Experimental Investigation of Mechanical Properties of Banana and Glass Fiber Reinforced Epoxy Based Hybrid Composites with Filler Materials

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Abstract: ***Natural fibers are fibers obtained from plants, animals and geological processes. These are of low cost and light in weight because of which, they are used in various engineering applications. Hybridization is a process of incorporating synthetic fiber with natural fiber to get the better material properties. Filler materials are those materials which on addition improve the properties of composite. An investigation is carried out to find the effect of filler materials on mechanical properties of hybrid composites by changing the content of filler. Experiments are carried out as per ASTM standards to find the mechanical properties. The effect of fiber length and % of filler on tensile strength, flexural strength, Impact strength and hardness of composites is studied.***

Keywords: Composites, Banana fibre, epoxy resin, glass fibre, SiC, fly ash

1. Introduction

Natural fibers are used as reinforcement in composites for many applications. Light weight, high strength, bio degradable, non- abrasive, eco-friendly and low cost of fiber are the main factors because of which it is attracting the interest of engineers, scientists and research professionals.

In recent years, conventional materials are being replaced by polymers because of its advantages over conventional materials. Fiber-reinforced polymers offer additional options when specific properties are required. Banana fiber reinforced composites have recently gained importance. They can be used for door panels, room partitions, wall cladding, food packaging, home appliances, automotive parts, building and construction, and electrical housing.

Determining the Mechanical properties by varying the fiber loading is important. This helps us to determine the range of usefulness and service life of the composite. It is also necessary to determine the effect of change in temperature on the properties of fiber-reinforced epoxy composites because an increase in temperature results in the decrease in strength and ductility. The composites made from both fiber/filler reinforcement performed well in many practical situations.

Nowadays specific fillers/additives are added to enhance and modify the quality of composites. Among the thermosetting polymers, epoxy resins are the most widely used for high-performance applications. Epoxy resins are characterized by excellent mechanical and thermal properties, high chemical and corrosion resistance, low shrinkage on curing and the ability to be processed under a variety of conditions. But, they have some disadvantages related to the matrix dominated properties which often limit their wide applications. In the industry, the addition of filler materials to a polymer is a common practice. This improves not only stiffness, toughness, hardness, heat distortion temperature, and mold shrinkage, but also reduces the processing cost significantly.

Agarwal et al [1], studied effect of addition of silicon carbide (SiC) filler in different weight percentages on physical properties, mechanical properties, and thermal properties of chopped glass fiber-reinforced epoxy composites. They concluded that the physical and mechanical properties of SiC-filled glass fiber-reinforced epoxy composites are better than unfilled glass fiber-reinforced epoxy composites. Viscoelastic analysis for different compositions indicate that adding too much SiC content results in degradation in energy absorption capacity of the material and hence overall performance of the composites, whereas adding too much (more than 10 wt.%) SiC content increases the elastic behavior of the composite.
Ashwani Kumar et al [2], prepared banana fiber reinforced epoxy composite for the evaluation of tensile strength, flexural strength and impact strength. Banana fiber in combination with glass has proved to be excellent for making cost effective composite materials. The tensile strength has shown the highest value when a 10% of banana fiber and 20% of glass fiber is used. The impact strength shows the highest value .When banana fibers and glass fibers are reinforced in a ratio of 1:2.

P. Prasanna [3] et al, observed a gradually increase in tensile, flexural and impact strength can be with the increase in the fibre length up to 15 mm of composites, Conversely, further increase in fibre length there is a decrease in the strength properties. The hardness value increases with increase in fibre length.

K. Naresh Kumar [4] et al, observed that maximum tensile strength is obtained for 20 % (weight) of coal ash among all the different weight percentages and maximum flexural strength is obtained for 16 % (weight) of coal ash among all the different weight percentages. The maximum Compression strength is obtained for 12 % (weight) of coal ash among all the different weight percentages. No significant effect is observed in the impact strength values with the increase of coal ash percentage in GFRP composites.

K. Devendra [5] et al, it was observed that composite filled by 10% volume of $Mg(OH)_2$ exhibited maximum ultimate strength, composites were filled by 10% volume of fly ash having high impact strength and composite filled by Mg (OH)2 exhibited maximum hardness.

From the research of many researchers found that the mechanical properties of composites reinforced with natural fibers have high value depend on the adhesion between fibers and the matrix [7 - 9].

Short banana fiber content has a greatly effect on mechanical properties of the fiber reinforced polyster composites. [10]. Venkateshwaran et al. [11, 12] studied the mechanical properties of tensile, flexural, impact and water absorption tests were carried out using banana/epoxy composite material.

In this paper tensile, flexural, impact strengths and hardness of epoxy based banana and glass fiber composites with fly ash and SiC as filler materials are experimentally determined. Optimization technique topsis is used to find the best composition among the composites.

2. Material and Methods

Matrix:

Epoxy resin araldite-LY 556 and amine hardener HY 951 was used.

Composite Materials:

Glass fiber, banana fiber, Epoxy resin, Epoxy Hardener and filler materials (fly ash and silicon carbide) were the raw material for the composite.

Mould is made of aluminium with dimensions 200x200x8 mm. After curing of composites, specimens were cut according to ASTM standards for different tests.

Figure 1: Materials used and mould of composite

3. Manufacturing Method

Hand lay-up technique:

Hand lay-up technique is the easiest way which is generally used for preparation of composite materials with lesser number of steps and equipment. Hand lay-up is a molding process where fiber reinforcements are placed by hand, then wet with resin. The manual nature of this process allows for almost any reinforcing material to be considered, chopped strand or mat.

Table 1: Preparation of composites

Sample composite	Composition
S1	Epoxy resin(60wt%)+banana fiber(10wt%)(length 15mm)+glass fiber(20wt%) + fly ash (10wt%)
S2	Epoxy resin(60wt%)+banana fiber(10wt%)(length 20mm)+glass fiber(20wt%) + fly ash (10wt%)
S3	Epoxy resin(60wt%)+banana fiber(10wt%)(length 15mm)+glass fiber(15wt%) + fly ash (15wt%)
S4	Epoxy resin(60wt%)+banana fiber(10wt%)(length 20mm)+glass fiber(15wt%) + fly ash (15wt%)
S5	Epoxy resin(60wt%)+banana fiber(10wt%)(length 15mm)+glass fiber(20wt%) + SiC (10wt%)
S6	Epoxy resin(60wt%)+banana fiber(10wt%)(length 20mm)+glass fiber(20wt%) + SiC (10wt%)
S7	Epoxy resin(60wt%)+banana fiber(10wt%)(length 15mm)+glass fiber(15wt%) + SiC(15wt%)
S8	Epoxy resin(60wt%)+banana fiber(10wt%)(length 20mm)+glass fiber(15wt%) + SiC (15wt%)

4. Preparation and experimental methods

Experimental study of composites includes study of mechanical properties of different types of composites which are formed by varying the fiber length and % of filler.

Banana fiber and glass fiber of short length are used as reinforcement. Epoxy resin araldite LY556 and Amine hardener HY 951 are mixed in 10:1 ratio which is further mixed with filler material acts as matrix material. Mould used for composite fabrication is prepared according to ASTM standards. The short banana and glass fibres are mixed with matrix material by simple mechanical stirring. The composites are prepared for two different lengths, two different % of filler material for two filler materials (Sic, Fly ash) using simple hand lay-up technique.

The mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The cast of each composite is preserved under a load of about 20 kg for 24 hours before it is removed from the mould cavity. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Specimens of appropriate dimension are cut for mechanical tests. The determination of fiber weight ratio can be derived from the fiber/resin volume ratio. The approach is as follows:

We have,

$V_f = 1 - V_r - V_{voids}$ (Assume Zero Voids)
$V_f = 1 - V_r$

Where,
V_f= volume fraction of fibre
V_r = volume fraction of resin

Determine the Fiber matrix volume ratio:
and we have,
$V_r = \frac{1}{1+\left(\frac{V_f}{V_r}\right)}$
From above expression we can find $\frac{V_f}{V_r}$

To determine the fiber / resin weight ratio:
We have,
$\frac{V_f}{V_r} = \left(\frac{W_f}{W_r}\right)\left(\frac{\rho_r}{\rho_f}\right)$
Here, ρ_r is density of resin,

ρ_f is density of fiber ={ $\frac{\%fraction\ \ of\ banana}{\%fraction\ \ of\ fiber}$ x density (banana) + $\frac{\%fraction\ \ of\ glass}{\%fraction\ \ of\ fiber}$ x density (glass)+ $\frac{\%fraction\ \ of\ fly\ ash}{\%fraction\ \ of\ fiber}$ x density(fly ash)}
we can get $\frac{V_f}{V_r}$

weight of fiber = $\rho_f \times Vf \times w_f$
weight of resin = $\rho_m \times V_r \times w_m$

Where,
V is the volume ratio,
ρ is density of material
w is Equivalent weight fraction
sub scripts f denotes fibre, r for resin and m for matrix

Table 2: Equivalent weight and volume fractions of composites

Sample composite	Equivalent weight fraction of matrix(w_r)	Equivalent weight fraction of fiber(w_f)	Volume fraction of matrix (V_r)	Volume fraction of fiber(V_f)
S1	0.6	0.4	0.69	0.31
S2	0.6	0.4	0.69	0.31
S3	0.6	0.4	0.65	0.35
S4	0.6	0.4	0.65	0.35
S5	0.6	0.4	0.75	0.25
S6	0.6	0.4	0.75	0.25
S7	0.6	0.4	0.74	0.26
S8	0.6	0.4	0.74	0.26

Table 3: Weights of materials for all samples

Sample composite	Weight of resin (mg)	Weight of banana fiber (mg)	Weight of glass fiber (mg)	Weight of filler (mg)
S1	265	44.2	88.4	44.2
S2	265	44.2	88.4	44.2
S3	251.72	42.63	63.94	63.94
S4	251.72	42.63	63.94	63.94
S5	288	49	98	49
S6	288	49	98	49
S7	285	47.5	71.25	71.25
S8	285	47.5	71.25	71.25

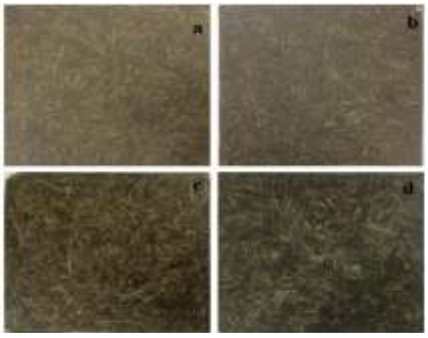

Figure 2: Specimens removed from Mould after curing. a - S1, b - S3, c - S5, d - S7

5. Mechanical property tests

Tensile test:

Tensile test was conducted in universal testing machine. The specimen was cut according to ASTM D-638 standard. The dimensions of the test specimen are 165x19x7 mm.. The specimen surface is made rough so as to fix between grippers of UTM without slipping. Load is applied and deformation is observed. The corresponding value is noted and stress is calculated.

Figure 3: Specimen after tensile test

Flexural test:

Test was conducted on three point bending machine. Test specimen was cut according to ASTM D-790 standard. Dimensions of specimen are 90x10x3 mm. Load is applied gradually and deformation is noted down.

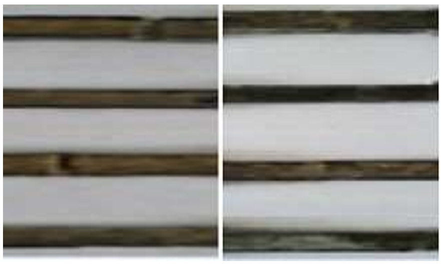

Figure 4: Specimen after flexural test

Impact test:

Test conducted was charpy impact test. The specimen was prepared according to ASTM D-256 standard. The dimensions are 63x12.7x3mm.specimen was fixed on the slot and load is applied suddenly by swinging pendulum. Load at the breakage point is noted down.

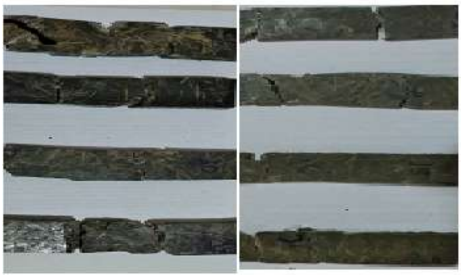

Figure 5: specimen after impact test

Hardness test:

Rockwell hardness testing is done to determine the hardness. Test specimen was prepared according to ASTM D785 standard. The dimensions of the specimen are 30x30x3 mm. specimen is fixed and load is applied, the value at which indentation is observed is noted.

Figure 6: Specimen after hardness test

6. Results and Discussions

Tensile, flexural, impact and hardness tests are conducted. Results are tabulated below.

Table 4: Properties of Hybrid composite observations

Sample composite	Tensile strength	Flexural strength	Impact strength	Hardness number
S1	58.6	73	98.6	45
S2	55	70	91.2	47
S3	53.5	71.1	99.2	43
S4	51	68.7	93.4	44
S5	49	132.5	128	54
S6	46.3	128.7	125.6	57
S7	44	145	139	58
S8	42.4	141	135.4	61

Mechanical Behaviour of Composites:

Influence of fiber length and %of filler on tensile strength of composites:

On increasing length from 15mm to 20mm will decrease the tensile strength, this may be due to curling of long banana fiber. On increasing the % of filler material also the tensile properties are decreasing, this may be due to the properties of fillers (fly ash, SiC).

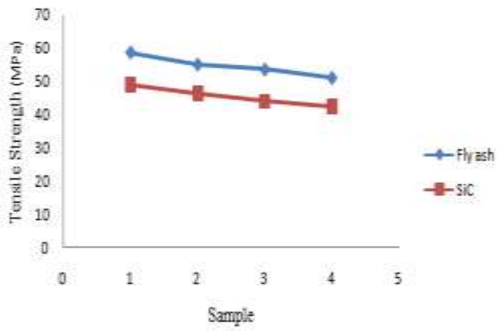

Figure 1: Tensile strength for different samples

Influence of fiber length and % of filler material on flexural strength of composites:

Silicon carbide shows better flexural strength than fly ash composites. On increasing the length of fiber there is a decrease in the flexural property, while on increasing the % of SiC there is an increase.

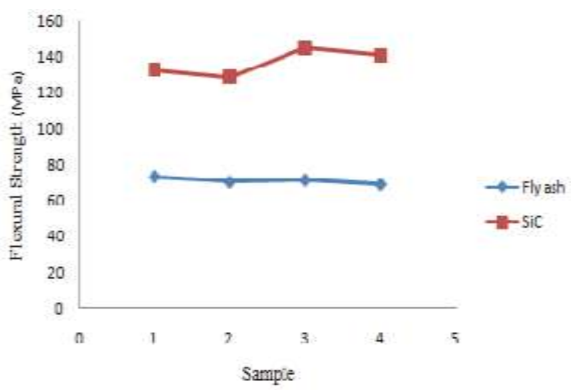

Figure 2: Flexural strength of composites

Influence of fiber length and % of filler on impact strength of composites:

Influence of fiber length and % of filler is shown in figure 6.3. It is observed that on increasing the length there is a decrease in impact strength for both the filler materials. On increasing the % of filler there is a increase in strength in both the fibers.

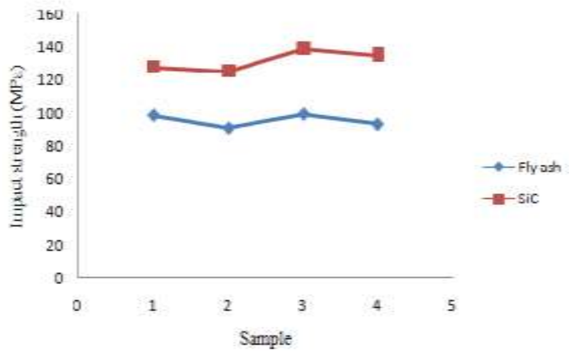

Figure 3: Impact strength of composites

Influence of fiber length and % of filler on Hardness of composites:

On increasing the length, Hardness is increased for both the filler materials. On increasing the percentage of filler there is an increase in hardness for silicon carbide filled composite. Whereas, there is a decrease in hardness of fly ash filled composite.

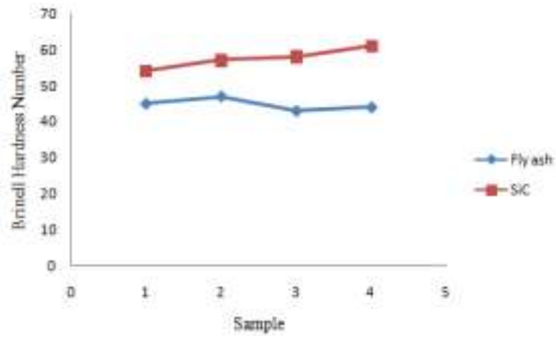

Figure 4: Hardness of composites

TOPSIS:

All the composite materials are compared based on the TOPSIS method and ranking has been done to determine the best composite. The decision matrix, normalization matrix, weight normalized matrix, ideal Positive and ideal negative solution, separation measure, relative closeness value and ranking are done and final ranking is tabulated.

Table 5: Ranking for fly ash composites

Composite	Relative closeness	Ranking of composites
S1	**0.813**	**1**
S2	0.5157	2
S3	0.4192	3
S4	0.1394	4

Table 6: Ranking of silicon carbide composites

Composite	Relative closeness	Ranking of composites
S5	0.40299	3
S6	0.3040	4
S7	**0.63837**	**1**
S8	0.5837	2

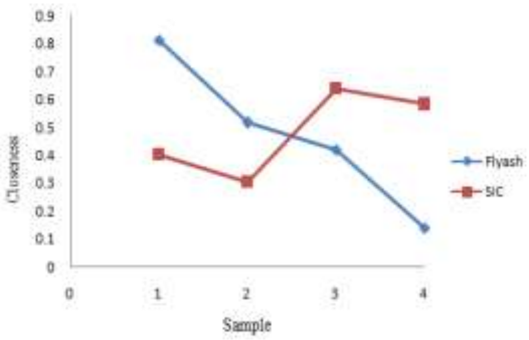

Figure 5: Ranking of different composites

7. Conclusions

The mechanical properties of the hybrid composites using banana and glass fiber reinforced epoxy resin with filler materials 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, there is a gradual decrease in tensile strength with increase in both the length and % of filler in both the composites.

Flexural strength decreases gradually on increasing the length and % of fly ash, whereas, flexural strength decreases with increase in length but increases with increase in % of silicon carbide in composites.

Impact strength decreases with length of banana fiber but increases with % of fillers for both fly ash and silicon carbide.
Hardness increases with increase in length of banana fibre for both fly ash and silicon carbide. On increase in % of filler hardness decreases for fly ash and increases for silicon carbide.

Silicon carbide exhibits better properties for flexural, impact strength and hardness compared to fly ash which exhibits better property in tensile strength.

TOPSIS method is used to select a best alternative from a set of alternatives. The proposed new procedure for hybrid composite selection is to find the best composite among available ones in results using decision making method. It is observed sample S1 is identified as the best hybrid composite among the fly ash composites which has the best relative closeness value 0.813 and S7 is identified as the best among silicon carbide composites with relative closeness value 0.6383.

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