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Investigation of Tensile and Flexural Behaviour of Hybrid Fiber Composites Based On Basalt and Kenaf Fibers

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Abstract

The hybrid fibers have grown as a potential material in the reinforcement of composites and thus gain attraction by many researchers. This is mainly due to their applicable benefits like they offer low density, low cost, renewable, biodegradability and environmentally harmless and also comparable mechanical properties with synthetic fiber composites. In this work, the tensile and flexural behaviour of Basalt and Kenaf fibers reinforced epoxy hybrid composites was studied. Short fibers of Basalt and Kenaf of lengths 4mm, 6mm, 8mm, 10mm, 12 mm are used in this work. The Kenaf fibers are chemically treated in 2% NaOH solution. The hand layup method was adopted for fabrication of hybrid fiber composites. Specimens were cut from the fabricated hybrid fiber composite lamina as per ASTM standard for tensile, flexural test. It is observed that the hybrid fiber composites with fiber length 8mm has shown better tensile and flexural behavior than other fiber lengths used in this work.

Keywords:—*Hybrid fiber composite, Basalt fiber, Kenaf fiber, Epoxy*

I. INTRODUCTION

A composite material is a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual materials that make up the composite. Matrix (in the form of metal, ceramic, or polymer) and Reinforcement (in the form of fibers, sheets, or particles) together constitute a composite material. Composites typically have a fiber or particle phase to carry the load to the fibers and to provide strength, stiffness, thermal stability, and other structural properties in the composites. 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. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.

Hybrid composites are more advanced composites as compared to conventional fiber reinforced polymer composites. Hybrid composites contain more than one reinforcing phase in a single matrix phase. They have unique features that can be used to meet various design requirements in a more economical way than conventional composites. The concept of hybridization gives flexibility to the design engineer to tailor the material properties according to the requirements, which is one of the major advantages of the composites. Hybrid composites have taken the attention of many researchers as a way to enhance mechanical properties of composites. However, hybrid composites using natural fibers are less studied. And in such studies, the hybrid composite often consists of one natural fiber and one artificial fiber.

1.1 Fibers Details

1.1.1 Basalt Fiber

Basalt is a type of igneous rock formed by rapid cooling of lava at the surface of the planet. It is the most common rock in the Earth's crust. Basalt as a fiber used in fiber reinforced polymers and structural composites has high potential and is getting a lot of attention due to its high temperature and abrasion resistance. Basalt fiber is dark colored, fine grained solidified volcanic rock. Basalt is an environment friendly natural material. The processing of basalt fiber involves two stages i.e., lava to rock and then rock to fibers. The process of producing fibers from basalt is based on selecting the richest chemical proprieties basalt rocks with the use of quality tests, crushing the rocks and melting to high temperatures. The processing of basalt fiber is as shown in the figure 2.

Figure 1: Basalt fiber

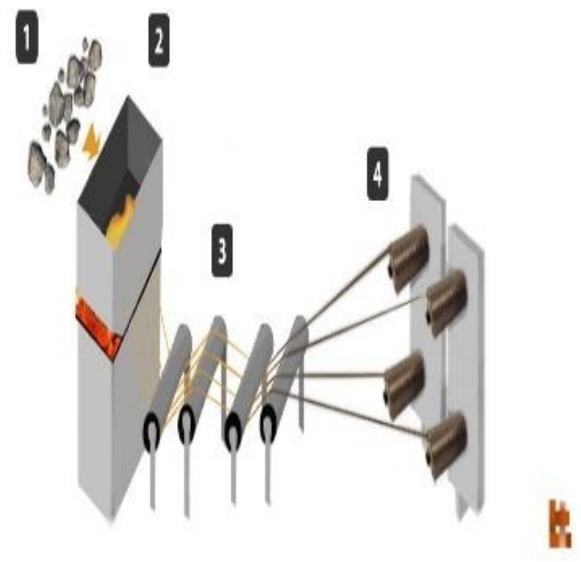


Figure 2: Processing of basalt fiber

1.1.2 Kenaf Fiber

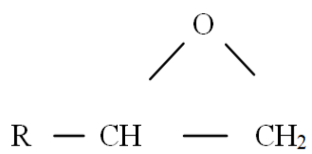
Kenaf is one of the natural (plant) fibers used as reinforcement in Polymer Matrix Composites. Kenaf with its scientific name Hibiscus Cannabinus is a warm season annual fiber crop closely related to cotton and jute. Historically, Kenaf has been used as a cordage crop to produce twine, rope and sack cloth. Now a days, 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 is well known as a cellulosic source with both economic and ecological advantages, in 3 months (after sowing the seeds), it is able to grow under a wide range of weather conditions, to a height of more than 3 m and a base diameter of 3–5 cm.

Figure 3: Kenaf Plant

Figure 4: Kenaf Fiber

1.2 Resin Details

The materials used for matrix are epoxy, unsaturated polyester and vinyl ester. Epoxy resin is defined as a molecule containing more than one epoxide groups. Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide end groups.



These resins are thermosetting polymers and are used as adhesives, high performance coatings and potting and encapsulating materials. These resins have excellent electrical properties, low shrinkage, good adhesion to many metals and resistance to moisture, thermal and mechanical shock.

II. Literature Review

M.R. Sanjay, B. Yogesha studied mechanical properties of Jute/E-Glass Fiber Reinforced Epoxy Hybrid Composites. They found that hybrid composite of jute/ E-glass fiber has far better properties than that of jute fiber composite. However, it is found that the hybrid composite has better strength as compared to jute fiber composite fabricated separately with glass fiber.

Hemant Patel, Prof. Ashish Parkhe, Dr. P.K. Shrama evaluated mechanical properties such as tensile and flexural properties of hybrid banana and sisal reinforced epoxy composites they have been employed in combination with plastics. The mechanical properties will be change with change in composition of fibers. On combination of sisal and banana where banana is in excess amount than sisal tensile strength value is high but bending values are low. Composite made from 50% Sisal and 50% banana had less strength from composite having 80% Sisal and 20% banana fiber ratios.

H. Raghavendra Rao, M. Ashok Kumar, G. Ramachandra Reddy studied the effect of fibers on mechanical properties in hybrid composites. Two different hybrid composites such as treated and untreated bamboo fibers were fabricated and effect of alkali treatment of the bamboo fibers on these properties were also studied. It was observed that, impact strength and frictional co-efficient properties of the hybrid composites increase with increase in glass fiber content. These properties found to be higher when alkali treated bamboo fibers were used in the hybrid composites.

T. Hariprasad, G. Dharmalingam and P. Praveen Raj study of mechanical properties of Banana-Coir Hybrid Composite using experimental and Fem Techniques showed that the tensile and impact tests of the treated banana-coir epoxy hybrid composites have higher tensile strength and impact strength than untreated composites. However, untreated fiber composites have greater flexural strength than the treated fiber composites. The finite element analysis (FEA) software ANSYS has been employed successfully to evaluate the properties. The model output was compared with the experimental results and found to be close.

III. Problem Definition

The objective of the present work is to study the tensile and flexural behaviour of the hybrid fiber reinforced composite made of two short fibers of different materials. This study aims at prediction of some of mechanical properties of the hybrid composite. The influence of length of the fiber on mechanical behaviour of hybrid composite is examined by varying the lengths of both the fibers and the length of the fiber for which the hybrid composite shows good mechanical properties is found.

IV. Research Methodology

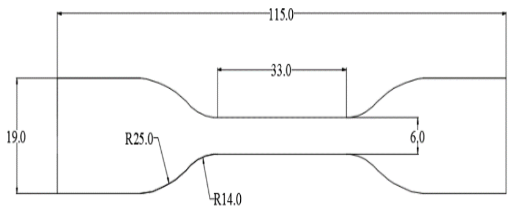
Short fibers of Basalt and Kenaf of lengths 4mm, 6mm, 8mm, 10mm, 12mm are used in this work. The kenaf fibers are allowed to undergo chemical treatment. For this process, water by volume is taken along with 2% of NaOH and the fibers are soaked in water for 24hrs. The treated fibers are washed thoroughly with distilled water to remove the final residues of alkali. This treatment was used to remove the lignin content in the fiber. The lignin content may affect the Young's modulus of the fiber. Bonding between the fibers and resin are also increased by chemical treatment.

Figure 5: Fabricated Laminas

In this study, manual hand lay-up method is used for preparing composite laminates First of all, wax is applied on the mould surface to avoid sticking of epoxy to the surface and then Poly Vinyl Alcohol (PVA) is applied which provides glossy finish to the surface of the laminate. Thin plastic sheets are used at the top and bottom of the mould plate to get a good surface finish of the product. The mixture of Epoxy and hardener are mixed in proper proportions (1:10) then it is applied in the mould cavity. This mixture is uniformly spread with the help of the brush. Reinforcement in the form of Basalt and Kenaf fibers are cut as per the required sizes (4, 6, 8, 10, 12 mm) and placed on the resin-hardener mixture. Then the top base plate that was already applied with the wax and PVA is placed on the laid resin. After curing at room temperature, the mould is opened and the developed composite part is taken out and further processed. For epoxy based system, normal curing time at room temperature is 24 - 48 hours.

4.1 Tensile Testing

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The commonly used specimen for tensile test is the dog-bone type and the standard used for tensile testing is ASTM D638. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is (115×19×6)mm. Typical points of interest when testing a material include: ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) Instron 1195 and results are analyzed to calculate the tensile strength of composite samples. 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).



All dimensions are in mm

Figure 6: Tensile testing specimen

Figure 7: Before testing

Figure 8: After testing

4.2 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. This stress decreased due to the flexural load is a combination of compressive and tensile stresses. 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, flexural test is more relevant for design and specification purpose than tensile test. The dimension of specimen is 60.8mm × 12mm × 6mm.

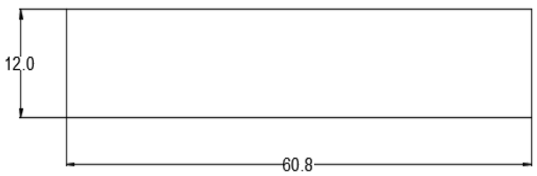


Figure 9: Flexural testing specimen

Figure 10: Before Testing

Figure 11: After Testing

4.2.1 Flexural Strength

Flexural strength is the maximum stress in the outer specimen at the moment of break. When the homogeneous elastic material is tested with three-point system, the maximum stress occurs at the midpoint. This stress can be evaluated for any point on the load deflection curve using equation.

$$\sigma = \frac{3PL}{2bt^2}$$

Where, σ = stress in the outer specimen at midpoint. MPa

P = load at a given point on the load deflection curve, N L = support span, mm

b = width of beam tested, mm t = depth of beam tested, mm

V. Results and Discussions

5.1 Tensile Testing Results

The tensile strength for different lengths of fibers are as shown in the following bar graph figure 12.

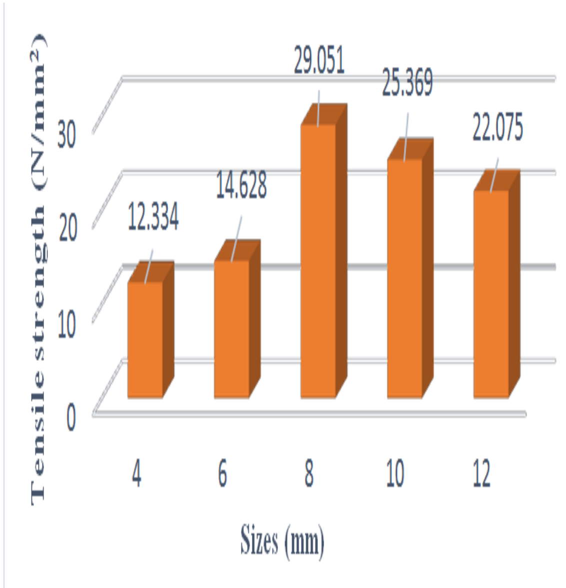


Figure 12: Tensile Strength of different lengths of Basalt-Kenaf fiber composites

Table 1. Tensile Properties of Different Lengths of Basalt-Kenaf Fiber Composites

S. No	Size of fibers (mm)	Tensile Strength (MPa)	Specific Tensile Strength (MPa/gm/cm^3)	Load at Peak (kN)	Tensile Modulus (MPa)	Specific Tensile Modulus (MPa/gm/cm^3)
1	4	12.334	13.6498	0.480	342.611	379.16
2	6	14.628	16.369	0.527	365.7	409.243
3	8	29.051	26.567	0.880	486.616	445.048
4	10	25.369	26.54	0.910	539.76	564.838
5	12	22.075	22.411	0.920	324.63	329.43

5.2 Flexural Testing Results

The flexural strength for different lengths of fibers are as shown in the following bar graph figure 13.

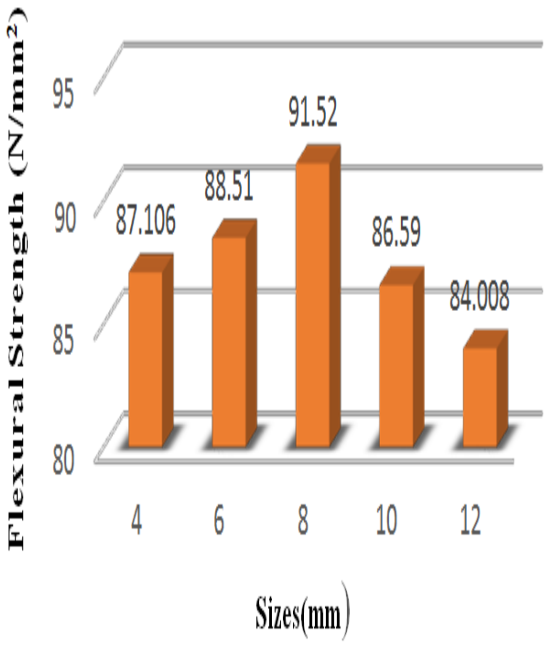


Figure 13: Flexural Strength of different lengths of Basalt-Kenaf fiber composites

Table 2. Flexural Properties of different lengths of Basalt-Kenaf fiber

S.no	Size of fibers (mm)	Flexural Strength (MPa)	Specific Flexural Strength (MPa/gm/cm^3)
1.	4	65.90	72.930
2.	6	66.97	74.9944
3.	8	69.245	63.329
4.	10	65.50	68.54
5.	12	63.45	64.4162

Table 3. Summary of Mechanical properties observed with Tensile and Flexural tests

Property	4mm	6mm	8mm	10mm	12mm
Tensile Strength (MPa)	12.334	14.628	29.051	25.369	22.075
Specific Tensile Strength (MPa/gm/cm^3)	13.6498	16.369	26.567	26.54	22.411
Load at Peak (kN)	0.480	0.527	0.880	0.910	0.920
Tensile Modulus (MPa)	342.611	365.7	486.616	539.76	324.63
Specific Tensile Modulus (MPa/gm/cm^3)	379.16	409.243	445.048	564.838	329.43
Flexural Strength(MPa)	65.90	66.97	69.245	65.50	63.45
Specific Flex-ural Strength (MPa/gm/cm^3)	72.930	74.9944	63.329	68.54	64.4162

VI. CONCLUSIONS

The present work clearly shows that the basalt and kenaf reinforced hybrid fiber composites will become a future alternative for the conventional single fiber composites due to its enhanced mechanical properties and availability.

From the tests (Tensile and Flexural) conducted the following conclusions are drawn:

- The hybrid fiber composites of lengths 8mm and 10mm show better tensile strength than other lengths. Hybrid fiber composites of 8mm length shows better than 10mm.
- The 4mm hybrid fiber composite shows poor tensile strength

compared to other lengths of hybrid fiber composites.

- The hybrid fiber composites of lengths 8mm and 6mm show better flexural strength than other lengths. Hybrid fiber composites of length 8mm shows better than 6mm.
- The 12mm hybrid fiber composite shows least flexural strength compared to other lengths of hybrid fiber composites.

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