COMAT

The 10th International Conference on ADVANCED COMPOSITE MATERIALS ENGINEERING

Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

22-23 October 2024

HEMP-BASED COMPOSITE MATERIALS AS A SUSTAINABLE SOLUTION FOR MODERN INDUSTRIES

Mitroi R.D.[1], Buican G.R.*[2], Bencze A. [3]

1. University Transilvania of Brașov, Brașov, Romania, razvan.mitroi@student.unitbv.ro
2. University Transilvania of Brașov, Brașov, Romania, buican.george@unitbv.ro
3. University Transilvania of Brașov, Brașov, Romania, andrei.bencze@unitbv.ro
   *Corresponding author: buican.george@unitbv.ro

Abstract: *In the global effort to develop sustainable solutions, hemp-based composite materials have emerged as a viable, less toxic and environmentally friendly alternative to traditional materials. Due to its physical and mechanical properties, hemp is a renewable resource with significant potential in industries such as aerospace, construction, transportation, and energy. This article aims to investigate the manufacture and tensile strength of hemp roving, hemp coupled with fiber glass and fiber glass composites. Microscopic observations are also made to evaluate the failure of the test specimens.*

Keywords: *Composite materials, hemp, hemp roving, fiber glass, tensile strength*

1. INTRODUCTION

The increasing demand for sustainable and environmentally friendly materials has driven extensive research into natural fiber composites.[1] Among these, hemp fiber has emerged as a promising alternative due to its mechanical properties, low cost, biodegradability, and minimal environmental impact compared to synthetic fibers.[2] As industries such as automotive, construction, and aerospace explore the use of renewable resources, there is a growing interest in understanding the potential of hemp composites in various combinations.[3,4,5,6]

This paper investigates the mechanical properties and performance of different composite materials, specifically focusing on combinations of hemp, hemp fiber with fiberglass and fiberglass. By combining hemp with these synthetic fibers, the goal is to assess whether the natural fiber's benefits can be enhanced by the superior strength and durability offered by fiberglass. [5,6]

The research aims to evaluate properties such as tensile strength, bending strength and overall structural integrity. This study will contribute to a deeper understanding of how hemp-based composites perform in comparison to traditional composite materials and explore the potential for these hybrid composites in both structural and non-structural applications.

The findings of this study will help inform the future design and development of sustainable composite materials that can be applied across a range of industries, ultimately supporting a transition to more eco-friendly manufacturing practices.

2. Fabrication

To assess the mechanical properties, we prepared three types of composite materials. The first type consisted of hemp roving fibers, the second type combined hemp roving with fiberglass, and the third type utilized only fiberglass. An unsaturated polyester resin (ENYDYNE H 68372 TA) served as the matrix material, with BUTANOX M-50 as the hardener, applied at a ratio of 200 mL of resin to 4 mL of hardener. The working time of the resin is approximately 20 to 24 minutes, while the hardening time is determined experimental and for this case is 24 hours.

To eliminate air bubbles from the hemp roving woven fabric impregnated with resin, we employed a specialized roller to facilitate the impregnation of the material within the fabrication matrix, as illustrated in Figure 1.

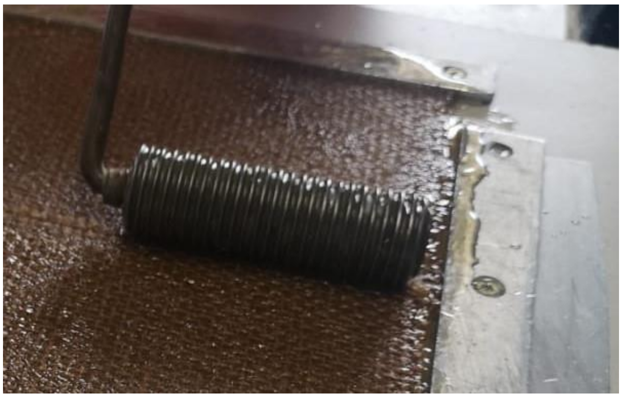

Figure 1: Hemp resin treated for air bubbles.

3. Method

In order to evaluate the hemp composite mixtures, we followed the guidelines of ISO-527-4:2021, issued by EASA, to define the geometry and dimensions of the test specimens. Based on this standard, we fabricated test samples for composites reinforced with continuous fibers, maintaining a uniform thickness of 2 mm. The thickness of compression-molded materials must be consistent at all points, with deviations not exceeding 2% of the mean value. Initially, we will employ the Type 2 test specimen, as depicted in Figure 2, for tensile strength testing, and the Type 1 test specimen for bending tests, as shown in Figure 3.

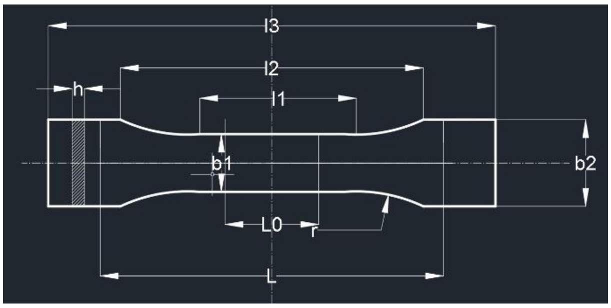

Figure 2: Type 2 test specimen.

Figure 3: Type 1 test specimen.

For the investigation of mechanical properties such as tensile and bending strength, and to determine the modulus of elasticity and Poisson's ratio, we utilized a Universal Testing Machine (WDW 150-S), as shown in Figure 4.a).

a) b) c)

Figure 4: a) General view of Universal Testing Machine WDW 150-S; b) Tensile strength configuration of WDW 150-S; c) Bending test configuration of WDW 150-S.

To characterize the mechanical properties of the three types of composites, five test specimens were manufactured for each fiber combination in accordance with ISO 527-4:2021. The first set consisted of hemp roving fibers, the second set combined hemp roving with fiberglass, and the third set utilized only fiberglass. These specimens were coded as shown in Table 1.

Table1. Specimen coding for tensile strength

Fiber glass	Fiber glass + Hemp	Hemp roving
S-1	SC-1	C1
S-2	SC-2	C2
S-3	SC-3	C3
S-4	SC-4	C4
S-5	SC-5	C5

In figure 5 we can see test specimens after tensile strength testing.

a)

b)

c)

Figure 5: a) Test specimen Fiber glass after testing; b) Test specimen Fiber glass + Hemp after testing; c) Test specimen Hemp roving after testing.

Table 2 and Figure 6 display the tensile strength values for each tested specimen. The mean values for each type of fiber are as follows: 48.8 MPa for fiberglass composites, 25 MPa for fiberglass with hemp composites, and 8.5 MPa for hemp composites.

Table2. Tensile strength values

Test specimen	Max tensile strength Fiber Glass [MPa]	Test specimen	Max tensile strength Fiber Glass Hemp[MPa]	Test specimen	Max tensile strength Fiber Glass Hemp roving[MPa]
S-1	42	SC-1	21	C-1	6
S-2	54	SC-2	20	C-2	10
S-3	43	SC-3	29	C-3	6
S-4	50	SC-4	32	C-4	6
S-5	55	SC-5	23	C-5	14

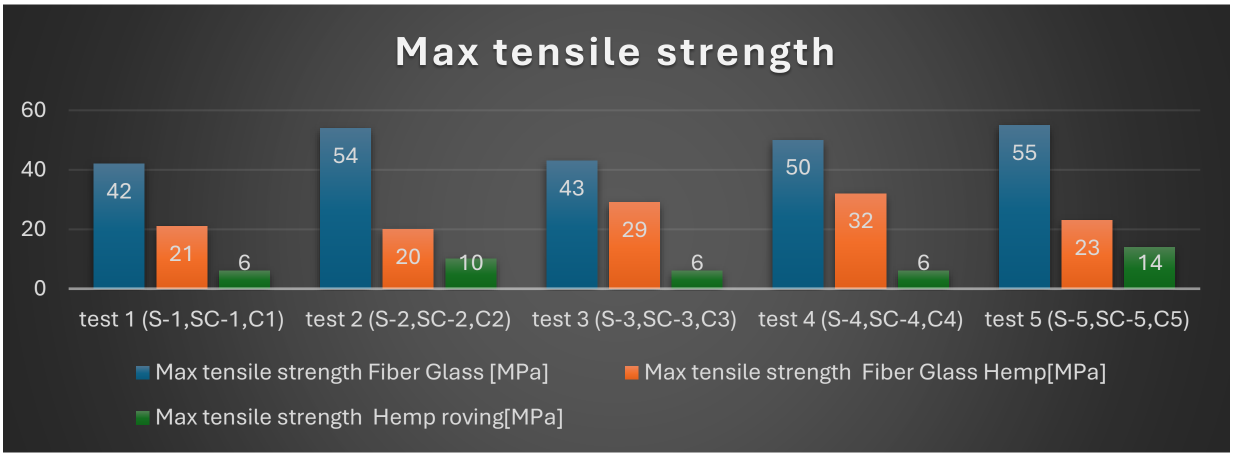

Figure 6: Tensile strength results for fiberglass fibers, fiber glass with hemp and hemp roving

The data presented in Table 2 and Figure 6 highlight the tensile strength values for each tested specimen, revealing important insights regarding hemp fiber. While fiberglass composites exhibit the highest tensile strength with a mean value of 48.8 MPa, the incorporation of hemp fibers into these composites results in a reduction of tensile strength to 25 MPa. Additionally, hemp composites alone demonstrate the lowest tensile strength at just 8.5 MPa.

Despite this decrease, the combination of hemp fibers with fiberglass offers notable benefits. By coupling hemp fibers with fiberglass, we enhance the overall performance of the composite, potentially improving its sustainability and environmental impact while still achieving substantial strength. This approach demonstrates that integrating hemp fibers into fiberglass composites can create a balanced material that leverages the advantages of both fibers.

Table3. Bending strength values

Test specimen	Max bending strenght Fiber glass [MPa]	Test specimen	Max bending strenght Fiber glass with Hemp [MPa]	Test specimen	Max bending strenght Hemp [MPa]
S-1	210	C-1	84	SC-1	181
S-2	240	C-2	84	SC-2	174
S-3	205	C-3	58	SC-3	147
S-4	225	C-4	58	SC-4	188
S-5	240	C-5	52	SC-5	100

For the bending test, we utilized a Type 1 geometry for the test specimens, as shown in Figure 3. The coding remained consistent with that used for the tensile strength tests, as indicated in Table 1.

Table 3 and Figure 7 display the bending strength values for each tested specimen. The mean values for each type of fiber are as follows: 224 MPa for fiberglass composites, 158 MPa for fiberglass with hemp composites, and 67,2 MPa for hemp composites.

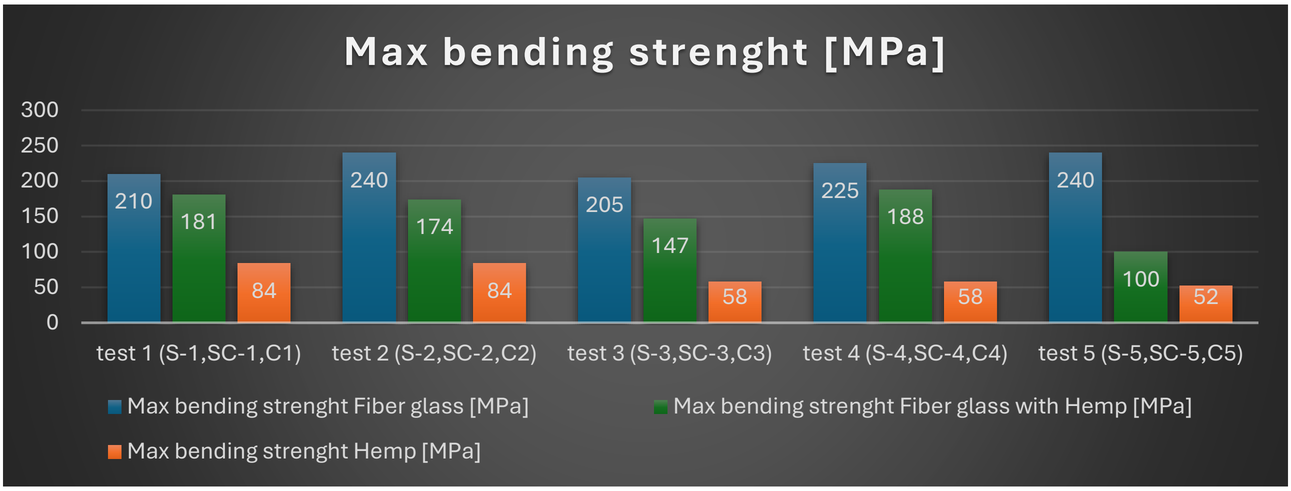

Figure 7: Bending strength results for fiberglass fibers, fiber glass with hemp and hemp roving

The data presented in Table 3 and Figure 7 highlight the bending strength values for each tested specimen, revealing important insights regarding hemp fiber. While fiberglass composites exhibit the highest tensile strength with a mean value of 224 MPa, the incorporation of hemp fibers into these composites results in a reduction of bending strength to 158 MPa. Additionally, hemp composites alone demonstrate the lowest bending strength at just 67,2 MPa. This highlights the advantages of combining hemp fibers with fiberglass; despite a decrease in strength, the resulting fiberglass with hemp composites offers a balanced performance that capitalizes on the sustainability and environmental benefits of hemp. Thus, this composite provides a practical solution for applications that require both strength and eco-friendliness.

4. CONCLUSIONS

Based on this testing, we conclude that hemp composites alone, with a tensile strength of 8,5 MPa and bending strength of 67,2 MPa, are not suitable for structural parts. However, they can effectively be used for internal components such as chairs, chair arm inserts or floor and ceiling panels due to their good bending resistance. While these composites may sacrifice some strength, they excel in sustainability, as hemp fibers are less toxic to both the environment and human health. Future research could explore replacing the matrix with bio-resin and testing the composite for fire and smoke generation.

Additionally, when combining fiberglass with hemp roving weaving, we achieve a composite that retains roughly half the properties of pure fiberglass composites, which have a tensile strength of 48.8 MPa and bending strength of 224 MPa, while significantly reducing toxicity. This hybrid material, with a tensile strength of 25 MPa and bending strength of 158 MPa, could be viable for certain structural applications.

Further investigations should focus on using bio-resins and experimenting with various organic fibers, such as flax, silk, and hemp, both individually and in combination, to develop a fully organic and non-toxic composite material.

5. 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.

BIBLIOGRAFIE

[1] Vershinina A.V., Veselova O.V., Ivanova S.N., Investigation of the Characteristics of Bio-based Raw Materials: Technical Hemp Fibers, Nanotechnol Russia 18, 64–72 (2023)

[2] Dahal R.K., Acharya B., Dutta A., Mechanical response of the hemp biocarbon-filled hemp-reinforced biopolymer composites. J Polym Res 30, 267 (2023)

[3] Dahal R.K., Acharya B., Dony B., Dutta A., Biocarbon Filled Hemp-Epoxy Composite: Its Physical, Mechanical, and Thermal Properties. Appl Compos Mater 29, 2185–2202 (2022)

[4] Salpriyan P.M., Krishna K., Singh T., Recent developments in natural fibre polymer composite materials for interior design applications: an overview from acoustic perspective. Int J Interact Des Manuf (2024)

[5] Gangwar A., Kumar V., Yaylaci M., Panda S.K., Computational Modelling and Mechanical Characteristics of Polymeric Hybrid Composite Materials: An Extensive Review. Arch Computat Methods Eng 31, 3901–3921 (2024).

[6] AL-Oqla F.M., Hayajneh M.T., Nawafleh, N., Advanced synthetic and biobased composite materials in sustainable applications: a comprehensive review. emergent mater. 6, 809–826 (2023)