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Experimental Investigation on Mechanical Behavior of Banana, Coconut and Glass Fibre Reinforced Composites

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Abstract

The present work aims to experimentally investigate the mechanical behavior of composite specimens made using natural and synthetic fibres. The prepared composite specimens using banana, coconut and glass fibre reinforcements are further tested for its mechanical properties such as tensile, bending and impact strength per ASTM standards. The specimens made out of Glass fibre is found to have superior mechanical properties than natural fibres in all the three different mechanical properties at a higher percentage. The coconut fibre has less strength than banana fibre in case of bending strength and higher strength in tensile property consideration.

Keywords: ASTM Standards, Banana Fibre, Coconut Fibre, Glass Fibre .

1. Introduction

The use of renewable materials as reinforcement in composites is growing steadily. In particular, advantages such as accessibility, low cost, non-hazardous nature and positive impact on environment have attracted attention of the researchers towards natural fibres. The replacement of synthetic fibres with natural ones does not occur in high loading application. Nevertheless, medium load application, especially in the automotive sector, can accommodate natural fibre reinforced composites more easily based on decreased fuel consumption. The composites are developed using various natural fibres such as banana, coconut, bamboo, flax, hemp, sisal, jute and coir. The development of composites with natural fibres expresses a lot of challenges. The natural fibres have wide range of physical and mechanical properties that is related to the original sources such as diameter, length, specific gravity, methods of processing treatment etc. governing its wider applications. Among different natural fibres, banana fibres, pines and sabai grass are still some of the unexplored high potential fibres having similar chemical constituents, mechanical properties and thermal resistance to other natural fibres such as jute, sisal, hemp and bamboo.Natural fibre reinforced composites reflects outstanding and comparable mechanical properties to steel and aluminium, leading to extend its application for special engineering materials such as automotive, aerospace industry and construction structures.

Because of these, natural fibres can be a potential substitute for the traditional man-made fibres such as glass fibre.Although short fibre reinforced composites offer better mechanical performance compared to their unreinforced counterparts, there is still a substantial gap between the mechanical properties of additively manufactured composites and conventionally manufactured fibre reinforced composites, which mainly use continuous fibre reinforcement, in terms of mechanical properties. There is a need to characterize the mechanical properties and fracture behaviours of the additively manufactured continuous fibre reinforced composites to give product designers a detailed understanding on the characteristics of the additively manufactured continuous fibre reinforced composites. Glass fibre are relatively inexpensive and exhibit fairly good mechanical properties and are suitable for parts that are less stringent on weight and strength so that parts can be fabricated at lower cost various mechanical properties that are relevant to sport, automotive and aerospace industries.

2. Literature Survey

The following research works has been analyzed to understand the research carried out in the area of composites using natural and synthetic fibres in the evaluation of mechanical and other properties.

Subba Reddy et.al [1] has investigated the effect of adding the banana fibre with resin in making composite specimens to evaluate the mechanical properties such as tensile, flexural and impact strength. The authors have prepared the composite specimens using hand layup technique by making them to cure in a mould with epoxy resin and banana fibre for 24 hours at room temperature. The specimens have been cut in to pieces as per ASTM standards and the authors have concluded that the decrease in fibre volume fraction increases the tensile strength of the specimen and the alkali treatment has increased the flexural strength of the specimens at 40% volume fraction and the impact strength of the specimen decreases when the fibre volume fraction percentage increases.

A.Alavudeen et.al [2] has studied the effect of weaving patterns and random orientation over the mechanical properties of banana, kenaf and banana/kenaffibre reinforced hybrid polyester composites. The authors have prepared the specimens by hand layup method with two different weaving patterns namely plain and twill type. The prepared specimens have been tested to observe the variation in mechanical properties such as tensile, flexural and impact strength of the specimens. The authors have reported that the specimen is found to have maximum tensile properties with the plain type weaving pattern rather than the twill type. The authors have concluded that the strength of hybrid composites have shown superior strength than the individual fibre specimens. The fractography study conducted by the authors have revealed that the fracture behavior of the composite indicate that a better fibre matrix adhesion exists in the hybrid composite due to interlocking of fibres and the SLS treatment provided to the specimens at 10% have shown an additional improvement of mechanical properties.

Amir.N et.al [3] has investigated the effect of fibre configuration over the mechanical properties of high performance polypropylene (PP) composites, using continuous banana fibre as reinforcement with polymer to fibre by weight percent ratio of 70:30. The authors have varied the configuration of banana fibre as raw banana fibre, banana yarn and banana fibre mat. The authors have evaluated the mechanical properties of the composite specimens as per ASTM D638 and ASTM D790 standards. The authors have reported that the PP/Banana yarn composites exhibits the highest tensile strength and flexural strength with the increment of 294% and 72%, respectively when compared to those of unreinforced PP. The authors have concluded that the banana fibre yarn is the best fibre configuration for obtaining the improved mechanical properties in PP composites.

Daniel et.al [4] have examined the effect of adding random, short coconut fibres to various cementitious composites on the mechanical properties, plastic cracking, and impact resistance of these composites. The mixtures of the cementitious composites designed by densified mixture design algorithm (DMDA) method were made using different volume fractions of random, short coconut fibre (0%, 1%, 2.5%,and 4%) and water binding ratios The presence of coconut fibre improved the flexural behaviour of cementitious composites significantly. The increase in coconut fibre content from 0% to 4% increased the 28-day flexural strength of the cementitious sheet and the modulus of rupture from 5.2-7.4MPa and 6.8-8.8MPa, respectively. The addition of coconut fibre to the composites samples enhanced first–crack deflection and toughness indices remarkably. The first-crack deflection increased from 0.235-0.558mm when the coconut fibre volume fraction rose from 0%-4%. Further, at 28 days of edge, the toughness index 124 the cementitious composites specimen with 1%,2.5% and 4% coconut fibre were, respectively, 120%, 247% and 302% greater than their counterpart without coconut fibre.

HaohuiXin et.al [5] has analysed the material behaviour of pultruded glass fibre reinforced polymer laminates. The authors have extended the use of pultruded glass fibre reinforced polymer (GFRP) composite materials to practically consider the fibre volume fractions and the equivalent thickness of each lamina as important parameters in their study. The average test value with 95% guaranteed rate, suggested design value by MOHURD GB50608-2010 and ASCE-MOP 102 of longitudinal and transverse elastic modulus, shear modulus, longitudinal and transverse tensile strength and shear strength of three different laminates are determined in this paper based on material experiments. To simplify the innovative multi carpet plots with fibre fraction from 20% to 75% is proposed in this paper. The multi carpet plots allow designers to preliminary design and predict the engineering constants of GFRP laminate without complicated calculation.

3. Materials and Mechanical Testing

The present study considers two different natural fibres such as banana fibre and coconut fibre and glass fibre for comparing the mechanical properties after testing. The description about the various fibres considered for reinforcement are explained in the next section.

3.1 Banana Fibre

The availability of the agricultural waste in our country is in abundance which makes it an interesting one to consider them as reinforcements. The cultivation and utilization of banana in our country is genrally high and the waste is not considered for technical means. Many researchers have made their research travel by using banana fibres as an option to use as reinforcement in composite materials . Banana fibres have been used in many other applications in making commercial products in many number of countries . Industries such as Automotive, Aersospace, Contrsution and many other are considerring banana fibre as reinforcement for making composite products and observed a good response in their desired applications. The figure no 3.1 shows the banana fibre used in the present study.

Fig No 3.1 Banana Fibre

3.2 Coconut Fibre

The usage of coconut for our day to day food preparation makes our recipes tasty and also provides a healthy dish in many aspects. The fibres that coves the coconut has appreciable properties to use as a reinforcement in making composite materials. The fibres that are present in the outer shell are generally taken for making bags, mats, mattresses, gift items and toys. The commercially available coconut fibre ranges in length between 4-12 m. The coconut fibres can be used as a raw one in form to act as reinforcements in the composites. The coconut fibres are found to have good flexural strength than other natural fibres in consideration. The Fig No 3.2 shows the coconut fibre used.

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Fig No 3.2 Coconut Fibre

3.3 Glass Fibre

Glass fibres are in existence to act as reinforcements for composites materials for a long stint as they possess a reasonable comparative mechanical properties to their counterpart's carbon and polymer fibres. The popular fibreglass contains less or no air or gas present in it and it has a trade name in the composite field when getting adopted to make products made out of plastics called as Glass Fibre Reinforced Plastics. The glass fibres possess poor thermal insulation properties than glass wool. The major advantages of using glass fibres are found to be high energy saving, weight reduction , improved aerodynamic characteristics and reduced component numbers. The Fig No 3.3 shows the glass fibre used in the present study for making specimens.

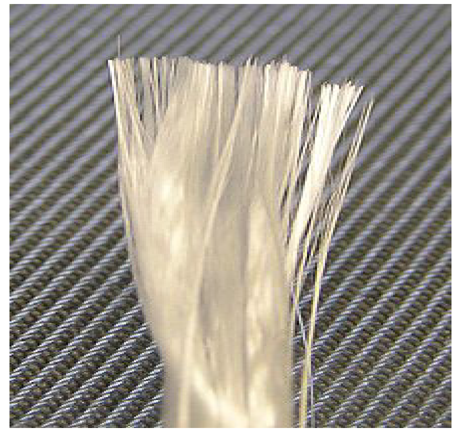


Fig No 3.3 Glass Fibre

3.4 EPOXY RESIN(LY 1556)

Epoxy resins in the form of liquid has been used for making composites with reinforcements such as banana, carbon and glass fibres. The epoxy resin finds application in the production of aerospace and marine structures where higher performance is the desirability. The superior properties possessed by the epoxy resin to its counterparts in case of mechanical, ease of processing make them suitable for making composite materials. Epoxy resins have shown good adhesive nature with fibre reinforcements than polyester resins. The reasons behind the selection of epoxy resin LY 1556 are due to less weight it provides and the good adhesive strength. The Fig No 3.4 shows the epoxy resin used in the present study for making composite specimens.

S.No	Property	Value	S.I Unit
1	Tensile Strength	85	N/mm^2
2	Tensile Modulus	10500	N/mm^2
3	Flexural Strength	112	N/mm^2
4	Flexural Modulus	10000	N/mm^2
5	Compressive Strength	190	N/mm^2
6	Water Absorption @ 24 Hrs	5 - 10	mg
7	Density @ 25 °C	1.15- 1.20	g/cm^3
8	Viscosity @ 25 °C	10000-12000	Mpa

Fig No 3.4 Epoxy Resin

The Table No 3.1 represents the properties of epoxy resin

3.5 HARDENER (XB 3403)

The viscosity at 25^0C is $5 - 20$ Mpas and the density at 25^0C is 1.0 g/cm^3. It is used for coating application where an exceptionally clear, moisture resistant, natural wood finish is desired and to produce a rapid cure that develops its physical properties quickly at room temperature. The Fig No 3.5 shows the hardener used in making specimens

Fig No 3.5 Hardener

Table 3.1 Properties of Epoxy Resin

3.6 Specimen Preparation

In the present work the specimens for conducting the experimental work are prepared by varying the resin and fibre content in percentage. Composite specimens were prepared with weight fractions of 60% of epoxy resin and 40% of coconut fibre; 60% of epoxy resin and 40% of banana fibre; 60% of epoxy resin and 40% of glass fibre. Intotal eight layers were prepared for each fibres. Epoxy resin and hardener were mixed uniformly on the surface of each fibre and the plates are prepared by using the compression moulding process. The plates were allowed for two days for drying. After getting dried, the plates were given for the testing purposes in the laboratory. The prepared specimens are further used utilized for conducting the testing process to evaluate the mechanical properties of the prepared specimen. The test results are further compared to understand the variation of mechanical properties in connection with the variation of specimen composition.

3.7 Tensile Testing

After fabrication, the specimens are subjected to various mechanical testing. The tensile strength of the fibre, matrix, fibre matrix interaction and fibre length. Tensile test specimens were made in accordance with ASTM A370 standard to measure tensile properties by universal testing machine. The test consists of applying constant strain on the fibre and measure the load.

(a)

(b)

(c)

Fig No 3.7 (a), (b) and (c) shows the loaded banana, coconut and glass fibre reinforced specimens for tensile testing

The Fig No 3.7 shows the various specimens prepared using natural and synthetic fibres for evaluating the tensile strength.

6.2 Three Point Bending Test

Bending strength is the capacity of a material or structure to withstand maximum load before fracture of the specimen in to parts. The specimen is loaded ta the centre and it is supported at two different points below the specimen like an overhanging beam on either sides of the support.The specimen undergoes a deformation at loaded area and finally attains fracture.The three point bending test is conducted as per ASTM A370

(a)

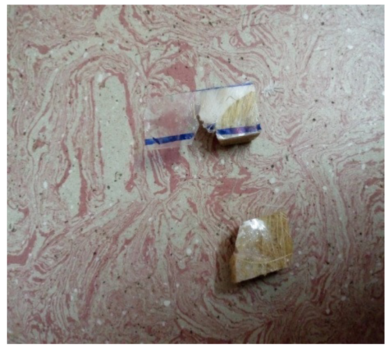
(b)

(c)

Fig No 3.8 (a), (b) and (c) shows the loaded banana, coconut and glass fibre reinforced specimens for bending test

6.3 Impact Test

The impact test are done as per ASTM D256 using an impact tester. The charpy impact testing machine has been used for measuring the impact strength. The Fig 3.8 (a), (b) and (c) shows the fractured banana, coconut and glass fibre reinforced specimens after charpy impact testing



(a)

(b)

(c)

Fig No 3.8 (a), (b) and (c) shows the fractured banana, coconut and glass fibre reinforced specimens after charpy impact testing

4. Results and Discussion

The experimental results are further tabulated for all the three different composite specimens made out of banana, coconut and glass fibre reinforcements. The experimental values are compared and it is found that the tensile strength, bending strength and impact strength of glass fibre is superior than natural fibres. The natural fibre coconut has shown better results in case of tensile strength than banana fibre and banana fibre has higher bending strength than coconut fibre. The table 3.2 shows the various observed mechanical properties of different fibres considered in the present study.

Table 3.2 Observed Mechanical Properties of Different Fibres

S.no.	Fibre	Bending Strength (MPa)	Tensile Strength (MPa)	Impact Strength (J)
1	Banana fibre	0.579	1.377	2
2	Coconut fibre	0.501	3.384	4
3	Fibre glass	1.04	13.797	6

5. Conclusions

From the experimental work carried out the following points may be arrived for concluding the present study.

1. The evaluation of tensile strength of the composite specimens made out of fibres such as coconut, banana and glass fibre reinforcement has revealed that the tensile strength of coconut fibre is higher than banana fibre by 59% and lesser than glass fibre by 75.4%. Both the natural fibre reinforcements have shown lesser tensile strength than glass fibre.
2. From the results of three point bending test, the bending strength of coconut fibre is less than banana fibre by 13.47% and lesser than glass fibre by 51.8%,
3. The impact strength of glass fibre was found to be higher than coconut fibre by 33% and banana fibre by 66%.
4. The glass fibre is found to have the superior mechanical properties than the natural fibres considered in the present study.
5. The experimental wok carried out for the less number of specimens may be avoided by extending the study by adopting experimental design by varying the levels of input variables suitably.

6. The optimization study may be included for the identification of significant input variable and optimized parameter setting for the enhancement of properties may be considered.

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