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Research Article

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A Study on Absorption Characteristics and Mechanical Properties of Hybrid Polymer Composites

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Abstract

Most fabrication corporations use hybrid polymer composite substances in the latest years because of their higher mechanical properties. The usage of natural fibers in polymer composites has developed renewed interest in the improvement of composites due to their biodegradable nature. Abundant utilization of natural fibers is discovered in the composite polymers because of elements including availability, value economy, and low density in comparison to artificial fibers, smooth processing, and biodegradability. The effect of nano clay content in the hybrid composites for mechanical properties and water absorption is the main aim of the present study. The durability performance of hybrid composites is improved by combining natural hybrid composites with the addition of certain nanofillers. Significant hybrid aging characteristics of composite polymers under various climatic conditions are also investigated in the present study. Atmospheric aging time function in different solutions for various proportions of fillers in hybrid polymer matrices is also investigated.

Keywords

Composite, Nano clay, Mechanical properties, Absorption

Introduction

Research on enhancing the mechanical characteristics of polymer matrix composites has been the content area of numerous studies in the literature. Low density, a high strength-to-weight ratio, processing-related fracture toughness, a low energy content, and recyclable are just a few of the benefits of natural fiber composites [1, 2]. Natural fiber-reinforced composites are utilized in a variety of industries, including packaging, consumer goods, building and construction, and transportation. Fiber composite materials have been widely studied for the last decades and have been studied through intensive studies. Their characteristics and properties were used in various engineering areas. Composite materials used for products, and power supplies, and composite effects of power supplies from the plants [3], bamboo [4], and jute [5]. Failure of natural fibers overcomes these problems. Sustainable methods must be used for processing composite materials made from renewable resources. The phrase "Think Global, Act Local" ought to be incorporated into a core industry [6, 7].

The characteristics of composite made of natural fibers rely on the type of polymeric material, the alignment of the fiber matrix, the percentage by weight of the fiber, and the type of fiber reinforcement. In it, the properties of sisal fiber-reinforced hybrid composites were investigated and reported [8]. Compressed bio-composite samples were used to fabricate banana fiber reinforced epoxy bio-composites and reinforced epoxy bio-composites. Hybrid composite

performance and water absorptions studies on different fiber combinations were studied and the results were reported [9]. Hemp, perhaps, and the fibers of sisal, rami, and kenaf were one of the most prevalent and studied fiber materials in the past two decades. Natural fiber polymer composite materials have many benefits. The quality variability, such as water absorption, limited treatment temperature, synthetic analogy, fiber, and polymer matrices such as low strength, reduced the durability [10].

Waste banana and coconut fiber is utilized to create biodegradable polymer composites that are readily available. A twin-screw extruder and injection at varying loads are used to create these samples. Banana/coir reinforced hybrid composites' impact strength first rises by up to 10% by fiber weight, then falls. Absorption is directly proportional to immersion time [11]. ANSYS finite element analysis software was used to evaluate the property successfully. Stress at the interface of banana fiber. Applying a matrix evoked by various load conditions, Tension, impact, and bending characteristics using the finite element analysis model [12]. Reinforced with two-way woven fabrics of fiberglass and jute, along with polyester fabric (core mat) as a centre layer and performed three-point bend and tensile tests and failure mechanism analysis were also studied. Greater absorption was noticed for composites compared with commonly observed glass fiber composites [13].

Sugar cane baggage waste has been used as a polymer resin reinforcement for the production of low-cost composites [14]. When environmental performance over the life cycle of fiber composites and glass fiber reinforced composites has been evaluated, it has been found that natural fiber composites are better for the environment in researched applications [15]. A several types of chemical treatment processes have been identified as effective treatment processes for the production of less hydrophilic composites. It aims to reduce the hydroxyl groups in the fiber and increase the bond between the fiber and the matrix [16].

Zamri et al. [2] studied the water uptake behaviour by submerging the composite sample under three different conditions: water, distilled water, and NaCl + distilled water left at room temperature for one week. From the obtained water absorption curve, the characteristic parameter of the maximum water content (mm) was obtained. This study included the effects of various aquatic environments on the properties of tensile, bending, and impact tests. It is very critical to examine the water absorption capacity of the composite, as the sample's mechanical characteristics are decreased by the presence of moisture in the composite.

Zamri et al. [10] studied how varied water conditions—such as acidic solutions, distilled water, and seawater solutions at ambient temperature effected the mechanical characteristics of jute/polyester unsaturated glass fiber composites. A list of cessations drawn from the results is: the behavior of the water absorption model is not fickle. The highest values of the samples' maximum moisture (mm) and diffusion coefficient (D) were noted. The tensile strength tests were performed on the mechanical properties of hybrid fiber-reinforced polymer composites in contrast to several natural fiber types, including sisal, kenaf, hemp, jute, and coir [11]. According to their findings, the use of hybrid material multiplies mechanical properties by 60 [12].

Arthanarieswaran et al. [17] worked on fiber physico-chemical treatment and came to the conclusion that it might be a way to get over the problems mentioned above. Utilizing a hybrid composite material that can be abandoned is an additional option. The disadvantages of "natural mono-fiber composites" outweigh their benefits in terms of monitoring. The creation of high-strength hybrid composites can be sped up by careful fiber design and selection, as well as striking the correct price-performance balance. Reinforcements coated with epoxy silane maintain the epoxy composites' hydrophobicity. The volume of nano clay in big composites has seen very slight variations. Compared to pure epoxies, the silane-treated reinforcement's hydrophobicity minimizes water absorption. These qualities strengthen the epoxy composite hybrid fiber, which can be employed in a variety of engineering applications [18].

The current study's goal is to investigate how fiber composition in hybrid composites affects water absorption. Hybrid composite's durability and performance are improved by the incorporation of both natural and synthetic fibers, as well as certain nanofillers. Significant hybrid aging characteristics under various climatic conditions for a particular polymer composite is also investigated in the present study and the suitable applications were presented. Water absorption characteristics of jute and nano clay as reinforcements in polymer composites is not found in the literature.

Materials and Method

Materials

One of the least expensive natural fibers is jute as shown in figure 1. Cellulose and lignin make up the majority of their makeup. So, some are fibrous fibers, and some are lignocelluloses fibers. Glass fiber mesh as follows in figure1 in this research, H-mat glass fiber was selected based on its properties as a reinforcing material. Wax is usually used in polishing, stiffening, or friction reduction. Epoxy resin-BF-H-205 shown in figure 1. Crack and fix are a surface



Figure 1: Fibers and resins used in the work.

temperature polymerization system primer for concrete, epoxy, injection grout, epoxy mortars, and repair compound. The low viscosity of the system mixture enables a high filling load and has outstanding mechanical and chemical resistance properties. Hardener DF-R105 is shown in figure 1. Crack and fixed hardener are blended with epoxy so that the epoxy resin gets started hard and fragile. Nano clay results of numerous investigations on montmorillonite nano clays, such as structure, properties, diverse applications, and biocompatibility are shown in figure 1.

Composite specimen preparation

The composite material is created using a hand lay-up method (open mold technology). A 150 mm x 150 mm and 3 mm thick mold is made of glass as shown in figure 2. After making the mold of the required dimensions, wax was applied to the inside of the mold to facilitate the release of the composite without sticking to the wall.

In addition, the epoxy was mixed with the curing agent at a constant ratio of 2:1. In all hybrid composites, the layer order of the composite is displayed. First, wax the mold. Natural fiber was placed over glass fiber reinforced polymer and then filled with epoxy until the resin dries (10 - 15 min). The glass fiber was then applied over the natural fiber. The fibrous layer is created by adding the required amount of epoxy with a roller to distribute it over the entire surface, which helps eliminate air gaps in the layer. The composite was hard-pressed and dried to remove excess resin [19, 20]. The equipment was cured in a loaded state of 20 kg for about 24 h. Finally, after removing the void between the resin and the fiber by weighing the sample, it was maintained for a certain period to obtain an accurate sample.

The fiber layers were made by adding the necessary dose of epoxy resin with the help of a roller to extend it over the entire surface. This eliminates the air gaps within the layers during this process. The excess resin was removed under pressure on the composite and dried. Lastly, the samples were compressed to eliminate the air gaps between the resin and fiber, and then kept for a while to obtain exact samples. The prepared composite plate was cut as per ASTM specimen dimension D638 tensile test specimen. The burrs were removed with smooth emery cloth and the specimens were cleaned. The designations for these hybrid composites are 10G + 0N + 10J, 10G + 3N + 10J, 10G + 6N + 10J, and 10G + 9N + 10J (the letters G, N, and J stand for glass fiber mesh, nano clay powder, and jute mesh, respectively), as shown in figure 3. At a temperature of 70 °C, the composite sheet was cured for a duration of 24 h. Before being employed for various tests including tensile, flexural, and impact test, these composite sheets are trimmed to the appropriate sample size. Table 1 displays the weight distributions of the hybrid composite components.

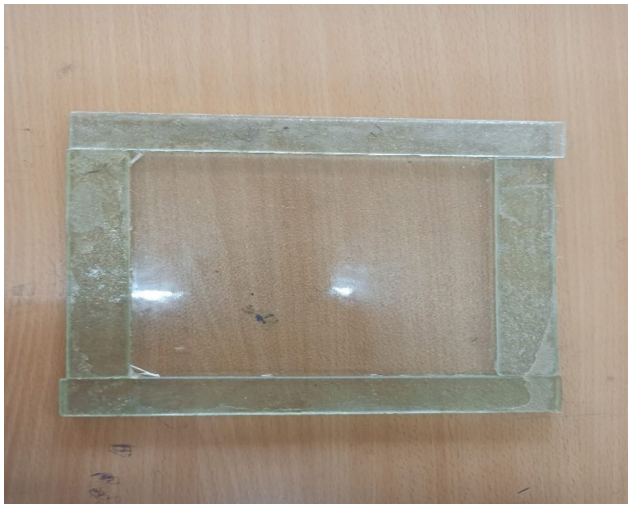


Figure 2: Glass mold.

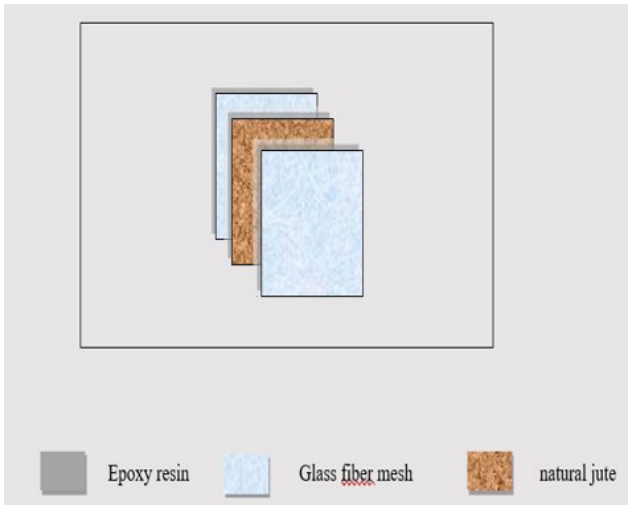


Figure 3: Layer-by-layer arrangements of fibers in the composite specimens.

Table 1: Glass fibre/nano clay powder reinforced hybrid polymer composite with other composites.

Samples	Composition (G + N + J)	Nano clay (N)	Glass fiber mesh (G)	Jute (J)
Sample 1	(10G + 0N + 10J)	0 g	10 g	10 g
Sample 2	(10G + 3N + 10J)	3 g	10 g	10 g
Sample 3	(10G + 6N + 10J)	6 g	10 g	10 g
Sample 4	(10G + 9N + 10J)	9 g	10 g	10 g

Experimental method

Tensile test

INSTRON3369 universal testing machine was used for the tests to determine the tensile properties. In compliance with ASTM D638 for the tensile test, a tensile test item with a flat form was created. The raw composite material samples were put to the test, and the average result was noted. Tensile tests are performed to assess an object's total strength. Tensile testing is done by placing the sample between two grips and pulling it slowly until it breaks.

Characteristics: The sample size was 150 mm long, 15 mm wide, and 3 mm thick, and the tensile properties were measured following ASTM: D638. The samples were tested on a universal testing machine at a crosshead speed of 10 mm/min.

Flexural test

On a universal testing machine of the INSTRON3369 type, flexural property tests were performed. The three-point

bend test was used to determine the flexural characteristics. Raw composite material samples were examined, and the average result was noted. Bending testing evaluates the overall strength of a given object by testing each sample of each composite material and recording the results. In a bend test, a load is applied by placing the specimen between two grips and pulling it slowly sideways until it breaks.

Characteristics: The flexural properties of a specimen having a length of 150 mm, a width of 12.7 mm, and a thickness of 3 mm were measured according to ASTM: D638. Samples were tested using a universal testing machine at 10 mm/min head speed. Bending testing of samples on universal testing machine is performed based on the standards of ASTM: D638 test.

Impact test

The purpose of the IZOD impact test is to evaluate a material's total impact strength. This high load test reveals the sample's energy absorption rate under load situations as well. Investigations were done into the material's actual impact resistance. The raw composite material samples were examined, and the average result was noted. The impact angle during the test is between 450 degrees. The specimen is held vertically during the Izod impact test, with a notch on the other side of the impact.

Characteristics: The sample length is 75 mm, width of 12.7 mm, and a thickness of 3 mm, which is used by IZOD.

Water absorption characteristics

Three different aquatic conditions were used to submerge the samples: water, distilled water, and NaCl + distilled water. The sample was taken out of the fluid, dried off to eliminate any moisture from the surface, weighed with an electronic balance, and its mass was tracked throughout the aging procedure [21]. The pre-absorption (two) and post absorption (wt) weights of each sample were used to compute the water content (M%) as follows:

$$\text{Water absorption test formula}, M\% = \left(M_i - \frac{M_o}{M_i} \right) \text{x } 100$$

Here, the water content is specified by M (%), the weight of the wet sample at specific time is M_i (g) and the initial weight of the sample is M_o (g).

Results and Discussion

This concerns the discussions and the outcomes of the tests carried out the sample tensile test, the bending test, and the impact test to identify it.

Tensile/stretch test

The universal testing machine is used to test a variety of composite sample pieces. This test is performed fibrous combinations of fiber's sample 1, sample 2, sample 3, and sample 4. Four types of test samples were considered: natural jute and fiber glass-reinforced epoxy composite with nano clay content varying from 3 g weights to 9 g. Tensile loads are applied to the above-prepared hybrid composites specimens, and their tensile properties, such as tensile stress and maximum elongation, are shown in figure 4 and figure 5. Figure 4 shows that increasing fiber content increases tensile stress in composites, with peak values at (10G + 9N + 10J). Similar observations were made by other researchers in the literature as well [22, 23]. Compared to samples without nanofiller, they possess low tensile strength, the clay content increases the tensile strength rapidly. Under wet and dry conditions, the tensile strength gradually increased as the proportion of nano clay increased. Compared with the wet condition, tensile strength in the dry state is high. Sample1 (10G + 0N + 10J) is weak compared to other samples as shown in table 2.

Figure 5 shows that the hybrid composite exhibited the low tensile modulus values of 42 MPa in (dry) and 31 MPa in (wet) conditions by sample 1 (10G + 0N + 10J). The hybrid composite sample 4 (10G + 9N + 10J) showed the best result with values of 79 MPa in (dry) and 65 MPa in (wet) conditions.

Flexural/bend test

Bending tests help determine the force required to bend a composite. A material's flexibility is measured by its flexur-

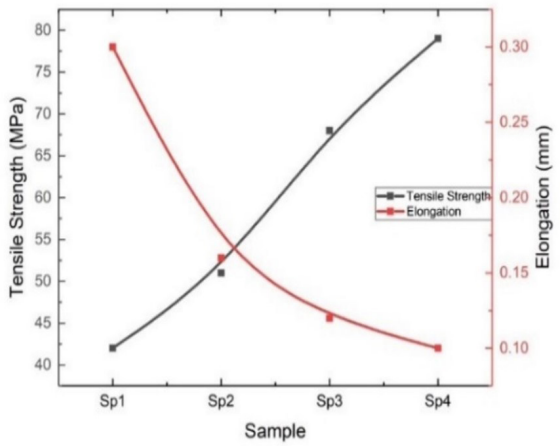


Figure 4: Tensile strength vs elongation.

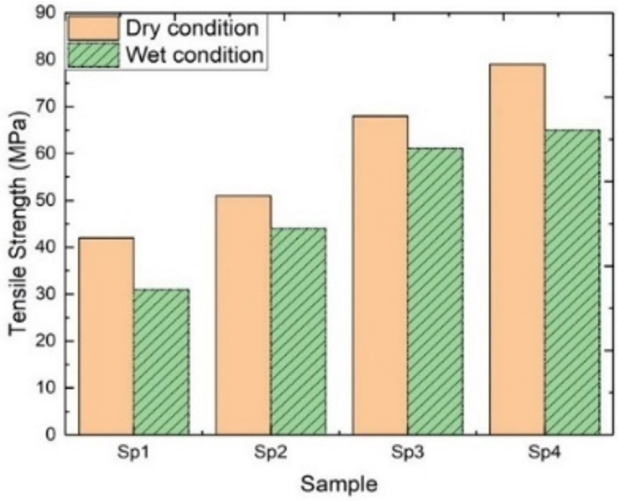


Figure 5: Tensile strength dry and wet conditions.

Table 2: Tensile test output results.

Samples	Dry condition	Wet condition
Sample 1	42	31
Sample 2	51	44
Sample 3	68	61
Sample 4	79	65

al modulus. Bend with permanent distortion. This test is run on four samples. Table 3 shows the bending characteristics (wt.%) of the sample corresponding to nano clay. Compared to sample 1 (10G + 0N + 10J) without nano clay and sample 4 (10G + 9N + 10J) with nano clay. Sample 1 has lower stress and intensity, and sample 4 is much higher. Bending strength increases the fiber content, reaching a maximum of 92.95 (N/mm^2). This indicates that increasing the nano clay content increased the bending strength of the sample. Similar observations were made by other researchers in the literature as well [22, 23]. Both in dry and wet conditions, the bending strength gradually increased as the nano clay ratio increased. Sample 1 is hydrophobic in nature with less amount of water compared with other samples.

Figure 6 shows that the hybrid composite exhibited the low flexural strength values of 55 MPa in (dry) and 48 MPa in (wet) conditions for sample 1 (10G + 0N + 10J). The hybrid composite sample 4 (10G + 9N + 10J) showed the best result with values of 112 MPa in (dry) and 106 MPa in (wet) conditions.

Impact test

Fiber reinforced hybrid composite specimens' impact strength was tested using the impact tester, and the findings are shown in table 4. It has been discovered that as the weight of the fiber and nano clay content increases, the impact strength of reinforced hybrid polymer composites also increases. When compared to the samples that include nano clay, sample 1 (10G + 0N + 10J) has a low quantity of impact strength. The impact strength gradually rose as the weight fraction (wt.%) of the nano clay filler grew from 0% to 9%. The impact strength

Table 3: Flexure test output results.

Samples	Dry condition	Wet condition
Sample 1	55	48
Sample 2	74	71
Sample 3	95	88
Sample 4	112	106

Table 4: Impact test output results.

Samples	Dry condition	Wet condition
Sample 1	125	112
Sample 2	144	121
Sample 3	156	126
Sample 4	172	132

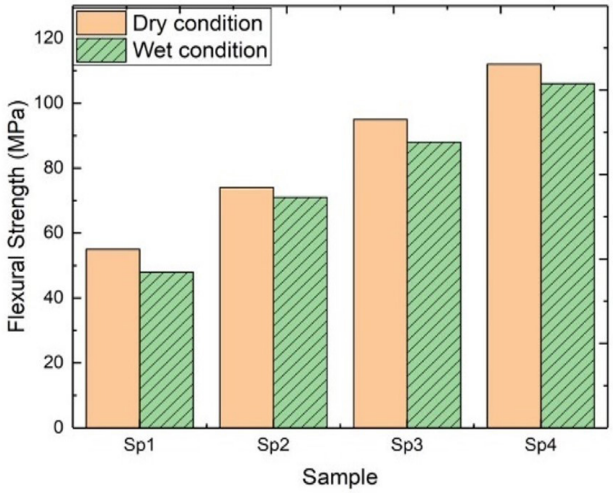


Figure 6: Flexural strength dry and wet conditions.

reached its maximum at 172 kJ/m^2 with the addition of 9% by weight of filler. Table 4 displays the impact strength output for both dry and wet circumstances. The strength of composites is improved with nano clay filler in both dry and wet environments. When compared with without filler its strength is quite low. Similar observations were made by other researchers in the literature as well [22, 23].

Figure 7 shows that the hybrid composite set out the low tensile modulus values of 125 MPa in (dry) and 112 MPa in (wet) conditions by sample 1 (10G + 0N + 10J). The hybrid composite sample 4 (10G + 9N + 10J) showed the best result with values of 172 MPa in (dry) and 132 MPa in (wet) conditions.

Water absorption

Samples were tested for the number of days to test the absorption content of composite samples with and without fillers under certain room temperatures. Later on, the next day sample is removed from the water. Then, wipe off the water with a dry cloth and tested the weight of samples on the weighing machine until reach accurate absorption.

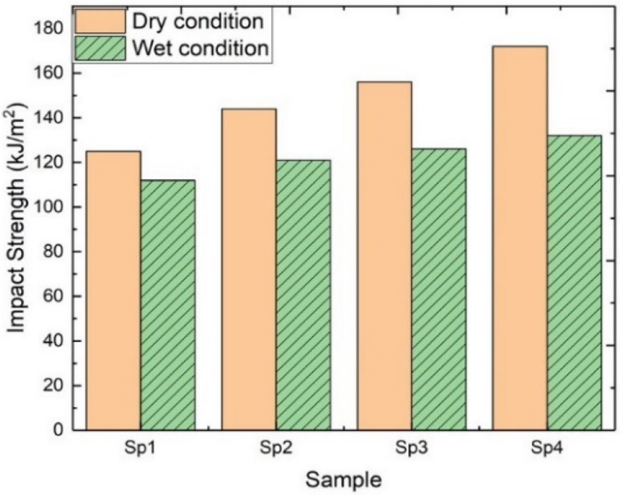


Figure 7: Impact strength dry and wet conditions.

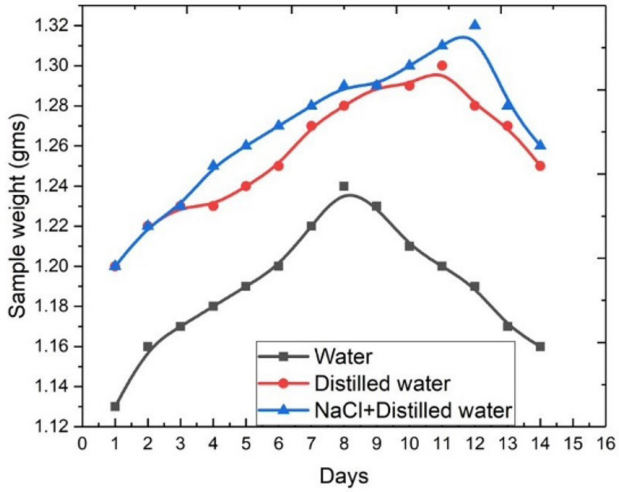


Figure 8: Absorption characteristics of sample 1.

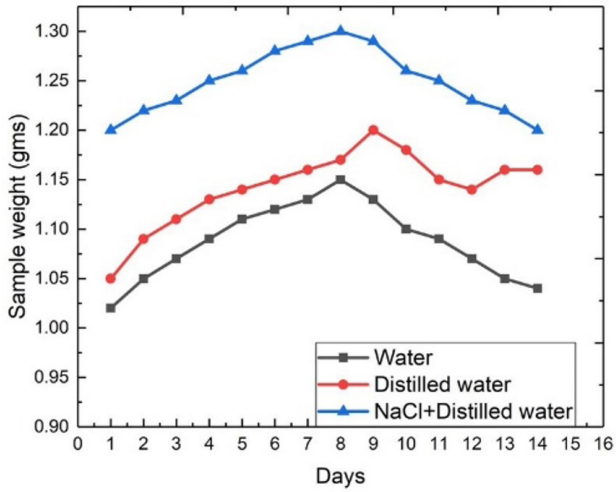


Figure 10: Absorption characteristics of sample 3.

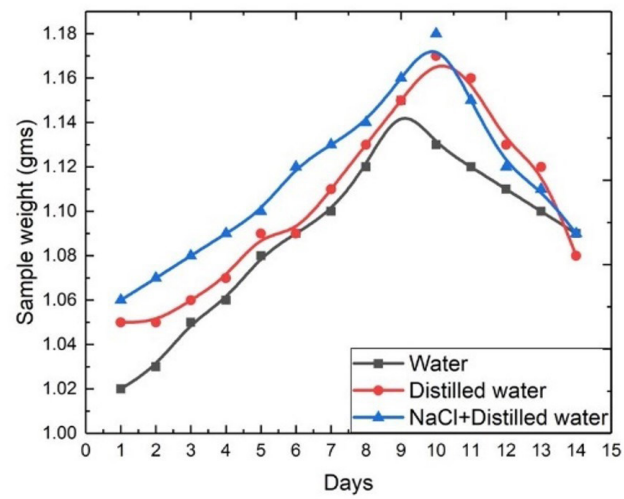


Figure 9: Absorption characteristics of sample 2.

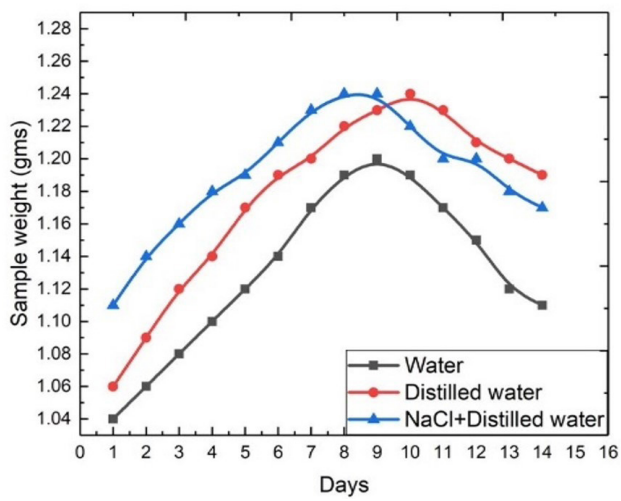


Figure 11: Absorption characteristics of sample 4.

Figure 8, figure 9, figure 10, and figure 11 shows absorption characteristics of composite samples for all the four samples. The graph shows that the samples absorbed the highest amount of (NaCl + distilled water) solution when compared with the other two samples (Water and distilled water). Water as solution absorption by samples was the least.

With nano clay filler of 3 g sample 2 (10G + 3N + 10J) absorbed a greater number of different solutions then followed by other two sample of 3 and 4 with 6 and 9 g of nano clay as fillers in each. Without nano clay filler in hybrid composite sample 1 (10G + 0N + 10J), it required less time for the absorption of various solutions.

There are three main processes that account for moisture absorption into nanocomposites, and they are as follows. Water diffusion into the tiny spaces across the polymer chains, permeability transport of water molecules into the imperfections there at interaction, and crack formation in the interface systems were all caused by insufficient moisture content and procreation at the fiber-polymer interface [24, 25]. Figure 8, figure 9, figure 10, and figure 11 display the hybrid polymeric sample's absorption at various circumstances and at various saturation times. Due to the cavities in the samples in figure 8, a small proportion of moisture absorption is seen for samples lacking nano clay. Due to the existence of a hydrophilic film in resin, sample 2 (3 g nano clay) exhibits the highest moisture content. The natural fiber that serves as a skin layer has hydrophilic hydroxyl groups, which accounts for the behavior of greater moisture absorption [26]. The increased water absorption may be caused by the substance's interface and internal micro-cracks, natural fiber expansion from wetness, and subsequent fiber matrix cracking from the extra cellular matrix of the wet and hot atmosphere.

Conclusions

In this study, experiments bring about the mechanical properties of the fibrous epoxy hybrid complex in various amounts of nano clay. Four different hybrid composites are prepared with and without nano clay powder added epoxy composite material using the hand lay-up process. Following conclusions were observed in the study:

- Maximum tensile strength, bending strength, and impact strength are found to be 79 MPa, 112 MPa, and 172 J/M,

respectively.

- The tensile test results were highest for sample 4 (10G + 9N + 10J) in both conditions (dry and wet), with the values of 79 MPa and 65 MPa. Then followed by sample 3 (10G + 6N + 10J) was 68 MPa (dry) and 61 MPa (wet).
- The flexural test results were highest for sample 4 (10G + 9N + 10J) in both conditions (dry and wet), with the values of 112 MPa and 106 MPa. Then followed by sample 3 (10G + 6N + 10J) was 95 MPa (dry) and 88 MPa (wet).
- The impact test results were highest for sample 4 (10G + 9N + 10J) in both conditions (dry and wet), with the values of 172 MPa and 132 MPa. Then followed by sample 3 (10G + 6N + 10J) was156 MPa (dry) and 126 MPa (wet).
- The mechanical properties and water absorption of composites with nano clay of 3 g, 6 g, and 9 g as the filler has high strengths in dry and wet conditions. Whereas without nano clay composite, since those composites acts as hydrophobic.
- Water absorption tested under various conditions, (NaCl + distilled water) absorbs more solution when compared with water and distilled water. The high amount of water absorption took by sample 2 (10G + 3N + 10J).
- From the results of the present work, the composites can be used for marine parts, automotive components, and aerospace components that mainly play an important role in tensile strength and humidity absorption.

Acknowledgements

None.

Conflict of Interest

None.

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