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Moisture Absorption Studies of COIR and Sisal Short Fiber Reinforced Polymer Composites

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Abstract: Easy availability of natural fibre, low cost and ease of manufacturing have urged the attention of researchers towards the possibility of reinforcement of natural fiber to improve their mechanical properties and study the extent to which they satisfy the required specifications of good reinforced polymer composite for industrial and structural applications. Polymer composites made of natural fiber is susceptible for moisture. Moisture absorption in such composites mainly because of hydrophilic nature of natural fibers. Water uptake of natural fiber reinforced composites has an effect on different. Lot of researchers prepared the natural fiber reinforced composites without conducting water absorption tests; hence it is the potential area to investigate the behavior of the composites with different moisture absorption. In this research the experimental sequence and the materials are used for the study of coir and Sisal short fiber reinforced epoxy matrix composites. The coir and Sisal short fibers are made into the short fibers with 10 mm x 10 mm x 5 mm size. The Epoxy Resin-LY556(Di glycidyl ether of bi phenol) and Hardner-HYD951 (Tetra mine), the water absorption behaviors are analyzed in the coir and Sisal short fibers reinforced epoxy composites. The water absorption behaviors of the epoxy composites reinforced with the coir and sisal short fibers with 25, 30 and 35wt% were analyzed at three different water environments, such as sea water, distilled water, and tap water for 12 days at room temperature. It was observed that the composites show the high level of the water absorption percentage at sea water immersion as compared to the other water environments. Due to the water absorption, the mechanical properties of macro particle/epoxy composites were decreased at all weight percentages.

Keywords: Natural fibre, Moisture absorption, Coir and sisal short fibre, Reinforced polymer composites, Water absorption behaviour Polymer matrix composite (Epoxy resin) using Coir and sisal short fibre and to study its moisture absorption behaviour

I. INTRODUCTION

Composite is a material comprising of at least two insoluble materials, which are joined to make a helpful designing material having a few properties not acquired by the constituents taken independently. The primary reason to fabricate composite materials is to get new material with expanded properties, principally from the mechanical perspective and low weight.

Natural fibre reinforced composites are quickly becoming the focus area of principal research as they are inexhaustible, modest, totally or somewhat recyclable, and biodegradable. Plants, for example, flax, cotton, hemp, jute, sisal, Roselle, Kenaf, Pineapple, Ramie, Bamboo, Banana, etc are increasingly more regularly applied as the support of composites. Their accessibility, sustainability, low thickness, and cost just as good mechanical properties make them an appealing environmental choice to glass, carbon and man-made filaments utilized for the preparation of composites.

Coconut coir and sisal fiber are common fiber material, biodegradable, ease and effectively accessible in nature. Having numerous application such as Car body, Door board, Name board, Window outline, Instrumental board, Automobile entryway, Ceiling boards and boards isolating the motor and traveler compartments, Mirror packaging, Paper weight, Projector spread, Helmet and rooftop.

Moisture absorption is one of the major drawbacks in fibre reinforced polymer composites. This restricts the successful application of natural fibres in composites which are not limited to non-structural and interior applications. It is mainly because of the hydrophilic nature of natural fibres. Natural fibres are made up of a large number of hydroxyl groups (–OH), but all the constituents don't contribute to the moisture absorption Fundamentally there are three kinds of analysis to obtain results related to the dynamics of moisture absorption in porous solids: analytical, numerical, and experimental. performing experiments of moisture absorption in the laboratory has the disadvantage since the results are dependent on the predefined operational conditions. The water absorption process is too slow, thus, the material takes a lot of time to reach the hygroscopic saturation condition.

Analytical methods are restricted to problems whose hypotheses are simplified and applied a simple geometry, which limits the use. Numerical methods are practically unrestricted, can be used in more complex problems, with boundary conditions defined in arbitrary geometries, and show faster and more economical results than other methods.

Theoretical studies of water absorption in polymeric composites reinforced with fibers using Langmuir model have been reported in the literature

In natural fiber reinforced polymer composites, water absorption by composites is influenced by several factors like fiber volume fraction, temperature, nature of fibre, water circulation difference within the composite, degree of crystallinity and cross linking, diffusivity. Diffusion is the major mechanism which drives the Moisture absorption into composite materials.

Diffusion is a process by which a substance is transported from high concentration to lower concentration because of random molecular motion. The diffusion of water molecules into the composite material, involves:

1) Movement of water molecules into the small or micro gaps between polymer chains,
2) Movement of water molecules by micro cracks in the matrix, occurs due to the swelling of fibers
3) Capillary transport of water molecules into gaps at the interface in between the fibers and the polymer, resulting in poor impregnation and wetting.

II. LITERATURE REVIEW

Peret et al. used finite element method in a one-dimensional approach to solve problems related to Fickian and non-Fickian water diffusion mechanics in carbon fibre and glass-reinforced polymer composites. The simulations were performed at a macroscopic level to record the heterogeneity of composite materials and study comparatively the Fick’s and Langmuir’s models. The authors concluded that there are significant discrepancies between the two models in moisture diffusion process in the transient state.

Melo et al. have reported important information about water absorption process in polymer composites. Emphasis was addressed to Langmuir–type model application in this process. In this work, the authors have cited analytical and numerical solutions of the Langmuir-type model, in one-dimensional (1D) approach, and applied the study for polymer composite reinforced with Caroá vegetable fibre.

Santos et al. studied, theoretically, the anomalous behaviour of transient and one-dimensional moisture absorption in polymer composite reinforced with vegetable fibres using the Langmuir model. In this research, the authors developed analytical and numerical solutions for the study, and they verified that water absorption is faster in the initial stages, tending to decrease for long periods until equilibrium. The predicted average moisture content data obtained from the numerical solution developed showed a good agreement with the experimental data reported in the literature

K Rana, et al. in their work demonstrated that the utilization of compatibilizer in jute filaments expands its mechanical properties. At 60% by weight of fibre stacking, the utilization of the compatibilizer improved the flexural quality as high as 100%, rigidity to 120%, and sway quality by 175%. The accompanying ends might be drawn from this paper

III. METHODOLOGY

The coir and Sisal short fibers are made into the short fibers with the length of 10 mm. The Epoxy Resin-LY556 (Di glycidyl ether of bi phenol) and Hardner-HYD951 (Tetra mine), the water absorption behaviors are analyzed in the coir and Sisal short fibers reinforced epoxy composites**.**

A. Materials

1) *Epoxy:* The epoxy used in this project is di glycidyl ether of biphenyl-A (LY 556) and the hardener used is triethylenetetramine (HY 951) as polymer grid in this examination. The properties of the selected epoxy pitch ($C_{18}H_{21}ClO_3$) used in this investigation are given in Table 1.

Properties of Epoxy resin	
Density (g/cm3) at 25 °C	1.15 – 1.20
Weight per epoxide (g)	188.68 g (LY556) & 187.57 g (Lapox L-12)
Viscosity at 25 °C (m Pas)	10000 – 12000
Molecular weight (g/mol)	320.8483

Table 1: The typical properties of the epoxy resin (C18H21ClO3)

Epoxy resin with hardener

2) *Coir and Sisal Fibre:* Coir and Sisal fibers are selected as reinforcements, which is extracted mechanically and they are cleaned manually and then they are chopped manually, 10 mm fiber lengths of fiber is obtained are used in this study. The typical properties of coir and sisal fibers are shown in table 2

Name of the Fibre	Density in (g/cm3)	%Elongation	Tensile strength in (MPa)	Elastic Modulus in (GPa)
Coir	1.2	30	593	4.0-6.0
Sisal	1.5	2.0-2.5	511-635	9.4-22

Table 2: The typical properties of coir and sisal fibers

Coir and sisal fibre

Sisal fibres drying in furnace

B. Preparation of Composites

ASTM standards selection for various tests: The ASTM standards are referred to arrive at the specific dimensions for test specimens and various procedures to adopt for the testing of the specimens. Preparation of mould to fabricate the composites: The specimen's preparation process being adopted is to create a laminate. A surface plate with smooth surface for laminates using wooden strips. On this surface, the laminate dimensions are marked on wooden strips glue tape is pasted on wooden strips to surface plate to form the boundary of the laminate.

For the fabrication of composites, Hand layup followed by compression moulding method is used with a size of 100 mm × 100 mm × 5 mm, prior to the process; a releasing agent is sprayed into the mould box to ensure the easy removal of the cured composites as shown in figure 4.3. hardener (HY 951) to Epoxy resin (LY 556) mixing ratio is 1:10 with after curing, the composites are taken away from the mould and cut into specimen size according to the ASTM. After removal of specimens from mould curing process has to be done. The fiber in the matrix phase may not be bonded hence, in order to improve properties, enhance more strength, good bonding between molecules. Pre-curing specimens is 24 hours. Post curing has to be done at muffle furnace from 80-120°C with an interval 1 hour each.

Figure 1: Fabrication of coir and sisal fibre reinforced composite

C. Testing of Specimen

The water absorption behavior of the two types composite specimens were studied in accordance with ASTM D 570-10 (2010). The two types of composites are coir and sisal short fiber reinforced epoxy matrix composites specimens are used for the test. The specimens are cut in to 10 mm x 10 mm x 5 mm size and dried at room temperature shown in figure 2 and initially weighted using digital weight balancing machine. In this study the specimens are immersed in the three types of water such as sea water, tap water, and distilled water. The coir short fiber reinforced epoxy composite specimens with 25, 30 and 35wt% are individually immersed in to three types of water. Similarly, the Sisal short fiber reinforced with epoxy composite specimens is tipped into the same three types of water for 24 hours. After that the specimens were taken out from the water by mechanical fork and the water particle was removed using tissue paper. Then each specimen is weighted in the electronic weighing machine. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted.

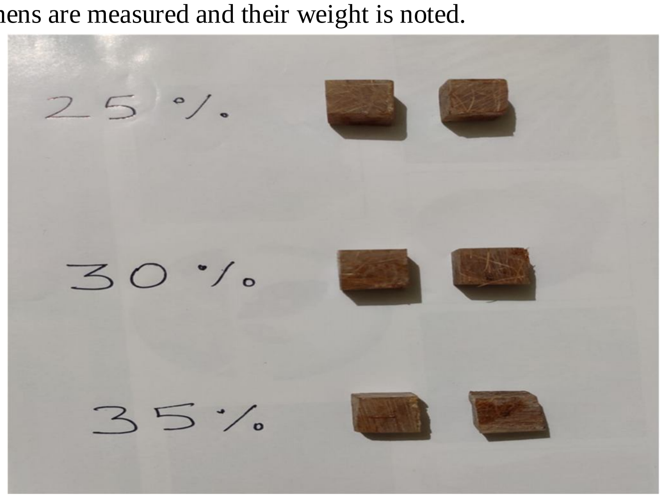

Figure 2: Specimens for water absorption test

The following formula is used to find out the water absorption of the specimens (Alamri & Low 2012):

$$M_t = \frac{W_t - W_o}{W_o} \times 100$$

Where,
Mt is the percentage of moisture content in the specimen
Wt is the weight of the specimen during the immersion time in terms of grams and
Wo is the weight of the specimen measured before the water absorption test is done in grams.
In this section, the details of materials and methodology used for preparation of epoxy composites reinforced with the coir and sisal short fibers were presented. The water absorption tests were conducted on two different epoxy composites at three types of water environments (sea water, tap water, and distilled water) as shown in figure 3.

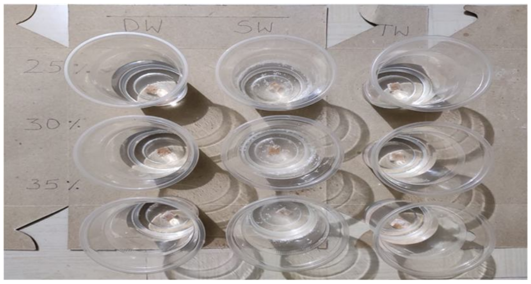

Figure 3: Composite specimens immersed in different water environment

IV. RESULTS AND DISCUSSION

Water absorption behavior of coir and sisal short fiber reinforced epoxy composites were studied at three types of water environments such as sea water, tap water, and distilled water

A. *Water Absorption Studies in Sea Water*

The water absorption of the prepared 25 % weight of coir and sisal short fiber reinforced epoxy composite samples were calculated and formulated in the figure 4.

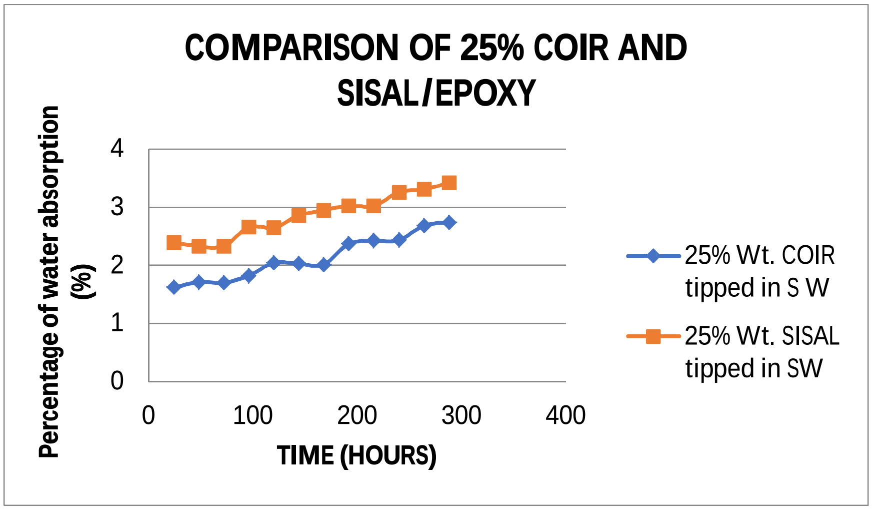

Figure 4: Comparison of 25 % Coir and Sisal Short Fiber

The Coir short fiber reinforced epoxy composite specimen with 25wt% composite, dry specimen weight was 0.5638 gm and the specimen immersed in the Sea water for 24 hours. Then the weight of the specimen is 0.5728 gm so, the weight percentage was increased to 1.618% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.74% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

This process is continued for 12 days and every 24 hours, the weight of the specimen is measured and percentage of water absorption for every 24 hours is shown in figure 4. Similarly, The Sisal short fiber reinforced epoxy composite specimen with 25wt% composite dry specimen weight was 0.6042 gm and the specimen immersed in the Sea water for 24 hours. Then the weight of the specimen is 0.6182gm so, the weight percentage was increased to 2.34% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.42% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

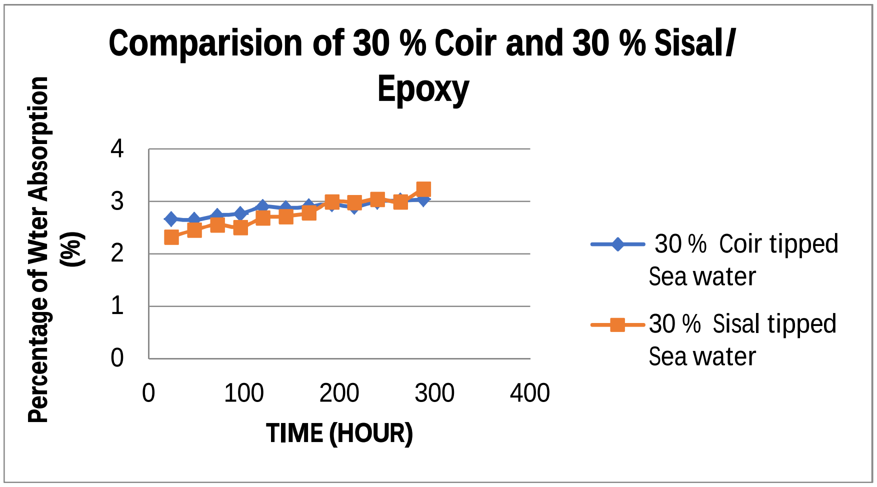

Figure 5: Comparison of 30 % Coir and Sisal Short Fiber

The Coir short fiber reinforced epoxy composite specimen with 30wt% composite dry specimen weight was 0.5996 gm and the specimen immersed in the Sea water for 24 hours. Then the weight of the specimen is 0.6156 gm so, the weight percentage was increased to 2.67% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.04% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 5. Similarly, The Sisal short fiber reinforced epoxy composite specimen with 30wt% composite dry specimen weight was 0.6190 gm and the specimen immersed in the Sea water for 24 hours. Then the weight of the specimen is 0.6334 gm so, the weight percentage was increased to 2.33% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.24% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

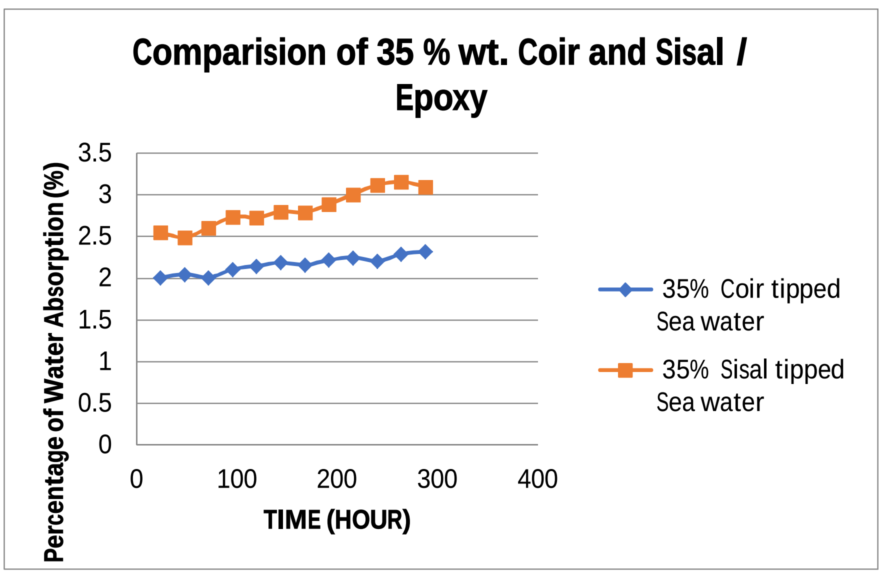

Figure 6: Comparison of 35 % Coir and Sisal Short Fiber

The Coir short fiber reinforced epoxy composite specimen with 35wt% composite dry specimen weight was 0.5592gm and the specimen immersed in the Sea water for 24 hours. Then the weight of the specimen is 0.5704 gm so, the weight percentage was increased to 2.01% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.32% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the higher concentration of natural fibers. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 6.

Similarly, The Sisal short fiber reinforced epoxy composite specimen with 35wt% composite dry specimen weight was 0.5814 gm and the specimen immersed in the Sea water for 24 hours. Then the weight of the specimen is 0.5962 gm so, the weight percentage was increased to 2.55% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.1% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the higher percentage of reinforcement.

B. Water Absorption Studies in Tap Water

The water absorption curves for 25 wt. percentages of coir and sisal short fiber reinforced epoxy composites are illustrated in figure 7.

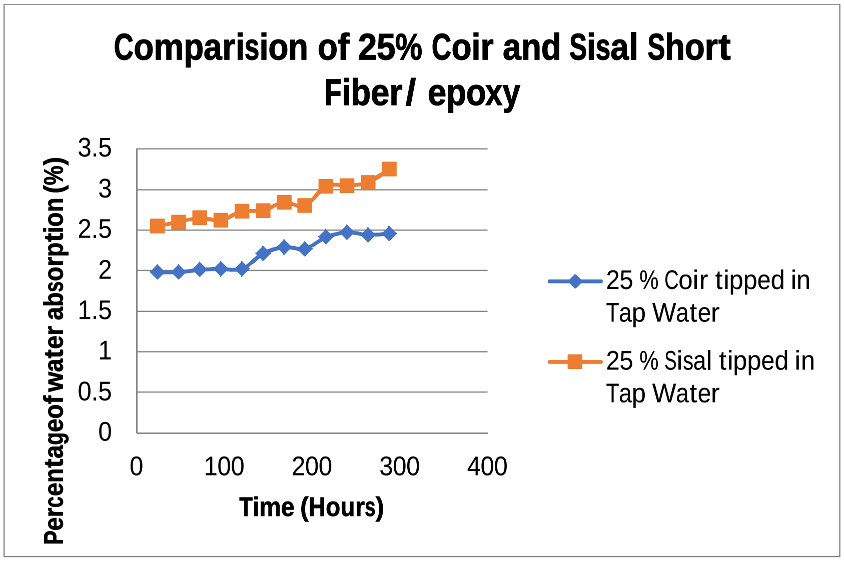

Figure 7: Comparison of 25% Coir and Sisal short fiber / Epoxy tipped in Tap Water

It can be seen from the figure 7 that the water absorption by the composites increases with immersion time The Coir short fiber reinforced epoxy composite specimen with 25wt% composite dry specimen weight was 0.6026 gm and the specimen immersed in the Tap water for 24 hours. Then the weight of the specimen is 0.6144 gm so, the weight percentage was increased to 1.982% higher than the initial weight of the specimen.

The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.458% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 7.

Similarly, The Sisal short fiber reinforced epoxy composite specimen with 25wt% composite dry specimen weight was 0.5884 gm and the specimen immersed in the Tap water for 24 hours. Then the weight of the specimen is 0.6034 gm so, the weight percentage was increased to 2.55% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.25% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

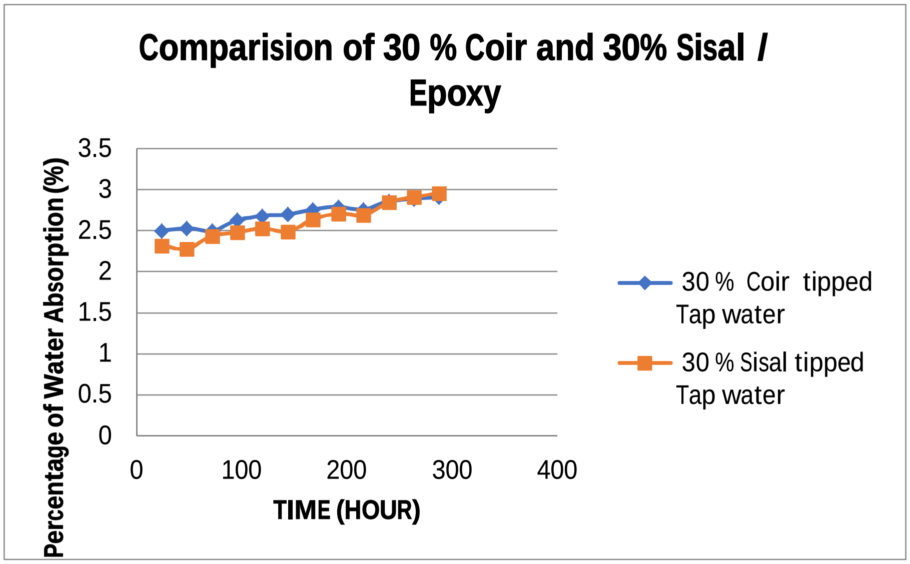

Figure 8: Comparison of 30% Coir and Sisal short fiber / Epoxy tipped in Tap Water

It can be seen from the figure 8 that the water absorption by the composites increases with immersion time The Coir short fiber reinforced epoxy composite specimen with 30wt% composite dry specimen weight was 0.6234gm and the specimen immersed in the Tap water for 24 hours. Then the weight of the specimen is 0.6388 gm so, the weight percentage was increased to 2.5% higher than the initial weight of the specimen.

The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.91% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 8.

Similarly, The Sisal short fiber reinforced epoxy composite specimen with 30wt% composite dry specimen weight was 0.5638 gm and the specimen immersed in the Tap water for 24 hours. Then the weight of the specimen is 0.5768 gm so, the weight percentage was increased to 2.32% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.96% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

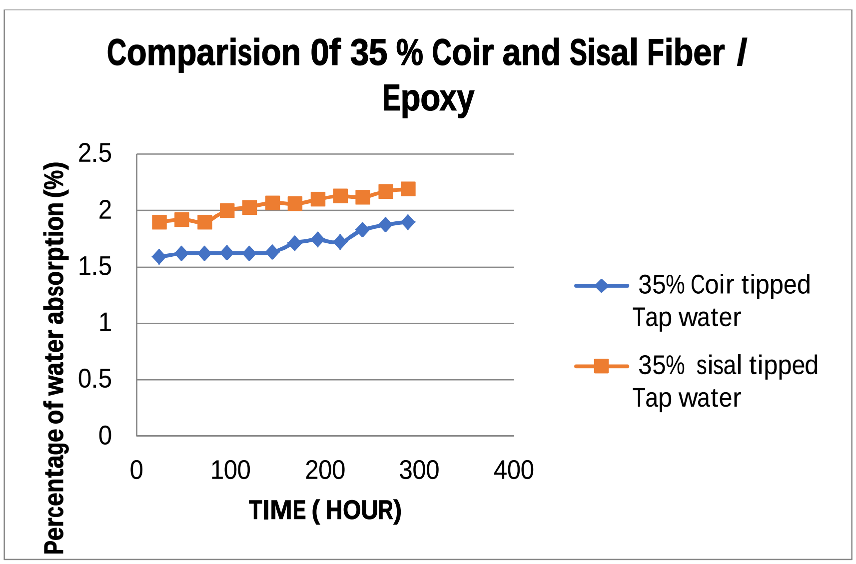

Figure 9: Comparison of 35% Coir and Sisal short fiber / Epoxy tipped in Tap Water

It can be seen from the figure 9 that the water absorption by the composites increases with immersion time The Coir short fiber reinforced epoxy composite specimen with 35wt% composite dry specimen weight was 0.6204gm and the specimen immersed in the Tap water for 24 hours. Then the weight of the specimen is 0.6302 gm so, the weight percentage was increased to 1.59% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 1.9% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 9.

Similarly, The Sisal short fiber reinforced epoxy composite specimen with 35wt% composite dry specimen weight was 0.5808 gm and the specimen immersed in the Tap water for 24 hours. Then the weight of the specimen is 0.5918 gm so, the weight percentage was increased to 1.9% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.19% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the higher percentage of reinforced natural fibers.

C. Water Absorption Studies in Distilled Water

Composite specimen was immersed in distilled water at room temperature for about 288 hours, weight measurements were taken for every interval of 24 hours. The weight gain curves as a function of time and percentage of water absorption are shown in figure 10.

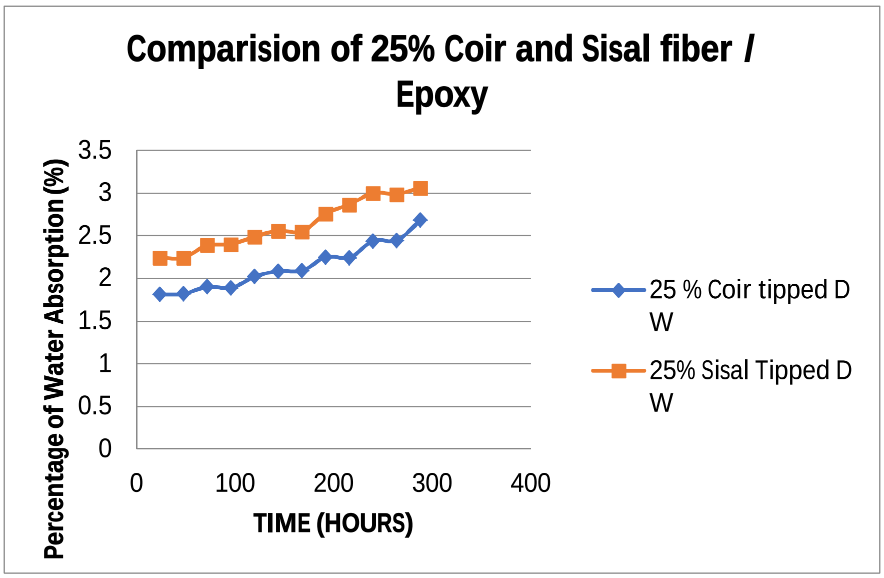

Figure 10: Comparison of 25% Coir and Sisal short fiber / Epoxy tipped in Distilled Water

It was absorbed from the figure 10 that, the water absorption by the composite increases with immersion time. The Coir short fiber reinforced epoxy composite specimen with 25wt% composite dry specimen weight was 0.5828gm and the specimen immersed in the distilled water for 24 hours. Then the weight of the specimen is 0.5932 gm so, the weight percentage was increased to 1.813% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.685% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 10.

Similarly, The Sisal short fiber reinforced epoxy composite specimen with 25wt% composite dry specimen weight was 0.6201gm and the specimen immersed in the distilled water for 24 hours. Then the weight of the specimen is 0.6344 gm so, the weight percentage was increased to 2.24% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.06% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

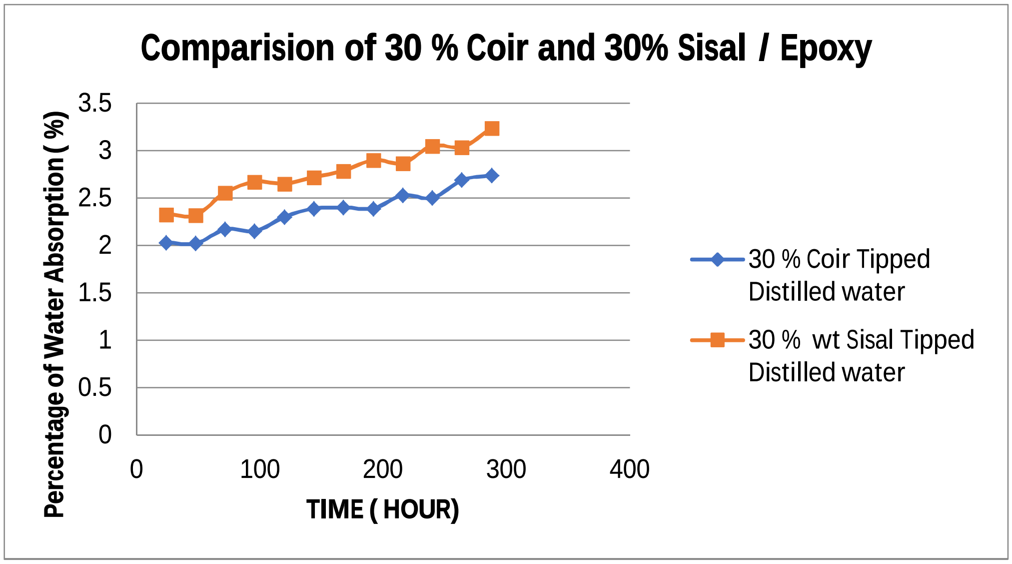

Figure 11: Comparison of 30% Coir and Sisal short fiber / Epoxy tipped in Distilled Water

It was absorbed from the figure 11 that, the water absorption by the composite increases with immersion time The Coir short fiber reinforced epoxy composite specimen with 30 wt% composite dry specimen weight was 0.6104 gm and the specimen immersed in the distilled water for 24 hours. Then the weight of the specimen is 0.6226 gm so, the weight percentage was increased to 2.03% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.74% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 11.

Similarly, The Sisal short fiber reinforced epoxy composite specimen with 30wt% composite dry specimen weight was 0.6316 gm and the specimen immersed in the distilled water for 24 hours. Then the weight of the specimen is 0.6462 gm so, the weight percentage was increased to 2.33% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.24% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion.

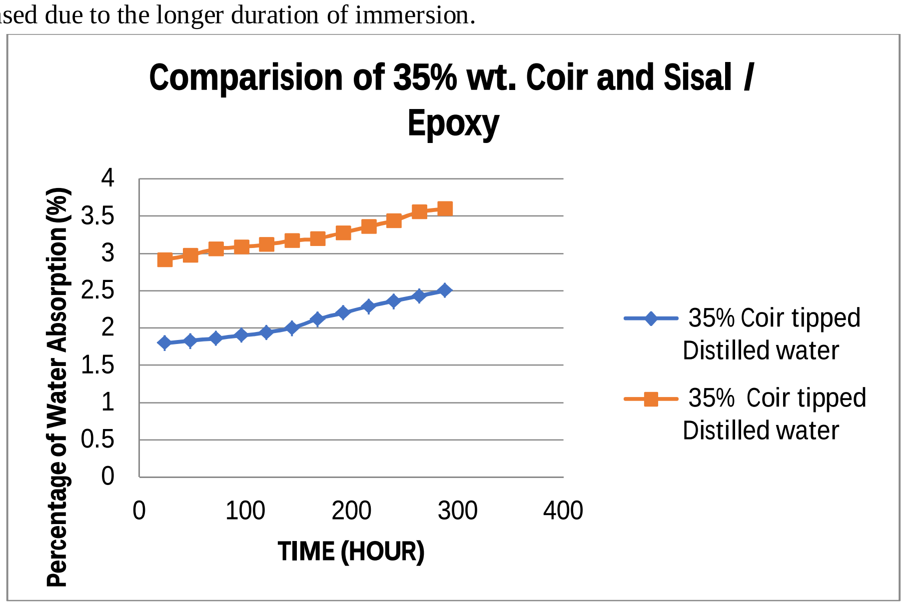

Figure 12: Comparison of 35% Coir and Sisal short fiber / Epoxy tipped in Distilled Water

It was absorbed from the figure 12 that, the water absorption by the composite increases with immersion time. The Coir short fiber reinforced epoxy composite specimen with 35wt% composite dry specimen weight was 0.5784 gm and the specimen immersed in the distilled water for 24 hours. Then the weight of the specimen is 0.5888 gm so, the weight percentage was increased to 1.8% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 2.5% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the longer duration of immersion. This process is continued for 12 days and every 24 hours the specimens are measured and their weight is noted and percentage of water absorption for every 24 hours is shown in figure 12.
Similarly, The Sisal short fiber reinforced epoxy composite specimen with 35wt% composite dry specimen weight was 0.6034 gm and the specimen immersed in the distilled water for 24 hours. Then the weight of the specimen is 0.6210 gm so, the weight percentage was increased to 2.92% higher than the initial weight of the specimen. The time of immersion is increased up to 288 hours and the weight percentage was increased to 3.6% compared to the initial weight of the specimen. It shows that the water absorption rate is increased due to the higher percentage of reinforced natural fibers.

V. CONCLUSION

In recent years, the plant based natural cellulose fiber-reinforced polymer composites have attracted the attention of many researchers and material engineers due to their advantages of specific properties over synthetic fibers. The proper selection of the materials and fabrication methods for the preparation of natural fiber polymer composites is necessary to achieve the application of composites. In the present work the coir and sisal short fibers as reinforcing agents to epoxy matrix composites are prepared by hand layup followed by compression molding technique. The water absorption characteristics of the coir and sisal fiber reinforced with epoxy composites are studied.

The following conclusion can be made

1) The short fiber reinforced epoxy composites are successfully fabricated by hand layup followed by compression molding method.
2) The water absorption behaviors of the composites were analyzed in Sea Water environment and it is observed that, the maximum percentage of water absorption is 3.04% for 30 % coir fiber reinforced composites and minimum 2.32 % absorption recorded for 35% coir fiber reinforcement.
3) In tap water environment maximum percentage of moisture absorption 2.91 % is found at 30% and least amount of absorption 1.9% is recorded at 35% coir reinforced composites respectively.
4) 2.5% of water uptake is recorded at 288 hours for 35% coir fiber reinforced composites and 2.74 % of water absorption found at 288 hours for30% coir fiber composites.
5) The highest of 3.42% and least of 3.1% of water absorption is found in 25% and 35% reinforcement of sisal fiber composites respectively at sea water environment.
6) 2.19% of least water absorption is found at 35% and maximum of 3.25% is found at 25% sisal fiber reinforced composites at tap water environment.
7) At distilled water environment, the highest moisture uptake is recorded at 35% sisal fiber is 3.6% and least is recorded at 25% sisal fiber reinforced composites is 3.06%.
8) The rate of water absorption is faster at initial days and decreases afterwards.

A. Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper

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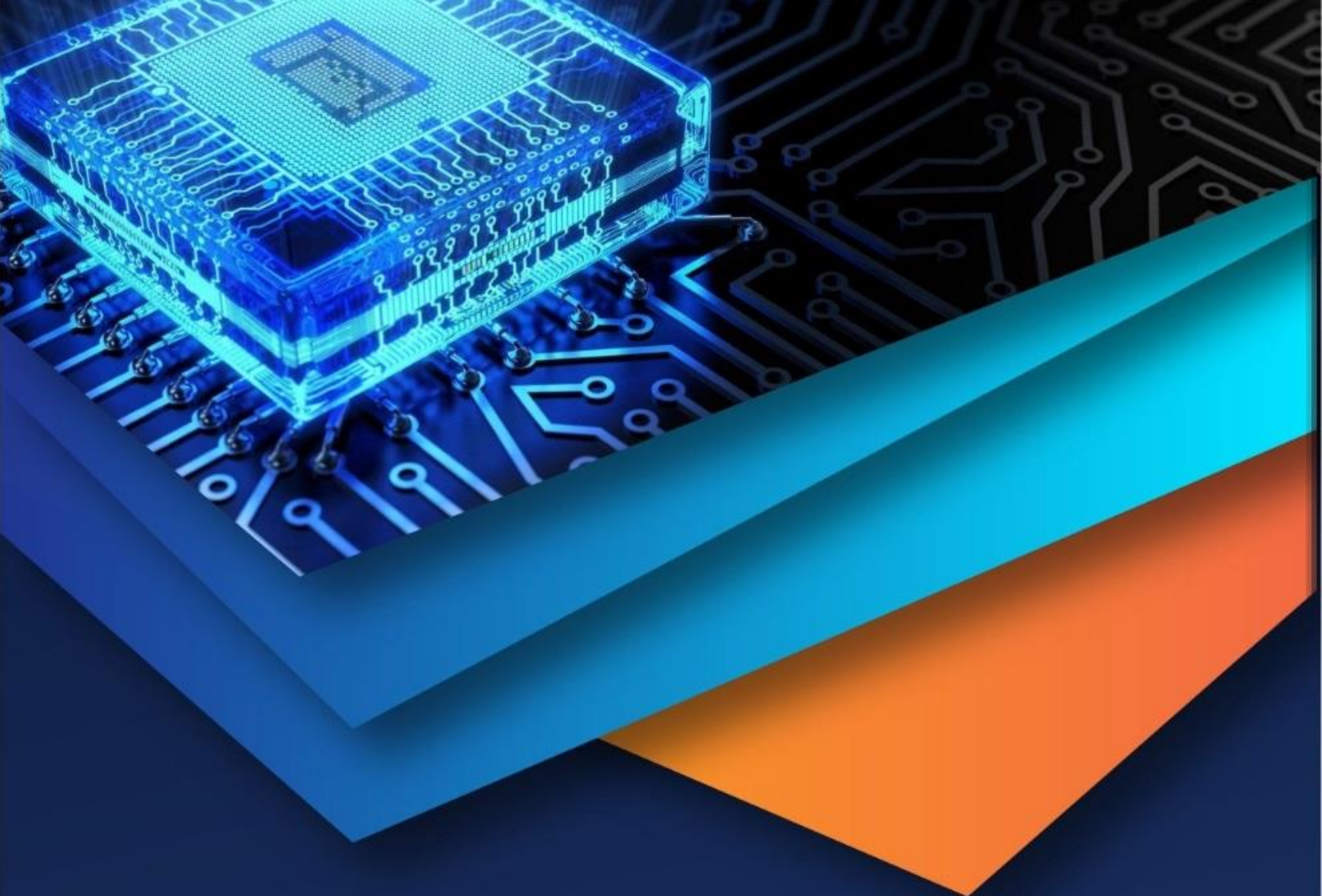

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