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EXPERIMENTAL INVESTIGATION ON FLEXURAL STRENGTH AND FRACTURE TOUGHNESS OF HYBRID HEMP AND E-GLASS COMPOSITES

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Abstract

Natural fiber composite materials are grabbing the attention of industries due its eco-friendly and sustainability. These are effectively replacing many of metals and ceramic comprised components in termsof accessibility, cost, strength and weight. The study of a material to resist a load which is having cracks internally is the important parameter, this which internally describes the fracture toughness of a material. Understanding of flexural strength (bending strength) helps to avoid the internal de-lamination. In this research a composite specimen is prepared using a naturally available hemp fiber along with commercially available E-glass. Traditional hand layup fabrication method is used to prepare the composite specimens. Fracture test specimen is prepared according to ASTM E399 and the flexural (bending) specimen is developed according to ASTM D790. The fracture toughness of the hemp/E-glass composite has with stand a critical load of 1192N with a yield stress of 50MPa. The fracture toughness strength up to 11.77MPa can be with stand by the composite specimen. Fracture toughness increases with respect to the alignment. Orientation of fibers increases the strength. Bending strength resist by the composite laminate is about 4.8MPa and this will be decreased due the improper bonding between the layers. SEM test helps to identify the reasons for failure.

Keywords: Fracture Toughness, flexural strength, Hemp/E-glass fiber, SEM.

1. Introduction

There are many environmental issues are facing now a days due to the use of metal matrix composites. Global warming, in sufficient quantity of fossil fuels considering all these factors many of the researchers are attempting to utilizing naturally available fibers to develop new category of natural fiber composite materials [1,2,3]. Few of the natural fibers like bamboo, banana, hemp etc., find its applications in automobile and structural streams [4]. Some properties like stiffness, strength of natural fiber composites allows them to use in athletic equipment's, musical equipment's etc. [5].Some factors like inherent properties of matrix and reinforcement, nature of chemical and physical treatment, surrounding conditions, Material properties and hybridization influences the fracture strength of the natural fiber composite[6]. Adding of metal with the natural fibers reduces the total weight of the product by 60% and will not cause any allergic symptoms on human body [7]. Natural fibers are effective reinforcements for matrix in place of synthetic fibers due to its cost, specific characteristics, low density[8].Adding of number of fibers together develops the composite in order to obtained superior properties. Hybridization helped to improve inherent properties, and characteristics of composite specimen [9]. Adding of E-glass to natural fibers like banana, hemp etc. increases the mechanical properties and reduces the moisture absorption [10].The strong affinity of water absorption influences the strength of the composite and which also leads to the poor bending strength due to the de-lamination between the layers of fibers[11-12]. For any structural material, the flexural property is essential parameter which can replace the fibers instead of steel[13]. In order to make the natural fibers suitable for use in structural members, it is require that, the composite should showbetter strength under flexural loading. It must maintain the better bonding between the layers of fibers [14]. The fibers area subjected to chemical treatment before preparing the composite laminate. This will enhance the adhesion between reinforcement and matrix. Also the moisture absorption characteristic of natural fibers makes them to think for using in outdoor applications [15]. This study involves identifying the fracture strength of developed hemp/E-glass composite laminate along with the effect of de-lamination on flexural strength (bending strength).

2. Materials and Methods

The composite laminate has been prepared using manual method, natural hemp fiber and e-glass is procured for external agency form Ahmedabad. The die of 300*300*3mm is prepared using mild steel.

Hemp is one of the strongest and durable plants and it can be grown in almost all the climates. The maintenance of this plant is less and it has good compatibility of moisture absorption [16]. Piece of hemp fabric is as shown in the figure1. Hemp has more solvent resistance and the fibers can carry up to 80 percent of load. The inherent bonding strength of hemp fiber relay on chemical fix and external load acting [17].The composite specimen developed with hemp and polyester matrix enhanced by increasing the amount of fiber by 10%/ [18]. Physical properties of hemp fiber shown in the table1.

Figure1. Hemp fabric

Table1 Physical and Mechanical Properties of Hemp Fiber[19, 16]

Properties	Range
Length in 'mm'	8.3-14
Diameter in 'µm'	17-23
Length/diameter	549
Specific Gravity	1500
Tensile strength in 'MPa'	310-750
Flexural Strain	2-4

Banana fiber is produced from the cultivated banana waste, this will be available at free of cost, by undergoing alkaline process the fibers will be extracted from the stem of banana plant[20]. The range of volume fraction highly influences the dynamic mechanical behavior of the composite. It is observed that, the 40% of fiber loading gives the maximum strength[21]. A mechanical property of a banana fiber is represented in table2.

Table2. Mechanical Properties of Banana Fiber[16, 22]

Properties	Range
Tensile strength in 'MPa'	529 to 914
Young's Modulus in 'GPa'	27 to 32
Failure Strain	1 to 3
Density in 'Kg/m^3'	750 to 950

Using fine fibers of glass, glass fiber reinforced polymers are made. Electrode glass is strong, bearable weight and it can be used in various industrial applications. The addition of E-glass with the natural fiber improves the strength and reduces the sensitivity of moisture [24]. Physical Properties of E-glass is shown in table3. Figure2 shows the E-glass fabric.

Table3. Physical Properties of E-glass[25]

Properties	Range
Orientation	Plain Woven fabric
Modulus	1 GPa
Density	1.9 g/cc

Figure2. E-glass

2.1Method of Fabrication

Hand Layup process is adapted for preparing hemp/E-glass reinforced natural composite. Each layer of hemp fiber is having a thickness of 0.25mm and the banana fiber is of 0.23mm. The mats of fiber impregnated with the Polyester resin and catalyst Methyl Ethyl ketone Peroxide (MEKP). Catalyst helps to provide the bonding strength between the mats of fibers and the accelerator, Cobalt Nepthanate helps to takes place curing process within the room temperature[23]. The Hand layup process involves adding of alternative layers of fiber mats and adding the matrix between them. For this work a range of 1:0.02:0.026 is adapted, means for 1% resin, 0.02% of catalyst and 0.026% of accelerator is added. After placing of each layer of fiber mat, a pressure is applied evenly on entire surface using a roller. Figure3 shows the hand layup process using for composite laminate preparation. Figure represents the methodology followed in this study.

Figure3. Hand Layup Process

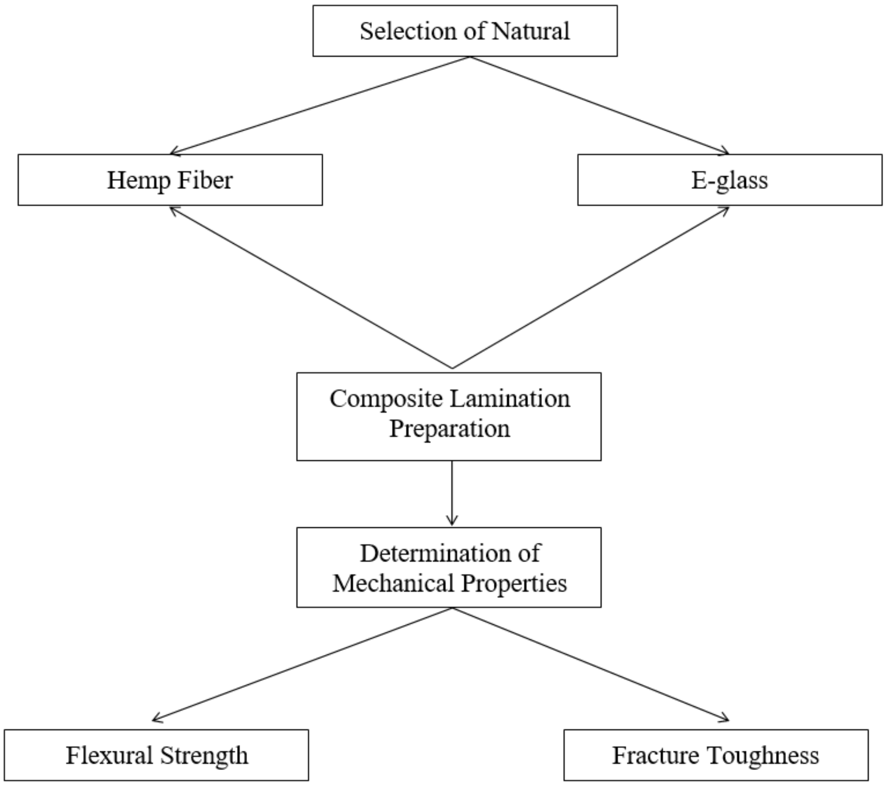

Figure4. Methodology

2.2 Determination of Fiber Volume Fraction

Fiber volume fraction is a percentage of fiber reinforced in the matrix material. The volume of matrix material was obtained by using rule of mixture. It is calculated as follows:

Mass of Hemp Fiber (Mh) = 0.44gm.

Mass of E-Glass Fiber (ME) = 0.09gm.

Density of Hemp Fiber (Dh) = 0.00146 gm.

Density of E-Glass Fiber (DE) = 2.55 gm.

Therefore, Volume of Fiber = $M_h/D_h + M_E/D_E$

= (0.44/0.00146) + (0.09/2.55)

.= 325.63cm³

Volume of composite = 1x30x0.545

= 16.35 cm³.

Volume of fiber fraction $= \frac{\text{Volumeoffibre}}{\text{Volume of composite}}$ = 24.52 %

Law of mixture:

Weight of fibers (Mh + Me), Wf = 0.53 gm.

Weight of composite, WC = 3.8586 gm.

Weight of fiber fraction = $\frac{Wf}{WC}$ = 0.53/3.8586

= 0.1373

= **13.73 %**

Wf +Wm =1

Wm = Weight of matrix

Wm = WC - Wf

= 3.8586 – 0.53

= **3.3286** gm.

Weight of matrix fraction = $\frac{Wm}{WC}$

= 3.3286/3.8586

= 0.86264

= **86.264%**

Therefore law of mixture satisfied, 13.73% + 86.264 % = 99.99% ≈ 100%

3. RESULTS AND DISCUSSION

The hemp and banana fiber reinforced by polyester resin were subjected to flexural and facture toughness test.

3.1Flexural Strength

The ability of a composite specimen to withstand bending force applied perpendicular to its axis is determined using flexural test. For this study 2 specimens are taken and are subjected to bending load at the center length of beam. Specimen is supported between two end rollers and the load is applied gradually till the specimen bend to its maximum extent. Figure 5 shows the specimen positioning and load application for flexural test. Figure6 shows the specimen after flexural test.

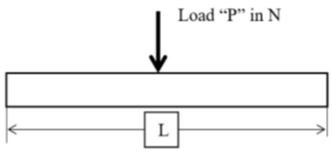

Figure5. Flexural test specimen setup

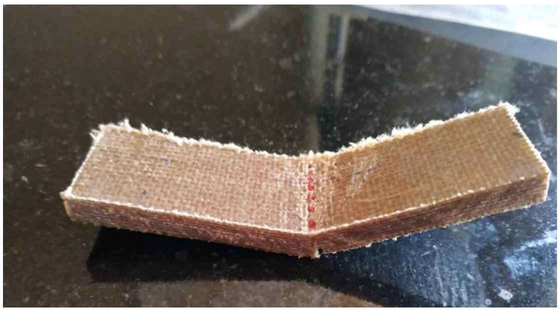

Figure6. Flexural test after failure

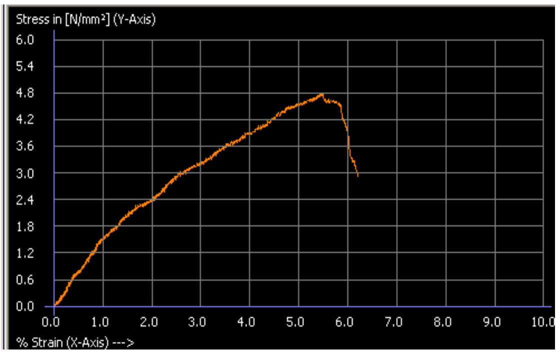

Figure7. Stress v/s strain curve of specimen1

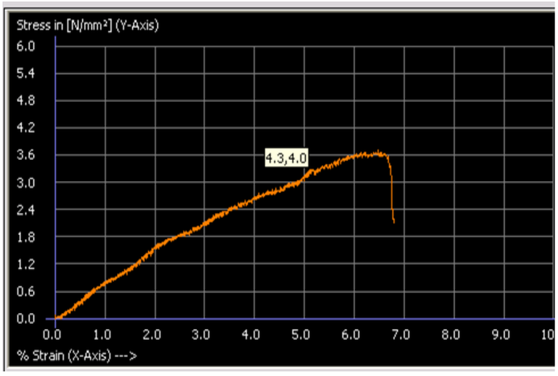

Figure8. Stress v/s strain curve of specimen2

Two composite specimens of same composition (50:50 matrix and reinforcement) are prepared using hemp and E-glass. The above graph i.e. figure 7 and figure 8 shows the stress v/s strain curve obtained after performing flexural (3 point bending) test, Its been observed that, the specimen1 resists more stress that is 4.8N/mm^2 as compare to the specimen 2 i.e. 3.6N/mm^2. Though both the specimens prepared with the same composition had shown different strength, this is because of hand layup fabrication process leads to error like uneven quantity of resin supply, environmental condition, curing weather, improper loading etc. This can be avoided by adapting injection molding process to prepare the laminates.

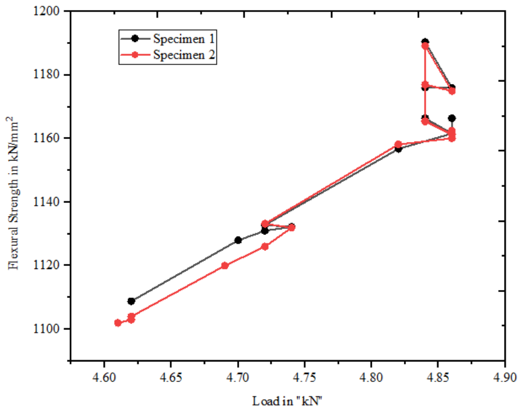

Figure9. Cumulative flexural strength

The figure9 represents the flexural strength comparison of two specimens. It can be clearly visualize that, the flexural strength of specimen2 is 1192MPa and it is better than the specimen1 i.e. 1189MPa. This 0.3% variation is due to operator error while preparing the specimen and environmental conditions like, curing temperature, weather etc.

Fracture Toughness:

This test helps to identify the presence of cracks and voids which leads the specimen to failure. This can be find in terms of stress intensity factor (K).

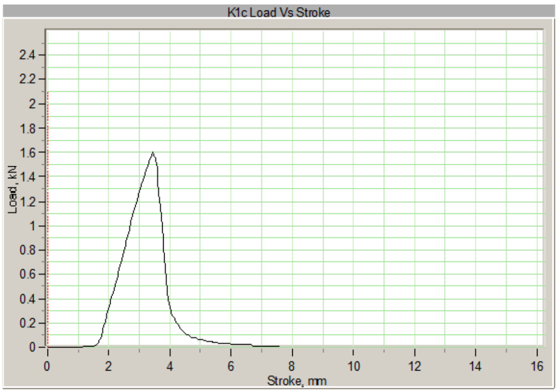

Figure10. Load v/s stroke curve of specimen1

The above graph9 show the result obtained by fracture strength test of specimen1. We can observe that, the specimen has fractured at after reaching a crack length of 11.250mm with an a/w ratio of 0.3. Maximum load resist by the specimen1 before fracture is 1.160kN and the obtained fracture strength is 50MPa.

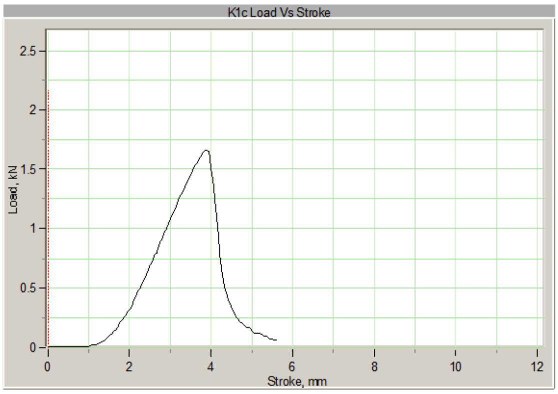

Figure11. Load v/s stroke curve of specimen2

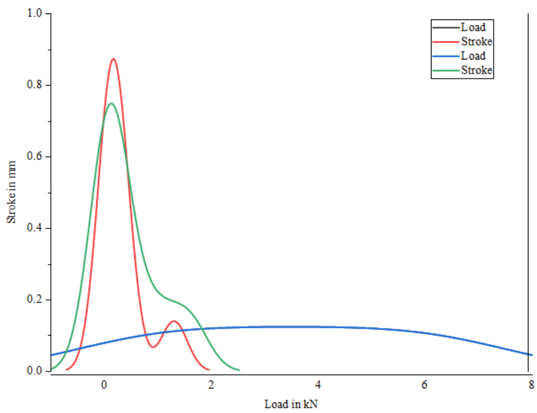

Figure12. Cumulative Load v/s stroke curve

Figure10 is the fracture load v/s stroke representation of specimen2. From the graph we can understand that, the specimen2 can resists a load up to 1.65kN and the crack length which penetrates upto 11.250mm. Stroke of crack propagation is up to 5.8mm, the maximum fracture strength the specimen2 can take is $48N/mm^2$. Figure12 demonstrates the variation of load with respect to the stroke of both the specimens together. The difference is clearly noticed with this representation.

CONCLUSION

This work committed to demonstrate the importance of flexural strength and fracture toughness of hemp/E-glass natural composite specimen. The flexural strength has been found in this case is 4.8MPa which is quite better in nature as compare to few other natural fibers. This strength is better suits for finding its applications in prototype aerospace part making, automobile casings etc. Fracture toughness is one more important factor helps to identify the presence of cracks. This has been successfully identified in this study through stress intensity factor (K). In this case, the prepared hemp/E-glass composite specimen can resists a fracture intensity factor of 11.77MPa. This is quite acceptable value for natural fibers.

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