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Effect of Fillers on E-Glass/Jute Fiber Reinforced Epoxy Composites

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ABSTRACT
In this work, an investigation was carried out on E-glass fiber/jute fiber reinforced epoxy composites filled with varying concentrations of bone and coconut shell powder. The composites were fabricated by hand lay-up technique and the mechanical properties such as ultimate tensile strength, flexural strength, inter laminar shear strength (ILSS), tensile modulus, impact strength and hardness of the fabricated composites were tested. The test results of these were compared with unfilled HFRP composites. From the results it was found that the mechanical properties of the composites increased with the increase in filler content. Composites filled with 15% volume coconut shell powder exhibited maximum flexural strength, inter laminar shear strength (ILSS), tensile modulus and hardness. Maximum impact strength was achieved by addition of filler (15% Vol.) of bone powder.
Key words: Bone powder, Coconut shell powder, HFRP composites, Mechanical Properties.

I. INTRODUCTION

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable [1-4]. Plants such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo and banana have satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites [5-10]. The effect of stacking sequence on tensile, flexural and inter laminar shear properties of untreated woven jute and glass fabric reinforced epoxy hybrid composite have indicated that the composite properties can be considerably improved by incorporation of glass fiber as extreme glass piles [11-13]. Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, Sri Lanka and India. Many works have been devoted to use of other natural fillers in composites. Coconut shell filler is a potential candidate for the development of new composites because of their high strength and modulus properties. The coconut particles also have remarkable interest in the automotive industry owing to its hard-wearing quality, high hardness, good acoustic resistance, non toxic and not easily combustible [14,15]. The additions of carbonized bone particles reinforcement in composites have superior properties with an increase in the compressive strength, hardness values, tensile strength and flexural strength [16]. Keeping this in view the research work has been undertaken to develop a Hybrid Fiber Reinforced Polymer (HFRP) composites by using jute and glass fiber as reinforcement filled with varying concentration of bone and coconut shell powder. Mechanical Properties were determined and analyzed.

II. EXPERIMENTATION

2.1 MATERIALS

HFRP composites were made from E-glass fiber (7 mill), jute fiber and epoxy as a resin (L-12). Bone and Coconut shell powder were used as filler materials. Fabrication was done at room temperature by hand layup techniques and composites were cured at room temperature.

2.2 FABRICATION OF HFRP LAMINATES

The HFRP composites were prepared by keeping constant 50% volume fibers (40% glass fiber volume and 10% jute fiber volume). The filler material with varying concentrations of bone and coconut shell powder (0%, 10% and 15% volume) was added as shown in “Table 1”. The volume fraction of fiber, epoxy and filler materials were determined by considering the density, specific gravity and mass. Fabrication of the composites was done at room temperature by hand lay-up technique [17]. The required ingredients of resin, hardener and fillers were mixed thoroughly in a basin and the mixture was subsequently stirred constantly. The woven glass and jute fiber was positioned manually in the open mould. The mixture so made was brushed uniformly over the plies. Entrapped air was removed manually with squeezes or rollers to complete the composite laminates and was cured at room temperature as shown in "Fig. 1".

Table 1 List of fabricated HFRP laminates with constant 50% fiber volume fractions

HFRP Laminates	Epoxy (% Volume)	Filler materials (% Volume)
GJE	50	Nil
GJEB1	40	10% Bone powder
GJEB2	35	15% Bone powder
GJEC1	40	10% Coconut shell powder
GJEC2	35	15% Coconut shell powder

Fig. 1 HFRP laminates

2.3 SPECIMEN PREPARATION

The prepared laminates of the composites were taken from the mould and then specimens were prepared from composite laminates ("Fig. 2") for different mechanical tests according to ASTM standards as shown in "Table 2". Three identical test specimens were prepared for different tests.

Table 2 ASTM standards

Test	ASTM standards
Tensile	ASTM-D3039
Flexural	ASTM-D790
Impact Resistance	ASTM-E23
Brinell hardness test	ASTM-E10-00a
Inter Laminar shear strength	ASTM-D 2344-84

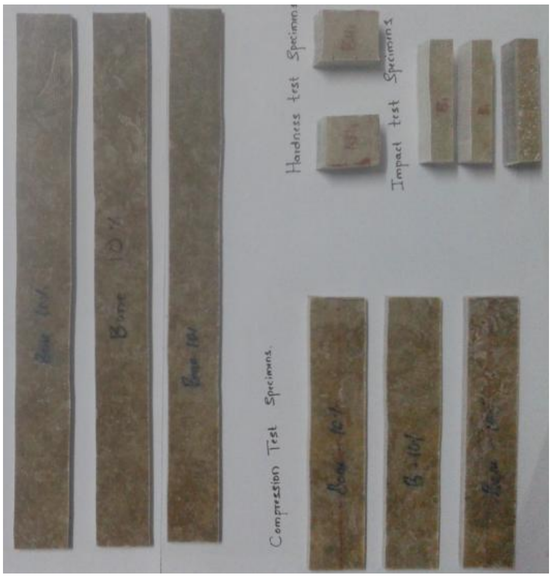

Fig. 2 ASTM standard specimens

2.4 MECHANICAL PROPERTIES

2.4.1 TENSILE STRENGTH

The tensile test was carried out according to ASTM D 3039-76. The specimen dimensions was 250 mm x 25 mm x 3 mm and load was applied on both the ends. The test was performed in the universal testing machine.

Details of Universal Testing:

Machine Make - Micro Control Systems, Model - MCS-UTE60, Software - MCSUTE STDW2KXP System uses add-on cards for data acquisition with high precision and fast analog to digital converter for pressure/Load cell processing and rotary encoder with 0.1 or 0.01 mm for measuring cross head displacement (RAM stroke). The test was repeated three times on each composite type and the mean value was reported as the tensile strength of that composite.

2.4.2 FLEXURAL AND INTER-LAMINAR SHEAR STRENGTH (ILSS)

The flexural strength was carried out according to ASTM D790. The three point bend test was conducted on all the composite samples in the universal testing machine. The dimension of each specimen was 130 mm x 25 mm x 3mm and Span length 100 mm. Three identical test specimens were tested for calculating the flexural strength and inter laminar shear strength (ILSS). The flexural strength of the composite specimen was determined using the following "equation 1".

$$\sigma f = \frac{3PL}{2bh^2} \quad (1)$$

where, σ_f - Stress in the outer fibers at midpoint (MPa), L - Span length of the sample (mm), P -

Maximum load (N), b - Width of specimen (mm), h - Thickness of specimen (mm)

The ILSS were calculated by the following "equation 2".

$$\text{ILSS} = \frac{3F}{4bt} \quad (2)$$

where, ILSS - Inter-laminar shear strength (MPa), F - Maximum load (N), b - Width of specimen (mm), t - Thickness of specimen (mm)

2.4.3 IMPACT STRENGTH

The charpy impact strength of composites was tested using a standard impact machine as per ASTM E23. The impact test specimens 55mm x 10mm x 10mm cross section having 45^0 V-notch and 2mm deep were used for the test. Each test was repeated thrice and the average values were taken for calculating the impact strength.

2.4.4 BRINELL HARDNESS TEST

Brinell hardness test was conducted on the specimen using a standard Brinell hardness tester. A load of 250 kg was applied on the specimen for 30 sec using 2.5 mm diameter hard metal ball indenter and the indentation diameter was measured using a microscope. The hardness was measured at three different locations of the specimen and the average value was calculated. The indentation was measured and hardness was calculated using following "equation 3".

$$BHN = \frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)} \quad (3)$$

where, BHN - Brinell hardness number, P - Applied force (kgf), D - Diameter of indenter (mm), d - Diameter of indentation (mm)

III. RESULTS AND DISCUSSION

The Ultimate tensile strength, Flexural strength, Brinell hardness number, Charpy impact strength, Inter laminar shear stress (ILSS) and Tensile modulus of prepared composites are presented in "Tables 3-8". Obtained results are shown in the "Fig. 3, 5, 7-10" respectively. "Fig. 4" and "Fig 6" shows the tested specimens of the HFRP composites.

3.1 ULTIMATE TENSILE STRENGTH

Table 3 Tensile strength

HFRP composites	Ultimate tensile strength (MPa)
GJE	176
GJEB1	221.6
GJEB2	195.2
GJEC1	236
GJEC2	227.2

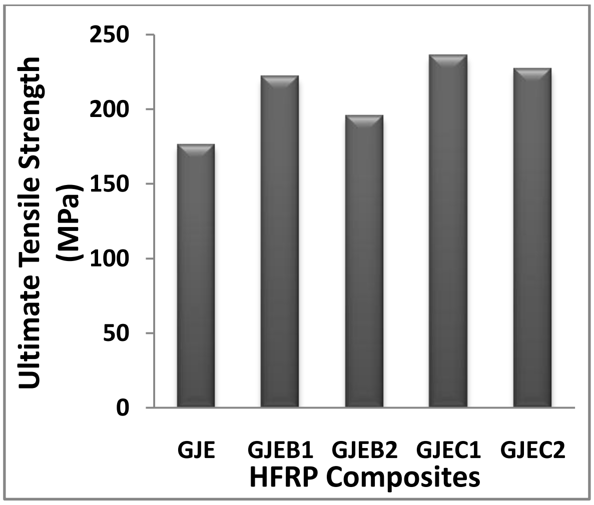

Fig. 3 Ultimate tensile strength (MPa)

Fig. 4 Ultimate tensile strength tested specimens

From the "Fig. 3" it was observed that the tensile strength of all filled composites having higher values when compared with unfilled composite GJE. The composite GJEC1 exhibited the maximum tensile strength. This may be due to the restriction of the mobility and deformability of the matrix with the introduction of mechanical restraint and the filler particle size. Tensile strength decreases with increase in filler content this would be because of poor adhesion, direct contact of shell particles and void formation [18].

3.2 FLEXURAL STRENGTH

Table 4 Flexural strength

HFRP composites	Flexural strength (MPa)
GJE	780
GJEB1	1020
GJEB2	1080
GJEC1	1380
GJEC2	1440

Flexural strength for composites with different filler volume fraction of HFRP composites were compared in "Fig. 5". Flexural properties of composites increased with increase filler content [19]. The maximum flexural strength of HFRP composite was observed in GJEC2. Unfilled HFRP composite GJE was having the minimum flexural strength.

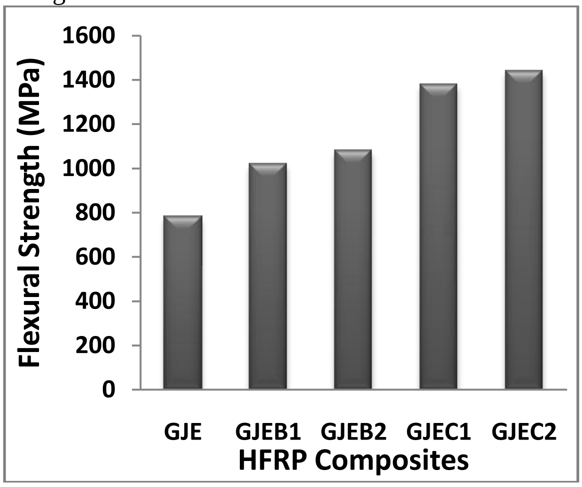

Fig. 5 Flexural strength (MPa)

Fig. 6 Flexural strength tested specimens

3.3 BRINELL HARDNESS NUMBER

Table 5 Hardness test

HFRP composites	Brinell hardness number (BHN)
GJE	55.25
GJEB1	30
GJEB2	57.1
GJEC1	41.75
GJEC2	71.58

"Fig. 7" indicate that composite filled by 15% volume coconut shell powder exhibited maximum hardness number of 71.58 BHN when compared to other filled composites, this may be due to uniform dispersion of particles and good bonding strength between fiber and matrix. But hardness of GJEB1 and GJEC1 decreased because of porosity and weak bond strength between the matrix and reinforcements. Literature survey revealed that the increase in hardness was a function of filler content and hardness was directly proportional to the filler content.

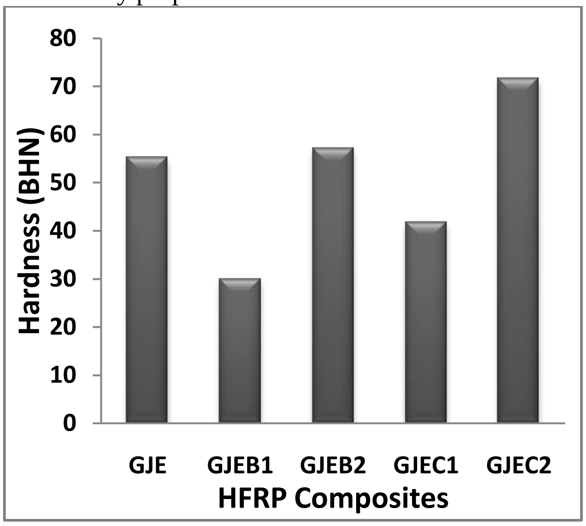

Fig. 7 Hardness (BHN)

3.4 CHARPY IMPACT STRENGTH

Table 6 Impact strength

HFRP composites	Charpy impact strength (J/mm^2)
GJE	0.3375
GJEB1	0.3076
GJEB2	0.4357
GJEC1	0.288
GJEC2	0.3043

From the "Fig. 8" the maximum impact strength was observed in GJEB2 than the other composites this may be due to increase in addition of bone filler to composites. This resulted in decrease of inter-particle spacing which often slowed down the nucleation of cracks by absorbing some fraction of energy [16]. The non-uniform distribution of coconut shell particles in the composite was the major factor responsible for the decrease in strength when compared with the control sample having 0% coconut shell particles [20,21].

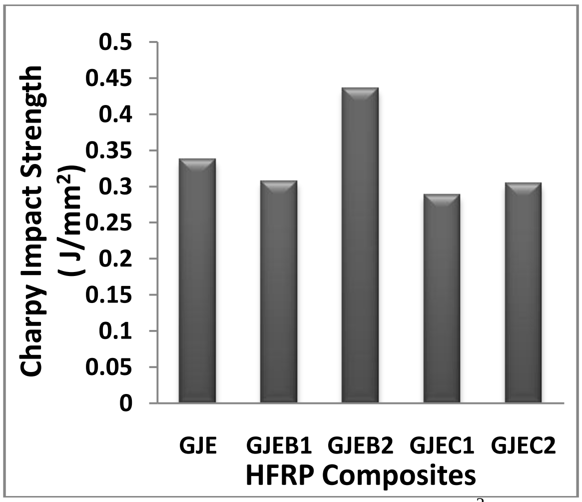

Fig. 8 Charpy impact strength (J/mm^2)

3.5 INTER LAMINAR SHEAR STRESS (ILSS)

Table 7 Inter laminar shear strength

HFRP composites	Inter laminar shear stress (MPa)
GJE	7.8
GJEB1	10.2
GJEB2	10.8
GJEC1	13.8
GJEC2	14.4

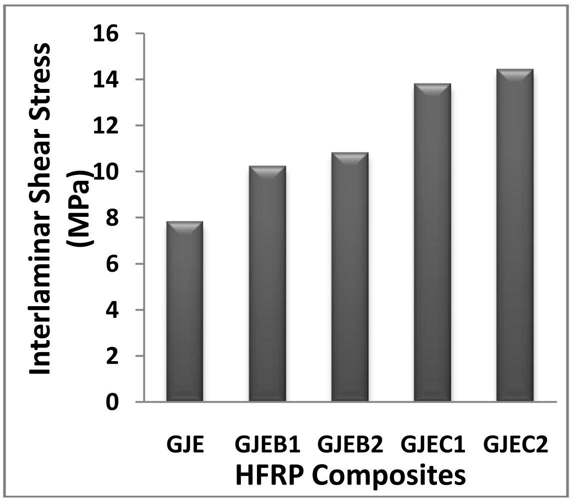

Fig. 9 Inter laminar shear strength (MPa)

"Fig. 9" indicates that GJE laminate exhibit inter laminar shear stress value of 7.8 MPa. Inter laminar shear strength depends primarily on the matrix properties and fiber matrix interfacial strength rather than the fiber properties. ILSS can be improved by increasing the matrix tensile strength [22]. The maximum value of ILSS for GJEC2 is 14.4 MPa. This may be due to the higher tensile strength of matrix and better adhesion of matrix with glass fibers and filler material.

3.6 TENSILE MODULUS

Table 8 Tensile modulus

HFRP composites	Tensile modulus (GPa)
GJE	4.221
GJEB1	5.258
GJEB2	5.491
GJEC1	5.961
GJEC2	6.165

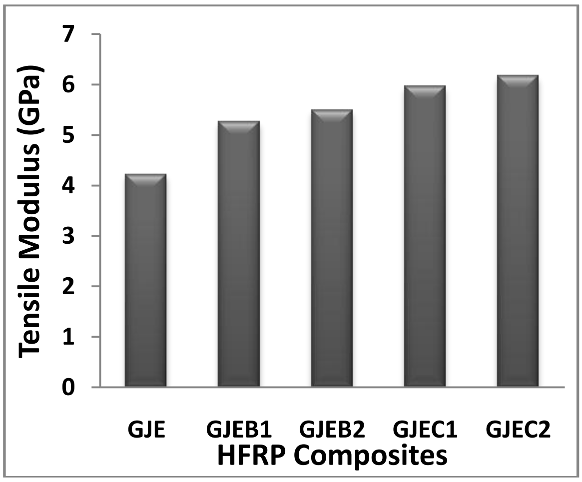

Fig. 10 Tensile modulus (GPa)

"Fig. 10" indicates that GJEC2 laminate has a maximum tensile modulus of 6.165 GPa, the tensile modulus increased with increase in addition of filler content in the laminates. This may be due to the restriction of the mobility, deformability of the matrix and the filler particle size. Normally, the fibers in the composite restrain to the deformation of the polymer matrix reducing the tensile strain. During tensile loading partially separated micro spaces were created which obstructed stress propagation between the fibers and matrix [23].

IV. CONCLUSIONS

The investigation of mechanical behaviour of bone powder and coconut shell powder filled HFRP composites lead to the following conclusions:

- The mechanical properties of the composites were greatly influenced by the filler content.
- The test result shows that composites filled by 10% volume coconut shell powder exhibited maximum ultimate tensile strength.
- Composites filled with 15% volume coconut shell powder exhibited maximum flexural strength, inter laminar shear strength (ILSS), tensile modulus and hardness.
- Composite filled with 15% volume bone powder exhibited maximum impact strength.

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