Australian Journal of Science and Technology
ISSN Number (2208-6404)
Volume 7; Issue 3; September 2023

Original Article

# Development and characterization of natural polymer composites using sisal fiber and flax fiber

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**ABSTRACT**

Composite materials have brought about a revolutionary transformation in the world of materials, particularly with the significant impact of natural fiber composites. Natural fiber composites offer numerous advantages over their synthetic counterparts, including lightweight, low density, biodegradability, easy availability, and cost-effectiveness, all while maintaining good mechanical properties. The utilization of plant or tree fibers in composite material development is witnessing substantial growth, as it serves as a substitute to replace synthetic materials that contribute to pollution. In addition, fibers from nature-based composites require minimal production energy consumption. Synthetic fibers are man-made, produced through the synthesis or polymerization of chemicals derived from petroleum-based sources. Synthetic fibers offer benefits such as affordability, durability, strength, and resistance to moisture. They find usage in various sectors, such as automotive, home furnishings, textiles, and electrical industries. The study's results indicate that hybrid natural fiber samples demonstrated lower performance, while hybrid samples comprising a blend of natural and synthetic fibers exhibited higher performance. This suggests that blending natural and synthetic fibers in composites can lead to improved material properties and performance characteristics.

**Keywords:** C-glass fibers, epoxy, flax, hand layup, hybrid, sisal

**Submitted:** 09-07-2023, **Accepted:** 03-08-2023, **Published:** 30-09-2023

## INTRODUCTION

A composite material is formed by coalescing two or more constituents, each possessing distinct physical or chemical properties, resulting in a material with unique and optimized characteristics. These composites can be tailored to exhibit enhanced mechanical, chemical, and physical properties. The need for such resources has grown steadily since the 1960s, particularly in aerospace, energy, civil engineering, mechanical engineering, and various structural applications, where there is a requirement for materials that offer higher strength and stiffness while remaining lightweight. Asma *et al.* have examined the mechanical capacity of these natural fiber composites, exploring their ductile strength and flexural behavior. The study provides insights into the potential applications and suitability of these eco-friendly reinforcements in various industries.[1] Nagamadh *et al*. work deals with the influence of textile properties on the dynamic mechanical analysis aspect of epoxy composites covered with woven sisal fabrics. It delves into the relationship between the textile characteristics, such as fiber orientation, weave pattern, and fabric thickness, and the resulting dynamic mechanical characteristics of the composite material. The study aims to gain a comprehensive understanding of how these textile parameters impact the performance and potential applications of sisal fabric-reinforced epoxy composites.[2]

Venkatesan and Bhaskar evaluated and compared the mechanical points of fiber abaca-sisal composites. It examines the tensile, flexural, and impact opposition of the composite material, shedding light on its potential applications in various industries. The study aims to provide insights into the performance and suitability of abaca-sisal composites as eco-friendly alternatives to traditional materials.[3] Balaji *et al*. study explores the mechanical and morphological features of the composites to understand their mechanical performance and potential applications.[4] Vishnuvardhan *et al*. showed that the mechanical abilities of the Sisal Fiber Reinforced Epoxy Composites. The research aims to provide valuable data for the development of high-strength and eco-friendly

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epoxy composites utilizing sisal fibers as reinforcements.[5] Arthanarieswaran *et al*. showed in their work that, strength-based properties improved on use of banana and sisal fibers, with a focus on the influence of glass fiber hybridization. The study investigates the tensile strength, flexural strength, and impact resistance of the composites, considering the effects of hybridizing with glass fibers.[6]

Boopalan *et al*. investigation have assessed mechanical resistance of the composites, aiming to identify the differences and similarities in between such fiber-based reinforcements. The performance of jute and sisal composites has been discussed.[7] Palanikumar *et al*. have aiming to assess the mechanical performance and sustainability of the green materials. The potential applications and advantages of using sisal and glass fibers in production of polymer composites.[8] Premnath showed optimization of surface treatment techniques for enhancing the mechanical properties of sisal and jute reinforced epoxy composites.[9] Khanam *et al*. study assesses the strength-based and resistance to chemical degradation of the composites. This work has explored the potential applications and performance advantages of sisal/carbon fiber-reinforced hybrid composites in various industries.[10] Rana *et al*. studied the performance and potential applications of sisal/glass fiber-reinforced epoxy hybrid composites.[11] Sekaran *et al*. investigate mechanical features of the hybrid composite material. Which revealed the performance and suitability of aloe vera and sisal fiber-reinforced epoxy composites for various engineering applications.[12] Siva *et al*. reported in their work regarding that, the strength was improved while using sisal and banana fiber-reinforced epoxy hybrid composites.[13] Vimalanathan *et al*. analyzed the mechanical and morphological properties of interpenetrating polymer network (IPN) composites reinforced with banana and sisal fibers. The study investigates mechanical strengths and morphological characteristics of the materials. This research work has provided valuable insights into the performance and potential applications of banana/sisal fiber reinforced IPN composites in various industries.[14] Understanding the necessity to develop composites and its hybrids made out of sisal, glass, and flax fiber being reinforced with epoxy polymer matrix material and to mechanically characterize them as per ASTM standards as an attempt to study a newer material system made as an objective of this research work.

## MATERIALS AND METHODS

### Materials

In Figure 1, three types of fibers were utilized as materials: Sisal fiber with a weight of 155 gsm, flax fiber with a weight of 195 gsm, and C-glass fiber with a weight of 400 gsm. To create various laminates, these fibers were combined with a thermosetting polymer matrix material known as Epoxy Grade Lapox L-12, along with hardener K-6, in a ratio of 100:10. Table 1 provides details on the material configuration.

### Fabrication Method

Hand lay-up is a traditional and time-tested method for processing open-mold composite materials. It involves manually applying layers of resin and reinforcement onto an open mold surface until the desired component thickness is achieved. The hand lay-up process comprises five main steps: Cleaning, gel coating, laying-up, curing, and part removal. The initial step involves thoroughly cleaning the mold surface and applying a release agent or film to facilitate easy part removal. Subsequently, a thin gel coating may be applied to the outer surface of the mold, especially if the product's surface quality is crucial. The gel coat resin is evenly distributed using a hand roller. Moving on to the third step, once the gel coat partially sets, resin and fiber forms are manually added in successive layers onto the open mold. Each layer is consolidated using a roller to ensure proper impregnation of resin into the fiber and to eliminate any trapped air bubbles. The fourth step involves the curing stage, where the component is allowed to harden. Finally, in the fifth step, the cured component is carefully removed from the mold and is ready for subsequent trimming and surface finishing processes. Figure 2 illustrates the specimens cut in accordance with ASTM standards.

## MECHANICAL CHARACTERIZATION

The samples were subjected to different mechanical loads to understand its mechanical behavior as per ASTM standards is shown in Table 2.

## RESULTS AND DISCUSSION

### Tensile Properties of Composites

$SC_1$ combination of flax and C-glass fibers yields a composite material with superior mechanical properties compared to using either fiber in isolation with 91.8 MPa as UTS and 5834.5 MPa as E from Table 3. This advantage arises from the complementary nature of the two fibers, where their individual strengths and weaknesses synergistically enhance the overall performance of the material. Specifically, C-glass fibers possess a higher ultimate tensile strength than flax fibers, but they also exhibit higher stiffness and brittleness. Conversely, flax fibers have a lower ultimate tensile strength but excel in flexibility and impact resistance. In contrast, when sisal and flax fibers are combined in a composite material, there may be a reduction in the ultimate tensile strength compared to composites reinforced solely with glass fibers. The specific properties of such composites made with sisal and flax fibers depend on various factors, including the ratio of the two fibers, the processing technique used to manufacture the composite, and the conditions under which its mechanical properties are evaluated. As evident in Table 3, the hybrid combination $SC_1$ demonstrates a higher ultimate tensile strength, while $SC_2$ exhibits a lower ultimate tensile strength.

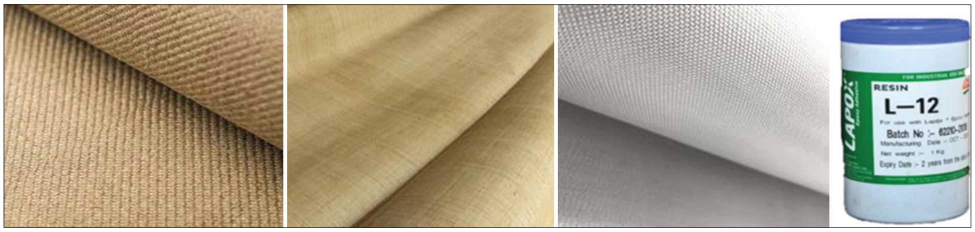


**Figure 1:** Sisal, Flax and C-glass Fibers with Lapox L-12 Epoxy Resin

**Table 1: Composite material configuration**

| Sample code | Laminate prepared | Reinforcements | | | Matrix epoxy resin (wt.%) |
|---|---|---|---|---|---|
| | | C-glass fiber (wt.%) | Sisal fiber (wt.%) | Flax fiber (wt.%) | |
| $SC_1$ | C-S-F-S-F-C | 15 | 20 | 20 | 45 |
| $SC_2$ | C-F-S-F-S-C | 15 | 20 | 20 | 45 |
| $SC_3$ | C-F-F-F-C | 10 | 0 | 45 | 45 |
| $SC_4$ | S-F-S-F-S-F-S | 0 | 30 | 25 | 45 |
| $SC_5$ | F-S-F-S-F-S-F | 0 | 15 | 40 | 45 |

**Table 2: Mechanical tests as per ASTM standards**

| S. No. | Test | ASTM standards |
|---|---|---|
| 1 | Tensile test | ASTM D-638 |
| 2 | Charpy impact | ASTM D-256 |
| 3 | Izod impact | ASTM D 6110 |
| 4 | ILSS | ASTM D-2344 |

The relatively lower Young's modulus values of sisal and flax, as compared to synthetic fibers like C-glass, stem from the heterogeneous microstructure of natural fibers. This non-uniform composition, comprising cellulose and lignin components, renders natural fibers more susceptible to deformation under stress, thereby resulting in a decreased Young's modulus. On the other hand, C-glass fibers possess a higher Young's modulus due to their uniform microstructure. As depicted in Table 3, the hybrid combination $SC_1$ exhibits a higher Young's modulus, while $SC_2$ displays a lower Young's modulus due to the presence of natural fibers.

## Impact Properties of Composites

### *Izod impact strength of composites*

Table 3 shows the Izod Impact strength of composites prepared. Izod Impact resistance is that a material is capable of resisting breaking under a shock charge or is capable of resistance to high-speed fracture under stress. One of the most defined mechanical properties of engineering materials is impact behavior. The effect tests for epoxy composite reinforced are carried out by Izod method. Table 3 shows the Izod impact strength exhibited by the hybrid composite. The $SC_1$ epoxy composite resulted in higher Izod Impact strength under testing conditions of 844.7 J/m. The $SC_2$ epoxy composite resulted in the lower Izod Impact strength under testing conditions of 522.6 J/m. Higher impact strength indicates the energy absorption capacity of the composites. This is because the fiber and matrix are strongly interfacial bonded. It also depends on the natural fiber and synthetic fibers nature. The main reason is that in $SC_{1,}$ both the synthetic and natural fibers are used and in $SC_2$ only natural fibers are used.

### *Charpy impact strength of composites*

Table 3 shows the Charpy impact strength of composites fabricated. Charpy impact resistance refers to a material's ability to withstand fracture or breaking under the impact of a sudden load or high-speed stress. It is considered one of the most significant mechanical properties in engineering materials, reflecting their impact behavior. The Charpy method is employed to conduct impact tests on epoxy composites with reinforcement. Figure 5 illustrates the Charpy impact strength demonstrated by the hybrid composite. The $SC_1$ epoxy composite exhibited a higher Charpy impact strength of 103.43 kJ/m$^2$ under the specific testing conditions, while the $SC_2$ epoxy composite showed a lower Charpy impact strength of 57.76 kJ/m$^2$. A higher impact strength implies greater energy absorption capacity in the composites, mainly attributed to a strong interfacial bond between the fibers and the matrix. In addition, the impact strength is influenced by the nature of both natural and synthetic fibers. The discrepancy in impact strength between $SC_1$ and $SC_2$ can be attributed to the use of both synthetic and natural fibers in $SC_1$, whereas $SC_2$ relies solely on natural fibers for reinforcement.

## Interlaminar Shear Strength (ILSS) of Composites

Table 3 shows the ILSS values of composites produced. ILSS pertains to the measure of the bond strength between adjacent

**Table 3: Mechanical properties of composites**

| Sample code | Ultimate tensile strength (MPa) | Young's modulus (MPa) | Izod impact strength (J/m) | Charpy impact strength (kJ/m$^2$) | ILSS (MPa) |
|---|---|---|---|---|---|
| $SC_1$ | 91.8 | 5834.5 | 844.70 | 103.43 | 53.6 |
| $SC_2$ | 58.2 | 3991.8 | 522.60 | 57.76 | 32.6 |
| $SC_3$ | 65.4 | 4230.8 | 674.37 | 71.71 | 42.4 |
| $SC_4$ | 75.6 | 4160.7 | 742.40 | 85.40 | 52.4 |
| $SC_5$ | 87.7 | 5016.1 | 650.81 | 58.70 | 34.6 |

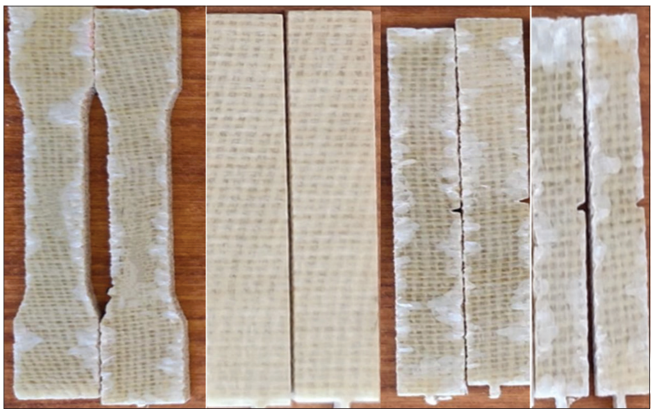

Figure 2: Specimens as per ASTM standards

layers in a composite material. The combination of flax and C-glass fibers can lead to an increased ILSS compared to using either fiber in isolation due to their complementary characteristics. Conversely, when sisal and flax fibers are combined in a composite, the ILSS may be lower than desired, primarily due to differences in stiffness and surface texture between the two fiber types. In the case of the $SC_1$ epoxy composite, where both synthetic and natural fibers are utilized, a higher ILSS of 53.6 MPa was observed under the testing conditions. However, the $SC_2$ epoxy composite, incorporating only natural fibers, exhibited a lower ILSS of 32.6 MPa. These differences in ILSS can be attributed to the presence of synthetic fibers in SC1, contributing to a more robust interfacial bond, unlike $SC_2$, which solely relies on natural fibers for reinforcement as shown in the Figure 5.

## CONCLUSION

The study demonstrates that the combination of flax and C-glass fibers offers promising potential for producing composites with improved mechanical properties. However, when using sisal and flax fibers together, careful consideration of their heterogeneous nature and the resulting impact on the composite's properties is essential. The findings highlight the importance of understanding the interactions between different fibers and the matrix to design and engineer composite materials with desired performance characteristics for specific applications. Further, optimization of the fiber ratios, processing methods, and testing conditions can lead to even more tailored and high-performance composite materials.


## FUNDING RECEIVED

No.


## CONFLICTS OF INTEREST

No.


## ACKNOWLEDGMENT

We thank our teachers for their guidance and valuable suggestions and also we would like to thank CIPET Mysuru for providing the testing facilities.


## REFERENCES


1. Asma B, Laouici H, Bouchoucha A. Tensile and flexural properties of polymer composites reinforced by flax, jute and sisal fibres. Int J Adv Manuf Technol 2018;108:95-16.
2. Nagamadhu M, Jeyaraj P, Kumar M. Influence of textile properties on dynamic mechanical behavior of epoxy composite reinforced with woven sisal fabrics. Sādhanā 2020;45:14.
3. Venkatesan K, Bhaskar GB. Evaluation and comparison of mechanical properties of natural fiber abaca-sisal composite. Fibers Polym 2020;21:1523-34.
4. Balaji A, Sivaramakrishnan K, Karthikeyan B, Purushothaman R, Swaminathan J, Kannan S, *et al*. Study on mechanical and morphological properties of sisal/banana/coir fiber-reinforced hybrid polymer composites. J Braz Soc Mech Sci Eng 2019;41:386.
5. Vishnuvardhan R, Kothari RR, Sivakumar S. Experimental investigation on mechanical properties of sisal fiber reinforced epoxy composite. Mater Today Proceed 2019;18:4176-81.
6. Arthanarieswaran VP, Kumaravel A, Kathirselvam M. Evaluation of mechanical properties of banana and sisal fiber reinforced epoxy composites: Influence of glass fiber hybridization. Mater Des 2014;64:194-202.
7. Boopalan M, Umapathy MJ, Jenyfer P. A comparative study on the mechanical properties of jute and sisal fiber reinforced polymer composites. Silicon 2012;4:145-9.
8. Palanikumar K, Ramesh M, Reddy KH. Experimental

investigation on the mechanical properties of green hybrid sisal and glass fiber reinforced polymer composites. J Nat Fibers 2016;13:321-31.
9. Premnath AA. Impact of surface treatment on the mechanical properties of sisal and jute reinforced with epoxy resin natural fiber hybrid composites. J Nat Fibers 2019;16:718-28.
10. Khanam PN, Khalil HP, Jawaid M, Reddy GR, Narayana S, Naidu SV. Sisal/carbon fibre reinforced hybrid composites: Tensile, flexural and chemical resistance properties. J Polym Environ 2010;18:727-33.
11. Rana RS, Kumre A, Rana S, Purohit R. Characterization of properties of epoxy sisal/glass fiber reinforced hybrid composite. Mater Today Proceed 2017;4:5445-51.
12. Sekaran A, Jeya S, Kumar KP, Pitchandi K. Evaluation on mechanical properties of woven *Aloe vera* and sisal fibre hybrid reinforced epoxy composites. Bull Mater Sci 2015;38:1183-93.
13. Siva R, Kesavaram B, Martin JJ, Mathiselvan G, Navas KB, Sangeetha M. Mechanical behavior of sisal and banana fiber reinforced hybrid epoxy composites. Mater Today Proceed 2021;44:3692-6.
14. Vimalanathan P, Suresh G, Rajesh M, Manikandan R, Kanna SK, Santhanam V. A study on mechanical and morphological analysis of banana/sisal fiber reinforced IPN composites. Fibers Polym 2021;22:2261-8.