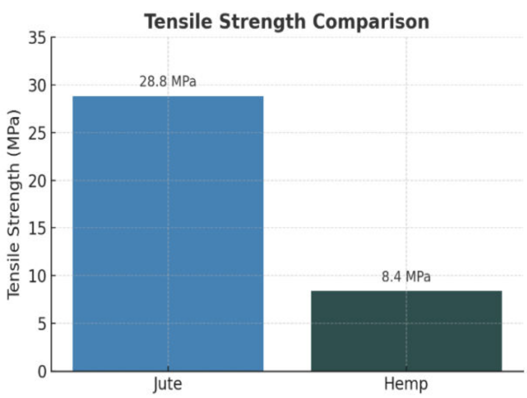


FIG. 10 Tensile Strength Comparison

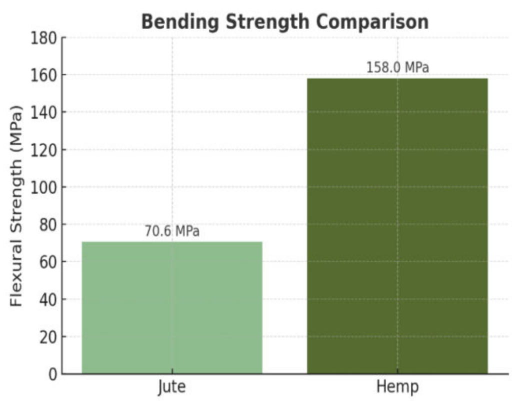


FIG. 11 Bending Strength Comparison

ACKNOWLEDGEMENT

We also acknowledge PRO-DD Structural Founds Project (POS-CCE, O.2.2.1., ID 123, SMIS 2637, ctr. no 11/2009) for providing the infrastructure used in this work.

REFERENCES

[1] Munikenche Gowda, Bledzki and Gassan, Sreekala et al. Physical and Mechanical *Properties of Oil Palm EFB and Jute Fiber*. 1999;

[2] Press, Oxford University, *Oxford English Dictionary*. 1989;

[3] K.L. Pickering*, A review of recent developments in natural fiber composites and their mechanical performance*. 2015;

[4] UP, CRAFT. Craft Up Romania, https://craftup.ro/?gad_source=1&gad_campaignid=20286120457 &gbraid=0aaaaadea4csrldau4fdfjmi_ellmv1rtp&gclid=cj0kcqjwlrvbbhdnarisaheqgoqvnfayrop_tbm8j8 dr-lpof9qcsb5m0zseun5_usfcqp7vzsuygwsaavmjealw_wcb. [interactiv];

[5] Composites, Easy. Easy Composites, https://www.easycomposites.eu/LB2-epoxy-laminating-resin. [Interactiv];

[6] btools. Best Tools Brasov, https://btools.ro/shop/agent-demulare-wax200s?search=wax& description=true. [interactiv];

[7] RD Mitroi, GR Buican, A Bencze*, Hemp-based composite materials as a sustainable solution for modern industries*. 2024/10.