Influence of Kenaf on Mechanical Properties of Glass Epoxy Composites

Anant Joshi1,2, P S Shivakumar Gouda2*, Santosh Savanur1, Vinayak Uppin3
Veereshkumar G B4
1Department of Mechanical Engineering KLS VDIT, Haliyal
2* Department of Mechanical Engineering SDM College of Engg. & Tech.
Dharwad
3Department of Mechanical Engineering NNRG School of Engineering,
Telangana
4Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Amrita University,
Bangalore Campus, India

Corresponding Author: Dr. P.S. Shivakumar Gouda (ursshivu@gmail.com)

Abstract. Composite materials are replacing with traditional materials, because of its superior properties such as high tensile strength, low thermal expansion, high strength to weight ratio. Kenaf were processed by retting process then treated with sodium hydroxide and were cut using crusher. Mixing of kenaf fiber with glass is finding increased applications due to its versatility. Present study focuses on the development of kenaf glass fiber reinforced composites by the aid hand lamination technique. The composite is investigated for their mechanical properties such as tensile strength, flexural strength and impact strengths. The results indicated that the incorporation of kenaf fiber with GFRP can improve the properties. Further, the fractured specimens are analysed for their failure mechanism using optical microscopic study.

Keywords: Kenaf fiber, Tensile strength, Flexural strength

1. Introduction
In the present day practical applications, composite materials experience mechanical loading and are exposed to severe environmental conditions. The reason why composites are selected for many applications are high strength to weight ratio, high creep resistance, high tensile strength at high temperatures, improved toughness. The natural fiber reinforced composite materials are reasonably strong, light in weight and are free from health hazard; therefore, it has the capacity to be used as material for strong components or structures such as like building materials, shipping, automotive etc. In spite of the various advantages listed above, they possess some drawbacks such as poor moisture resistance predominantly absorption and low strength compared to synthetic fiber such as glass fiber. Natural fibers are renewable and are considered being green and eco-friendly. The major reason to use natural fiber is because it causes less effect on the environment which is established as natural fiber can be recycled thermally. The natural fiber used in this study was Kenaf fiber. Kenaf fiber is obtained from stems of plants genus Hibiscus, family of Malvaceae and the class of H. Cannibinus. Natural fibers including kenaf fibers consist of 60–80% cellulose, 5–20% lignin (pectin), and up to 20% moisture. The figure.1 represents kenaf plants. The figure 2 shows a picture of cell wall of natural fibers. The cell wall constitutes of a hollow tube with four different layers; one primary cell wall, three secondary cell walls, and a lumen; which is an open channel in the center of the micro fibril. Each layer is composed of cellulose surrounded in a matrix of hemicelluloses and lignin; a structure that is similar to artificial fiber reinforced composites. Hemicellulose is composed of highly branched polysaccharides, including glucose, mannose, galactose, xylose and others. Lignin is made up of aliphatic and aromatic hydrocarbon polymers located around fibers. The structure and contents of the cell wall varies extensively between diverse species and between different parts of the plants. The most interesting aspect of natural i.e plant fiber is their positive environmental impact. Natural fibers are bio-degradable and their making requires little energy. Natural fiber composites are less costly and have low tool wear rates. Natural fiber composites have decent formability, acoustic properties and
thermal shielding properties. Apart from these advantages, drawbacks like hydrophilic properties, low impact strength, non-uniformity and low processing temperature are unfavorable and limit their application to nonstructural automotive components. Hybridization of materials with glass fiber offers a method to enhance the mechanical properties of natural fiber composites [1]. Due to the hydrophilic nature of the fiber that is very delicate towards water absorption, causing instability in the properties. The mechanical strength of woven banana/kenaf fiber hybrid composites rises due to the hybridization of kenaf with banana fibers [2]. Hybridization of natural fibers can also be made in order to attain the desired properties. Hybridization of banana and kenaf fiber reinforced composites offered better resistance to water absorption as compared to un-hybrid composites [3]. The factors such as length of fiber, fiber loading or volume fraction of fibers, fiber aspect ratio, orientation of fiber or interfacial adhesion between fiber-matrix. The cellulose content is responsible in providing the mechanical properties to the composites [4]. Mechanical properties of natural fibers are highly influenced by the matrix-fiber adhesion property between the polymer matrix and fibers [5-7]. The void of the composite material as the fiber volume content increases and subsequently reduces the strength of the composite material [8]. The flexural properties of the KFRE composite are highly affected by the kenaf fiber surface characteristics [9]. In the present work kenaf fibers are reinforced with glass fiber and epoxy to make hybrid composite and the specimens are evaluated for mechanical properties in accordance with ASTM standards.

2. Materials
E-glass unidirectional glass fiber (220 GSM) is used in the present work and is provided by Mark Tech Composites Pvt. Ltd. Bangalore, India. Resin used was Epoxy with polyamine hardener in the ratio of 10 parts of epoxy to 1 part of hardener by weight. The matrix constitutes medium viscosity epoxy resin (LAPOX L-12) and is cured at room temperature. Polyamine hardener (K-6) is a low viscosity room temperature curing liquid hardener supplied by ATUL India Pvt. Ltd, Gujarat, India. Kenaf fibers were processed at department of Textile, University of Agriculture Science, Dharwad, India. The details of the Kenaf fiber are shown in Figure 3. The properties, chemical name and densities of all the individual materials are listed in Table 1.
Figure 3: Kenaf fiber after retting process

Table 1: Physical Properties of Materials

| Material     | Trade name and chemical name                          | Density, kg/m³ |
|--------------|--------------------------------------------------------|----------------|
| Glass Fiber  | E Type Fiberglass with SiO₂, Al₂O₃, CaO+MgO           | 2550           |
| Kenaf        | 60–80% cellulose, 5–20% lignin                         | 1152           |
| Epoxy        | LAPOX L-12 Diegycidyl Ether of Biphenyl A (DGEBA)      | 1160           |
| Hardener     | TriethyleneTetra amine K-6 (TETA)                      | 955            |

Table 2: Mechanical properties of glass fiber and epoxy resin

| Name of the property | Glass fiber | Epoxy resin |
|----------------------|-------------|-------------|
| Tensile strength, GPa| 3.5         | 0.1         |
| Tensile modulus, GPa | 72.0        | 4.0         |
| Poisson’s ratio      | 0.2         | 0.3         |
| Strain to failure    | 4.7         | 4.5         |

2.1. Composite fabrication

Composite laminates were prepared using semi-automated coating technique by uniform distribution of kenaf over the Glass fiber surface with varying quantity of kenaf fillers. Specimens were cut according to ASTM standard. Pristine glass fiber composite was coded as GE and Kenaf and Glass fiber composite is coded as KGEC. Table 3 represents various concentration of kenaf with glass fiber.

Table 3: Various concentrations of kenaf with glass fiber

| Concentration | Percentage of kenaf fiber (%) | Resin (gms) | No. of layers | Amount of kenaf fiber (gms) |
|---------------|------------------------------|-------------|---------------|----------------------------|
| KGEC-1        | 5                            | 90.35       | 10            | 12                         |
| KGEC-2        | 7.5                          | 90.35       | 9             | 18                         |
| KGEC-3        | 10                           | 90.35       | 8             | 24                         |
| GE            | 0                            | 90.35       | 11            | 0                          |
3. Experimentation

Experiment was conducted for tensile and flexural test under room temperature. Specimens were cut by means of band saw cutter according to ASTM D 5083[10] standard for tensile test and for the flexural test ASTM D 7264 [11] standard was referred.

3.1 Tensile test

The tensile strength of a particular material is the maximal amount of tensile stress that it can accommodate before failure. During the test a uniaxial load is applied through both the ends of the specimen. The tensile test is performed in the universal testing machine (UTM) with displacement rate of 1.5mm/min. Tensile load was applied until the specimen breaks and the corresponding load extension values were recorded for further analysis. The results were analyzed for the calculation of tensile strength of composite samples. All tests were carried out at room temperature.

![Figure 4: Dimension of tensile test specimen](image)

3.2 Flexural test

Flexural strength can be termed as the ability of material to confront deformation under load. It is also stated as cross breaking strength where ultimate stress developed when a bar-shaped test piece acting as a simple beam is exposed to a bending force perpendicular to the bar. The specimen is placed in a simply supported beam fashion and bending load is applied with displacement rate of 1.5mm/min. Bending load was applied until the specimen underwent failure and load extension rates were recorded. This test is performed in accordance with ASTM standard using UTM under room temperature.

![Figure 5: Dimension of flexural test specimen](image)

The specimens were rigidly mounted with proper clamping on universal testing machine for tensile test and flexural test. Figures 6 and 7 shows test set up for tensile test and flexural test of the specimen respectively.
4. Results and discussions

The tensile test and flexural test were carried out on specimens of various percentages of kenaf fiber. The tests were conducted in universal testing machine in accordance with ASTM standards to evaluate mechanical properties.

4.1 Tensile test and flexural test

The tensile test was conducted according to ASTM D 5083 using UTM. The specimens with various concentrations of Kenaf fibers reinforced with glass fiber were tested to determine the mechanical properties.

![Figure 6. Tensile test arrangement](image1)
![Figure 7. Flexural test arrangement](image2)

**Figure 8** Load v/s Displacement curve for tensile (a) and flexural test (b).

**Figure 8** (a) and (b) represents load v/s displacement curves for tensile and flexural test. It is observed that specimens with 5% Kenaf fiber exhibited greater load bearing capability as compared to others. As the percentage of Kenaf increases, the stiffness of the material lowers as a result load bearing capacity reduces. The load bearing capacity under tensile test in case of 5% KGEC is increased by 10.77% with 28kN load as compared to GE composites. It is observed that ultimate flexural load of 0.48 KN and strength of 443.08N/mm². The plain glass epoxy composite material has maximum flexural load of 0.35 kN. Further it is evident that the percentage increase in load bearing capacity of 5% KGEC is 27% as compared to GE composites.
Figure 9 Stress v/s Strain curve for tensile test

Figure 9 represents stress v/s strain plot obtained for various concentrations of kenaf glass epoxy composites. In 5% KGEC it is seen that greater stress at higher strains i.e. 0.13 as compared with other variations of Kenaf glass epoxy composites which exhibits lower stress plateaus. Fiber breaking at the interface increases as the percentage of Kenaf fiber increases which is due to poor interfacial adhesion between glass fiber and kenaf fiber.

4.2 Microstructure

Figure 10 Micrographs showing fractured surfaces (a) 5% KGEC (b) 7.5% KGEC (c) 10% KGEC and (d) GE

Figure 10 shows the micrographs of fractured surfaces of GE and KGEC specimens after the test. Here it was seen that the distribution of epoxy on the glass fiber reinforced composite was good and also in kenaf glass epoxy composites i.e. KGEC specimens kenaf and glass fibers were seen to be properly impregnated with epoxy and exhibited good bonding between the fibers which is essential requirement for hybrid composites.
5. Conclusion
Specimen preparation was done successfully by ensuring uniform distribution of chopped kenaf fibers on unidirectional glass fiber lamina. The specimens were made according to ASTM standards and tested to evaluate the mechanical properties of the hybrid composite. The bonding between kenaf fibers and glass fiber was observed to be good which was observed in microstructure of the composite specimens. Specimen coated with 5% Kenaf fillers exhibited 10.77% increase in tensile strength and 27% enhancement in flexural strength. The peak stress value for 5% KGEC was high at higher strain as compared to other concentrations of kenaf glass epoxy composites and also it was observed that as the percentage of kenaf fiber increased there was significant reduction in strength due to poor interfacial adhesion between the fibers in composite.

6. Future scope
The use of natural fibers is increasing significantly in present scenario as they possess many desirable properties which give them edge over synthetic fibers. The characteristics like bio-degradability are the need of the hour. The natural fibers have the potential to serve the demands. The natural fibers can be treated chemically with various chemicals in order to achieve the desirable properties to suit the practical applications. Further the use bio resins along with natural fiber will give absolute bio degradable material which is the necessity of the hour.

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