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Experimental study of mechanical properties of Sisal/banana fiber hybrid sandwich composite

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ABSTRACT

Composites are becoming increasingly popular as a result of their useful features, like higher strength-to-weight ratio, higher modulus-to-weight ratio, resistance to corrosion and abrasive resistance. The purpose of this study is to examine the impact of moisture absorption on the mechanical characteristics of hybridized sandwich composite scaffolds made from epoxy resin, strengthened by woven fabrics of banana (B) and Sisal (S) fibers, and a fundamental layer of polyethylene foam (F). The buildings in this investigation were made using a hand layup approach. Samples of the composite are submerged in room-temperature water for varying amounts of time to determine the fibers' water absorption qualities. Several sandwich composite constructions are made and compared to a composite made from 100% Sisal fiber. According to the results, including foam into the Sisal/banana fibres increases their mechanical qualities. However, the composites' tensile, flexural, and impact strengths were diminished after prolonged exposure to water due to water permeating the fibre/matrix contact.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Advanced Materials and Modern Manufacturing.

1. Introduction

New composites use are constantly being developed as technology advances. At the same time, researchers have been working to enhance the composites' mechanical and physical qualities. Synthetic fibers can be combined with natural fibers or vice versa, or numerous synthetic fibers can be used to create a hybrid[1]. Synthetic fibers have been utilized in conjunction with natural fibers to increase mechanical qualities in recent years. Because of its unusual characteristics, research into FRP composites has been substantial. Eco-friendly, biodegradable, less cost, minimum density, higher strength, easy accessibility, and dispensation are just a few of the many benefits of natural fibers over synthetic fibers [2]. Since the higher elongation fibers can support the weight without causing the matrix to fail, the stress transfer is enhanced. Sandwich-structured composites are a subset of composites made by sandwiching a lightweight but stiff core between two thin and stiff shells. Because of its increased thickness, the core material, that is often a less strength material, contributes to the sandwich composite's higher bending stiffness and overall less density [3,4]. The purpose of this study is to determine how a hybrid sandwich composite reacts to moisture and how that affects its mechanical properties. There are examples of the hybrid composite being used in engineering in place of fiber banana composites [5]. We use polyethylene foam for the mat's support structure and a composite of Sisal, banana fiber, and epoxy. Sandwich structures made from bio-based materials and synthetic fibers were developed and compared in detail by [6]. Multiple textiles and polyethylene foam were used to create sandwich composites using natural and synthetic material components. The results demonstrate that the facing compressive stress is highest in the banana/Sisal hybrid sandwich structure, though the core shear stress, face bending stress, and water absorption percentage are all highest in the bam-

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boo/banana hybrid structure. [7] analyzed how stacking affected the tensile, flexural, and interlaminar shear properties of a material. Epoxy is used as the resin and both Sisal and banana fiber are used as reinforcement in this paper's novel hybrid composite, that is constructed as a multilayer mat with no breaks in between the layers [8,9]. Composites made from banana fibers benefit from the L5 hybrid's added 75 % strength. The L5 (Sisal-Banana-Banana-Sisal) material has the highest tensile strength after banana fiber composites. For flexural strength, S3 (Sisal-Banan-Sisal-Banana) is second only to banana fiber composites. Based on the findings, the L-5 (Sisal-Banan-Banana-Banana) stacking sequence is superior to other stacking sequences due to its superior qualities. Water struggle and impact capabilities of a hybridized sandwich composites made of sisal and banana were investigated by [10]. It demonstrates that sandwich composites made from banana woven composites and Sisal woven composites slow the pace at water penetrates the materials [11,12]. On comparing the standard Sisal woven composites, Sisal-banana woven composites have superior bending and impact properties. Sisal composites' water absorption is much diminished once banana composites are used as an exterior layer. Composites made from bamboo fibers and epoxy resin were studied [13]. The slotting method was used to produce both square and triangular honeycomb structures. The authors described the flexural behavior of a hybrid sandwich panel [14,15]. The researchers discovered that compared to a standard sandwich panel, the panel with JFC transitional layer can handle 29.6 % more weight, and the Hybrid Fiber Coaxial intermediate layer can handle 93.46 % more weight than standard sandwich panel [16]. It was also determined that the hybrid sandwich panel failed due to core shear and delamination. The sandwich architectures of were discussed, that had both prismatic and foam cores [17]. Here, we take a close look into Sisal and banana fiber reinforced hybrid sandwich composites of varying stacking sequences and analyze their mechanical properties from tensile strength and flexural strength to impact resistance[18 –20].

In this manuscript, the hybrid natural fiber composite is analyzed. The sandwich structure is studied for several load factors. From this work, the mechanical characterization of sandwich natural fiber composite materials is taken as output.

2. Experimentation

Epoxy resin, polyethylene foam, Sisal and Banana fibers are used in this project. The composite is prepared using a hand layup methodology. Several mixtures, each with a unique stacking order, are created. The composites get wet, we can see how they degrade over time. After that, physical parameters like water absorption, void fractions, and Inter laminar Shear Stress are determined by subjecting the specimens to a battery of tests. At last, the graphs and comparisons of these numbers are shown.

2.1. Sandwich structured composites

The trend towards using this is rising significantly. Sandwich composites are strong and durable despite their low weight because of the high mechanical characteristics of the sandwich layers [21]. Fig. 1 shows the hybrid Sandwich composites. There is a difference between the inner core and the top and bottom face sheets of this sandwich composite construction. Different specifications call for different densities, wall thicknesses, and levels of solidity in the core. Both the thickness and the material of the face sheets in a sandwich structure are typically constant [22]. These outer sheets help the sandwich structure withstand bending forces. In many cases, the top and bottom face sheets of an application are made from different materials and/or are of different thicknesses. It comes to main loads and bending stresses, the face sheet material in foam and honeycomb form of composite holds its own, though the core holds its own against transfer loads. The sandwich composite constructions of truss as well as web core types, the core provides some resistance to bending stresses [23,24].

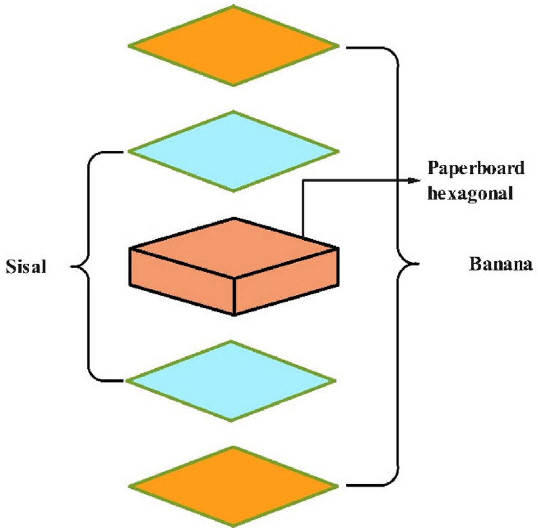

Fig. 1. Shows the hybrid sandwich composite.

2.2. Material selection

Polyethylene foam is employed alongside a reinforcing matrix [25]. Sisal and banana fiber are two examples of the reinforcements employed. Epoxy resin and the catalyst needed to solidify it serve as the matrix. If we compare the production, consumption, and availability of natural fibers, we find that sisal is second only to cotton in importance. In most cases, the fiber's diameter will be around 20 mm. Despite synthetic fibers increasingly taking Sisal's place, the biodegradability of Sisal still has several applications someplace it is preferable to non-biodegradable synthetic fibers. Banana fiber has several applications and is widely utilized. Armor for the flight deck, as well as seats and floors for helicopters, are common uses for E-banana fiber. E-banana composites, in addition to their outstanding mechanical performance, are non-conduction and have less radar thermal outlines, allowing the armed to see without being seen. Specifically, it's a matrix substance in the face sheets. For the fibers, this adds tensile strength in every direction. On using epoxy adhesive, cross-link F is very resilient and sturdy. F is commonly used for cushioning fragile items and insulating items from high temperatures.

2.3. Fiber arrangement

Epoxy resin functions as a matrix. Seven layers make up the hybridized fiber sandwich composites structures, and they are arranged as follows: [S/B/B/F] and [B/S/B/F] As illustrated in Table 1,

Table 1
Fibers arranged in a stacking pattern.

Composites	Loading setup
Specimen1 (S1)	B-B-B-B-B-B
Specimen2 (S2)	S-B-B-F-B-S
Specimen3 (S3)	B-S-B-F-B-S-B

a core mat consists of three layers: a Sisal layer, a Banana layer, and a Sisal layer again. Polyethylene foam forms the basis of the mat.

2.4. Fabrication of sandwich composites

A hardened steel square mold is used in the preparation of the composite structures. The mold's square inches are 365. The building's dimensions can be adjusted as necessary. The hand lay-up technique is preferred for preparing the sandwich composite structure because it allows for greater freedom in the choice of materials and results in a relatively high quality surface finish. The procedure is easy to implement and does not call for complex or costly machinery. Sandwiches are made by layering woven S and B fiber with F and epoxy glue.

3. Testing of mechanical properties

3.1. Tensile test

In this analysis, ASTM D 3039 is used to comportment a tensile test on flat specimens [24,25]. Composite specimens are to measure 250 mm in length, 25 mm in width, and 3 mm in thickness, as specified by the ASTM standard. Universal Testing Machine depicted in Fig. 2. We get data from a tensile test run on a computerized Universal Testing Machine (UTM) at 10 mm/min. Three of each type of composite were examined, and the average of the results was recorded as a characteristic of that composite[26–29].

3.2. Flexural test

Using an Instron 1195 UTM and following the protocol laid out in ASTM D 790, a flexural test was conducted on rectangular sample of composite components[30]. Per the ASTM standard, the composite specimen's longitudinal dimensions are 125 mmx13 mm × 3 mm. The 25 kN load cell was used in the test, with a loading speed of 10 mm/min. Every type of composite had three replicates examined, and the average of those results was recorded as the composite's characteristic.

3.3. Impact test

Impact test was performed on rectangular flat sample. Specimen has longitudinal measurements of 100 mm x10mm x3mm. The impact test used in this study was a Charpy impact test using a pendulum hammer, with energy loss and cross sectional area measured and correlated [31].. The average of the results from three independent tests performed on each type of composite is presented here.

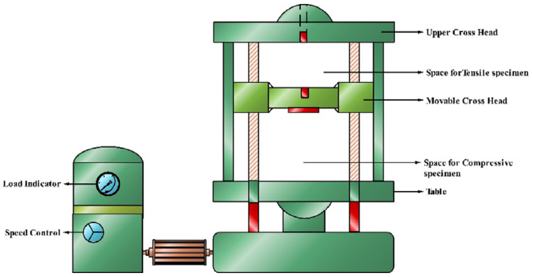

Fig. 2. Universal Testing Machine.

3.4. Water absorption

The sum of water absorbed by the composites is determined with an absorption test. The ASTM D 570 standard governs the preparation of test specimens for water absorption[32]. This sample is 30 mm × 30 mm × 3 mm in size. Six distinct laminates will have their test specimens put through their paces in a water tank [33–40]. Weighing and testing specimens requires first ensuring that they are uniformly dry. The sample are removed from the plastic tub, dried off by gently blotting off any residual water, and weighed every 24 h [41–48]. All three specimens show signs of water absorption. The difference in mass between the dry and wet samples is then utilized to derive the moisture content of the sample [49–56]. The percentage of water absorbed by the composite specimen was calculated using the formula below. Composite specimens' water absorption ages are recorded at 0, 8, 24, 40, 56, 72, 88, and 104 days.

$$\text{Water absorption} = [(W_1 - W_2)/W_2]x100 \tag{1}$$

however.
W_1 = Weightage of the dry specimen.
W_2 = Weightage of the wet specimen.

4. Results and discussions

4.1. Analysis of tensile test

UTS is determined by the unique qualities of individual fiber, both artificial and natural. Sisal and banana fiber reinforced hybrid sandwich composites of varied weight-percentages have their ultimate tensile strength investigated [57–64]. Sisal-banana fiber epoxy sandwich composites with varying tensile strengths as a function of sample stacking sequence is depicted in Fig. 3. The initial tensile strength of the composite is lower once it is wet compared to after it is dry, as shown by the data [65–72]. Degradation of the composite happens not only due to the breakdown [73–81] of its separate components but also due to the interaction loss between them. In Table 2, we see the wet and dry UTS values of the composite specimen S1, S2, and S3.

4.2. Analysis of flexural test

The three-point bend test is used to determine the flexural strength of hybrid sandwich composites in both dry as well as wet situations [82–90]. See Fig. 4 for an illustration of how the flexural strength of Sisal-banana fiber-reinforced epoxy sandwich

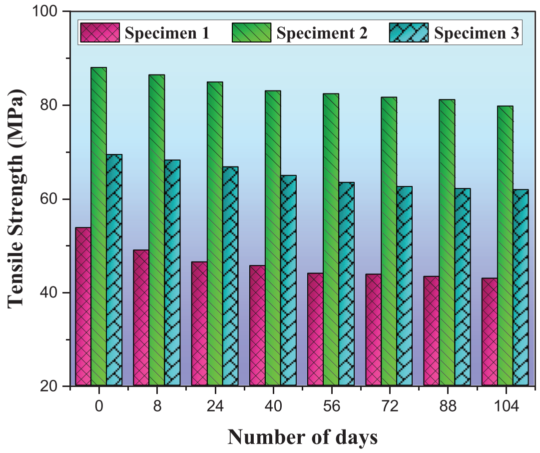

Fig. 3. Tensile Strength under Dry and Wet Conditions.

Table 2
Composite sample's Ultimate Tensile Strength.

Days	Ultimate Tensile Strength, MPa		
	S1	S2	S3
0	53.742	88	69.4
8	48.93	86.423	68.2
24	46.403	84.9	66.75
40	45.6	83.02	64.905
56	43.99	82.4	63.42
72	43.75	81.63	62.54
88	43.304	81.13	62.104
104	42.909	79.76	61.85
percentage reduction	18.32%	9.12%	12.36%

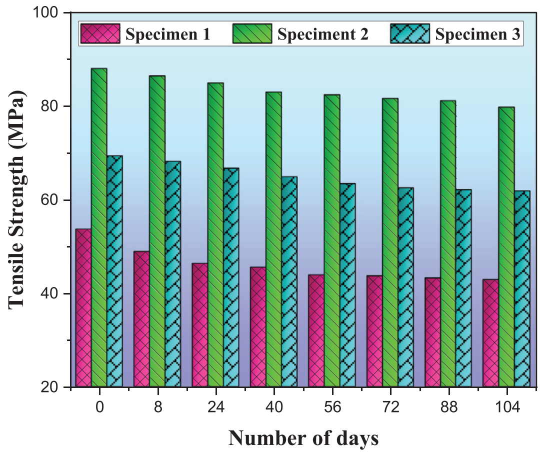

Fig. 4. Flexural Strength under Dry and Wet conditions.

composites varies according on the order in with the samples are stacked. Data shows that compared to S1 and S3 composites, S2 has higher flexural strength [91–96]. Banana fiber in the composite's upper layer, along with the foam, allows it to tolerate greater flexural loads.

On equating the hybrid sandwich composite made of Sisal and banana fiber, the mechanical qualities of pure Sisal degrade more quickly and to a greater extent. With longer periods of immersion, the flexural stress is seen to diminish. The flexural test relies heavily on the core-mat. A hybrid sandwich composite is used in to boosts both the flexural strength and stiffness (See Table 3).

4.3. Impact test analysis

Employing the Charpy test, we can determine the amount of energy absorption by sandwich composites in both dry and wet situations. Fig. 5 displays the variance in energy absorbed for different arrangement of Sisal-banana fiber-strengthened epoxy sandwich composites. According to the analysis of the data collected, the S2 composite outperforms the S1 and S3 variants in terms of energy absorption. Banana fiber contributes to the composite's increased resistance to the effects of Energy degradation. On comparing to a hybrid sandwich composite made of Sisal and banana fiber, the mechanical characteristics of pure Sisal far more quickly and significantly.

Table 3
Composite samples' s Flexural strength.

Days	S1	S2	S3
0	71.53	123	116
8	71.85	111	103
24	65.23	108	100
40	63.28	109	98
56	62.42	106	96
72	61.3	105	95
88	60.2	104	93
104	59.7	102	91
Percentage reduction	23.07 %	18.35 %	22.16 %

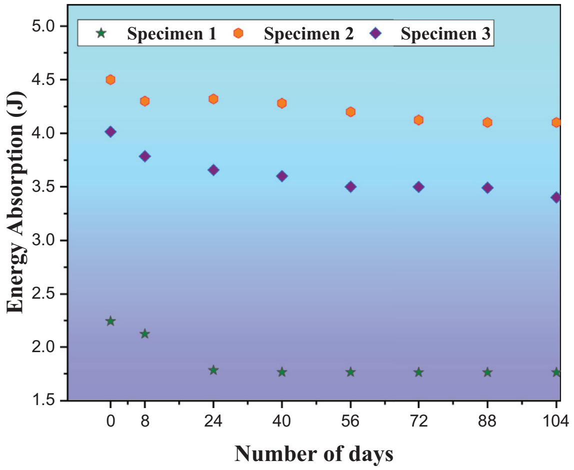

Fig. 5. Energy Absorption through Dry and Wet Conditions.

4.4. Analysis on water absorption test

The purpose of the water absorption is to determine how much water is taken in by the composite specimen. Table 4 displays the percentage rise in water absorption recorded at various times after exposure to the composite specimens (0, 8, 24, 40, 56, 72, 88, and 104 days).

The first 30 days have a much higher absorption rate than the rest of the time combined. Sisal fibers and the core-mat contribute greatly to the hybrid sandwich composite's high-water absorption rate in this study. Epoxy matrices absorb almost no moisture. As can be seen in Fig. 6, the pure Sisal fabric sample S1 has the highest water absorption rate, but the sandwich composite specimen S2 with banana fiber as the outer layer has the lowest. Fig. 6 is a comparison of how much water various laminates absorb.

5. Conclusions

Hybridized sandwich composites based on epoxy and reinforced with Sisal and Banana fiber were made utilizing a straightforward hand-lay approach. In this study, mechanical characteristics of epoxy hybridized sandwich composites strengthened by Sisal-Banana fiber were characterized through experimental analysis. The many properties of composites have been determined through testing.

- After being submerged in water for 90 days, the hybrid sandwich composite absorbs a maximum of 6.05 % moisture. The hybrid sandwich composite's core-mat and moisture absorption % are lower than those of composites made from Sisal fibers, with this article deals. Due to their hydrophilic composition, sisal fibers readily absorb moisture.
- Mechanical qualities were nearly improved to a greater level by incorporating natural, artificial fibers and foam into the polymeric composites. As a result, more products are being made from natural fibers.

Table 4
Results on Water absorption test.

Absorption content (wt %)	Immersion Duration in days							
	0	8	24	40	56	72	88	104
S1	0	4.12	5.33	6.134	6.81	7.32	7.923	8.32
S2	0	1.14	1.81	2.352	2.946	3.41	3.68	3.75
S3	0	2.61	3.85	4.98	5.31	5.62	5.81	6.05

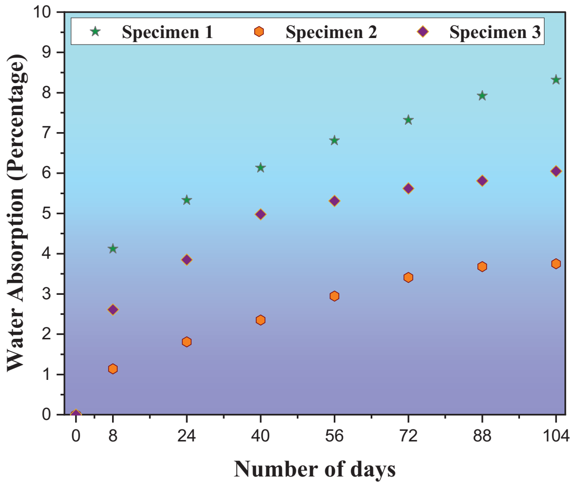

Fig. 6. Water Absorption (Wt %) vs Immersion Time (Days).

- The hybrid sandwich composites experienced a decline in mechanical characteristics under tensile, bending, and impact loading on exposing to water,.
- According to experiments, tensile qualities suffer greatly after being exposed to water. Tensile strength values decline by 18.32 %, 9.12 %, and 12.36 %, respectively, for composites of the S1, S2, and S3 structures on exposed to moisture.
- In S2 composite, once foam is present, flexural strength is highest. The Flexural strength values of S1, S2, and S3 structural composites decrease by 23.07 %, 18.35 %, and 22.16 %, respectively, after being exposed to water.
- According to experiments, impact characteristics suffer greatly once the material absorbs water. Energy absorption values drop by 20.29 %, 10.94 %, and 16.07 %, respectively, for the first, second, and third structure composites after they absorb water.
- Due to water absorption, the strength of the composites decreased with increased immersion times. However, the cellulose structure began to break down with time, leading to an increase in the failure strain. There is potential for use of these composites in aeronautical and automotive settings.

CRediT authorship contribution statement

R. Chithra Devi: Conceptualization, Writing – original draft. **R. Girimurugan:** Project administration. **S. Nanthakumar:** Investigation. **P. Rajasekaran:** Resources. **S.K. Hasane Ahammad:** Validation. **S.J.P. Gnanaraj:** Supervision.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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