Moisture absorption studies on Kenaf composites at various temperatures

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Abstract. In the world of manufacturing and production industries, composites are emerging to be the best of all the other available sources. Their lightweight, high strength, ease of manufacture and usage makes them superior to other materials. Nowadays, the applications of composites is almost everywhere. From household applications to automotive and aviation industries they are used. The composition of most composites mainly consist of glass, carbon fibers with epoxy resin, all these materials provide good mechanical properties to the composite but at the same time, they are very hard to dispose of as they are non-biodegradable. As these composites are not eco-friendly we can replace these synthetic fibers with natural fibers. Comparing different natural plant fibers, kenaf fibers show immense use in the automotive industry. Kenaf fibers are obtained from the plant kenaf (Hibiscus cannabinus) which is commonly called as Deccan hemp. In this paper, the kenaf fibers are studied for their flexural properties, moisture-absorbing capacity, and diffusion coefficient at different environmental and physical conditions. The weight of the fiber in the composite is varied for different percentages such as 10, 20, 30, 40 and 50. The experiments are conducted at two different temperature conditions, at 30 °C and 50 °C and the results are noted down separately. The flexural properties are tested under three conditions, at 30°C, 50°C and at the dry condition. Experimental results show that the flexural properties are optimum for 20% weight of fiber at the dry condition. The water-absorbing properties were found to be low for lower weight ratios at 30°C. The fiber exhibited good diffusion properties at 50°C for almost all weight ratio.

1. Introduction

The Over the span of 50 years, there is a developing eagerness in the utilization of plant fibers in the composite world. Plant fiber composites gives several points of interest in contrast with the synthetic fibers. The supremacy of these composites is that the tool wear is low, less density, low cost of fiber, easy accessibility, furthermore, eco-friendly nature. They possess splendid insulation of thermal and acoustic properties. The most well-known natural plant utilized in applications is bast fibers, for example, jute, hemp, fiac, sisal, and kenaf. The major reason for this increasing interest is that the plant fibers have a greater specific quality than that of glass fibers and the comparative specific modulus. Among them, the kenaf fiber is receiving more recognition among the production centers and experimenters to make use of it in various polymer composites. Kenaf fibers when reinforced with epoxy resin results in improved firmness for the composites.

A specialized report TR2101-ENV [1] concluded that the absorbing nature of kenaf core can be used for the oil spills cleaning. The examination demonstrated that the other common absorbent
materials have been beaten by the core of the fiber by a critical margin. Also ACI Committee 544 [2]

stated that the tensile characteristics of these plant fibers are practically identical to the other plant-based fibers, such as bamboo, flax, and jute, which have been used earlier in the yielding of natural fiber reinforced concrete. A researcher studied about the improvement of composites utilizing natural fibers and inferred that the geometric properties and firmness of plant-based fibers predominantly rely on the development condition, area of emergence and different attributes which impact the mechanical properties of these composites. The same researcher [3] assured that mechanical quality and thermal properties of kenaf composite are superior to other plant-based composites, therefore it is appropriate for high-performance cases. In an experiment, it is observed that kenaf can develop to an extent of around 350 cm to 450 cm in a time period of 5 months with a yearly yield of fiber, 5000 to 10000 kg of withered fiber per acre of land. Whereas the southern pine trees produce a yield of only one-fourth of kenaf [4]. Another discovery states that the CO₂ absorbed by the plant is nearly one and a half times of its weight. Of many plants studied by the researchers, kenaf exhibits the highest level of absorption [5]. Plant-based composites are hydrophilic in nature so they absorb moisture. The moisture enters composite material between polymer chains through the micro pores [6]. The height, fiber quality and fiber alignment of this fiber which influence intensive and extensive properties of fiber strengthened soy related organic composites [7]. It was discovered that kenaf composites can be used as an alternative for gasoline related composite materials in huge numbers of the industrial implementation and suggesting creative natural, farming, production and purchaser benefits detailing strategies [8-10]. The kenaf plant fiber is obtained from the shoot of plants variety Hibiscus, Malvaceae family and the Hibiscus Cannabinus species. It needs only a small amount of water to develop on the grounds that kenaf fiber has a life span of 5 to 6 months with a normal product of 1700 kilogram/hectare [11]. With the likelihood of growing the plant two times annually, kenaf has an incredible capacity to be utilized as a supplement derivation of fiber for medium-density fiber board and particle board production [12]. The tensile modulus of Kenaf fibers reduced drastically when immersed in seawater, acidic rainwater and distilled water [13]. The utilization of kenaf fibers for the advancement of eco-friendly, the mechanical-accommodating resources for the automotive, sports enterprises, food packaging and carpentry trade line is emerging fast [14]. Researchers state that the bast fibers of kenaf have good tensile and flexural properties that make them as a substitution to glass fibers, a reinforcing component in composites as they are obtained from various parts of that plant and is appropriate for different uses [15-17]. Kenaf fibers are broadly contemplated as appropriate organic assets and alternative for non-renewable energy sources and wood-pulps [18]. The mechanical properties of flax-kenaf mixed breed composites and inferred that hybrid composites have preferable properties over single fiber composites. The most fascinating part of natural fibers is their positive ecological effect [19-20]. Natural fibers are sustainable assets, eco-friendly and their generation needs only less effort [21]. A noteworthy downside of plant fibers in comparison to polymer fibers is their dissimilarity, assortment of measurements, and their mechanical properties [22]. In this manner, the significant assignment to be fathomed, so as to help the acknowledgment of plant fibers as a standard option in comparison to traditional fibers, is to grow elite natural fibers reinforced composites [23-24]. Natural fibers contain a lot of the OH⁻ group, this makes the fiber opposed and deliquescent. Plastics, in general, are water-hating in nature. When adding hydrophilic natural fibers to water-hating plastic it will bring about an end product with low tensile strength owing to the uneven scattering of fiber in the matrix and in the interphase [25]. This polar nature likewise brings about increased moisture absorption in natural fibers based composites, prompting fibers bulging and minute pores in the interphase of the fiber matrix. The water content, if not expelled from natural fibers before intensifying by withering, will bring about a permeable product. Increased moisture absorbing capacity could likewise result in low tensile and flexural strength and cause instability in the dimension [26-27]. About one-third of kenaf is bast fibers, which is appropriate for commercial products and about two of it is core [28]. A mono fiber of kenaf can have a tensile strength of 11900 MPa and tensile modulus of 60000 MPa [29]. The capability of kenaf as a reinforcing fibers in a polypropylene matrix and contrasted the mechanical properties and other ordinarily utilized composites [30].
The prime aim is to study the moisture-absorbing property and flexural properties of the kenaf fiber reinforced composite by varying the weight ratio of kenaf fiber in the composite at various temperatures.

2. Materials and methods

The materials used in the making of kenaf fiber composite are Kenaf fiber, epoxy resin (LY-556) and hardener (HY-556). The composite is made by using the hand layup method under room temperature. The hand layup method is an open molding method where fiber reinforcements are kept by human hand and then it is made wet using resin. This method is ideal for lower volumes as it exhibits low production volume per mold. First of all, the matrix is made by mixing epoxy resin with hardener in the ratio 10:1. The matrix is mixed well using a mechanical stirrer. Then the kenaf fiber with various weight percentages (10%, 20%, 30%, 40% and 50%) is added to the matrix and the composites are made. They are allowed to cure under room temperature. No heating process is carried out throughout the preparation of composites. The cured composite is then subjected to various methods of characterization. The characterization carried out for the kenaf fiber composite includes the following methods.

2.1. Moisture absorption

Moisture absorbing capacity of natural fiber reinforced composite is an important affair predominantly when it comes to outdoor applications. Moisture absorption depends on various factors such as the quantity of the fiber, fiber alignment, temperature, area of open surface, the porosity of fiber, vacant space and deliquescence of every single component [31-34]. Moisture absorbing capacity in kenaf fibers takes place mainly by two methods namely, through microspores and capillary action. Here the kenaf fiber reinforced composites were tested for moisture absorption under two conditions - by varying the weight percentage of kenaf fiber, by changing the temperature (30°C and 50°C). These tests were done over a period of immersion time. It is calculated from the following formula,

\[
\% \text{ absorption} = \frac{W_o - W}{W}
\]

Eqn. (1)

Where,

\(W_o\) is the weight after absorption,

\(W\) is the initial weight before absorption.

2.2. Flexural strength

Flexural strength is a material property characterized as the failure stress in bending of the structure. This is equivalent or slightly greater than the stress at failure during tension. Flexural strength of a construction and manufacturing materials is usually measured so as to understand the bending and load-carrying capacity of the material. As this Kenaf fiber reinforced composite is to be used for such purposes, flexural strength is measured for various weight percentages and at different temperatures. The flexural strength is determined using the following formula,

\[
\sigma = \frac{3FL}{2bd^2}
\]

Eqn. (2)

Where, \(F\) is the force applied, \(L\) is the length, \(b\) is the breadth and \(d\) is the depth of the composite material.
2.3. Flexural modulus

The flexural modulus is a property which is figured as the proportion of stress to strain during the flexural distortion. It is the propensity of bending resistance of a material. The value from the slope of a stress-strain curve of the testing of flexural gives the value of the flexural modulus. It is on a very basic level equivalent to the elastic modulus, which is actually the elasticity of the material. Specifically, in polymeric materials, these two properties generally have different values. Flexural modulus of kenaf fiber reinforced composite material is studied and measured under various weight percentage of kenaf fibers in the composite at two different temperatures.

2.4. Diffusion coefficient

The diffusion coefficient can be given as the volume of a substance that spreads out from one area to another and passes through every area of cross-section per unit of time at unit volume-concentration gradient. It is an unchanging physical factor which depends on the sub-atomic size and different properties of the diffusing substance just as on temperature and pressure. Diffusion coefficient of Kenaf fiber reinforced composite material is measured under various weight percentage of kenaf fibers in the composite at two different temperatures and is represented graphically.

3. Results and discussion

3.1. Moisture absorption at 30°C

![Figure 1](image)

**Figure 1.** Co-eff. of moisture absorption % of the composite for varied wt. over the time of immersion of the composite materials in water at 30°C.

3.2. Moisture absorption at 50°C

The block diagram of the experiment setup is shown in figure 1. It consists of a capacitive type moisture sensor, a Light Dependent Resistor (LDR), temperature and humidity sensor (DHT11), solenoid valve, relay to operate the solenoid valve, Arduino, ESP8266 Wifi module and mobile/laptop to monitor the values.
Figure 2. Co-eff. of moisture absorption % of the composites over the time of immersion for varied wt. % of the composite material in water at 50°C.

From the above graphs shown in figure 1 and figure 2, it is observed that the moisture absorption coefficient at the initial hours increased drastically and after that, it showed a gradual increase. But in the case of less weight percentage (10 wt. %), there is a gradual increase from the starting to the ending. And finally in the later hours when the fibers obtained saturation moisture absorption stopped. The moisture absorption is comparatively greater for composite with high weight percentage and decreases accordingly.

In the second case there is not much of a difference in concern to the weight of fiber in composite, the composites exhibited drastic increase for the first 75 hours (approx.) then the value maintained over the same value for the rest of the hours until saturation. Interestingly, it is detected that the kenaf fiber reinforced composites illustrates an alternate extent of assimilation for the above-stated conditions.

3.3. Flexural strength at various temperatures

From the graphs shown in the figure 3 and figure 4, it is noticed that three sets of graphs can be observed there the first set shows the value of flexural strength of fiber composite for various weight percentages at 30°C, second set at 50°C and the third at dry conditions. Clearly, the flexural strength is maximum at dry condition. Moreover, among various weight percentages 20% weight ratio seems optimum. Flexural modulus value at different temperature conditions namely 30°C, 50°C and at dry condition are observed for various weight percentages. Flexural modulus is found to be maximum at dry condition.

Figure 3. Differentiation of flexural strength of kenaf fiber reinforced composites of various wt. % A- at 30 °C, B- at 50 °C and C- at dry conditions.
3.4. Diffusion coefficient curve

From the figure 5, the diffusion coefficient is observed for composites with varying fiber weight percentages at two different temperatures 30°C and 50°C. At 30°C the diffusion coefficient stays almost the same for all weight percentages. And at 50°C it is minimum for 10% weight and a drastic increase is observed for 20% and after that a gradual increase is observed.

4. Conclusion

Researches on kenaf fiber reinforced composites are getting high scrutiny owing to its extremely good properties and environmental deliberations. As these plant fiber composite materials take an important position in automobile and construction industries, the study of their properties is necessary. This paper includes the experimental studies such as flexural strength and flexural modulus, moisture absorption property and diffusion coefficient of kenaf fiber reinforced composite materials. It is noticed that the moisture absorbing capacity of kenaf fiber reinforced composite is found to be different at different temperature conditions. Moreover, the moisture absorption increased drastically over the initial period of immersion, later it increased gradually and then attained a stable condition when it is saturated. While comparing the flexural strength and modulus at different conditions, the composite exhibited high results during dry conditions. The diffusion coefficient is also compared at two different temperatures and the diffusion coefficient curves are plotted.
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