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Influence of Fiber Length on Mechanical Properties of Kenaf fiber Epoxy Composites

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ABSTRACT: The present work describes the development of natural fiber based on composites consisting of kenaf fiber as reinforcement and epoxy as matrix material. The fibers are chemically treated in 5% NaOH solution at room temperature. Three different specimens were made by varying the length of the fiber 20, 30 and 40 mm at 10% wt. fiber loading using the hand lay-up method. The tensile strength, flexural strength and impact strength of the composite were investigated. Experimental results show that the tensile strength, flexural strength and impact strength had their maximum values at 30 mm fiber length composites.
KEY WORDS: Kenaf fiber, natural fiber, plant fiber, epoxy, fiber length, mechanical properties

I. INTRODUCTION

Now a days, using of natural fibers as reinforcement in the composite materials is getting more attention by researchers. Natural fibers possess some advantages like biodegradability, easy availability, easy collection, good thermal properties, high strength to weight ratio, light weight per unit volume, low cost, less health risk, non-abrasive to processing equipment, non-corrosive nature, non-irritation to the skin and renewability. In fact, certain drawbacks such as high level of moisture absorption, surface irregularity, insufficient adhesion between untreated fibers and the polymer matrix etc. To achieve a strong fiber-matrix interfacial adhesion there is an absolute need for the fibers to be treated either by using physical or chemical methods.

Fibers are classified as natural fiber and man-made (synthetic) fibers. Natural fibers can be basically divided into plant fibers (vegetable fibers), animal fibers, and mineral fibers. The plants fibers can be classified into bast or stem fibers (flax, hemp, isora, jute, kenaf, kudzu, madar, mesta, nettle, okra, ramie, rattan, roselle, urena and wisteria), seed fibers (cotton, kapok, loofah and milkweed), leaf fibers (abaca, agave, banana, cantala, caroa, curaua, date palm, fique, henequen, istle, piassava, pineapple, raphia and sisal), fruit fibers (coir, oil palm and tamarind), stalk fibers (barley, maize, oat, rice, rye and wheat), grass and reed fibers (bagasse, bamboo, canary, corn, esparto, rape and sabai) and wood (soft wood and hard wood). Chemical compositions such as cellulose, hemicellulose, lignin, pectin, wax, moisture and ash content vary with various natural fibers. Chemical composition of different natural fiber is shown in Table-1. Chemical composition is one of the important elements that influence the mechanical properties of a natural fiber.

Table-1: Chemical composition of different natural fibers

Fiber	Cellulose (wt%)	Hemicellulose (wt%)	Lignin (wt%)	Pectin (wt%)	Moisture content (wt%)	Wax (wt%)
Abaca	56-63	20-25	7-9	-	-	3
Alfa	45.4	38.5	14.9	-	-	2
Banana	63-64	10	5	-	10-12	-
Coir	32-43	0.15-0.25	40-45	3-4	8	-
Kenaf	45–57	21.5	8–13	0.6	6.2-12	0.8
Sisa	67	10–	8–	10	11	2

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l	–78	14.2	11			
Jute	61–71.5	13.6–20.4	12–13	0.2	12.6	0.5
Bamboo	26-43	30	1-31	-	9.16	-
Hemp	70.2–74.4	17.9–22.4	3.7–5.7	0.9	10	0.8
Ramie	68.6–76.2	13.1–16.7	0.6–0.7	1.9	8	0.3
Flax	71–78	18.6–20.6	2.2	2.3	3.9–10.5	1.7
Cotton	85-90	5.7	-	0-1	7.8-8.5	0.6
Henequen	60	28	8	-	-	0.5
Oil palm	65	10.12	17.5	-	-	4

Chemical treatment of the natural fibers can clean the fiber surface, chemically modify the surface, decrease the moisture absorption process, increase the surface roughness and improve the bonding between matrix and fiber. Natural fibers have also been treated with various chemicals such as acrylation, alkali, benzoylation, silane, peroxide, permanganate, stearic acid, isocyanate, triazine etc. It has been observed that some of these chemical treatments can significantly improve the mechanical properties of natural fibers by modifying their crystalline structure, as well as by removing weak components like hemicelluloses and lignin from the fiber structure. The alkali treatment also known as mercerization is one of the oldest and most used chemical treatments for natural fibers. This method consists of treating the fibers with sodium hydroxide (NaOH) in order to remove from the surface certain amounts of lignin and hemicellulose and completely remove pectin, wax, oils, and other organic compounds . After this removal, it is supposed to have more cellulose molecules exposed at the surface, the rich content of cellulose tends to improve the mechanical properties. A.Oushabi et al (2017) investigated the effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers. The fiber was treated with 0 wt%, 2 wt%, 5 wt% and 10 wt% NaOH solutions for 1 hour. They reported that 5 wt% NaOH treatment, waxes, oils and other impurities are removed completely without damaging the fiber surface. Wijianto et al (2019) reported that the banana fiber composite treated with 5% NaOH concentration has the highest tensile and flexural strength compare the other treated (0%, 10% and 15% NaOH solution) fiber composite. The alkali treatment process has some critical parameters like types of alkali used (NaOH, KOH & LiOH), concentration of the solution, treatment duration and temperature.

Two main kinds of polymers are thermosets and thermoplastics. Polymer-based thermoset composites constitute a very important class of thermosets, especially for structural applications in aeronautical, automotive, marine etc. Thermoset composite matrices include epoxies, polyesters, vinyl esters, bismaleimides, cyanateesters, polyimides and pheno lics. Epoxy resins are the polymer of choice in many applications because of their low shrinkage and low release of volatiles during curing, excellent mechanical and chemical properties, good corrosion resistance and good durability in hot and moist environments. Currently epoxies are the dominant resins used for low and moderate temperatures (up to 135 °C). Thermoset composites are manufactured using different kinds of reinforcements, particularly natural fibers. The long and short natural fibers are generally used depending on the properties required and the target application. Thermosetting polymer are found to be stronger when compared to thermoplastic to be used in higher service temperature. Thermoplastic polymer have tendency to melt at higher temperature and become hardened when cooled. Thermosetting plastics, however, harden permanently after being heated once. Polymer matrix is a kind of material that can hold and protect the reinforcement material from negative environmental effects while maintaining its position and orientation in the composite. The mechanical properties of natural fiber reinforced composite materials depend on many factors, such as percentage of fiber volume/loading, fiber length, shape, composition, orientation and distribution, as well as size. Mechanical properties of the matrix, manufacturing techniques and bonding between fibers and matrix also play an important role.

Applications of Natural Fiber Composites

The natural fiber composites are used in various applications such as

- Aircraft (e.g. pilot's cabin door, door shutters, flooring etc.),
- Automobiles (e.g. dash boards, door panels, head liners, seat backs, truck liners etc.),
- Marine field (e.g. boat hulls, fishing rods etc.)
- Sports (e.g. tennis rackets, snowboards, sports helmets etc.),
- Building and construction industry (e.g. walls, floor, ceiling, partition boards, roof tiles, window and door frames etc.),
- Packaging, storage devices (e.g. bio-gas container, post boxes etc.),
- Furniture (e.g. chair, table, shower, bath units etc.),
- Railway coaches,
- Military applications,
- Electronic devices,
- Toys,
- Consumer products etc.

II. MATERIALS AND METHODS

Matrix:

Epoxy is a thermosetting polymer that cures when mixed with a hardener. Epoxy resin of the grade LM-556 with a density of 1.1–1.5 g/cm^3 was used. The hardener used was HY-951. The matrix material was prepared with a mixture of epoxy and hardener HY-951 at a ratio of 10:1.

Alkali treatment of fiber

Alkali treatment or mercerization using NaOH is the most commonly used treatment of natural fibers to produce high-quality fibers. 5% NaOH solution was prepared using sodium hydroxide pellets and distilled water. The dry kenaf fiber was treated with 5% solution of NaOH for one hour to remove the hemi cellulose, pectin, lignin, etc. from the fiber. The fiber to solution weight ratio was maintained at 1 : 25. After 1 hour sisal fibers were washed with distilled water to remove the excess of NaOH sticking to the fibers. Treated sisal fibers were dried in sun light for one day. Then fibers were chopped to different fiber length (20mm, 30mm & 40mm).

Fabrication of Composites

Hand lay-up technique is the simplest method of composite processing. The processing steps are quite simple. The wood mould 300mm ×300mm ×4 mm was used for fabrication of composites. The mould was coated with a mould releasing agent for the easy removal of the sample from the mold after curing. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. The resin and hardener were taken in the ratio of 10: 1 parts by weight, respectively. Then, a pre-calculated amount of hardener was mixed with the epoxy resin and stirred for 5 minutes before pouring into the mold. Initial layer of the mould was filled with epoxy resin mixture and then kenaf fibers were randomly spread over the resin mixture and rolled with hand roller. Again, resin mixture is poured on the fibers and then pressed heavily for 5 hours before removal. Then, the top plastic sheet was removed from the mould and cured at ambient temperature for one day. After the curing process, test samples were cut according to the sizes of ASTM standards.

Mechanical Testing

The main objective is to determine three important mechanical properties of composite by conducting the following test. Mechanical testing was carried out at LMP R&D Laboratory, Near jeeva shed, Pallipalayam, Erode, Tamilnadu.

Tensile test

The testing sample specimen prepared according to ASTM standard D3039 (250mm x 25mm x 4mm) is using a hand cutter. Tensile tests were conducted using universal testing machine with across head speed of 5mm/min. Tests were carried out at room temperature and each test was performed until tensile failure occurred. Tensile test determines how strong a material is and how long it can be stretched.

Flexural test

The flexural specimens were prepared as per the ASTM D790 standards. The size of the samples testing is 127 mm × 13 mm × 4 mm. The 3-point flexural test is the most common flexural test and used in this experiment for checking the bending strength of the composite materials. The testing process involves placing the test specimen in the UTM and applying force to it until it fractures and breaks.

Impact test

The izod impact test unnotched specimens were prepared according to the ASTM D256 standard. The dimensions of the specimens as per this standard are 66mmx13mmx4mm. This test gives the maximum energy that a material can absorb when it is subjected to heavy impact load.

III. RESULTS AND DISCUSSION

Experimental results from the mechanical tests for different specimens with varying fiber length are presented in Table-2.

Table 2: Mechanical test results

S.No	Fiber length (mm)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J/m)
1	20	5.72	20.52	10
2	30	10.41	62.31	70
3	40	7.98	54.48	50

Tensile Strength

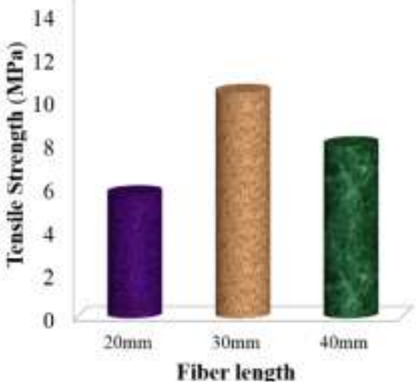

Figure-1: Tensile strength

The variation of fiber length on tensile strength of kenaf fiber epoxy composites is depicted in figure-1. It is clearly evident from figure that the tensile strength of kenaf fiber reinforced composites is increasing with increase of fiber length up to 30 mm. Further increase of fiber length has resulted in decreased tensile strength of the composite. Similar result was reported by C. Udayakiran et al (2007) on tensile properties of sun hemp, banana and sisal fiber reinforced polyester composites. The composites are prepared with random fiber orientations of different length (10, 20, 30, 40, 50, and 70 mm) and volume fractions (1-60%). He reported the tensile strength is increasing with the fiber length up to 30 mm. Further increase in fiber length has resulted in decrease of the tensile strength. In another research done by D. Ravindran et al (2010) the mechanical properties of randomly oriented short sansevieria cylindrical fibre/polyester composites. The raw sansevieria cylindrical fibre reinforced unsaturated polyester composites were prepared with fiber lengths of 10, 20, 30, 40 and 50 mm and fiber content of 10, 20, 30 40 and 50 wt%. The tensile strength increased with fibre length up to 30 mm and then decreased, indicating a critical fibre length of 30 mm for short SCFP composites. Similar types of results are published by Jyotishkumar Parameswaranpillai et al (2013), in their investigation on banana fiber reinforced phenol formaldehyde composites with different fiber lengths (10mm, 20mm,30mm and 40mm) and fiber loadings. Result showed that the tensile strength value increased up to 30mm fiber lengths and then decreased.

Flexural strength

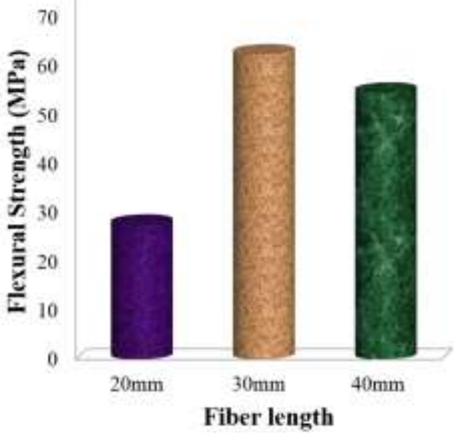

Figure-2: Flexural strength

Figure-2 shows the effect of fiber length on the flexural strength of composites. It is observed that the flexural strength increases with the increase in fiber length up to 30mm and further it decreases. The flexural strength of 30mm fiber length of kenaf fiber composites is increased by a factor of 3.03 compared with 20mm fiber length composite. This is similar to the findings of D. Ravindran et al (2010) investigated the Mechanical properties of randomly oriented short sansevieria cylindrical fibre polyester composites. The short sansevieria cylindrical fibre unsaturated polyester resin composites were prepared with different fiber length (10, 20, 30, 40 & 50mm). The flexural strength of short sansevieria cylindrical fibre composites is increasing with increase of fiber length up to 30mm. Moreover, N. Iqbal et al (2017) reinforced jute fiber in polystyrene resin to make composites and investigated. It was found that 30mm jute fiber reinforced polystyrene composite exhibited the highest flexural strength than 10mm and 20mm length of fiber composites. Jyotishkumar Parameswaranpillai et al (2013) have investigated on the influence of fiber content and length on mechanical properties of banana fiber reinforced phenol formaldehyde composite material. The length of fiber used were 10mm, 20mm, 30mm and 40mm using resin transfer molding and compression molding techniques. It was observed that the highest flexural strength found for composites reinforced with 30 mm fiber length.

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Impact strength

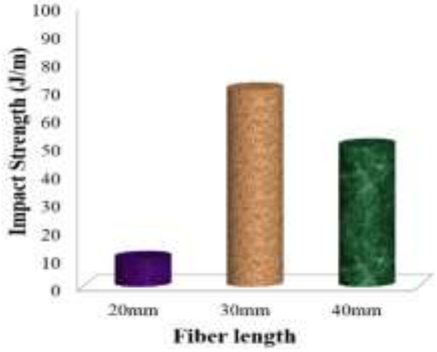

Figure-3: Impact strength

Figure-3 shows the effect of fiber length on the impact strength of composites. It is clearly evident from the figure-3 that the impact strength of kenaf fiber reinforced composite increases with an increase in the fiber length up to 30mm after which it is seen to decrease. Maximum impact strength of 70 J/m is obtained for 30 mm fiber length. Impact strength of 30 mm fiber length composites is increased by 7 times compared with 20 mm fiber length composites. D. Ravindran et al (2010) study the mechanical properties of randomly oriented short sansevieria cylindrical fibre polyester composites. Composites with different fibre length (10, 20, 30, 40& 50mm) and loading (10, 20, 30, 40 and 50wt%) were prepared and properties were evaluated. They reported that short SCFP composites the impact strength increased with fibre length up to 30 mm followed by a decrease. Similarly, Jyotishkumar Parameswaranpillai et al(2013) fabricated banana fiber reinforced composites by RTM and CM techniques. The influences of fiber length on banana fiber reinforced composites were determined. It was observed that the maximum impact strength found for composites reinforced with 30 mm fiber length. A. Karthikeyan et al (2012) investigated the effect of alkali (0%, 2%,4%, 6%, 8% & 10%NaOH solution) treatment and fiber length on impact behavior of coir fiber reinforced epoxy composites that were prepared with different fiber lengths of 10, 20, and 30mm. The impact strength is increasing from 10mm length of fibre up to 30mm for all the NaOH concentrations.

IV. CONCLUSIONS

This experimental examination of mechanical behaviour of kenaf fiber based epoxy composites indicates to the many conclusions:

- The fabrication of kenaf fiber based epoxy composites with different lengths of fiber is possible by hand lay-up process.
- From the current experiments results, it has been observed that fiber length has major effect on the mechanical properties of the composites like as tensile strength, flexural strength and impact strength.
- It has been observed that the highest value of tensile strength, flexural strength and impact strength found for composites reinforced with 30 mm fiber length.

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