

Evaluation of Flexural and Tensile Properties of Short Kenaf Fiber Reinforced Green Composites

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Abstract

The present work study flexural and tensile behavior of short Kenaf fiber reinforced composites. The fibers are chemically treated in 2% NaOH solution at room temperature. Short fibers of 4mm and 8 mm are used in the present work. The composite lamina is prepared by hand molding using isophthalic polyester resin. Flexural test and tension tests are carried out as per ASTM standards. The flexural strength and flexural modulus and tensile strength and tensile modulus of composite lamina are evaluated. The Effect of Fiber surface Treatment on flexural and tensile properties are observed. .

The Flexural Strength is increased by 13.8%, 12.8%, and 1.6% for Kenaf T-4 mm laminate, Kenaf T-8 mm laminate, Kenaf UT-4 mm laminate respectively when compared to resin lamina. . But it is observed that the Flexural Strength is decreased by 4.4% for Kenaf UT-8mm laminate when compared to resin lamina. Surface treatment of fiber had a significant effect on fiber/matrix adhesion due to this there is an increase in Flexural strength. The tensile strength is good for 8mm Treated lamina when compared to 4mm lamina.

Keywords: Natural fiber reinforced composites, Flexural strength & Tensile Strength.

1. Introduction

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the

other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness. The matrix also serves to protect the fibers from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc.

2. Plant Details

Kenaf Fig1 or its scientific name *Hibiscus cannabinus* L is a warm season annual fiber crop closely related to cotton and jute. Historically, kenaf has been used as a cordage crop to produce twine, rope and sackcloth. Nowadays, there are various new applications for kenaf including paper products, building materials, absorbents and animal feeds.

Kenaf has a single, straight and branchless stalk. Kenaf stalk is made up of an inner woody core and an outer fibrous bark surrounding the core. The fiber derived from the outer fibrous bark is also known as bast fiber. Kenaf bast fiber has superior flexural strength combined with its excellent tensile strength that makes it the material of choice for a wide range of extruded, molded and non-woven products. Kenaf fiber could be utilized as reinforcement material for polymeric composites as an alternative to glass fiber. While the whiter, inner fiber is called core and comprises 60% of the stalk's dry weight.

Retting is a process by which bundles of cells in the outer layers of stalk are separated from non-fibrous matter by removal of pectins and other gummy substances. The period of retting varies from 6 to 10 days depending upon the maturity of the crop at the time of harvesting, the temperature of water and the types of microorganisms

present. Retted bundles are removed and the bark is peeled off from the root upwards. The strips are gently beaten with a mallet or stick and rinsed in water to separate the fiber from adhering tissue. The clean fiber is washed and dried in the sun and made into bundles. The fiber strands are 2-3m long.



Fig. 1: Kenaf plant and extracted bast fibers.

3. Experimental

3.1 Fibers Resin and Laminas

The laminas are prepared by hand layup technique. The hand layup is the one of the Fabrication technique. First Wax polish is applied on the surfaces of the base plates and poly vinyl alcohol (PVA) is applied with a brush and allowed to dry for few minutes to form a thin layer. These two items will help in easy removal of the laminate from the base plates. PVA also provides a glossy finish to the surfaces of the laminate. The general purpose Unsaturated Isophthalic Polyester Resin is taken along with 2% each of catalyst-Methyl Ethyl Ketone Peroxide (MEKP) and accelerator- Cobalt Napthalate. The weight of the resin is 20 times the weight of the short fiber taken for the laminate. The catalyst initiates the polymerization process and the accelerator speeds up this process. Initially the catalyst is added and then the accelerator. The resin is mixed with the short fibers initially next catalyst is mixed and finally accelerator is added . The total composite is now evenly distributed in the mould by hand layup method. It is always preferable to add lesser quantity of accelerator than the specified amount to avoid solidification of the contents before they are poured and evenly layed up in the mould. Then the top base plate that was already applied with the wax and PVA is placed on the laid resin and a weight of about 1000 N is placed over for about 24 hours.

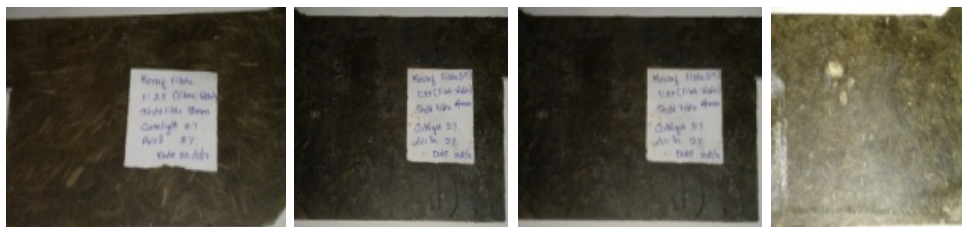


Fig. 2: Untreated & Treated 8mm and 4mm fiber laminates.

3.2 Flexural Testing

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Sometime it is referred as cross breaking strength where maximum stress developed when a bar-shaped test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar. There are two methods that cover the determination of flexural properties of material: three-point loading system and four point loading system. As described in ASTM D790, three-point loading system applied on a supported beam was utilized. Flexural test is important for designer as well as manufacturer in the form of a beam. If the service failure is significant in bending,



Fig. 3: 8mm & 4mm UT & T fiber specimens.

3.3 Tensile Testing

In a broad sense, tensile test is a measurement of the ability of a material to withstand forces that tend to pull it apart and to what extent the material stretches before breaking. The stiffness of a material which represented by tensile modulus can be determined from stress-strain diagram. Universal Testing Machine (Zwick / Roell Z010 10KN) was used at cross-head speed of 3mm/min. Fig.4 shows the Universal Testing Machine (Zwick / Roell Z010). The specimens were positioned vertically in the grips of the testing machine. The grips were then tightened evenly and firmly to prevent any slippage with gauge length kept at 50mm. The precise five tested result were chosen for each fiber loading of kenaf *fiber* in general purpose Unsaturated Isophthalic Polyester Resin matrix.



Fig. 4: Universal Testing Machine & Grips of the testing machine (Zwick / Zwick / Roell Z010)

As the tensile test starts, the specimen elongates; the resistance of the specimen increases and is detected by a load cell. This load value (F) is recorded until a rupture of the specimen occurred. Instrument software provided along with the equipment is recorded the load value (F). Figures 5.5 Shows the specimens after testing.

$$\text{Tensile Strength} = \frac{\text{Force (Load)}}{\text{Cross section area}}$$

Specimens for the Tensile Test are cut on a jig saw machine as per ASTM standards. The dimensional details of each type of specimen are presented in respective diagrams. Specimens are cut from laminas on a jig saw machine as per ASTM D 638 Standards. The standard Type IV dumbbell shaped specimens are used in the testing. The dimensions of the tensile test specimen are shown in the Fig.5 and the actual specimens are shown in fig 6.

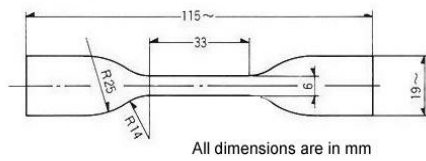


Fig. 5: ASTM D638 Type IV Tensile Test Specimen Details.



Fig. 6: Tensile Test Specimens.

4. Results and Discussion

4.1 Flexural Stress vs Deflection Graph To Determine Flexural Modulus

Graph showing Flexural Stress vs Deflection for different laminates

- Series 1- 4mm kenaf T-Laminate.
- Series 2- 8mm kenaf T-Laminate.
- Series 3- 4mm kenaf UT-Laminate.
- Series 4- 8mm kenaf UT-Laminate

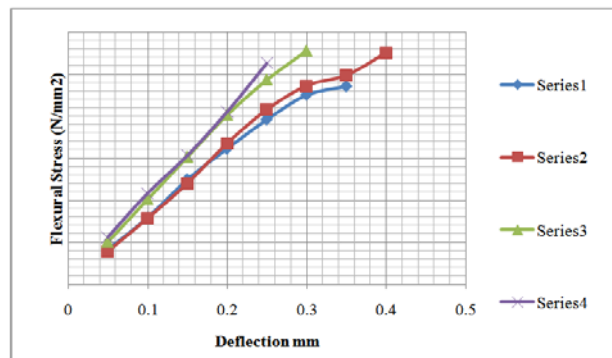
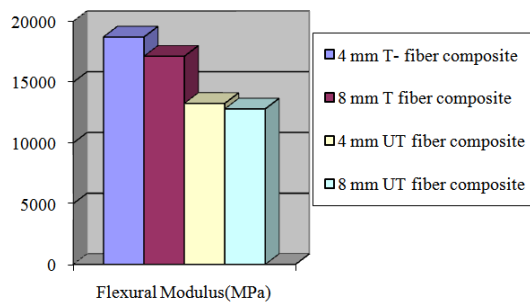
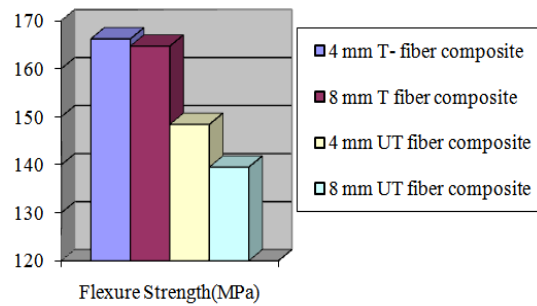


Fig. 7: Flexural Stress VS Deflection.

Results of flexural behavior for different composites are given in Table 1. The Flexural Strength for different laminas shown in Fig.9. The flexure strength of the 8 mm UnTreated fiber composite is 139.5 MPa. The composite with treated 4mm fibers has shown highest flexural strength of 166.2MPa. This shows, in case of treated fiber composite the flexure strength increased by 19.13% times.

Table 1: Flexural strength, Flexural Modulus for different composites.

Type of Composite	Flexure Strength(MPa)	Flexural Modulus(MPa)
4 mm T- fiber composite	166.2	18720
8 mm T fiber composite	164.7	17136
4 mm UT fiber composite	148.4	13256
8 mm UT fiber composite	139.5	12800

**Fig. 8:** Flexural Modulus (MPa) for different laminates.**Fig. 9:** Flexure Strength (MPa) for different laminates.

The Flexural Modulus for Different laminas shown in Fig.8. The 4 mm Treated fiber composite highest flexure modulus of 18720MPa; it is an increase of 9.1% to that of 8mm Treated fiber composite, and 70% to that of 4 mm UnTreated fiber composite. In case of treated lamina, increased adhesion between fiber and resin increased the flexure modulus.

4.2 Tensile Testing

The Results of tensile properties for different types of composites are shown in Table 2

Table 2: Tensile properties of different types of *kenaf* fiber composites.

Composite I.	II. Density of Lamina (g/cm ³)	III. UTS (MPa)	IV. Specific tensile strength (MPa/g/cm ³)	V. Tensile Modulus (MPa)	VI. Specific Tensile Modulus (MPa/g/cm ³)	VII. % of Elongation VIII.
IX. 4 mm UT	X. 0.934	XI. 18.28	XII. 19.57	III. 1037.03	IV. 1110.310	XV. 2.86
VI. 4 mm T	VII. 0.991	VIII. 19.12	XIX. 19.29	IX. 3685.13	XI. 3718.59	XII. 0.518
XIII. 8 mm UT	XIV. 1.120	XV. 34.13	XXVI. 30.47	VII. 1308.3	VIII. 1168.125	XXIX. 2.6
IX. 8 mm T	XXI. 1.213	XXII. 38.18	XXIII. 31.475	XIV. 1475.06	XV. 1216.042	XXVI. 2.6
XVII. Resin	XVIII. 1.265	XIX. 38.472	XL. 30.41	XLI. 398.8	LII. 315.256	LIII. 4.746

The Ultimate Tensile Strength for different composites are shown in Fig.10. The ultimate tensile strength for 4 mm treated laminas is 19.12 Mpa. For 4mm untreated lamina is 18.28 Mpa. The ultimate tensile strength for 8 mm treated laminas is 38.18 Mpa. For 8 mm untreated lamina is 34.13 Mpa. For 4 mm Treated kenaf composite lamina exhibited 4.595% higher ultimate tensile strength than untreated lamina. For 8 mm Treated kenaf composite lamina exhibited 11.87% higher ultimate tensile strength than untreated lamina.

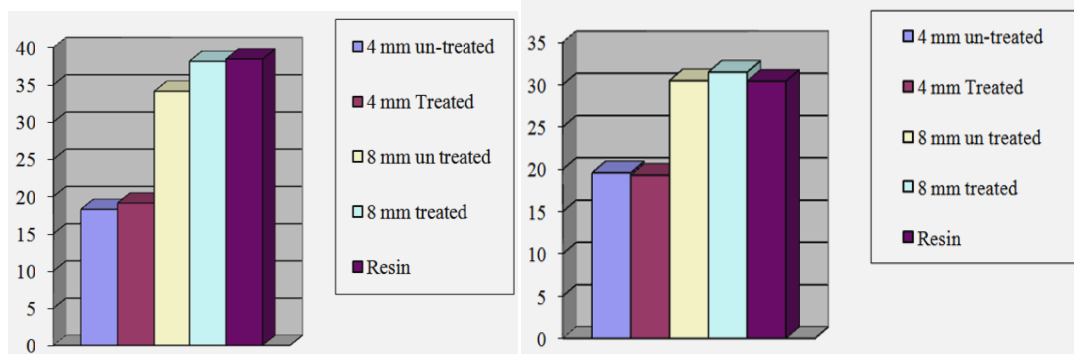


Fig. 10: Ultimate Tensile Strength. **Fig. 11:** Specific Tensile Strength.

The values of specific Ultimate Tensile Strength for different composites are shown in Fig.11. The specific ultimate tensile strength for 4 mm treated laminas is 19.29 Mpa. For 4mm untreated lamina is 19.57 Mpa. The specific ultimate tensile strength for 8 mm treated laminas is 31.475 Mpa. For 8 mm untreated lamina is 30.47 Mpa. For 4 mm Treated kenaf composite lamina exhibited 1.43% lower specific ultimate tensile strength than untreated lamina. For 8 mm Treated kenaf composite lamina exhibited 3.29% higher specific ultimate tensile strength than untreated lamina.

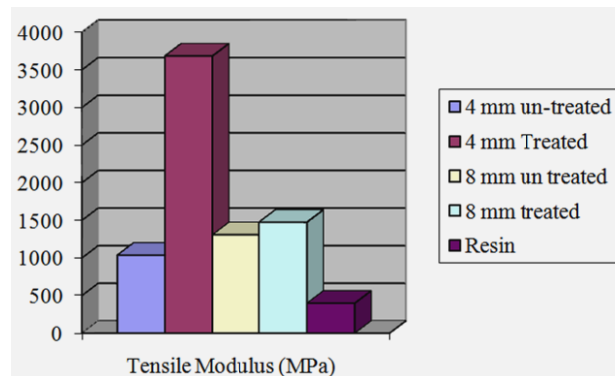


Fig. 12: Tensile Modulus.

The values of Tensile Modulus of different composites are shown in Fig.12. For 4 mm untreated kenaf composite, it is 1037.03 MPa and for 4 mm treated hybrid composite, it is 3685.13 MPa. For 8 mm untreated kenaf composite ,it is 1308.03 MPa

and for 8 mm treated kenaf composite, it is 1475.06 MPa Treatment with NaOH has increased the tensile strength of the kenaf composite. For 4 mm Treated kenaf composite lamina exhibited 255.35% higher tensile strength than untreated. For 8 mm Treated kenaf composite lamina exhibited 12.76% higher tensile strength than untreated.

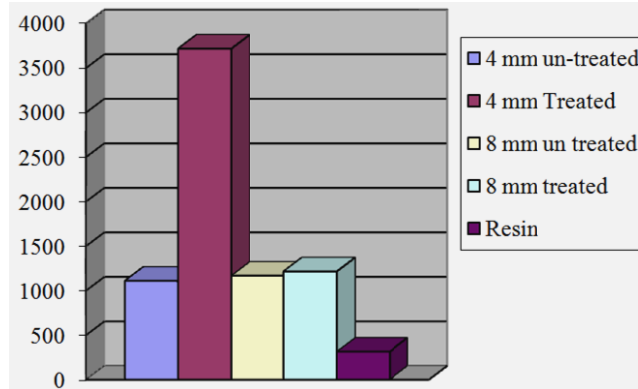


Fig. 13: Specific Tensile Modulus.

The values of Specific Tensile Modulus of different composites are shown in Fig.13. For 4mm untreated hybrid composite, it is 1110.310 MPa/g/cm³ and for treated kenaf composite, it is 3718.59 MPa/g/cm³. For 8 mm untreated kenaf composite, it is 1168.125 MPa/g/cm³ and for treated kenaf composite, it is 1216.042 MPa/g/cm³. Treatment with NaOH has increased the Specific tensile Modulus of the kenaf composite. For 4mm Treated kenaf composite lamina exhibited 234.9% higher Specific tensile Modulus than untreated kenaf lamina. For 8 mm Treated hybrid composite lamina exhibited 4.10% higher Specific tensile Modulus than untreated kenaf lamina.

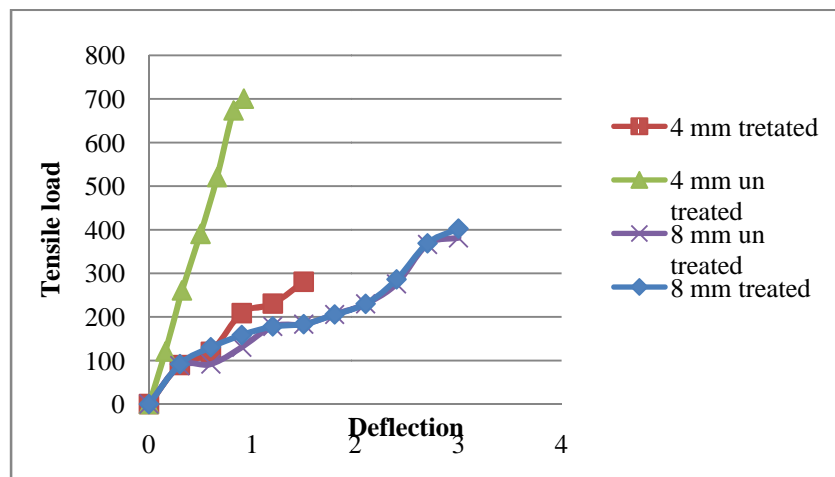


Fig. 14: Tensile Load – Deflection Curve.

5. Conclusions

Plant fiber resources are renewable, widely distributed, available locally, moldable, recyclable, versatile, nonabrasive, porous, viscoelastic, easily available in many forms, biodegradable, Combustible, and reactive. Plant fibers have a high aspect ratio, High strength to weight ratio, and have good insulation properties (sound, Electrical and thermal). Short natural fiber composite laminate is prepared using the *Kenaf* fiber and Polyester Isophthalic resin. Fiber matrix weight ratio of 1:20 has been employed. Three specimens for Short natural fiber composite laminate are prepared for Flexural and One for water absorption tests as per ASTM standards and Testing has been conducted as per ASTM Standards and are compared with Pure Resin lamina(14).

From the results we can say that the 8 mm treated lamina has highest value of ultimate tensile strength and un treated 4 mm lamina has least value of ultimate tensile strength. The fiber treatment has improved the tensile properties of composite lamina.

The following are the some of the mechanical properties observed.

Table 3: Summary of Results for various laminas.

Property	K- T- 4mm Lamina	K-T- 8mm Lamina	K-UT- 4mm Lamina	K-UT- 8mm Lamina	Neat Resin
Flexure Strength MPa	166.2	164.7	148.4	139.5	145.98
Flexural Modulus MPa	18720	17136	13256	12800	11214
Ultimate tensile strength MPa	19.12	38.18	18.28	34.13	38.47
Tensile Modulus (MPa)	3685.13	1475.06	1037.03	1308.3	398.8

The Flexural Strength is increased by 13.8%, 12.8%, 1.6% for Kenaf T-4mm laminate , Kenaf T-8mm laminate , Kenaf UT-4mm laminate respectively when compared to resin lamina. . But it is observed that the Flexural Strength is decreased by 4.4% for Kenaf UT-8mm laminate when compared to resin lamina . Surface treatment of fiber had a significant effect on fiber/matrix adhesion due to this there is an increase in Flexural strength. From the tensile testing results we can say that the 8 mm treated lamina has highest value of ultimate tensile strength and un treated 4 mm lamina has least value of ultimate tensile strength. The fiber treatment has improved the tensile properties of composite lamina.. By observing the results the Short Kenaf fiber reinforced composites can be used in many applications.

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