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EVALUATION OF MECHANICAL PROPERTIES OF ABACA-GLASS-BANANA FIBER REINFORCED HYBRID COMPOSITES

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Abstract: This work deals with fabrication and investigation of mechanical properties of natural fibres such as abaca and banana fibre and compares with the hybrid natural fibre composite. Tensile, flexural and impact strength of the composites are investigated in the process of mechanical characterisation. The Reinforcement material used is a by-product of epoxy resin namely Bisphenol-A. Hand lay-up technique is used to manufacture the composite and the fibre content is varied through volume fraction of upto 0.5. Glass fibre on top and bottom layers of the laminate improves its surface finish and adds up strength. The Natural fibre is sandwiched in intermediate layers with the glass fibre. It is found that Abaca-Glass composite is found to have better tensile strength than the other two combination and Abaca-Glass-Banana Hybrid Composite is found to have better Flexural strength and Impact value.

Keywords : Abaca fibre, banana fibre, Bisphenol-A, Glass Fibre

I. INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Fiber reinforced polymer materials are composites consisting of high strength fibers (reinforcement) embedded in polymeric matrices. Fibers in these materials are the load-carrying elements and provide strength and rigidity, while the polymer matrices maintain the fibers alignment (position and orientation) and protect them against the environment and possible damage. A pure polymer does not usually have requisite mechanical strength for application in various fields. The reinforcement by high strength fibers provides the polymer substantially enhanced mechanical properties and makes the fiber reinforced polymer composites (FRPCs) suitable for a large number of diverse applications ranging from aerospace to sports equipment. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The topic of interest here are two natural fibres namely Abaca and Banana fibres which are available abundantly in tropical India.

There have been a lot of works carried out in both the fibres individually which eventually resulted in positive results for various applications. Md. Rezaur Rahman et al., (2009) analyzed treated and untreated Abaca fibre reinforced with PP composites and found out that cases, the tensile strength of the treated abaca-PP composites is found to be higher than that of the composites of untreated abaca. For treated abaca composites, 15% abaca filled composite showed the highest tensile strength and then gradually decreased with further increases in filler loading. In both cases, Young's modulus, flexural

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strength, flexural modulus, impact strength and hardness values are also found to increase with an increase in filler loading. Bledzki et al., (2008) analysed PLA bio composites with abaca and man-made cellulose fibres and found the Charpy impact strength at ambient temperature increased by factor 3.60. Tensile strength rose by factor 1.45. Reinforcing with abaca fibres (30 wt%) enhanced both E-Modulus and tensile strength by factor 2.40 and 1.20 respectively. Vijay Ramnath et al., (2013) treated abaca, jute fibre with epoxy resins and found out that the abaca composite has very high impact strength.

The hybrid composite of Abaca-Jute had better tensile, flexural and shear strength when they maintained a volume fraction of about 0.4 %. Marissa A. Paglicawan., et al., (2013) analyzed tensile properties and water uptake behavior of plasma treated abaca fibers reinforced epoxy composites. The composites were prepared by vacuum assisted resin transfer molding. The effects of treatment on tensile properties and absorption characteristics of abaca fiber composites in distilled water and salt solution at room temperature were investigated. The tensile strength of the composites increased with plasma treatment. With plasma treatment, an improvement of 92.9% was obtained in 2.5 min exposure time in plasma.

Rajesh Gosh et al., (2011) used Banana fibres as reinforcement in Vinyl ester resin matrix. The influence of different volume fraction of the fibres in the composite is studied. It is seen that with the increase in the fibre fraction, the tensile strength have increased after an initial dip. At 35% of fibre volume fraction, an increase of 38.6% in tensile strength is noted. The specific tensile strength increased by 65%. With increase in mechanical properties it can be deduced that banana fibre can be reliably reinforced with vinyl ester resin which may be used in engineering utilities. S.Ragavendra., et.al., (2013) analysed the “Mechanical Properties of Short Banana Fiber Reinforced Natural Rubber Composites “and found out that increase in fiber concentrations improves the tensile strength. When fibre concentrations are less the matrix and fiber interface shows weak bonding. The incorporation of fibre into rubber matrix increases the hardness of the composite, which is related to strength and toughness. Using different surface modifications of fiber the strength of the composites can be increased. Sumaila et.al., (2013) found out the effects of Banana fibre length on the physical and mechanical properties of banana fibre /epoxy composite. Five different samples were produced by varying the length of the fibre between 5mm and 25mm at 30% wt. fibre loading using the hand lay-up moulding technique. The results showed that the percent moisture absorption, void content and the compressive strength increased with increase fibre length while a decrease in density was observed.

Vinod B., et.al., (2013) found out the “Effect of Fiber Orientation on the Flexural Properties of PALF Reinforced Bisphenol Composites” and said that the fiber orientation greatly influences the flexural properties of reinforced composites. A higher flexural strength of 105.5754 Mpa was obtained for inclined orientated fibers compared to that of Uni-directional & Bi-directional oriented fibers. The natural fibre with glass allows a significantly better heat and transport ability for the composites. Cicala et.al, (2009) have studied the properties and performance of various glass/natural fibre composites for the applications in curved pipes. Natural fibres are lighter and cheaper, but they have low mechanical properties than glass fibres. The use of hybrid fibres may solve this issue. Paul wambua et.al, 2003 analysed can natural fibres replace glass in fibre reinforced plastics. He concluded that specific properties of natural fibre composites were in some cases better than those of glass. These papers were analyzed in depths and found out that Abaca fibre and Banana fibre are suitable fibre materials. The reinforcement matrix material used is Bisphenol-A which is a by-product of epoxy. The mechanical properties were found out at .4 and .5 percentage of volume fractions and compared to show the best variation found after reinforcement.

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II. EXPERIMENTAL SETUP

A. MATERIALS

Experimental setup includes synthetic fibre woven Roving Glass Fibre (E glass type) with a density 610 g/cm^3 . Two natural fibres namely Abaca (Manilla hemp) and Banana (*Musa balbisiana*) has been used for fabricating the composite. Bisphenol-A resin has been obtained from S&S polymers, Chennai has been used as a resin.

ABACA FIBERS : Abaca fibre is obtained from the pseudo-stem of the plant. It is obtained from a plant belonging to the banana family. On an average, the plant grows about 12 feet (4 m) tall and the fibre is extracted from the trunk of the plant. The fibres are extracted from the base of the banana leaf. It is a bast fibre and is also known as Manila hemp. These fibres are generally used to make twines and ropes but nowadays it is gaining importance as a good reinforcement for composite materials. Since it is cheap, it is used for industrial and commercial purposes.

BANANA FIBRES : Banana fiber is a multiple celled structure. The lumens are large in relation to the wall thickness. Cross markings are rare and fiber tips pointed and flat, ribbon like individual fiber diameter range from 14 to 50 microns and the length from 0.25 cm to 1.3 cm, showing the large oval to round lumen. Banana fiber is a natural fiber with high strength, which can be blended easily with cotton fiber or other synthetic fibers to produce blended fabric & textiles. It is mainly used by cottage industry in Southern India at present. Banana Fiber also finds use in high quality security/ currency paper, packing cloth for agriculture produce, ships towing ropes, wet drilling cables etc.

BISPHENOL RESIN : Bisphenol-A (BPA) is an organic compound which belongs to the group of diphenyl methane derivatives and Bisphenol. The chemical formula is $(\text{CH}_3)_2\text{C}(\text{C}_6\text{H}_4\text{OH})_2$. BPA is used to make certain plastics and epoxy resins, it has been in commercial use since 1957. To improve the rate of the reaction, an accelerator and a catalyst are added to the original matrix material.

B. FABRICATION DETAILS

The following procedure is followed for fabricating the composite by preparing the mould initially followed by the preparation of resin and finally hand moulding is done to obtain the required specimen.

MOULD PREPARATION : To prepare the composite the glass fiber is cropped into a required number of plies of size 350x350 mm. The technique used is hand layup process. The glass fiber is kept in the top and bottom most layer of the laminate. The natural fibers are chopped to minimal desired length to be kept in intermediate layers between the glass fibers. The natural fiber weighing around 15-20 grams is spread in the laminate. In Abaca-glass composite and Banana-glass composite the plies are aligned in the order of intermediate glass fiber and natural fiber which constitutes totally 7 plies (4 plies of glass fibers and 3 plies of natural fiber). Likewise in Abaca-Banana-glass composite the plies are aligned in the order of intermediate glass fiber and natural fiber which constitutes totally 9 plies (5 plies of glass fibers and 2 plies of sisal fiber and 2 plies of coir fiber).

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PREPARATION OF RESIN : The matrix used to fabricate the fiber material is Bisphenol-A polyester having a density of 1.10 g/cc. To improve the rate of the reaction, an accelerator and a catalyst are added to the original matrix material. The methyl ethyl ketone peroxide (MEKP) is added as a catalyst and cobalt naphthanate is added as an accelerator, in the ratio 1:0.02:0.02. The solution is mixed and stirred before applying on the laminate.

FABRICATION PROCEDURE FOR SPECIMEN: To prepare the composite a mica sheeted table is used. The table is cleaned with distilled water to remove the impurities. Then a coat of wax layer is applied through out the board to facilitate easy removal of the laminate. Prior to the moulding process, an acid solution of poly vinyl acetate is applied on the surface of the table which acts as a releasing agent. This is followed by a dwell time of 5-10 minutes for the table to get dried. A coat of mixed resin is applied on the cleaned surface before placing a layer of glass fiber. Alternate layer of natural fiber is kept with a coat of resin over it. Consequent layers of natural and glass fiber are placed till the required thickness is obtained. The finished composite now is closed by wooden reapers and clamped at all the possible ends. Then a load of 50-60 kg is applied. The composite is made to cure for 48 hours under hot conditions. After curing the composites are sized according to ASTM standards.

C. TESTING OF COMPOSITES :

TENSILE TEST: The fabricated hybrid composite is cut using a saw cutter to get the dimension of the specimen for tensile testing as per ASTM: D638 standards. The test is carried out in universal testing machine make FIE (Model : UTN 40, SNo , 11/98- 2450) at room temperature (303K) . The test was carried out using a universal testing machine at a room temperature with 40% relative humidity. The tensile stress is recorded with respect to increase in strain. Three different types of specimens are prepared based on fibres used namely, abaca-GFRP, banana-GFRP and abaca-banana-GFRP (hybrid composites). The specimen was placed in the grip of the tensile testing machine and the test is performed by applying tension until it undergoes fracture. The corresponding load and strain obtained are plotted on the graphs.

FLEXURAL TEST : The flexural test is performed on the same tensile testing machine as per the ASTM: D790 standards. It is performed at room temperature and close to 40% relative humidity for three different types of specimens. In this test, the specimen to be tested is subjected to a load at its midway between the supports and until it fractures and breaks. This test determines the behavior of the specimen when it is subjected to simple beam loading. Flexural test determines the maximum stress induced in the outer most fibre.

When a beam of homogeneous, elastic material is tested in flexure as a beam simply supported at two points and loaded in midpoint, the maximum stress at the outer surface occurs at mid span.

The stress may be calculated from following equation

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

where :

σ – stress at the outer surface of mid-span, Mpa

P – applied force , N

L = support span , mm

b= width of beam, mm

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h=thickness of beam, mm

Flexural modulus could be found by the ratio of stress to strain in the flexural deformation. It determines the tendency of the material to bend. In the 3 point testing of the material the flexural strength could be found out by secant method where initial strain point is zero. It is expressed in MPa . It can be calculated by using the formula

$$E_f^{secant} = \frac{L^3 m}{4bh^3}$$

Where,

E_f - flexural secant modulus of elasticity, Mpa

L – support span, mm

b – width of the beam, mm

h – thickness of the beam, mm

m – slope of the secant of the force-deflection curve

IMPACT TEST : The impact specimen are prepared according to the required dimension following the ASTM-A256 standard. The test is carried out in Izod setup . During the testing process, the specimen must be loaded in testing machine and allows the pendulum until it fractures or breaks. Using the impact test, the energy required to break the material can be measured easily and can be used to measure toughness of the material and the yield strength. The effect of strain rate on fraction and ductility of the material can be analyzed by using the impact test. The energy measured would be in Joules. The impact strength can be found by using the formula

$$I = \frac{K}{A}$$

Where,

I – Impact strength (KJ/m²)

K- Energy required to break the specimen (J)

A –Area of cross section (cm²)

III. RESULTS AND DISCUSSIONS

A. TENSILE PROPERTIES

The three different composite specimens like Banana–GFRP, abaca-GFRP and abaca–banana–GFRP are tested in the universal testing machine to find the tensile properties. The various mechanical properties of the fabricated composite (abaca–GFRP, banana–GFRP, abaca–banana–GFRP) are summarized for better comparison. It is clearly seen that the tensile strength of the abaca composite is high in Fig.11. The tensile modulus of Abaca-Glass composite is higher than that of abaca and banana hybrid composite. The tensile modulus is calculated by taking the corresponding values of stress and strain from the linear portion of the graph. The stress increases linearly with respect to strain for all the composites as shown in the Fig. 10.The abaca-glass composite exhibits the ductile properties with the stress starting to decrease and the

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topmost point resemble the yield point of ductile material. Thus it can be concluded that the Abaca-Glass composite is more ductile than the Hybrid fibre composite. All the composites are manufactured at the highest volume fraction of 0.50. The breaking load of abaca-banana composite is found to be high. It is found that breaking load of abaca glass composite is 1.12 times higher than the hybrid composite and 2.02 times higher than banana glass composite. The percentage elongation of abaca glass composite is found to be higher than other composites, hence it is found to be more ductile in nature. From the results of the tensile test, it can be concluded that the Abaca-GFRP composite is well performing compared with other types of composites.

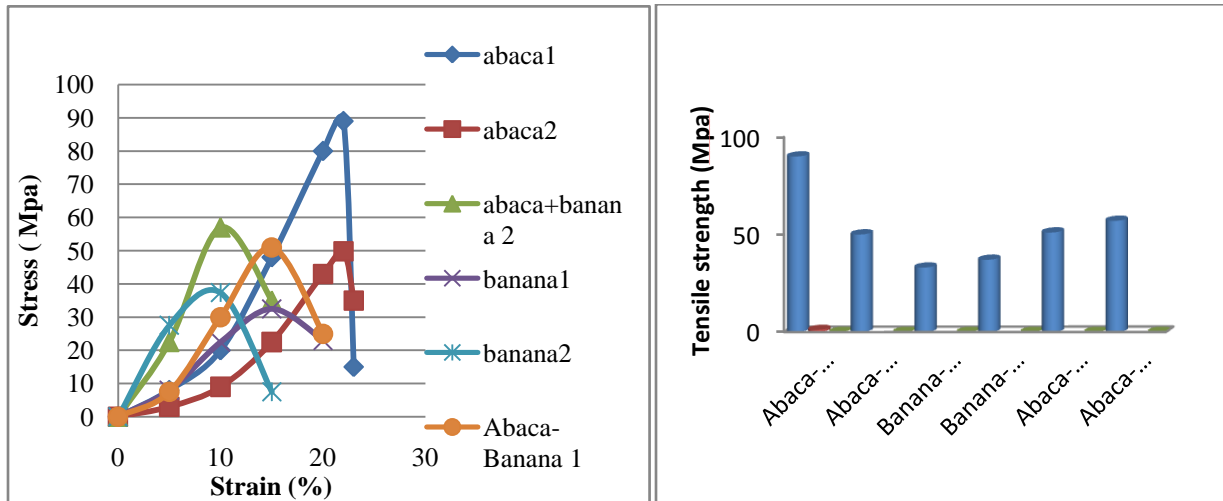


Fig 1 : Stress-Strain graph for Tensile loading

Fig 2 : Tensile strength for each specimen

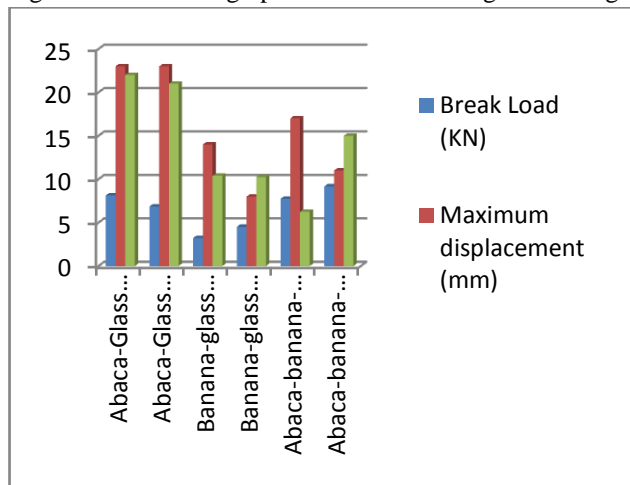


Fig 3 : Comparison of tensile test results

Fig 4 : Tensile Specimen

B. FLEXURAL PROPERTIES

The Load vs Displacement curve for three different types of composites is shown. The flexural property of Abaca-Glass composite is high. The curve increases linearly with respect to displacement up to the maximum flexural load and then it gets decreased. The adhesion between the Abaca and glass with Bisphenol polyester is far better than the other two combinations. The flexural modulus of the composite is found from the linear portion of the curve by determining the load and its corresponding displacement which shows Abaca-glass hybrid composite has highest flexural modulus when compared to other two composites.

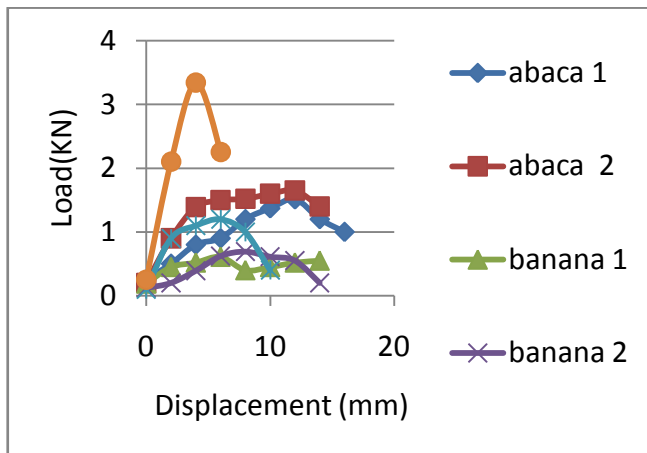


Fig 5 : Flexural strength variation



Fig 6 : Flexural Test Specimen

C. IMPACT TEST

Impact test is conducted to analyse the impact capability of the different specimens. The impact test is carried out using Izod impact test machine to determine the loss in energy. The Banana-Glass hybrid composite has high impact strength. The reason for such high strength is due to the presence of single type fibre in the matrix in alternating directions. The energy absorbed by each specimen when it is impacted by a heavy blow from pendulum crack is formed. The crack usually travels through the fiber and resin of the composite. So when crack propagates through the composite absorption of energy will be high.

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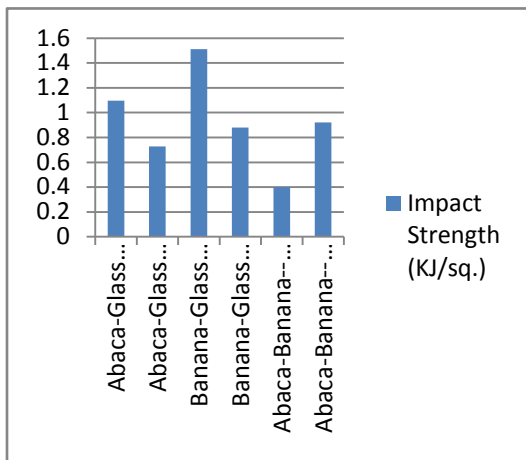


Fig 7 : Impact Strength variation

Fig 8 : Impact test Specimen

TABLE 1: EXPERIMENTAL VALUES OF THE ENTIRE TEST CONDUCTED FOR EACH SPECIMEN

Sample Number	Tensile Strength (MPa)	Flexural Load (MPa)	Impact Energy (Joules)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (MPa)	Impact Strength (KJ/sq.m)
Abaca-glass (40%-60%)	89.36	1.51	10	366.5	142.22	2840	1.098
Abaca-glass (50%-50%)	49.80	1.65	10	273.33	70.153	3266	0.727
Banana-glass (40%-60%)	33.06	0.61	14.66	250	65.270	1506	1.511
Banana-glass (50%-50%)	37.33	0.69	10.66	500	37.25	1234	0.88
Abaca-Banana-glass (40%-60%)	51.68	1.20	6	312.5	50.187	1595	0.40
Abaca-Banana-glass (50%-50%)	57.32	3.34	14.66	325	106.82	433	0.922

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IV. CONCLUSIONS

- In this work, different natural fibre composites are fabricated with fibres like Abaca, banana and combining them as well. All the composites have the highest volume fraction of 0.50 along with GFRP. Their mechanical properties like tensile strength, flexural strength, shear strength and impact strength are investigated and from the results obtained, the following conclusions were drawn.
- The tensile strength of abaca composite is the relatively more than abaca and banana composite and much higher when compared with banana composite. It has a value of 89.30 N.
- The percentage elongation of single fibre in tensile testing is found to be more than that of the hybrid composite. Therefore, the single composite withstands more strain before failure in tensile testing than the hybrid fibre composite.
- The flexural strength of the composite is in decreasing order from banana, abaca and banana hybrid, abaca composite. Abaca has the highest flexural strength since its strength increases with increase in interfacial adhesion. Flexural modulus is also found to be highest for the abaca–GFRP composite.
- Impact strength of banana composite is 15 J which is quite high when compared with the abaca and hybrid composite whose impact values are 10 J and 12 J respectively.
- From the above results, the Abaca composite is found to be the best option for all general application. Banana composite can be used in applications where high impact strength is necessary. Abaca and banana fibres are abundantly available from agricultural resources; they are cheaper than the conventional natural fibres like bamboo, sisal, etc. Moreover they have high mechanical properties as discussed above and hence can be used for a variety of applications like housing, automobile and packaging industry, etc.

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