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Investigating the Influence of Water Absorption and Mechanical Properties of Composites Reinforced with Banana and Roselle Fibers

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Abstract: Fiber-reinforced polymer composites are the best at many things because they have high specific strength and modulus. Plastics are reinforced with artificial or natural fibers. Glass, carbon, and other synthetic fibers have long been used in fiber-reinforced plastics. Despite having high specific strengths, glass and other synthetic fiber-reinforced plastics are rarely used due to the high cost of production. For this, researchers have studied roselle, a plentiful natural fiber from India. Natural fibers are lightweight, strong, and reasonably priced. This study develops and characterizes a new class of natural fiber-based polymer composites using roselle fiber and banana fiber reinforcement. The new composites' mechanical characteristics are described. Research is being done to better understand the mechanical behaviour of epoxy-based polymer composites. Composites made of banana fiber and roselle fiber are gaining attention as sustainable and cost-effective alternatives to synthetic fiber composites. In this study, six different compositions of these natural fiber composites were prepared, and six specimens were tested using tensile tests and water absorption tests, in accordance with ASTM standards. The results showed an increase in tensile strength with a 68% improvement observed when compared to pure epoxy resin. The water absorption tests were conducted by varying the weights of the composites and increasing the weights gradually over a period of 10 days. The findings showed that the composites exhibited excellent resistance to water absorption, with the weight gain being significantly lower than that of pure epoxy resin. These results suggest that composites made of banana fiber and roselle fiber can be a promising alternative to traditional synthetic fiber composites, with improved mechanical properties and resistance to water absorption.
Keywords: Banana Fiber, Roselle Fiber, Tensile strength, Water absorption, hand layup method.

I. INTRODUCTION

Researchers worldwide are developing high-performance engineering materials from renewable resources like natural fibres[1] [2]. Natural fibre composites grew 13% annually for ten years. However, replacing synthetic fibre with natural fibre has drawbacks, such as low mechanical properties due to incompatibilities between hydrophilic fibres and hydrophobic thermoplastics, which require further treatment to improve compatibility[3]. Even though these replacement materials have "green" features, they must work just as well as the original ones. Over three thousand years ago, natural fibres were used to reinforce materials[4]. Recent advances in technology have made it possible to mix these materials with polymers [5]. A variety of natural fibres, including kapok, roselle, sugar palm, sisal, pine apple leaf, jute, rice husk, wood, oil pump empty fruit bunches, barley oat coir, Kenaf, and abaca, have been used for this purpose [6]. According to the author, roselle fibre has the same potential as jute and Kenaf. Currently, jute and Kenaf are frequently used in the automotive sector, particularly when making automotive parts [7]. Natural fibres are superior to synthetic fibres in a number of ways, including price, better mechanical properties, availability, material renewability, biodegradability, nonabrasiveness, and ease of recycling[8][9]. In Borneo, Guyana, Malaysia, Sri Lanka, Togo, Indonesia, and Tanzania, natural fibres like roselle are grown. Roselle is one of the plants that has been found to be suitable for use in making natural fibres. The scientific name for roselle is Hibiscus sabdariffa L., and it belongs to the Malvaceae family. The hibiscus genus roselle is widely distributed in tropical areas. These plants are often used to make bast fibre in addition to being used as an infusion. Roselle can be put to a huge range of uses. The fruit is frequently used in the pharmaceutical[10][11],and culinary [12] [13] industries, whereas the fibre is used in the textile[14] and polymer composites[15] industries and as a textile reinforcement material. It has the capacity to grow annually and increase in height to between two and two and a half metres[16]. The best stem for producing fibre is one that is long and clear, without any branches or fruiting stalks that might break up the continuity of the fibre.

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A plant cannot be regarded as being of this calibre until it has grown for three to four months in the long, sunny days [17]. In comparison to traditional glass fibres, natural fibres have a number of technological and environmental advantages, such as superior mechanical properties, low density, and low cost [18]. Furthermore, compared to synthetic fibres, natural fibres typically have poor mechanical properties [19], [20], [21], [22], [23], [24]. Toxic artificial ones, perhaps. There is a diverse collection of fibrous plants that can be found in tropical regions. Some of these plants, such as the banana, are cultivated for use in agricultural settings. Lignocellulose, a fundamental type of plant fibre, can be obtained from bananas. Because it has satisfactory mechanical properties, cellulosic fibre that is obtained from the pseudo-stem of Musa sepientum is a desirable fibre [25]. Banana production almost always results in the creation of a by-product that is known as banana fibre. The procurement of banana fibre for use in industrial applications does not necessitate the incurrence of any further expenses for the input of additional materials. The use of banana fibres as reinforcement in polymer matrices has been the subject of a number of reports, and researchers have discovered that they perform admirably in PP matrices [26], [27], [28],[29].

The study focuses on creating composites using banana and roselle fibers as reinforcing materials, with roselle fibers being pre-treated before being combined with the matrix to form the composites. The mechanical and thermal properties of the composites with varying percentages of roselle fiber were compared to those of banana fibers to investigate the impact of roselle fiber. The study also looks at the effect of water absorption behaviour and tensile properties of hybrid roselle/banana fiber reinforced composites. Additionally, composite samples with superior properties underwent degradation studies to evaluate their potential for industrial applications.

II. MATERIALS & METHOD

A. Materials

The banana fibre and roselle fibre that were used as matrix materials in this study were the fabrication materials that were used. RK exports in Chennai, Tamilnadu, was responsible for the acquisition of the banana and roselle fibre. RK fibres in Chennai, Tamilnadu was the source for the acquisition of both the epoxy resin (LY556) and the corresponding hardener (Hy 951). When epoxy and hardener are mixed together, the weight ratio of the two components is 10 to 1. The fibre mats shown in Figures 1 and 2 are respectively made of banana fibre and roselle fibre.

Fig 1: Banana fiber

Fig 2: Roselle fiber

B. Methodology

The hand layup method was used as the procedure for preparing composite plates made of banana fibre and roselle fibre. At first, the fibres were woven together and dried at a temperature of 80^0 C for twenty-four hours. The composite plates had dimensions of 250 mm X 100 mm X 10 mm, and the hardeners used were HY951 and LY556 for the epoxy resin. The inner surface of the mould was prepared for hand layup by first being cleaned with acetone and then being sprayed with a releasing agent. This was done to prevent the composite plate from sticking to the mould surface. Polyvinyl glycol was utilised so that the laminate could be removed quickly and easily. After that, the unsaturated epoxy resin was poured into the mould, and each layer of fibre was placed repeatedly over the top of the resin until the desired thickness was obtained. This process continued until the fibre was completely embedded in the resin. Taking into consideration the fabric alignment tolerance, various weight percentages of banana and roselle composite plates were prepared. After pressing the mould with fifty bars to achieve full viscosity and leaving it at room temperature for twenty-four hours, air that had been trapped in the mould during the hand layup process was released. After that, in order to post-cure the plates, the composite plate was put back into the oven at 80^0 C for another two hours. Figure 3 illustrates the Schematic diagram of Hand layup method.

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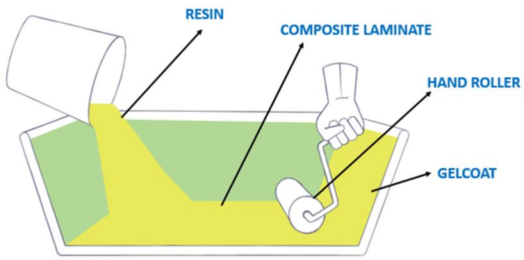

Fig 3: Schematic diagram of Hand layup method

III. EXPERIMENTATION

A. *Water Absorption Test*

A water absorption test was performed to assess the water absorption behaviour of composite plates made from roselle and banana fibre. For ten days, the composite plates were submerged in distilled water, and daily weight changes were recorded using a weighing machine. The samples were initially weighed and their starting weight was noted. They were soaked for 24 hours in distilled water after which they were removed. The samples were taken out of the water after 24 hours, the excess water was wiped away with a cloth, and the wet weight was calculated and noted. The samples were immersed in the same water each time, and the procedure was repeated every day for ten days. The initial weight was subtracted from the wet weight to determine the weight change, and the initial weight was multiplied by 100 to determine the percentage weight gain. The weight gain percentage of the various samples was compared in order to assess the composite plates' water absorption behaviour. The behaviour of the composite plates' water absorption was then examined using the data to determine the impact of the banana fibre and roselle fibre. Figure 4 depicts the test specimens of water absorption test.

$$\text{Water absorption } (\%) = [(W2 - W1)/W1] \times 100\%$$


Fig 4: Water absorption test specimens

B. *Tensile Test*

The tensile properties of the banana fiber and roselle fiber composite were evaluated using the ASTM standard D638-IV. A universal testing device with a crosshead speed of 2 mm/min was used to test six samples. The specimens were carefully prepared to ensure the absence of any defects or irregularities. During the tensile test, the load was applied to the samples until failure, and the tensile strength and tensile modulus were recorded. The composite could be used instead of traditional materials in many situations where high strength and stiffness are needed. Tensile specimens of the composite material are shown before and after a tensile test in Figures 5 and 6 respectively.


Fig 5. Before tensile test


Fig 6 After tensile test

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IV. RESULTS AND DISCUSSION

A. *Water Absorption Test*

The water absorption behaviour of the banana fiber and roselle fiber composite was investigated by conducting a water immersion test for 10 days. Six specimens were prepared with different weight ratios, and their weights were recorded every day to determine the amount of water absorbed by the composite. The results showed that the water intake increased exponentially over the 10-day period for the banana and roselle composite as shown in Figure 2. The initial weight of the specimens increased gradually as they absorbed water, and the rate of water absorption was dependent on the weight percentage of the roselle fiber in the composite. The composite with a higher percentage of roselle fiber exhibited a greater rate of water absorption compared to the composite with a lower percentage of roselle fiber. The water absorption test showed that the banana fiber and roselle fiber composite exhibited hydrophilic behaviour, with the rate of water absorption being dependent on the weight percentage of roselle fiber in the composite. There was a discernible shift towards a higher level of water retention after the addition of fibre, which was found in [30], [31]. The amount of non-crystalline components, the number of voids that are present in the fibres, and a larger interfacial area between the fibres and the matrix are all things that can be used to estimate the amount of water that is contained in the fibres[32]–[39]. The possibility that water molecules will attack the interface and cause internal de-bonding of the fibre and matrix is one of the factors that can lead to the collapse of the composite structure [40]. The presence of moisture and the subsequent absorption of water causes natural fibres to degrade and lose their strength, which leads to premature ageing [41]. For all of the samples, Table 1 shows the correlation between the percentage of weight gain (in %) and the duration of immersion.

Table 1: water absorption test data for 10 days

Specimen No	Specimen label	Day 1	Day 2	Day3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day10
1	60:30:10	0.7017	1.1027	1.5538	1.8045	2.1553	2.4561	2.7067	2.7568	2.8571	2.8571
2	60:10:30	0.2439	0.5487	0.8536	1.2195	1.4634	1.5853	1.5853	1.5853	1.5853	1.5853
3	60:20:20	0.1940	0.4852	0.5822	0.7763	0.9218	1.0674	1.1159	1.1159	1.1644	1.2130
4	70:20:10	0.5177	1.1094	1.6272	2.2928	2.5882	2.7366	2.8106	2.8106	2.8106	2.8846
5	70:10:20	0.5943	0.9658	1.4115	1.7087	1.9316	2.5260	2.8231	3.0460	3.0460	3.0460
6	70:15:15	0.2826	0.5653	1.1307	1.4840	1.8374	2.4028	2.4028	2.4028	2.4028	2.4028

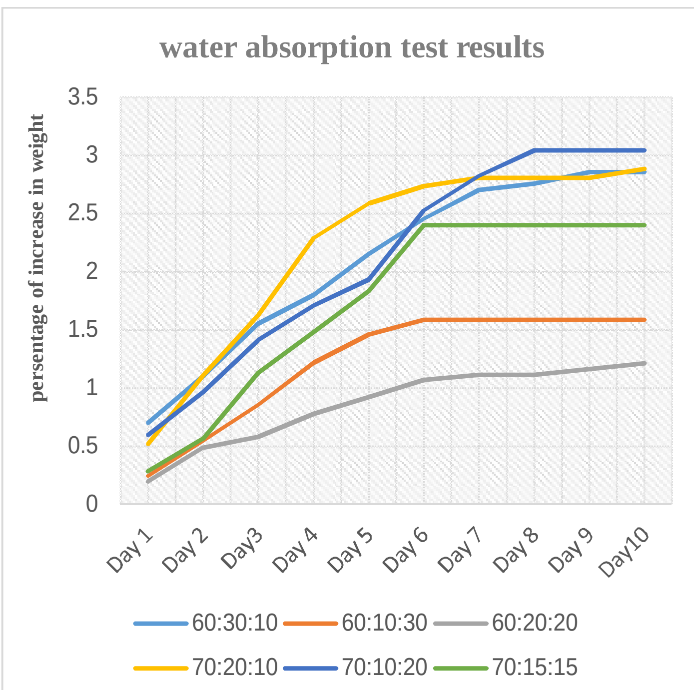

Figure 2. Percentage of increases in weight vs. composition (matrix: banana: roselle)

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B. Tensile Test

Tensile tests were performed on these fiber mats using a universal testing machine. The results of the tensile tests are presented in Table 2. The ultimate tensile strength (UTS) and maximum load for each specimen are reported. The before tensile test specimens are shown in figure 3. The after tensile test specimens are shown in below figure 4. The specimen labelled 70:15:15 had the highest UTS of 101.28 MPa when the maximum load was 12660 N. The specimen labelled 60:30:10 had a UTS of 40.93 MPa when the maximum load was 9210 N. The UTS of the 70:15:15 specimen was 68% higher than that of the 60:30:10 specimen. The increased tensile strength was an indication of the improved fiber-matrix adhesion and good wettability that the silane conditions promoted. This increased tensile strength made it possible for the matrix and the fibres to effectively transfer stress to one another [33]. More research has shown that the roselle fibre has a strong water absorption property, which frequently necessitates chemical treatment [34]. There is a trend towards an increase in tensile strength, flexural strength, and impact strength Izod when the banana fibre content reaches 20% by mass; there are signs of a decrease when the banana fibre content reaches 25% by weight. Complete [35] [36] [37] [38]. We can no longer follow this trend. The addition of fibre results in an increase in the weight fraction of the fibre, which causes the properties to improve. The primary reason for this is the high strength of the interface between the fibre and the resin [39]. The graphs for ultimate tensile strength and tensile strength are shown in figures 5, and 6 respectively.

Table 2: tensile properties of banana and roselle fiber

Specimen No	Specimen Label	Maximum Load	Load at break (standard)	Ultimate Tensile Strength (UTS)
		(N)	(N)	(MPA)
1	60:30:10	9210	4320	40.93
2	60:10:30	10830	5400	62.84
3	60:20:20	11170	6150	72
4	70:20:10	11000	6000	71
5	70:10:20	11580	6480	92.64
6	70:15:15	12660	6930	101.28

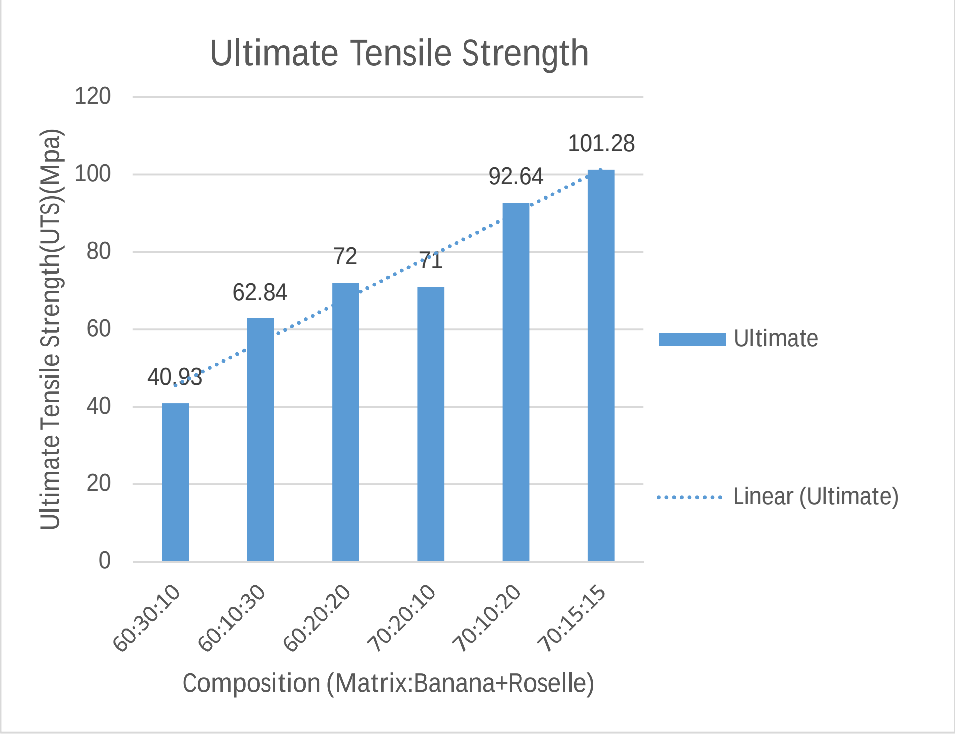

Figure 5.Ultimate tensile strength (MPa) vs. composition (matrix:banana+roselle)

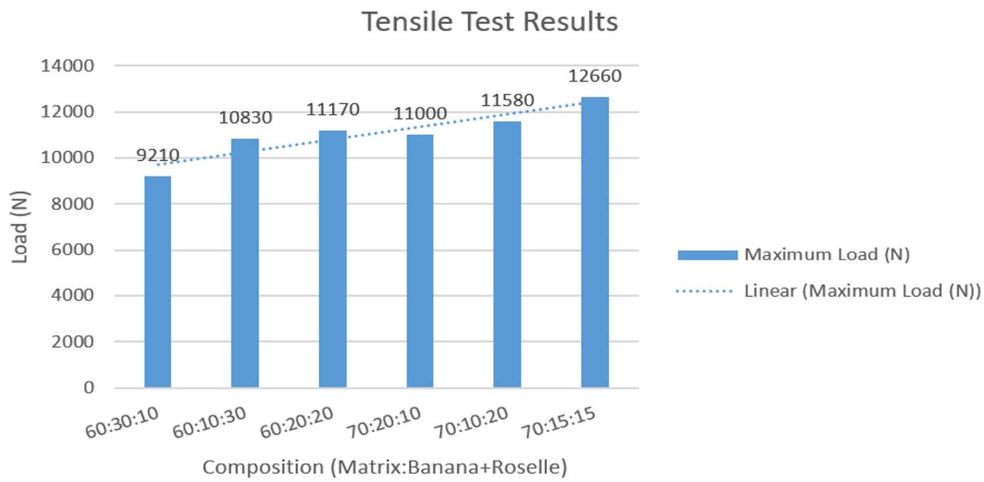

Figure 6. Load (N) vs. composition (matrix:banana+roselle)

V. CONCLUSION

The investigation of water absorption behaviour and tensile strength of banana and roselle fibers as reinforcement in composite materials showed an increasing trend in weight and thickness throughout the immersion period. The composites also demonstrated a significant increase in tensile strength, with a 68% improvement observed. These findings suggest that banana and roselle fibers have potential as effective reinforcements in composite materials.

1) The tensile tests indicate that the fiber mat with the composition of 70:15:15 demonstrated the highest ultimate tensile strength (UTS) of 101.28 MPa and a maximum load of 12660 N.
2) Water absorption behaviour of the banana fiber and roselle fiber composite revealed that the initial weight of the specimens increased gradually as they absorbed water. This information is important in determining the suitability of these fibers for various applications where exposure to water is a significant factor to consider.

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