Mechanical Behaviour of COIR/GLASS Fiber Reinforced EPOXY Based Composites

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Abstract - *Fiber reinforced polymer composites has been used in a variety of application because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fiber such as glass, carbon etc. has high specific strength but their fields of application are limited due to higher cost of production. Recently there is an increase interest in natural fiber based composites due to their many advantages. In this connection an investigation has been carried out to make better utilization of coconut coir fiber for making value added products. The objective of the present research work is to study the physical and mechanical behaviour of coir/glass fiber reinforced epoxy based hybrid composites. The effect of fiber loading and length on mechanical properties like tensile strength, flexural strength, hardness of composites is studied. Also, the surface morphology of fractured surfaces after tensile testing is examined using scanning electron microscopy (SEM).*

***Key Words*: Glass fibre, COIR, Epoxy, Scanning Electron Microscopy, Tensile Test, etc.**

1. INTRODUCTION

A composite material made from two or more constituent materials like reinforcement (fibres, particles, flakes, and/ or fillers) and matrix (polymers, metals, or ceramics). One or more discontinuous phases are, therefore, embedded in a continuous phase to form a composite. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed as the matrix [1].

Kelly [2] defined that the composites should not be regarded simply as a combination of two materials. It clearly states that; the combination has its own unique properties. In terms of strength to resistance to heat or some other desirable quality, it is better to attain properties that the individual components by themselves cannot attain. The composite materials have advantages over other conventional materials due to their higher specific properties such as tensile, flexural and impact strengths, stiffness and fatigue properties, which enable the structural design to be more versatile. Due to their many advantages they are widely used in aerospace industry, mechanical engineering applications (internal combustion engines, thermal control, machine components), electronic packaging, automobile, and aircraft structures and mechanical components (brakes, drive shafts, tanks, flywheels, and pressure vessels), process industries equipment requiring resistance to high-temperature corrosion, dimensionally stable components, oxidation, and wear, offshore and onshore oil exploration and production, marine structures, sports, leisure equipment and biomedical devices [3, 4].

1.1 Matrix Materials

Among different types of matrix materials, polymer matrices are the most commonly used because of many advantages such as cost effectiveness, ease of fabrication with less tooling rate and they also have outstanding room temperature properties. Polymer matrices can be either thermoplastic or thermosetting. The most commonly used thermosetting resins are epoxy, polyester, vinyl ester, Polyurethanes and phenolic. Among them the epoxy resins are generally used for many superior composites due to their many advantages such as tremendous adhesion to wide variety of fibres, superior mechanical and electrical properties and good performance at elevated temperatures. In addition to that they have low shrinkage upon curing and good chemical resistance. Due to numerous advantages over other thermoset polymers, epoxy is chosen as the matrix material for the present research work. It chemically belongs to the 'epoxide' family and its common name of epoxy is Bisphenol-A-Diglycidyl- Ether.

1.2 Fibre Material

In fibre reinforcement polymer composites, the reinforcements are either synthetic or natural fibres. Synthetic fibres are made from synthesized polymer or small molecules. The compound used to make this fibre come from raw material such as petroleum based chemicals or petro chemicals. These materials are polymerized in to a long linear chemical that bond to adjacent carbon atoms. Different chemicals compound used to produce different types of fibre. There are different types of synthetic fibres nylon, polyester, carbon fibre, glass fibre, metallic fibre etc.

Now-a-days, the natural fibres have a great attention as they are a substitute to the exhausting petroleum sources [7]. Among all reinforcing fibres, natural fibres have increased substantial importance as reinforcements in polymer matrix composites. Studies on cements and plastics reinforced with natural fibres such as coir, sisal, bamboo, jute, banana and wood fibres have been reported [8-12]. Among various natural fibres, coir finds a wide variety of applications around the world.

The natural fibre coir is pull out from the husk of coconut fruit. The husk consists of coir fibre and a corky tissue known as pith. It is a fibre richly available in India. It consists of water, fibres and small amounts of soluble solids. Because of the high lignin content, coir is more robust when compared to other natural fibres. With increasing demand on fuel efficiency, coir based composites have wider applications in automobiles and railway coaches & buses for public transport system. There is a great opportunity in fabricating coir based composites towards a wide range of applications in building and construction such boards and blocks as reconstructed wood, flooring tiles etc. Natural fibres have the advantages of low density, biodegradability and low cost. Glass is the most widely used synthetic fibre used in polymer matrix composites. Its advantages include its high strength, high chemical resistance, low cost and good insulating behaviour. The type of glass fibre used as reinforcement in this study is E-glass fibre. [13].

2. COMPOSITE FABRICATION

The short coir fibre is collected from local sources and E-glass fibres and Epoxy resin is purchased from market is used for fabrication of composite. The low temperature curing epoxy resin and corresponding hardener are mixed in a ratio of 10:1 by weight as recommended. A mould of dimension 210*210*40 mm^3 is used for casting the composite slabs. The short coir/glass fibres are mixed with epoxy resin by the simple mechanical stirring. The composites are prepared with three different fibre loading and four different fibre lengths keeping glass fibre content constant (20 wt%) 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 detailed composition and designation of the composites are presented in Table 1. The cast of each composite is preserved under a load of about 25 kg for 36 hours before it removed from the mould cavity. Then this cast is post cured in the air for another 36 hours after removing out of the mould. Specimens of appropriate dimension are cut for physical and mechanical tests.

Table -1: Designation of Composites

Composites	Compositions
A1	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 5 mm) (5wt %)
A2	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 10 mm) (5wt %)
A3	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 15 mm) (5wt %)
A4	Epoxy (75wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 20 mm) (5wt %)
A5	Epoxy (70wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 5 mm) (10wt %)
A6	Epoxy (70wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 10 mm) (10wt %)
A7	Epoxy (70wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 15 mm) (10wt %)
A8	Epoxy (70wt %) +Glass Fibre (20wt. %) +Coir Fibre (Fibre length 20 mm) (10wt %)

3 TESTING

3.1 Density

The actual density (ρ_{ce}) of the composite can be obtained experimentally by water immersion technique. The theoretical density of composite materials can easily be obtained as per the following equations given by Agarwal and Broutman [14].

$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}\right) + (W_m + \rho_m)}$$

Where, W and ρ represent the weight fraction and density respectively.

The Suffix m, f and ct stand for the matrix, fibre and the composite materials respectively.

The volume fraction of voids (V_v) in the composites is calculated by the following equation:

$$V_v = \frac{\rho_{ct} + \rho_{ce}}{\rho_{ct}}$$

3.2 Mechanical Properties tests

As per test standards the tensile test of composites is done using Universal Testing Machine. A uniaxial load was applied both the ends of composite specimens for the test. The test is repeated two times on each composite type and the mean value is considered. Figure 1 shows the experimental set up for tensile test.

A three point bend test is done to evaluate the flexural strength of the composites Universal Testing Machine. Before testing width and thickness of specimens measured at different point and mean value is taken. Samples were placed horizontally upon two points and midpoint is perpendicular to loading nose. For the test, the cross head speed is taken as 2 mm/min and a span of 40 mm is maintained. The loading arrangement for flexural test is shown in Figure 2.

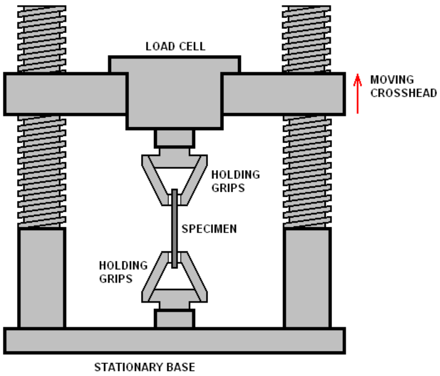


Fig -1: Block diagram for tensile test set up.

Fig -2: Loading arrangement for flexural test

Micro-hardness test of composite specimens is done using Leitz micro-hardness tester. A diamond indenter in the form of right-square pyramid having base angle of 1360is forced on the sample, when load is removed diagonals of indentation is measured and their arithmetic mean is taken. In present work a load of 0.3 kgf is applied over the composite surface.

4. RESULTS

4.1 Mechanical Properties of Composites

4.1.1 Physical and Mechanical Behaviour of Composites

The presence of void content in the composites significantly reduces the mechanical and physical properties of the composites. Table 2 presents the theoretical density, experimental density and their corresponding void content of all the composite specimens. It can observe from the table that the void content of composites increases with increase in both the fibre loading and fibre length. The similar tread of increase in void content with increase in fibre loading and length has already reported by previous researchers [15].

Table -2: Void fraction of hybrid composites

Composites	Theoretical Density (gm/cc)	Experimental Density (gm/cc)	Volume Fraction of Voids (%)
A1	1.248	1.197	4.115
A2	1.248	1.178	5.676
A3	1.248	1.177	5.757
A4	1.248	1.174	5.997
A5	1.254	1.177	6.163
A6	1.254	1.17	6.760
A7	1.254	1.149	8.434
A8	1.254	1.135	9.549

4.1.2 Effect of fibre loading and length on hardness of composites

Surface hardness of the composites is considered as one of the most important factor that governs the wear resistance of the composites. Chart 1 shows the effect of fibre loading and length on hardness of composites. The test results show that with the increase of fibre length, micro-hardness of the coir/glass epoxy composites is improved. As far as the effect of fibre loading is concerned composites with 5wt% fibre loading shows better hardness value as compared to 10wt% irrespective of fibre length except for 20mm length. The increase in hardness value is may be due to the incorporation brittle fibres in the epoxy resin.

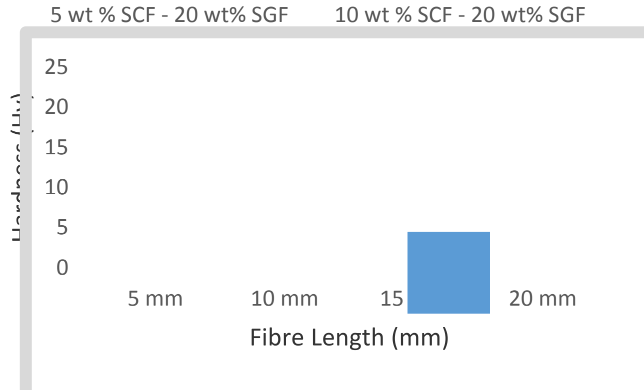


Chart -1: Effect of loading and length on hardness of composites

4.1.3 Effect of fibre loading and length on tensile properties composites

The effect of fibre loading and length on the tensile strength and modulus are shown in Chart 2 and 3 respectively. A gradually increase in tensile strength can be observed with the increase in the fibre length up to 15 mm of coir/glass epoxy based hybrid composites. This is due to the proper adhesion between the both types of fibre and the matrix. However, further increase in fibre length i.e. 20 mm there is a decrease in the tensile strength. The reason may be due to the curling effect of the long coir fibre [16]. The curly nature of fibres prevents the proper alignment of fibres in the (longitudinal direction) composites. The maximum tensile strength is observed for the composite with 10wt% fibre loading at 15mm length. Chart 3 shows the variation of the tensile modulus of coir/glass fibre reinforced hybrid composites with different fibre loading and lengths. It can be observed that with the increase of fibre length, the tensile modulus increases irrespective of fibre loading. As far as the effect of fibre loading is concerned, tensile modulus increases with increase in fibre loading irrespective of fibre length. Previous reports reveal that normally the fibres in the composite restrain the deformation of the polymer matrix, reducing the tensile strain [17-18]. So even if the strength decreases with fibre loading, the tensile modulus of the composite is expected to increase as has been observed in present investigation. The maximum tensile modulus is observed in composites with 5wt% fibre loading and 20mm fibre length.

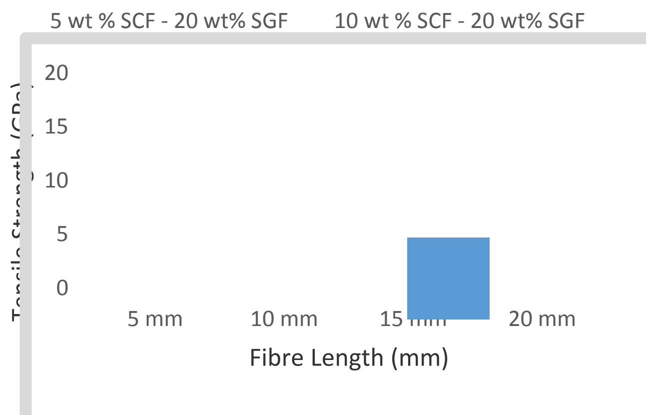


Chart -2: Effect of fibre loading and length on tensile strength of composites

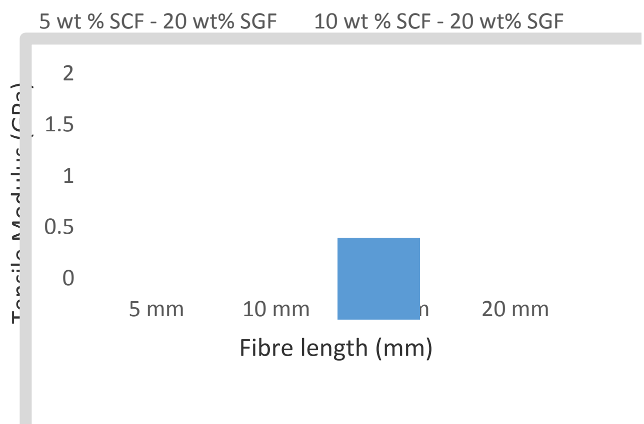


Chart -3: Effect of fibre loading and length on tensile modulus of composites

4.1.4 Effect offibre loading and length on flexural strength of composites

The effect of fibre loading and length on flexural strength of composites is shown in chart 4. It is evident from the chart that the flexural strength of composite increases with increase in fibre length up to 15 mm. However, further increase in fibre length (up to 20mm) the value decreases. As far as the effect of fibre loading is concerned, composites with 10wt% fibre loading shows better flexural strength value as compared to 5 wt% fibre loading. The maximum flexural strength of 63 MPa is observed for composites with 10 wt% fibre loading at 15 mm length.

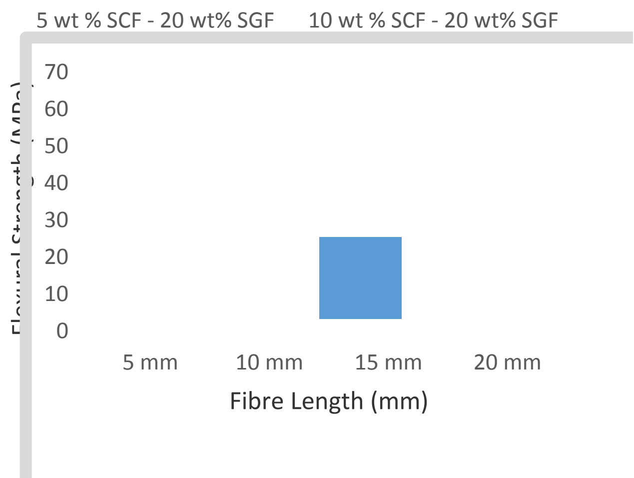
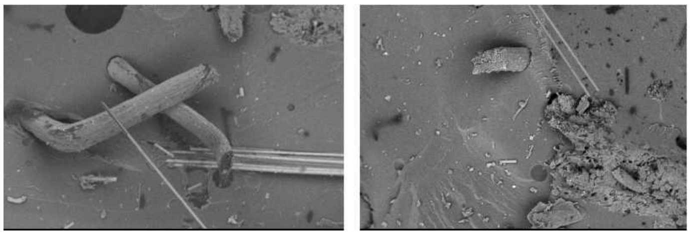


Chart -4: Effect of fibre loading and length on flexural strength of composites

4.2 Surface Morphology

Figure 3a and 3b shows the fracture surfaces of coir/glass fibre reinforced epoxy based hybrid composite after the tensile test with different fibre loading and fibre length. Figure 4.5a shows the tensile fracture of composite with 10wt% fibre loading and 20mm fibre length. It can be clearly observed from the figure that the fibres pull out from the resin surface due to poor interfacial bonding. Figure 4.5b shows the tensile fracture surface of composites reinforced with 10wt% fibre loading at 15mm fibre length. It is evident from the figure that surface without much fibre pull out is clearly visible may be due to the better adhesion fibre and matrix which leads to better of strength properties of composites.



(a) (b)

Fig -3: Scanning electron micrographs of coir/glass fibre reinforced epoxy composite specimens after tensile test

5. CONCLUSIONS

The experimental investigation on the physical, and mechanical behaviour of coir/glass fibre reinforced epoxy based hybrid composites lead to the following conclusions:

1. Successful fabrication of hybrid coir/glass fibre reinforced epoxy composites by simple hand lay- up technique.
2. It has been noticed that the various properties of the composites are greatly influenced by the fibre loading and fibre length. The void content of composites increases with increase in both the fibre loading and fibre length.
3. The micro-hardness value increases with increase in fibre length. As far as the effect of fibre loading is concerned composites with 5wt% fibre loading shows better hardness value as compared to 10wt% irrespective of fibre length except for 20 mm length.
4. A gradually increase in tensile and flexural strength can be observed with the increase in the fibre length up to 15 mm of composites. However, further increase in fibre length i.e. 20 mm there is a decrease in the strength properties.
5. It can be observed that with the increase in fibre length, the tensile modulus increases irrespective of fibre loading.
6. SEM images of the fracture surfaces of composites after the tensile test shows that the increase in strength properties of composites at 10wt% fibre loading and 15mm length is due to the better adhesion between fibre and matrix.

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