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Experimental investigation of Physical properties of Flax, Hemp, and Kenaf Epoxy reinforced composites

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Abstract:

The advantages of natural fibers over synthetic counterparts are mainly lightweight, less cost, biodegradable properties, and abundant availability. Recently the applications of fiber hybrid composites have increased consistently due to attractive Mechanical properties. Many state-of-the-art researchers have stipulated that natural fibers are also equivalent to synthetic fibers in many aspects including physical and Mechanical properties. The objective of the present endeavor is to investigate the water absorption, and moisture absorption along with the swelling index of natural fiber epoxy reinforced composites. Following ASTM standards, the specimens were prepared with a 20% volume fraction of the natural fiber utilizing the method of Hand layup technique. Immersing specimens in a bath having distilled water and saturated sodium chloride solution was done at room temperature for a specific time duration. Furthermore, swelling characteristics of the composite material samples were also found. It was evident that the water absorption percentage for Hemp reinforced composite is higher than those of the other two fiber composites, the variation was from 3.6 to 50.6. Moreover, Kenaf established a higher percent in moisture absorption and swelling index compared to the other two composites.

Keywords: *Flax, Hemp, Kenaf, Water absorption, Moisture absorption, swelling index*

1. Introduction:

It is worthwhile to note that natural fibers necessary for reinforcing composite materials have increased in the past decades [1]. The chief merits of the utilization of natural fibers in thermoplastics are low density, reduced cost; less consuming energy, biodegradable behaviors as well as easy availability of many varieties [2]. Subdivision of such fibers is seed hairs, bast-fibers, leaf fibers, and wood flour [3]. As per statistics, the production of bast fibers exceeds those of others. Moreover, the acceptance among researchers is relatively high [4, 5]. Furthermore, flax is very widely applied to belong to the bast family [6]. It is pertinent to record that the composition and micro composition of vegetable fibers allow moisture absorption resulting in weak bindings between the fiber and polymer structure. The chief advantages include the high hydrophilic nature of Flax fibers. However, the moisture-based variation is the main downside [7, 8]. Due to discrepancies in characteristics of hydrophilic plant fibers and hydrophobic thermoplastic/ thermo set matrices, special treatments are necessitated for augmenting the adhesion [6, 9, 10]. Susceptibility absorbing water-related to higher cellulose content restrains the use of natural fibers for reinforcing requirements. Due to water absorption and resultant swelling of fiber reducing Mechanical and dimension related properties because of cracks at fiber matrix spatial structure. According to [11-13], water absorption takes place through diffusion, capillary, and transport of water molecules. The main contribution to the absorption of moisture comes from hemicelluloses and amorphous cellulose because the open structure has groups of hydroxyl and acetyl [14]. The basic characteristics of plant fibers are impacted by the degree of polymerization; crystal structure; void structure and size; the specific interface, degree of crystalline, and fiber diameter [15]. The adhesion between matrix and fibers influences the ultimate mechanical properties of composites [16].

2. Materials and methods

Flax: Flax or linseed is a flowering plant belonging to the family Linum Usitatissimum. It is cultivated for food as well as fiber in various regions having temperate climates. It may be noted that the word flax also refers to the unspun fibers of the flax plant. The chief advantage of flax fibers is that they are twice or more strong in comparison with cotton. Moreover, these fibers are smooth and straight such that flax is used in special materials like linen.

Hemp: This is a class of cannabis Sativa used for industrial applications. By refining, it can be converted into commercial material such as paper, rope, textiles, clothing, biodegradable plastics, insulation, paint, biofuel, food, and feed for animals.

Kenaf: It is a plant in the family Malvaceae also called java jute or deccan hemp. This belongs to the genus of hibiscus and the scientific term is Hibiscus cannabis. It is pertinent kenaf is similar to jute and has very similar strength

Epoxy resin: This contributes to strength and durability as well as chemical resistance to the composites. High performance at elevated temperatures up to 121 degrees centigrade is ensured. Epoxies are available in various forms liquid, solid, or semi-solid forms. It may be noted that curing can be done by using amines or anhydrides.

Hardener: The hardener used with epoxy resin is Aradur HY 951. This is used for encapsulation or coating of various components. This has low viscosity and can be cured at room temperatures.

Flax fiber Hemp fiber Kenaf fiber

Fig 1: Photographs of the various natural fibers

2.1 Natural fiber reinforced composite preparation

The natural fibers treated with sodium hydroxide are commercially available in the form of mat, obtained from the Go Green products Pvt. Ltd, Chennai, India. The natural fiber composite specimens were prepared in a layer-by-layer fashion where the mixture of epoxy resin and Aradur HY 951 hardener is applied on top of each fiber layer to enhance the bonding. All the test specimens were prepared with a 20% volume fraction of the natural fiber using the hand lay-up method. The natural fiber reinforced composite test specimens were prepared with the required dimensions using the epoxy resin as a matrix material and the Aradur HY 951 hardener as a curing agent.

2.2 Water absorption, Moisture absorption, and thickness swelling tests of natural fiber composites.

2.2.1 Water Absorption Test

For the composite samples, absorption of water is determined by ASTM D570 standards. The behavior of the composite materials in a water environment is studied simultaneously. Square-shaped samples (3.1 cm x 3.1 cm) were taken from a sheet of composite. Three samples were kept in the oven at 100^0C. The samples were weighed and kept in a container of distilled water. For every 24 hours, the weights of samples are found for calculating the water absorption by the following formula

The percentage of water absorption is =

$$\frac{W2-W1}{W1} * 100$$

Where W_1 is the initial weight of the samples and W_2 is the measured weight of the samples seen after every 24 hours duration.

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2.2.2 Moisture Absorption Test:

Following ASTM D 570 standards, moisture absorption was assessed for the composite samples. This test is performed to calculate the amount of moisture absorbed and see the performance of the materials in humid environments. Three square-shaped samples (3.5 cm x 3.5 cm) were taken out from a sheet. The samples were put in an oven having 100^0C temperature for an hour followed by a measurement of weights. Then the samples were put into a container of a saturated solution of NaCl solution. It may be noted that the relative humidity of saturated NaCl is 74.87 ± 0.12 at room temperature (35°C). The moisture absorption percentage for every 24 hours is determined by the following formula.

The percentage of moisture absorption is =

$$\frac{M2-M1}{M1} * 100$$

Where M_1 is the initial weight of the samples and M_2 is the measured weight of the samples seen after every 24 hours duration.

2.2.3 Swelling Test:

ASTM D570 standards have been used to determine the swelling of composite in cold water to find the hydrophilic characteristic for the specimens of 3cm × 2.7cm size. The mean of three values found for variation in thickness indicated a percentage of the original mean thickness for the swelling value to be reported. For the thickness of swelling in water, the equation is

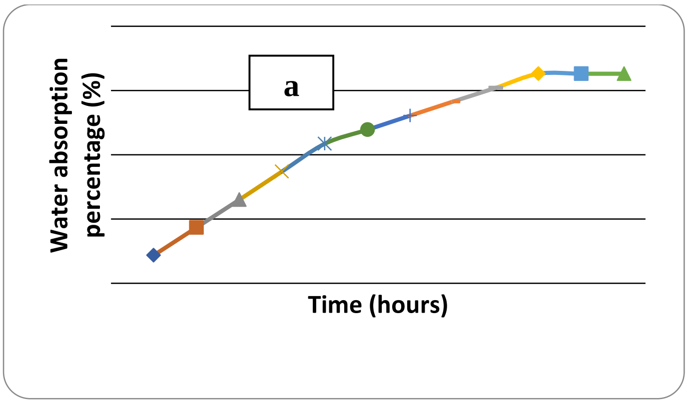
The percentage of swelling is =

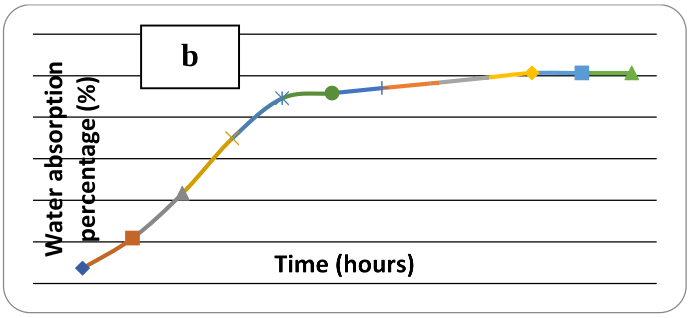
$$\frac{T2-T1}{T1} * 100$$

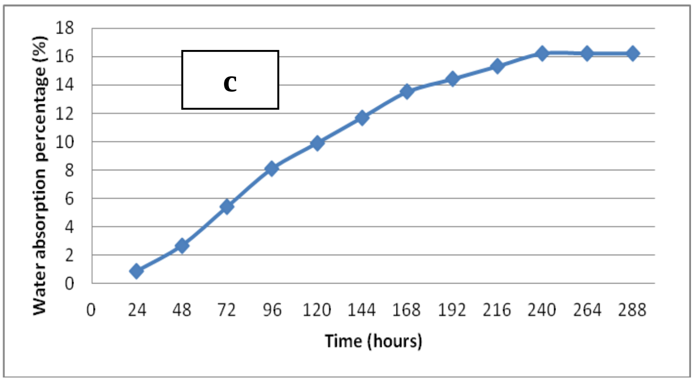
Where T_1 is the thickness in the beginning and T_2 is the thickness measured for every 24 hours duration.

3. Results and discussions:

Since Lignocelluloses fibres offer low resistance to moisture absorption, the natural fibre reinforced composites show undesirable characteristics regarding dimensional stability and mechanical properties in case exposure to moisture in the environment. It is imperative to study the behaviour of moisture absorption for natural fibre composites. Generally, water molecules percolate into the composites by (a) diffusion of moisture content within the micro-gaps between the polymer chains (b) capillary transport into the micro-gaps, and; (c) flaws in the interfaces between the fibres and the matrix. The interface between the fibre and the matrix and the fibre itself because of hydrogen bonding are the main areas of moisture absorption. The percentage of absorption of water in cases of Flax, Hemp, and Kenaf has been plotted against the time in hours as shown in Fig. 2. It may be noted that the percentage of water absorption, moisture absorption, and thickness swelling increases with time of immersion. Stability is reached after ten days. Further, in case of exposure to distilled water, the amount of water penetration increases linearly and reaches the state of saturation after ten days. From the experimental results on the percentage of water absorption, the lower and the higher percentage of water absorption for Hemp is highest among the other two were observed as 3.6145 and 50.6024.







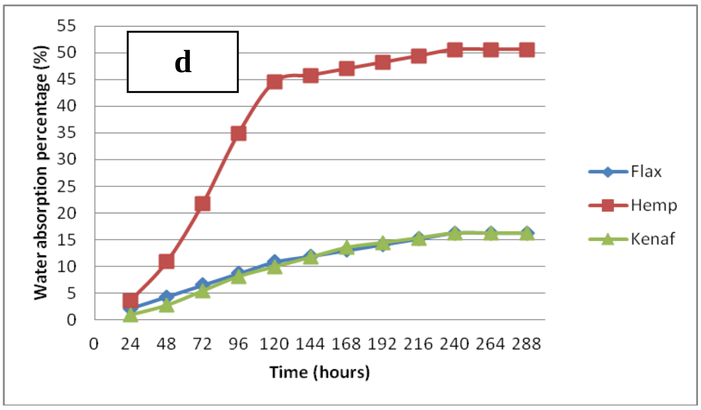


Figure 2. The percentage of water absorption (vs.) immersion time in hours graphs of (a) Flax (b) Hemp (c) Kenaf and (d) All three natural fibers

For all the composites exposed to a saturated solution of NaCl, the amount of moisture absorption increases linearly over time and reached a stable state after ten days of immersion. The percentage of moisture absorption for Flax, Hemp, and Kenaf was plotted against the time as shown in Fig. 3. From the moisture absorption results, it shows that the lower and the higher percentage of moisture absorption for Kenaf is highest among the other two were observed as 6.7961 and 35.9223.

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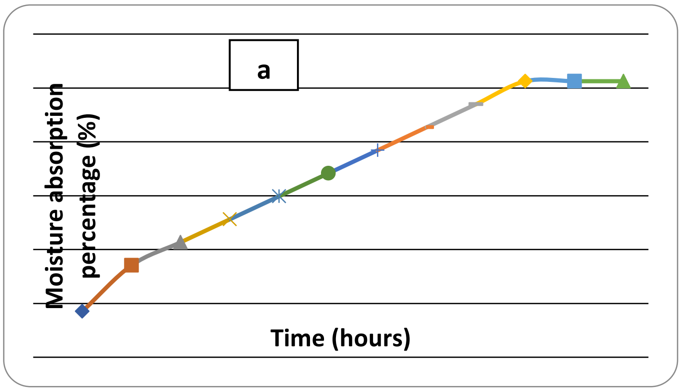
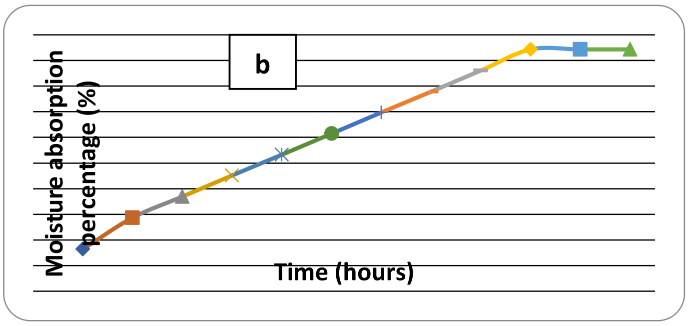
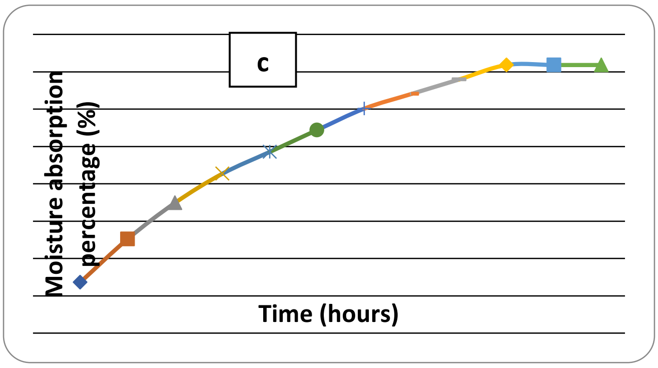






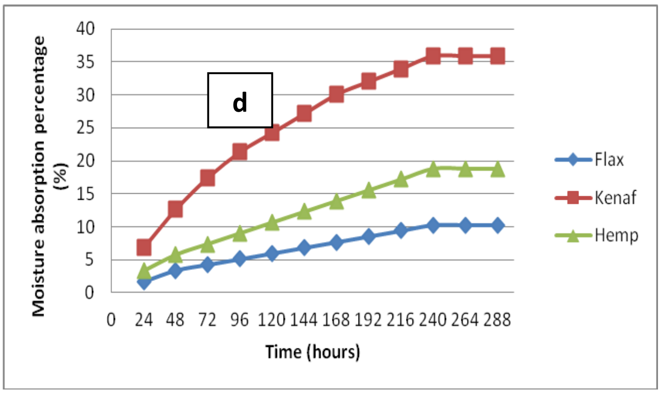
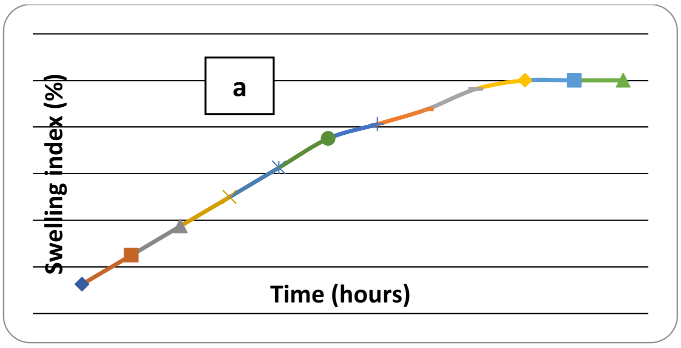
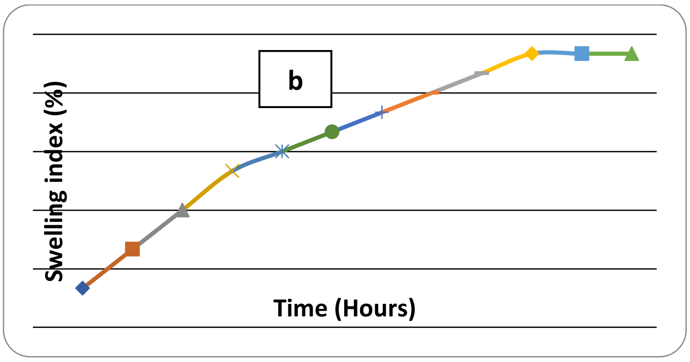
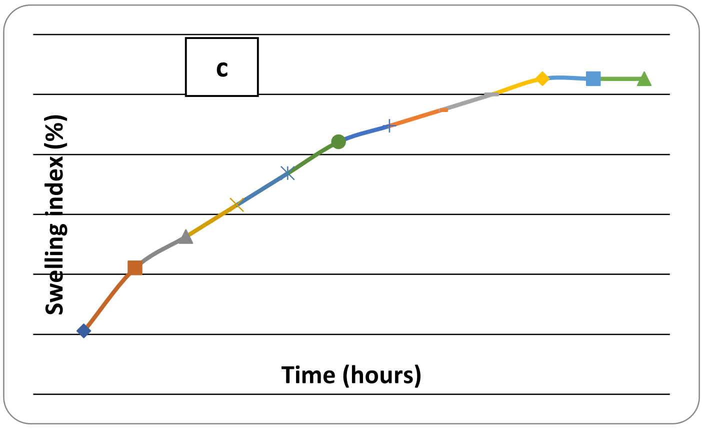


Figure 3. The percentage of moisture absorption (vs.) immersion time in hours graphs of (a) Flax (b) Hemp (c) Kenaf and (d) All three natural fibers

For all the composites exposed to cold water, the thickness swelling is increased linearly over time and reached a stable state after ten days of immersion. The percentage of thickness swelling for Flax, Hemp, and Kenaf was plotted against the time (hours) as shown in Fig. 4. From the thickness swelling results, it shows that the lower and the higher percentage of thickness swelling for Kenaf is highest among the other two were observed as 5.2632 and 26.3158.







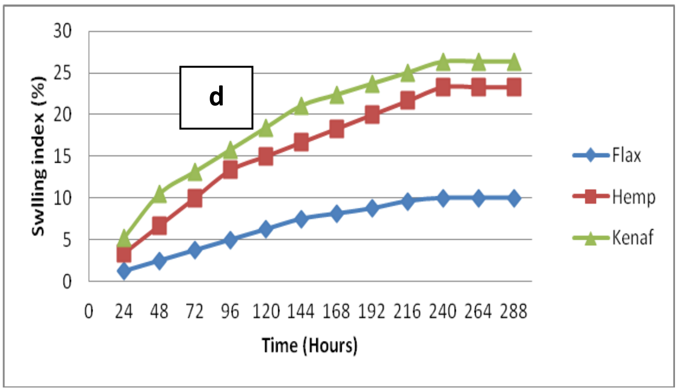


Figure 4. The thickness swelling percentage versus (vs.) immersion time curves of (a) Flax (b) Hemp (c) Kenaf and (d) All three natural fibers.

4.0 CONCLUSIONS

This paper presented the efforts made in the preparation and testing of natural fiber-reinforced composites. The percentage of water absorption, percentage of moisture absorption, and thickness swelling of Flax, Hemp, and Kenaf epoxy reinforced composites are assessed by conducting experimental tests. From the experimental results, it is observed that the percentage of water absorption is more for Hemp fiber compared with Flax and Kenaf. The percentage of moisture absorption and thickness swelling is more for Kenaf fibers compared with Flax and Hemp fibers. It shows that the percentage of water absorption increases with an increase in immersion time due to the high amount of cellulose content. The water penetrated the fibre affects the interfacial bonding which leads to poor strength for those composites.

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