

Physical Properties of Glass-Hemp-Banana Hybrid Fiber Reinforced Polymer Composites

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Abstract

Background/Objectives: In this experimental work the effect of mechanical properties on incorporation of glass fibre with treated banana-hemp fibres has been studied. **Methods/Statistical analysis:** Banana and hemp fibres are extracted by enzymatic processes for successfully removing lignin. The alkaline solution was used to treat the fibres since it increases their mechanical strength. The banana, hemp and glass fibres were reinforced with the epoxy matrix and the hybrid composites were fabricated by using hand layup process. Alternative orientations of fibres were used for the fabrication of the laminates in order to improve their strength. **Findings:** As per the ASTM standards, test specimens were prepared from the laminates with the stacking sequence of glass/banana fibre, glass/hemp fibre and glass/banana/hemp fibre. The mechanical characteristics were obtained by impact test, tensile test and flexural test for the fabricated samples. The interfacial analysis was conducted using scanning electron microscope to estimate voids, fractures and fibre pull out. The experimental result shows that the glass/banana/hemp fibre composite exhibits maximum tensile strength than the other two combinations. The hemp-glass fibre composite holds the maximum flexural strength followed by glass/hemp/banana fibre composites. The glass/banana fibre composites hold maximum impact energy and the value of the composites varies from 7.33 to 9.33 Joules. **Application/Improvements:** These composites are performing well in all kind of mechanical loadings. It is suggested that these materials can be used in the relevant fields.

Keywords: Alkaline Treatment, Banana Fiber, Hemp Fiber, Mechanical Properties, SEM Analysis

1. Introduction

In the field of science and technology the synthetic and natural fiber reinforced hybrid composite materials are highly preferred because of their superior properties. The natural fibers have excellent properties such as low density, high strength, low price, easy availability, thermal

and acoustic insulation and environmental friendliness¹⁻⁵. The production and use of synthetic fibers are creates lot of environmental issues. Synthetic fibers are replaced with natural fibers to reduce the cost of the composites without affecting the mechanical properties. Most of the researches attempts were made to improve the mechanical strengths of composites, fiber reinforcements and its

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matrix, new composite sample processing methods and new techniques in modelling etc⁶. The mechanical properties such as tensile strength, flexural strength and impact energy of the banana-glass fiber, hemp-glass fiber and hemp-banana-glass fiber hybrid laminates were evaluated and investigated. The synthetic fiber reinforced hybrid composite materials are replaced by hemp-banana-glass fiber hybrid epoxy composites. The morphological and interfacial properties of these laminates are studied by means of SEM analysis⁷.

The mechanical strength of bamboo, banana and sisal natural fiber composites were investigated and compared. The flexural and tensile modulus of vakka, banana and glass fibre composites was investigated. The vakka/ glass fiber composites hold maximum flexural modulus than that of the banana fibre reinforced composites. It is noted that the tensile strength of vakka fibre composites increases with increase in fibre volume fraction⁸. The mechanical strengths, thermal properties and water absorption characteristics of hybrid natural composite of jute and banana fibers are studied and compared. The different weight ratios have been followed to increase the mechanical strengths with incorporation of banana fiber with jute fiber. The experimental results of jute-banana-epoxy fibers composites upto 50 percentage of fiber weight shows that the increased mechanical strengths, thermal properties and decreased moisture content⁹. The musaceae/epoxy natural composites samples are prepared from woven banana fibers of different sizes. The experimental results of musaceae/epoxy composites shows that the maximum young's modulus and stress value along horizontal direction when compared with vertical direction¹⁰.

Due to the climate change and unbalanced environmental conditions the physical and geometrical properties of the fibers are affected. The effects of chemical treatment on the fibers and related tensile strengths were studied. The variation in fibers diameter and the corresponding tensile properties of treated fibers has been differentiated¹¹.

The thermo-mechanical properties of hemp fibers were performed by using a dynamic mechanical analyzer with the temperature range between 20°C to 220°C at a frequency of 1 Hz. When a periodic stress is applied to the fiber, there is an increase in the rigidity of the fibers during the initial stress related to structural rearrangements in the fiber¹². The visco-elastic properties are achieved because of thermal activation from the temperature 30°C to 200°C. The chemically treated banana fibre samples were analyzed by conducting dynamic mechanical analysis and the results were compared and analysed with

unmodified hybrid composites. The increased dynamic modulus and reduced damping readings shows the better interactions between the matrix and fiber¹³. The glass fibre/polyester hybrid composites were prepared with 45° orientation and the results were analysed by conducting the fatigue and impact tests. The degradation of tensile modulus and damage accumulation of different samples were studied. From these analyses it was found that the glass fibre reinforced composites can withstand the higher fatigue as well as impact strengths than the hemp fibre reinforced composites¹⁴.

The distribution of stress induced by thermal shock of ceramic matrix composites has been analyzed by using FEA with single layer coating. The stress distribution characteristics and the orientation relationship between the orthogonally arranged fibers, possible failure patterns and failure mechanism of the coated and uncoated composites has been studied in detail¹⁵. The experimental studies were made to evaluate the physical properties and mechanical strengths of composites where hemp fiber is used as reinforcement. The result shows that the hemp fiber can be used as reinforcement in synthetic hybrid composites. The effect of high moisture content, changes in fiber strengths and improper fiber mixture interfacial property also studied¹⁶.

The mechanical properties and effects of interfacial damage of hemp fiber reinforced starchy composites were studied by using digital image acquisition tensile test experiment. The single fiber thermo-moulded composites were designed to conduct sample testing normal to the direction of fibre alignment. The finite element analysis is carried out to explain the localised damages and weak adhesion between the phases¹⁷. The interfacial shear properties between hemp fibre and polypropylene composites were evaluated by using single fibre pull-out method and critical length of the composite grade hemp fibre has been calculated. The results of tensile modulus and strength of the hemp fibre reinforced polypropylene composites were reported by using Kelly-Tyson and Cox-Krenchel models. The model and experimental results were compared and validated based on volume fraction and length of hemp fibres¹⁸. In this experimental work the authors mainly focus in alkali treated hemp fibre reinforced composites by using compression moulding process. The long and short treated hemp fibres with different percentage of weight were used to prepare the composites. The mechanical properties of these composites were investigated and the results are compared by

conducting the flexural, tensile and impact tests. It was found from the comparison, that the 30 percentage of weight long aligned alkali treated hemp fibre reinforced composites has shown superior mechanical properties¹⁹.

The mechanical properties of pineapple leaf fiber reinforced polycarbonate composites were studied. The leaf fiber surfaces were treated with alkali solution and incorporated with two different functionalities such as c-aminopropyl trimethoxy silane and c-methacryloxy propyl trimethoxy silane. The treated pineapple leaf fibers laminates holds the highest Young's modulus than other two laminates. The modified c-aminopropyl trimethoxy silane laminates holds the maximum tensile and impact properties compared with c-methacryloxy propyl trimethoxy silane laminates. The thermo gravimetric studies were carried out to investigate the thermal stability of pineapple and neat polycarbonate resin composites. The morphological characteristics of pineapple fiber reinforced polycarbonate composites were observed and investigated by conducting SEM and Fourier transform infrared spectroscopy analysis²⁰.

The kinetic properties of untreated and treated sisal fibers has performed and studied by using broido method. It has been found that, the decreased thermal stability of the medium increases fiber content of the composites. The treated hybrid laminates has more thermal stability than the unmodified hybrid laminates. The thermal property has shown the significant improvement and decreased moisture property of treated laminates incorporated for high adhesion fiber and the matrix to improve the mechanical properties. The analysis and infrared studies were carried out to investigate the physical and morphological characteristics of sisal fiber²¹.

2. Experimental

2.1 Raw Materials

In this experimental study, hemp and banana hybrid composite laminates are fabricated with the reinforcement of glass fiber. The different fiber orientations are used to fabricate the hybrid laminates. The physical and mechanical strengths of banana, hemp and glass fibers are shown in the Table 1. The epoxy resin and hardener are supplied by Sakthi fiber glass Limited in Chennai. The fibers like banana, hemp and glass fiber are supplied by Chandra Prakash and company at Jaipur in India.

Table 1. Properties of banana and hemp fibers¹

Property	Hemp	Banana
Density (kg/cm ³)	300-1300	1350
Tensile strength (MPa)	90	54
Flexural modulus (GPa)	3-5	2-5
Young's modulus (GPa)	4.4	3.48
Moisture absorption (%)	10-12	10-11

2.2 Processing of Composites

The different base plates surface were cleaned with a thinner solution and the silicon gel is applied surface of the base plate. The solution was mixed with water in proper proportions in order to maintain a mixture ratio of composition 5% of NaOH solution in water. Once the mixture is prepared, both banana and hemp are separately kept immersed in the solution. The treatment was kept un-disturbed for 72 hours.

Then the fibers are taken out from the solution to remove the moisture content and kept under the controlled atmosphere for more than 48 hours. The hardener and epoxy resin are mixed in the ratio of 10:1 and stirred 30 minutes. The laminates are fabricated by using hemp-banana-glass fibers with epoxy resin by using hand lay process. Each laminates consisting of five layers of fibers with alternate orientation and fabricated the dimensions of 300×300×6mm. The laminates were kept under the load in the compression moulding machine for curing for 12 hours.

3. Mechanical Properties

3.1 Tensile Strength

The tensile test specimen of the hemp-banana-glass fibre hybrid laminates were prepared and tested as per ASTM D 638 standards. Three sets of test specimens were used for testing from each composite laminates. The computer controlled UTM is utilized to carry out the test by means of applying load on the test specimen and the readings were noted. The same methodology is followed for the remaining test specimen of banana-glass fibre and hemp-glass fibre to obtain the average tensile strengths for the further analysis

3.2 Flexural Strength

There are three different flexural strength test specimens of the hemp-banana-glass fiber reinforced hybrid laminates were prepared with the standard of ASTM D 790. Then the specimens were tested by using the computer controlled UTM by applying flexural load. The flexural strength readings and displacement of each sample of these composites were observed for the comparison of results.

3.3 Impact Strength

As per the ASTM A370 standard, the three different test samples of hybrid composite laminate reinforced with glass, hemp and banana fibers were prepared. The maximum impact energy of each test samples of hybrid composite laminates were tested by using computer controlled impact energy testing machine. The impact energy readings of each sample of these composites are observed for analysis of results.

4. Results and Discussion

Most of the research works are focusing to replace the traditional materials without affecting the load carrying capacity and price with the chemically treated hybrid composites in the field of engineering and technology. The hybrid laminates were prepared as per ASTM standards for this experimental study by incorporation of glass fiber with chemically treated banana and hemp fiber. Then the test specimens underwent tensile strength test, three point flexural strength tests and impact strength test by using the UTM and charpy impact energy testing machine. Finally the test readings of the hybrid composites specimens were noted and shown in Figures 1-3.

4.1 Tensile Property Analysis

The tensile test specimens of different combinations of hybrid composite laminates of glass, hemp and banana fibers were tested in the universal testing machine and the results were presented in the Figure 1. From the graph it can be noted that the banana-hemp-glass fiber combination showed better tensile strength which holds the maximum tensile strength of 60.99 MPa followed by glass/banana-fiber reinforced hybrid composites which holds the tensile strength of 60.45 MPa.

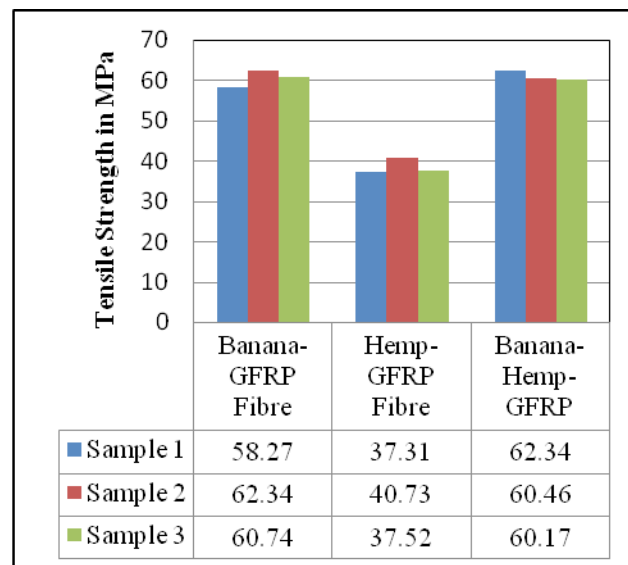


Figure 1. Tensile strength comparison of hybrid laminates.

4.2 Flexural Property Analysis

The flexural strength values of tested specimen of chemically treated hybrid laminates are presented in the Figure 2. From this figure it can be noted that the hemp-GFRP fiber laminates holds the maximum flexural strength of 1.20 KN followed by hemp-banana-GFRP treated hybrid laminates hold the value of 1.17 KN. From the above listed values the hemp-GFRP and hemp-banana-GFRP laminates serves better than banana-GFRP laminates in real applications.

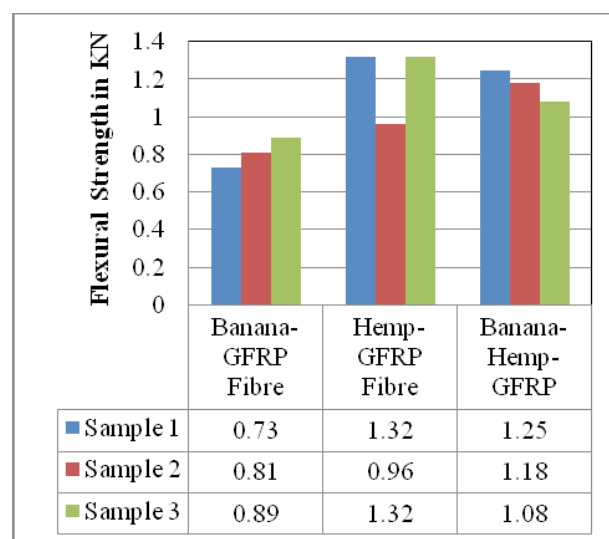


Figure 2. Flexural strength comparison of hybrid laminates.

4.3 Impact Property Analysis

The impact property of different chemically treated hybrid composite laminates were observed by using charpy- impact energy testing machine and the values are presented and compared in the Figure 3. The results showed that the banana-GFRP composites absorb the maximum value of 9.33 joules followed by hemp-banana-GFRP and hemp-GFRP composite laminates hold the same value of 7.33 joules.

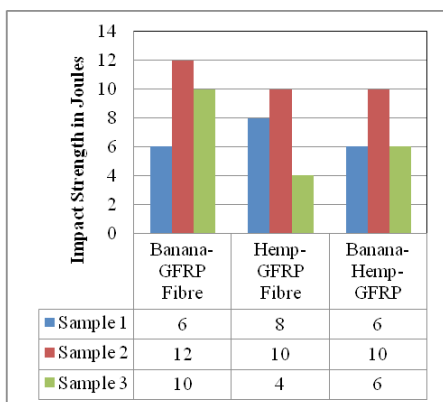


Figure 3. Impact strength comparison of hybrid laminates.

4.4 Morphological Property Analysis

The morphological characteristics of the tested chemically treated hybrid laminate specimens were studied by using scanning electron microscopy. The SEM images of the tested hybrid laminate samples are shown in the Figure 4-6. From the micrographs of SEM analysis, the morphological properties like fiber breakage, fractured edge of fiber, fiber pull out, dislocation of fiber and orientation of the fiber of each tested specimen and matrix due to mechanical loading were studied.

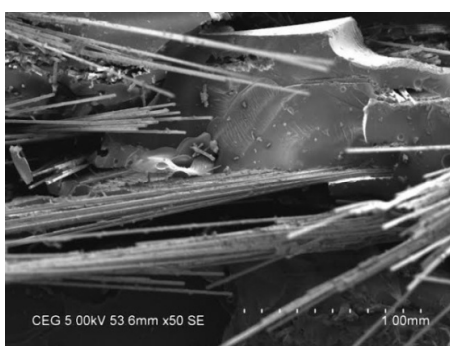


Figure 4. SEM micrograph of the composite sample subjected to tensile loading.

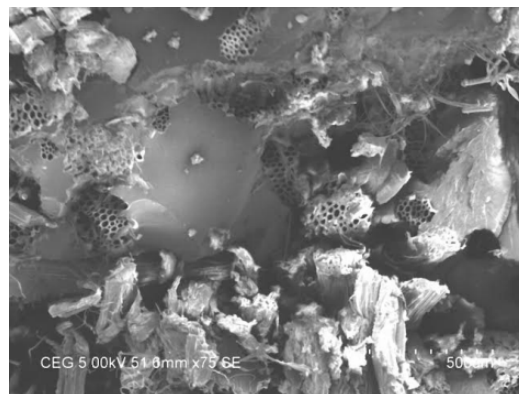


Figure 5. SEM micrograph of the composite sample subjected to flexural loading.

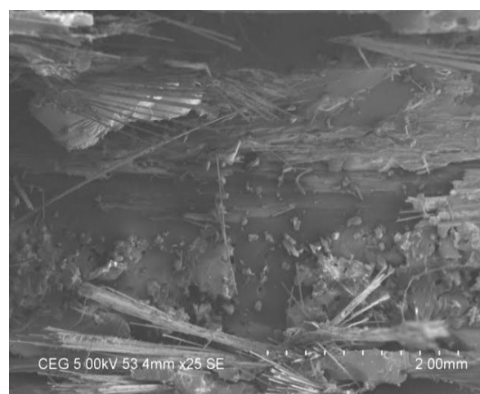


Figure 6. SEM micrograph of the composite sample subjected to impact loading.

5. Conclusion

Based on the values obtained from the various tests, the mechanical strengths of the chemically treated hybrid composite materials were evaluated and analyzed in detail. The results of the experimental study are as follows.

- The chemically treated hemp-banana-glass fiber hybrid laminates hold the high tensile property than other two combinations. It holds the maximum tensile property of 60.99 MPa followed by the chemically treated glass-banana fiber hybrid laminates which has the tensile property of 60.45 MPa.
- The chemically treated hemp- glass fiber hybrid laminates holds the maximum flexural property of 1.2 KN and followed by chemically treated hemp-banana-glass fiber hybrid composites has the flexural property of 1.17 KN.

- The energy absorbed by the hybrid composites during impact test varies from 7.33 to 9.33 Joules.
- The interfacial analysis was done by using scanning electron microscope to observe voids, fractures, fibre pull out and dislocation of fibres were clearly seen.
- Based on the experimental results, it is suggested that the chemically treated hemp-banana-glass fibers hybrid composites can be used instead of synthetic fibers in polymer composites.

6. References

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