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Abaca Glass Fiber Reinforced Composite Materials

Vishal A[1], Vinay B G[2], Rajeev K T[3]

[1]B.E student, Dept. of Mechanical Engineering, RIT, Hassan, Karnataka, India.
[2]B.E student, Dept. of Mechanical Engineering, RIT, Hassan, Karnataka, India.
[3]Assistant Professor, Dept. of Mechanical Engineering, RIT, Hassan, Karnataka, India.

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Abstract - *Natural fiber composites are nowadays being used in various engineering applications to increase the strength and optimize the weight and the cost of the product. Hybridization is a process of incorporating synthetic fiber with natural fiber to get the better material properties. In this connection an investigation has been carried out to make better utilization of abaca fiber for making value added products. The objective of the present research work is to study the mechanical properties of abaca and glass fiber reinforced epoxy based composites. Experiments are carried out as per ASTM standards to find the mechanical properties of the composite materials. The effect of fiber loading and length on mechanical properties like tensile strength, flexural strength, Impact strength of composites is studied.*

***Key Words*: Abaca fiber, Glass fiber, Epoxy resin, Tensile test, Flexural test, Impact test.**

1. INTRODUCTION

Composites are combinations of two or more materials in which one of the materials, called the reinforcing material, is in the form of fibers, sheets, or particles, and are embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites are used because overall properties of the composites are superior to those of the individual components.

There is an emerging potential for natural fiber composites to become future replacement of many conventional materials such as metals and plastics. Among the general advantages of these natural fiber composites include low density, low cost, high toughness, reasonable specific strength, recyclability & biodegradability. In countries like India & China the production of rice and areca fibers is in abundance. Rice husk has found its application in composites, for example - rice husk reinforced concrete bricks areca fibers which is rich in fibers is used to provide good strengths to composites, for example areca fibers used to produce composites which have better electrical properties.

Currently natural fibers form an alternative for glass fiber, the most widely applied fiber in the composite technology. The advantages of the natural fibers over synthetic fibers such as aramids, carbon or glass fiber are low density. Nonabrasive high filling levels resulting in high stiffness etc. These natural fiber composites also possess other properties such as biodegradable, low cost, good thermal and acoustic properties. The environmental impact from the natural fiber composite is negligible as these are recyclable. The natural fibers also offer a possibility in developing countries to use their own natural resources in their composite processing industries. Natural fibers primarily consist of cellulose hemicelluloses, pectin and lignin. The individual percentage of these components varies with the different types of fibers. Cellulose is a semi crystalline polysaccharide and is responsible for the hydrophilic nature of natural fibers. Hemicelluloses are a fully amorphous polysaccharide with a lower molecular weight compared to cellulose. The amorphous nature of hemicelluloses results in it being partially soluble in water and alkaline solutions. Pectin, whose function is to hold the fiber together, is a polysaccharide like cellulose and hemicelluloses. Lignin is an amorphous polymer but unlike hemicelluloses, lignin is made of aromatics and does not show any effect on water absorption.

1.1 Abaca Fiber and It's Extraction

Before The botanical name of abaca is Musa Textilis which is a species of banana grown extensively in Philippines. It is also called Manila hemp. Abaca plant belongs to the banana family Musaceae, Genus Musa and species Musa Textilis. The Republic of the Philippines is the largest producer producing around 50,000 tons per annum. It is mainly used in industrial cordage, handicrafts, fashion products such as hats and accessories, home and house ware and decorative products. Nowadays abaca shows promise as an energy-saving replacement for glass fibers in automobiles. Abaca fiber composites are used extensively in automotive industry.

The abaca/banana fibers are extracted from the pseudo stem of the banana plant (Musa species). These are growing up to 5–10 feet depending upon the region and climatic conditions. The length of the stalk depends upon the height of the plant and its width is about 3–5 cm with a thickness of 1–2 cm. The fibers are located at the outer sheath of the stalk. The qualified stalk of the plant is cut to a length of 100 cm and its outer sheath is removed. Then these sections are crushed between two roller drums with scraping blades at its circumference to remove the pulpy material between the fibers. The process of stripping the fibers from the stalk is known as tuxies. Finally the fibers are completely cleaned in water to remove the waste materials and then dried in sunshine for a few days to remove the moisture content.

2. PREPARATION OF COMPOSITES

2.1 Hand Lay-up Method

Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low. However, it is feasible to produce substantial production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates and consistent quality are obtainable. The fiber piles were cut to size from the groundnut shell. The appropriate numbers of fiber plies were taken: two for each. Then the fibers were weighed and accordingly the resin and hardeners were weighed. Epoxy and hardener were mixed by using glass rod in a bowl. Care was taken to avoid formation of bubbles. Because the air bubbles were trapped in matrix may result failure in the material. The subsequent fabrication process consisted of first putting a releasing film on the mould surface. Next a polymer coating was applied on the sheets. Then fiber ply of one kind was put and proper rolling was done. Then resin was again applied, next to it fiber ply of another kind was put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until alternating fibers have been laid. On the top of the last ply a polymer coating is done which serves to ensure a good surface finish. Finally a releasing sheet was put on the top, a light rolling was carried out. Then a 20 kg of weight was applied on the composite. It was left for 72 hrs to allow sufficient time for curing and subsequent hardening.

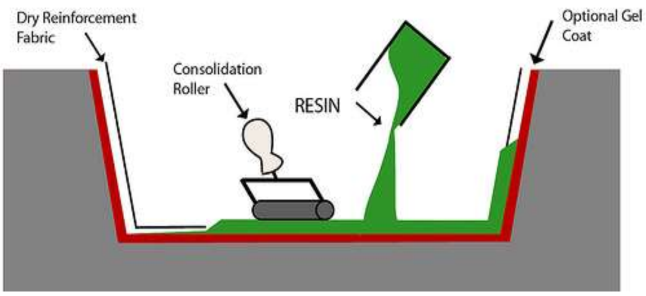

Fig-1: Schematic diagram of hand lay up process

2.2 Material Selection

Commercially available epoxy and hardener that is having the desirable properties to conduct this project will be used. The abaca or banana fibers are extracted from the pseudo stem of the banana plant. These are growing up to 5–10 feet depending upon the region and climatic conditions. The length of the stalk depends upon the height of the plant and its width is about 3–5 cm with a thickness of 1–2 cm. The fibers are located at the outer sheath of the stalk. The qualified stalk of the plant is cut to a length of 100 cm and its outer sheath is removed. Then these sections are crushed between two roller drums with scraping blades at its circumference to remove the pulpy material between the fibers. The process of stripping the fibers from the stalk is known as tuxies. Finally the fibers are completely cleaned in water to remove the waste materials and then dried in sunshine for a few days to remove the moisture content. Then the fibers are made into mat form in the form of cloth.

Fig-2: Abaca fiber

Glass Fiber

Glass fiber is material made from extremely fine fibers of glass. It is used as a reinforcing agent for many polymer products, the resulting composite material, properly known as Fiber-Reinforced Polymer (FRP).

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. It is much cheaper and significantly less brittle when used in composite. Glass fibers are therefore used as a reinforcing agent for many polymer products, to form a very strong and relatively lightweight fiber-reinforced polymer (FRP). Glass fiber is formed when thin strands of silica-based or other formulation glass is extruded into many fibers with small diameters suitable for textile processing. Glass is unlike other polymers, in that even as a fiber in its softened stage is very much like its properties when spun into fiber. One definition of glass is "an inorganic substance in a condition which is continuous with, and analogous to the liquid state of that substance, but which, as a result of a reversible change in viscosity during cooling, has attained so high a degree of viscosity has to be for all practical purposes rigid".

Fig-3: Glass fiber mat of 610gsm

Epoxy Resin

Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group. A wide range of epoxy resins are produced industrially. The raw materials for epoxy resin production are today largely petroleum derived, although some plant derived sources are now becoming commercially available. The resin system consists of Epoxy resin (L-12) and Hardener (K-6) in the ratio 10:1 by weight, both supplied by Petro Araldite Pvt. Ltd., Chennai, India.

Hardener

Hardener is a curing agent for epoxy or fiberglass. Epoxy resin requires a hardener to initiate curing; it is also called as catalyst, the substance that hardens the adhesive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determines the final characteristics and suitability of the epoxy coating for given environment. The choice of hardener is governed by the curing temperature, pot life and curing temperature required as well as the application method used. The hardener K-6 is used in this project for the fabrication process in the proportion 1:10 ratio.

3. MECHANICAL PROPERTY TESTS

3.1 Tensile Test

Tensile test, also known as tension test, is probably the most fundamental type of mechanical test that can be performed on material. To determine how the material will react to forces being applied in tension. As the material is being pulled, material will elongate. The maximum force at which the material fails is known as Ultimate Strength. The tensile test was finished by cutting the composite example according to ASTM D638. When the tensile load is applied to the specimen the system automatically calculates ultimate strength, ultimate load, and displacement and strain rate. The graph related to the above values is simultaneously plotted by the computer. The specimen is held in the grip and load is applied and the corresponding elongations are noted. The load is applied until the specimen breaks, ultimate tensile strengths are noted. Tensile stress and strain are recorded and load Vs length graphs are generated.

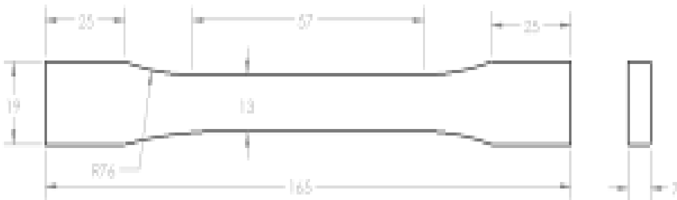

Fig-4: Tensile Test Specimen (ASTM D – 638)

3.2 Flexural Test

A flexural test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline. To ensure the primary failure comes from tensile or compression stress the shear stress must be minimized. This is done by controlling the span to depth ratio, the length of the outer span divided by the height of the specimen.

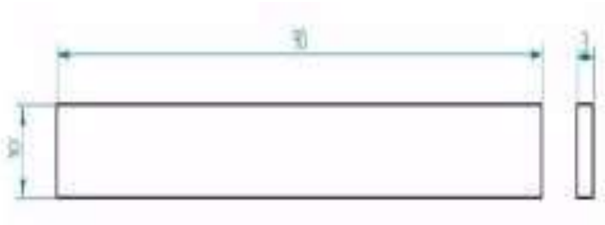

Fig-5: Flexural Test Specimen (ASTM D – 790)

3.3 Impact Test

The specimen is prepared according to ASTM standard method. The impact test is done in a Izod and Charpy impact setup as per ASTM standard. The specimen must be loaded in the testing machine and allows the pendulum until it fractures or breaks. Using the impact test, the energy needed to break the material is noted and used to measure the impact strength of the material. The composition shows more impact strength than other composition and the impact properties of composite can increase by the addition of the abaca fiber with epoxy resin.

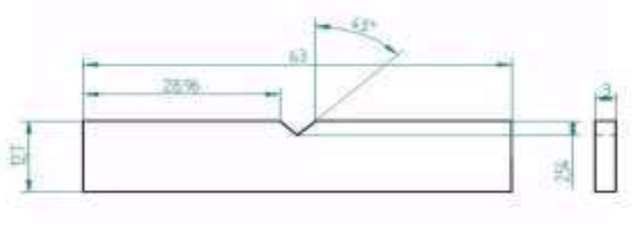

Fig-6: Impact Test specimen (ASTM D – 256)

4. RESULTS AND DISCUSSION

4.1 Tensile Strength

In the present study tensile tests were conducted according to ASTM D-638 standard. The tests were conducted using at a cross head speed of 5mm/min and stress-strain curves were recorded. The figure shows the UTM used for conducting tensile test.

Table-1: Tensile test reading for different composition

Sl. No.	Composition	Tensile strength (MPa)
1	Epoxy(40%)+Glass fiber(60%)	147.03
2	Epoxy(40%)+Glass fiber(50%)+Abaca fiber(10%)	144.19
3	Epoxy(40%)+Glass fiber(40%)+Abaca fiber(20%)	120.31
4	Epoxy(40%)+Glass fiber(30%)+Abaca fiber(30%)	108.18

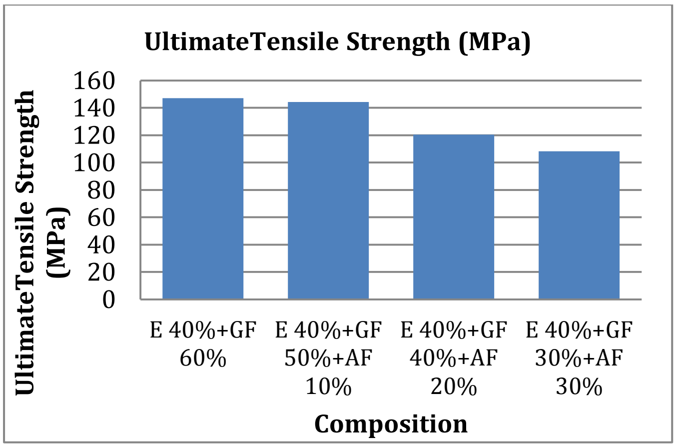

Chart-1: Composition v/s Ultimate Tensile Strength (MPa)

First specimen R60% and GF40% gives the tensile strength 147.03MPa which has the highest ultimate tensile strength and the composition E40%, GF30% and AF30% specimen has lowest ultimate tensile strength of 108.18MPa. The tensile strength of the specimen goes on decreases with increase in the percentage of abaca fiber.

4.2 Flexural Strength

In the present study flexural tests were conducted according to ASTM D-790 standards. The specimen is cut in to the dimension of 132 x 12.5 x 3 mm according to ASTM D-790 as shown in chart-2. The specimen is held by supporting at two ends. The load is applied at the center of the work peace till fracture occurs. Test results include flexural strength.

Table-2: Flexural test reading for different composition

Sl. No.	Composition	Flexural strength (MPa)
1	Epoxy(40%)+Glass fiber(60%)	634.99
2	Epoxy(40%)+Glass fiber(50%)+Abaca fiber(10%)	403.46
3	Epoxy(40%)+Glass fiber(40%)+Abaca fiber(20%)	438.37
4	Epoxy(40%)+Glass fiber(30%)+Abaca fiber(30%)	483.03

The composition tested under flexural load it seems that the presence of abaca fiber decreases initially. Then with the increase in percentage of abaca fiber the flexural strength of the composition goes on increasing. The flexural strength of the composition E(40%)+GF(60%) shows maximum amount of flexural strength of 634.99MPa. From chart-2 we can observe that flexural strength of the composition suddenly decreases with the implementation of abaca fiber. But with the increase in the percentage of abaca fiber the flexural strength increases gradually.

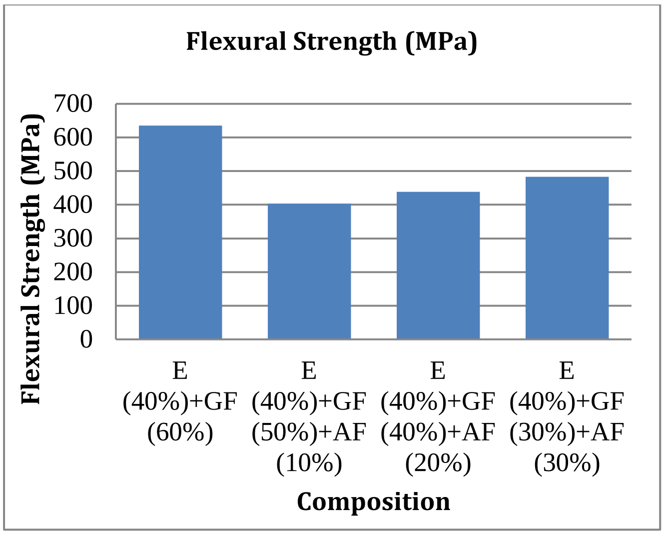

Chart-2: Composition v/s Flexural Strength (MPa)

4.3 Impact Strength

The Impact strength of various composites with varying weight fractions are shown in chart-3. From the graph the variation of impact strength with different composites specimen for the maximum impact loads.

The composition E40%, GF30% and AF30% specimen has highest impact strength of 169.56 kj/m² and the composition E40%, GF50% and AF10% specimen has lowest impact strength of 96.37 kj/m². The impact strength of composite is decreasing with the decrease of abaca fiber.

Table-3: Impact test reading for different composition

Sl. No.	Composition	Impact strength (kj/m²)
1	Epoxy(40%)+Glass fiber(60%)	107.11
2	Epoxy(40%)+Glass fiber(50%)+Abaca fiber(10%)	96.37
3	Epoxy(40%)+Glass fiber(40%)+Abaca fiber(20%)	169.24
4	Epoxy(40%)+Glass fiber(30%)+Abaca fiber(30%)	169.56

As shown in the Fig. 7.3 impact strength decrease gradually with the decrease in the amount of abaca fiber that shows the major contribution in the impact load is from abaca fiber.

The impact strength of the composition E40% and GF 60% is more than the composition E40%, GF50% and AF10%. Then the impact strength increases with increase of the percentage of the abaca fiber.

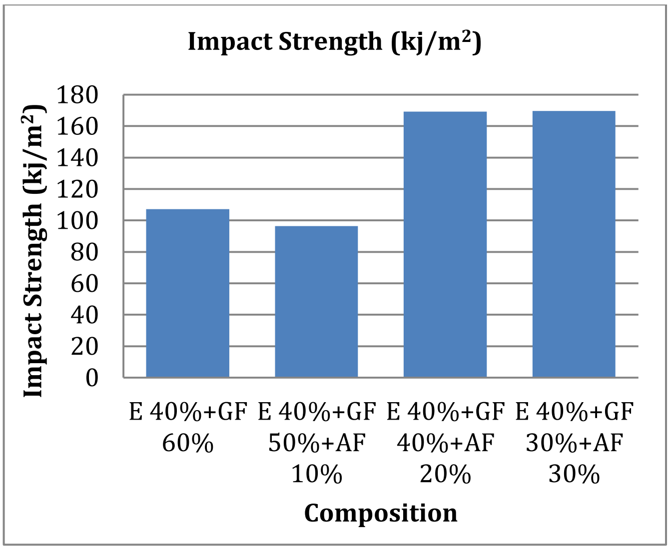

Chart-3: Composition v/s Impact Strength (kj/m²)

5. CONCLUSION

The mechanical properties and water absorption of the hybrid composites using abaca and glass fiber reinforced epoxy resin composites were studied in this work. The composites were fabricated by hand layup technique and tested according to ASTM standard. From the experiment the following conclusions have been drawn.

From the ASTM mechanical property tests, a gradually increase in tensile, flexural and impact strength can be observed with the increase in the abaca fiber percentage of composites after sudden drop in the mechanical property.

All the mechanical properties shows same type of result by sudden drop in the mechanical property and then gradually increase with the increase in percentage of abaca fiber.

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