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Fabrication and Testing of Natural Fiber Reinforced Hybrid Composites Banana/Pineapple

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ABSTRACT : *Work has been carried out to investigate the flexural properties of composites made by reinforcing banana and pineapple as the new natural fibers into epoxy resin matrix. The natural fibers were extracted by retting and manual process. The composites are fabricated using banana and pineapple fiber reinforcements. Hybrid composites were prepared using banana/pineapple fibers of 0/40, 15/25, 20/20, 25/15, and 40/0 Weight fraction ratios, while overall fiber weight fraction was fixed as 0.4Wf. It has been observed that the flexural properties increase with the increase in the weight fraction of fibers to certain extent. The hybridization of the reinforcement in the composite shows greater flexural strength when compared to individual type of natural fibers reinforced composites. All the composites shows increase in flexural strength in longitudinal direction. Similar trends have been observed for flexural modulus, inter laminar shear strength and break load values.*

KEYWORDS: *Natural fibers, Banana & Pineapple fibers, Hybrid composites, flexural properties, Inter laminar shear strength*

I. INTRODUCTION

Many researchers are searching for structural materials of high strength, less weight and low cost, in general strong materials are relatively dense and light materials have less strength. In order to achieve high strength and less weight, it requires combining two or more distinct materials to get composite materials. The combination results in superior properties not exhibited by the individual materials. Many composite materials are composed of just two phases one is termed as matrix phase, which is continuous and surrounds the other phase often called the dispersed phase or reinforcement phase [1-2]. The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite good properties. The matrix holds the reinforcements in orderly pattern. The matrix materials can be metallic, polymeric or ceramic. A metal matrix composite consists of a matrix of metals or alloys reinforced with metal fibers such as boron carbon. When the matrix is a polymer the composite is called polymer matrix composite (PMC).Ceramic matrix composites consists of a matrix reinforced with ceramic fibers such as silicon carbide, alumina or nitride. The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are extracted from plants. The fiber reinforced polymers (FRPs) consist of fibers of high strength and modulus embedded in or bonded to a matrix with a distinct interface between them. In this form, both fibers and matrix retain their physical and chemical properties.

The matrix phase binds the fibers together and acts as medium by which an externally applied stress is transmitted and distributed to the fibers. Only a very small portion of an applied load is sustained by the matrix phase and major portion is sustained by the fibers. The fibers are basically two types. They are natural and synthetic Fibers. Cotton, jute and sisal are some examples for natural fibers and glass, nylon and carbon are some examples for synthetic fibers.

Natural fibers, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, and renewable. Plant fibers are light compared to glass, carbon and aramid fibers. The biodegradability of plant fibers can contribute to a healthy ecosystem while their low cost and high performance fulfils the economic interest of industry. When natural fiber-reinforced plastics are subjected, at the end of their life cycle, to combustion process or landfill, the released amount of CO_2 of the fibers is neutral with respect to the assimilated amount during their growth. Natural fibers such as banana, cotton, coir, sisal and jute have attracted the attention of scientists and technologists for application in consumer goods, low cost housing and other civil structures. It has been found that these natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture. They are also renewable and have relatively high strength and stiffness and cause no skin irritations. On the other hand, there are also some disadvantages, such as moisture absorption, quality variations and low thermal stability. Many investigations have been made on the potential of the natural fibers as reinforcements for composites and in several cases the results have shown that the natural fiber composites own good stiffness but the composites do not reach the same level of strength as the glass fiber composite [3]. Hybrid composite materials are made by combining two or more different types of fibers in a common matrix. Hybridization of two types of short fibers having different lengths and diameters offers some advantages over the use of either of the fibers alone in a single polymer matrix. Most of the studies are on the hybridization of natural fibers with glass fibers to improve the properties [4–10]. They possess a good calorific value and cause little concern in terms of health and safety during handling. In addition, they exhibit excellent mechanical properties, have low density and are inexpensive.

This good environmental friendly feature makes the materials very popular in engineering markets such as the automotive and construction industry.

S.M. Sapuan et al [12] investigated the tensile and flexural properties of banana fiber reinforced with epoxy. The statistical analysis carried out, showed an increase in mechanical properties. Maries Idicula et al [13] studies Dynamic studies on mechanical properties of randomly mixed sisal and banana fibers were carried out and it is observed that the flexural and tensile modulus shows improvement in results. The damping behavior also improved for sisal polyester composites. N.Venkateshwaran et al [14] studied the tensile, flexural and water absorption studies of banana-epoxy composite materials which showed a poor result and it can be improved in a better way by the addition of sisal fiber along with banana fiber in different weight percentages. V.Naga Prasad Naidu et al [15] in their paper the hybrid composites of unsaturated polyester based sisal/glass fiber hybrid composites were prepared. Glass/sisal fibers were combined in the same matrix (unsaturated polyester) to make hybrid composites and the tensile and flexural properties are studied. A significant improvement in tensile and flexural properties of sisal/glass fiber hybrid composites was found. With this background, an attempt has been made in this present investigation to fabricate and to evaluate the properties of natural fiber reinforced hybrid composites.

II. MATERIALS AND METHODS

II.1 Materials: Banana fiber (Musaceae family) a type of bast fiber, is extracted from the bark of banana tree. Pineapple is multi-cellular and lignocelluloses materials extracted from the leave of plant Ananas cosomus belonging to the (Bromeliaceous family). The fiber is extracted by hand scraping after beating the leaves to break up the pulpy tissue. Both fibers are purchased from Perfect Banana fiber & Articles Manufacturer, Coimbatore, Tamilnadu. Hardener and Resin was purchased from Shakti glass fibers and Traders, Chennai, India. The properties of banana and pineapple fibers are given in Table 1 [11].

II.2 Extraction of fibers: The obtained fibers are cleaned with water and dried. Then the segregations are gently dispersed with hand sitting patiently. Pineapple and banana fibers after retting the husks are beaten with a hammer. These fibers are ripped from the husks and separated from the comb. After drying at the room temperature, both the fibers were combed with a cotton carding frame for several times further separate the fibers in to individual state. After that, both the fibers are measured for proper weight and length.

II.3 Weight fraction of the fiber: The weight of the matrix was calculated by multiplying density of the matrix and the volume (volume in the mould). Corresponding to the weight of the matrix the specified weight percentage of fibers is taken. For hybrid combination the corresponding weight of fiber obtained is shared by two fibers.

Fig. 1 - Banana fibers and Pineapple fibers

II.4 Preparation of epoxy and hardener: Epoxy LY556 of density 1.15–1.20 g/cm^3, mixed with hardener HY951 of density 0.97–0.99 g/cm^3 is used to prepare the composite plate. The weight ratio of mixing epoxy and hardener is 10:1. This has a viscosity of 10-20 poise at 25^{0}C. Hardeners include anhydrides (acids), amines, polyamides, dicyandiamide etc.

II.5 Mould Preparation: Mould used in this work is made of well-seasoned teak wood of 200 mm X 200 mm X 3 mm dimension with five beadings. The fabrication of the composite material was carried out through the hand lay-up technique. The top, bottom surfaces of the mould and the walls are coated with remover and allowed to dry. The functions of top and bottom plates are to cover, compress the fiber after the epoxy is applied, and also to avoid the debris from entering into the composite parts during the curing time.

Fig. 2 - Resin and Hardener

II.6 Composite fabrication: The moulds are cleaned and dried before applying epoxy. The fibers were laid uniformly over the mould before applying any releasing agent or epoxy. After arranging the fibers uniformly, they were compressed for a few minutes in the mould. Then the compressed form of fibers (banana/pineapple) is removed from the mould. This was followed by applying the releasing agent on the mould, after which a coat of epoxy was applied. The compressed fiber was laid over the coat of epoxy, ensuring uniform distribution of fibers. The epoxy mixture is then poured over the fiber uniformly and compressed for a curing time of 24 h, with load of 5kg. Composites are prepared by changing the weight fractions of both pineapple and banana fibers. Individual composites with banana and pineapple as reinforcement are also prepared under similar processing conditions for comparison purpose.

Table.1- Properties of Banana and Pineapple fiber.

Properties	Banana fiber	Pineapple fiber
Cellulose (%)	63–64	81-12
Micro febrile angle	11	14-8
Hemi cellulose (%)	6 - 19	16-19
Lignin (%)	5-10	4.6-12
Moisture content (%)	10-11	11-12
Density (kg/m^3)	1350	1440
Lumen size (mm)	5	2-3
Tensile strength (MPa)	529-914	413-1627
Young's modulus (GPa)	27-32	60-82

III. TESTING OF COMPOSITES

III.1 Flexural Test: Three point bend tests were performed in accordance with (ASTM) method D 790 [16] to measure flexural properties. The specimens were 100 mm long, 25 mm wide and 3 mm thick. In three point bending test, the outer rollers were 64 mm apart and samples were tested at a strain rate of 0.2 mm/min. Specimen were tested at a cross head speed of 2.5 mm/min, using associated universal testing machine (FIE) make. A three point bend test was chosen because it requires less material for each test and eliminates the need to accurately determine center point deflections with test equipment. In each case a set of five specimens were tested to obtain average value. The testing process is continued until the specimen fractures. A graph of load versus displacement curve was generated automatically by the computer. Flexural strength of the composite was calculated using the following relationship. $\sigma_f = 3PL/2bt^2$ Where σf = stress in the outer specimen at midpoint, P = load at a given point on the load deflection curve, L = support span, b = width of the sample d = depth of the sample.

Fig. 3 – Flexural Test Specimens

Flexural modulus is the ratio within the elastic limit of stress to corresponding strain. A tangent line will be drawn to the steepest initial straight line portion of the load deflection curve and the value can be calculated using equation $E_B=L^3M/4bd^3$ Where E_B = modulus of elasticity in bending, L = support span, M = slope of the tangent to the initial straight line portion of the load deflection curve, b = width of the sample, d = depth the sample.

III.2 Inter-Laminar Shear Test (ILST): It is three point bending test which generally promotes failure by inter-laminar shear. The short beam shear test (SBS) was carried out as per ASTM standard, using 5 Ton universal testing machine (FIE) make at a cross head speed of 2.5 mm/min. The inter-laminar shear strength (ILSS) is found out by using the equation ILSS= 3F/4bt .Where F is the maximum load, b the width of the specimen and t is the thickness of the specimen.

IV. RESULTS AND DISCUSSION

Table -2 Flexural Properties of different composite samples

% Weight fraction	Maximum Displacement	Flexural Strength (Mpa)	Flexural Modulus (Gpa)
0/40	2.63	212.15	0.506
15/25	2.26	203.40	0.319
20/20	3.45	192.47	0.474
25/15	3.77	277.77	0.706
40/0	4.33	137.17	0.252

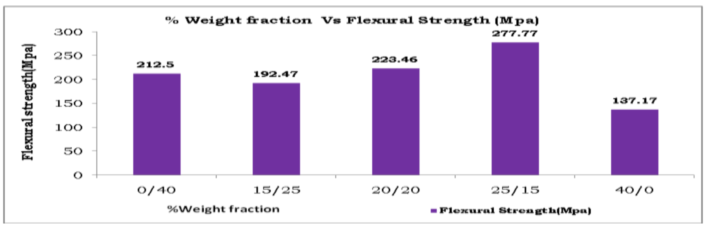

Fig. 4 – Flexural Strength Vs % Weight Fraction of Composites

The flexural strength of various composites with varying weight fractions are shown in figure 4. It can be observed that pure pineapple and pure banana composites shows a flexural strength of 212.5 Mpa and 137.17 Mpa respectively. The flexural strengths of the hybrid composites with weight fractions of 15/25 and 20/20 are found to be 192.47 Mpa and 223.46 Mpa respectively. The effect of hybridization is found to be negligible for the above two composites. However the flexural strength of the hybrid composite with 25/15 weight fraction is found to be 277.77 Mpa which is higher among the others. This behavior can be correlated to hybridization effect as both fibers contributed higher flexural strength to the composite.

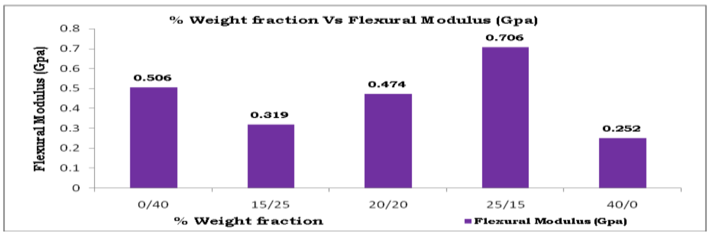

Fig. 5 – Flexural Modulus Vs % Weight Fraction of Composites

From the figure 5 it is evident that the flexural modulus of the pure banana composite (0/40) and pure pineapple composite (40/0) along longitudinal direction is 0.506 Gpa and 0.252Gpa respectively. The tensile modulus of hybrid composite (25/15) is 0.706 Gpa. This is higher among all the other composites. The tensile modulus of the other two hybrid composites with weight fractions 15/25, 20/20, is found to be 0.319 Gpa and 0.474 Gpa respectively, are very poor when compared to pure banana and 25/15 hybrid composite.

Table -3 Inter Laminar Shear Strength & Break load values of different composite samples

% Weight fraction	Inter Laminar Shear Strength (Mpa)	Break Load (Kn)
0/40	3.18	0.506
15/25	2.88	0.319
20/20	3.05	0.474
25/15	4.16	0.706
40/0	1.55	0.252

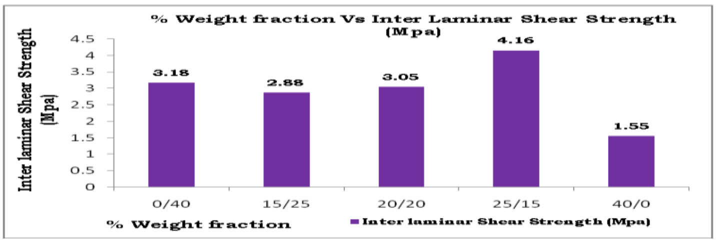

Fig. 6 – Inter Laminar Shear Strength Vs % Weight Fraction of Composites

The inter laminar shear strength of various composites with varying weight fractions are shown in figure 6. It can be observed that pure pineapple and pure banana composites shows inter laminar shear strength of 3.18 Mpa and 1.55Mpa respectively. Inter laminar shear strength of the hybrid composites with weight fractions of 15/25 and 20/20 are found to be 2.88 Mpa and 3.05 Mpa respectively. The effect of hybridization is found to be negligible for the above two composites. However the inter laminar shear strength of the hybrid composite with 25/15 weight fraction is found to be 4.16 Mpa which is higher among all the other composites. This behavior can be correlated to hybridization effect as both fibers contributed higher inter laminar shear strength to the composite.

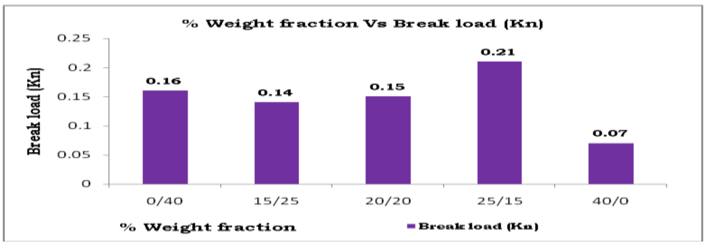

Fig. 7 – Break Load Vs % Weight Fraction of Composites

From figure 7, shows the trend of breaking strength with respect various weight fractions. Pure banana and pure pineapple composites have shown 0.16 Kn and 0.07 Kn at break point at 15/25 and 20/20 the values were observed to be low as compared to pure composite. This can be attributed to improper mixing, mismatch of individual fibers as a whole to the hybrid composite at 25/15, the hybrid composite has shown maximum breaking load (0.21 Kn) as compared to pure composite and other hybrid composites. This mixing ratio of both the fibers might have contributed proportionately thus resulted in superior breaking load capacity.

V. CONCLUSIONS

After determining the material properties of natural fiber reinforced epoxy hybrid composites with five different weight fractions of the materials, the following conclusions can be made.

1) The natural fiber reinforced epoxy hybrid composites are successfully fabricated using hand lay-up technique.
2) The banana/pineapple hybrid composite with weight fraction of 25/15 shows maximum flexural strength and maximum flexural modulus.
3) The banana/pineapple hybrid composite with weight fraction of 25/15 shows maximum inter laminar shear strength.
4) The hybridization of these natural fibers has provided considerable improvement of flexural strength when compared to individual reinforcement. This work also demonstrates the potential of the hybrid natural fiber composite materials for use in a number of consumable goods.
5) Due to the low density of proposed natural fibers compared to the synthetic fibers (Glass fibers, carbon fibers, etc...), the composites can be regarded as a useful materials in light weight applications.
6) The banana/pineapple hybrid composite with weight fraction of 25/15 shows maximum break load.

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