EXPERIMENTAL INVESTIGATIONS OF MECHANICAL PROPERTIES OF EPOXY COMPOSITES REINFORCED WITH BAMBOO FIBRES: THE EFFECT OF SIC PARTICULATES AND CARBON FIBRES

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***ABSTRACT**: Composites have been revealed to be the most promising and selecting material known in the 21st century. Currently, the automobile industry is seeking lightweight materials that provide great strength. In this regard, there is a growing appeal for natural and synthetic fibre reinforced composites. The combination of natural and synthetic fibres may be employed as reinforcement in this study, and epoxy polymer can be used as the matrix material. The main characteristics of bamboo fibre are its ability to decompose naturally, its strong resistance to stretching, and its lightweight nature. Multiple investigations have shown that bamboo fibres are not fully utilised as a reinforcing material in composite research. As a result, using bamboo fibres in composite manufacturing opens up more possibilities for developing cost-effective engineering goods. The effect of carbon fibre and Silicon carbide on bamboo was investigated experimentally in this research. Hand 1ay-up method with Epoxy LY556 resin & K-6 hardener was used to create the bamboo laminates. The effects of Carbon Fibre and Silicon carbide reinforcing with bamboo fibres for the determination of its mechanical properties, its physical properties were investigated using bamboo fibres filled in epoxy resin at various weight percent. According to mechanical testing performance, bamboo fibre mixed with carbon fibre and silicon carbide has the best mechanical properties.*

***KEYWORDS:** Composites; Synthetic fibres; Natural fibres; Bamboo fibre; carbon fibre; hand lay-up*

1 INTRODUCTION

As compared to metals, fibre reinforced polymer composites (FRPs) are a category of engineered materials renowned for their superior strength-to-weight ratio. Commercial polymers and fibres are generally derived from petroleum and are nonbiodegradable, aggravating environmental problems. Recently many countries have modified the environmental regulations to encourage the development of environmentally friendly materials, which certainly created an attention on using natural fibres and polymers in making composites (A. N. Netravali & S. Chabba, 2003), (A. May-Pat,et.al., 2013). When comparing the life cycle environmental performance of glass fibre reinforced composites (GFC) with natural fibre reinforced composites (NFC), it was discovered that the former was more ecologically friendly. NFCs usually have a higher volume fraction of fibres which certainly reduces the volume and weight fraction of polymers matrix utilized in making composites (S.V Joshi, 2003). Moreover, the NFCs exhibit brittle free characteristics on impact analysis which may be a greater advantage in particular applications such as passenger compartments (L. Osorio.et.al., 2011).

NFCs are favoured in various applications because of their lower environmental footprint and higher fibre content, leads to the improved efficiency and reduced pollution from polymers. The lightweight of this material will improve fuel economy and reduces emissions in automotive applications. According to many researchers, natural fibres and their composites have favourable advantages like poor wettability, high moisture absorption character. The natural fibre properties such as surface adhesiveness and chemical composition are critical in synthesis of NFCs. The main constituents of natural fibre are cellulose, hemicelluloses, lignin, ash, waxes, and compounds that dissolve in water. Bamboo is a cellulosic, abundant, antibacterial, and cheaply available natural resource, it also exhibits desirable characteristics such as low density and high mechanical strength among many available natural wood species (T. Shito et.al. 2002), X. Chen.et.al. 1998) & E.Trujillo.et.al. 2014).

Bamboo fibres have potential to function as polymer matrix reinforcement and it exhibits significant tensile properties (H. Chen et.al., 2015), (K. Okuboet.al., 2004) & S. C. Chin et.al., 2020). The mechanical properties of bamboo fibre reinforced composites, with or without filler components, have been shown to be dramatically changed by a number of examinations into the material. The purpose of this work is to evaluate how hybridization affects the properties of bamboo-epoxy composites that contain SiC particles and carbon fibres.

2 MATERIALS AND METHODS

2.1 Materials

Bidirectional 0.2 mm thickness Bamboo fibre mats were supplied by Go-green Fibre Enterprises, Chennai, Tamil Nadu, India. The woven mat Carbon fibres, Epoxy (Ly556) resin and the Kevlar, K-6 having density of 1.7, 1.2, and 0.95 gm/cm3 respectively are supplied by Herbana Enterprises, Chennai, India. Silicon carbide (average size of 30µm) is supplied by Amazon, India. Epoxy-hardener mixture is formed using weight ratio 10:1. Table 1 displays the physical characteristics of bamboo fibre and carbon fibre, whereas Table 2 presents the features of SiC particles.

Table 1. Physica1 properties of Bamboo and Carbon fibres

Physical Property	Bamboo Fibre	Physical Property	Carbon Fibre
Density (g/cm3)	1.1	Size (GSM)	200
Elongation at break (%)	10	Orientation	Woven fabric
Cellulose content (%)	45-50	Tensile strength (GPa)	3.2
Lignin content (%)	20-30	Tensile modulus (GPa)	230
Tensile strength (MPa)	350-500	Density (g/cc)	1.7
Elastic modulus (GPa)	84-87	Elongation (%)	1.4

Table 2. Properties of SiC particulates

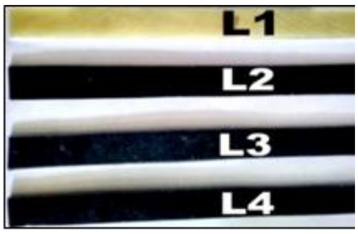
Property	SiC Particulates
Density (g/cm3)	3.1
Flexural strength (MPa)	550
Elastic modulus (GPa)	410
Melting Point (0C)	2200-2700

2.2 Fabrication of Composites

In the present study the hand lay-up process used to fabricate composite laminates. The hand lay-up technique is a quick and easy way to manufacture composite laminates (A. Gupta et.al., 2011). Initially, lubricant is sprayed on the surface of mold to prevent fibre from adhering to the surface and allowing it to be readily removed. To achieve a smooth and polished surface finish, thin plastic sheets are applied to both the upper and lower surfaces of the mould. The fibre woven mats are trimmed to the required size of the mold for reinforcement, which is 250x250 mm. The technique is conducted in order to achieve the desired quantity of layers and a lubricant is sprayed on bottom side of the upper mold plate for easy removal of composites and the complete setup is placed at room temperature for curing up to 48 hours. The cured composites are placed in micro woven with specific temperatures of 50-60 0C for 12 hours. Four laminates (L1, L2, L3 and L4) were synthesised by changing the composition of matrix, bamboo fibres (B), SiC particulates and carbon fibres(C). The sequence details of fabrication are shown in Table 3.

Table 3. Sequence of Laminates

Lamination Sequence	Composition of Layers
L1	B+B+B+B+B+B
L2	B+B+B+B+B+B (SiC)
L3	B+C+B+C+B
L4	B+C+B+C+B (SiC)



The weight percentages of components added to the epoxy matrix during preparation are presented in Table 4 below.

Table 4. Shows wt. % of materials added to the epoxy matrix

Laminates	Composition
L1	Epoxy (60 wt%) + Bamboo Fiber (40 wt.%)
L2	Epoxy (60 wt%) + Bamboo Fiber (34 wt.%) + SiC (6 wt.%)
L3	Epoxy (60 wt%) + Bamboo Fiber (25 wt.%) + Carbon Fiber (15 wt.%)
L4	Epoxy (60 wt%) + Bamboo Fiber (24 wt.%) + Carbon Fiber (10 wt%) + SiC (6 wt.%)
L5	Epoxy (60 wt%) + Carbon Fiber (40 wt%)

2.3 Mechanical Testing of Composites

Test specimens undergo a range of mechanical testing in accordance with ASTM standards. Figure 1 displays the test specimens that have been produced specifically for conducting tensile and flexural testing. The specimens utilised for the water absorption and hardness tests are shown in Figure 2. A tensile test was performed on test specimens measuring 220x20x3 mm3 in accordance with ASTM D3039. The test was completed at room temperature using a computerised Universal Testing Machine (UTM) with a crosshead speed of 10 mm min-1. A flexural test using three-point bending was performed according to ASTM D790 standards using a Universal Testing Machine (UTM). The crosshead speed during the test was set at 5 mm/min. The flexural test specimens had dimensions of 120x20x3 mm³.

The water absorption test, following the ASTM D570 standard, was performed by submerging the 30x30x3 mm3 laminates in distilled water at ambient temperature. Composites are tested for hardness using an ASTM E18-20 Rockwell machine. The test specimens measured 25x25x3 mm³.

Fig. 1. (a) Tensile test specimens; (b) Flexural test specimens

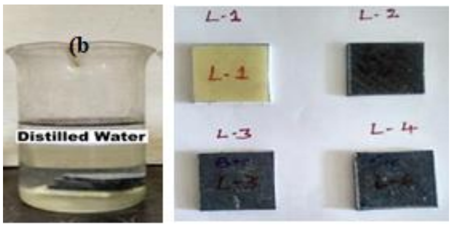


Fig. 2 (a) Hardness test specimens, (b) Test specimens under water absorption test.

3 RESULTS AND DISCUSSION

3.1 Tensile Test

Figure 3 displays the stress v/s strain curves for the L1, L2, L3, and L4 laminate compositions. All specimens were broken at the maximum length allowed by the gauge. The L1 laminates experienced early fractures with an ultimate tensile strength of 35.2 MPa as a result of the pure bamboo fibres present. Another study found bamboo epoxy composites had 18.07 MPa ultimate tensile strength (P. Lokesh. et.al., 2020). However, when tensile pressure is applied to composite laminates, the bonding can be released, indicating that fibre characteristics might play a crucial role during the tensile test experiment (M. Ramesh et.al., 2017). The highest ten-sile strength observed was 73.7 MPa for L4 laminates which consists of hybridized fill-er material. Detailed analysis of tensile strength for different laminates is presented in Figure 4. With addition of SiC tensile strength is improved, this can be attributed to improved load distribution among fibers in the specimen with the help of SiC particulates. The results show that SiC ceramic filler somewhat increases specimen tensile strength. This is due to fibre, matrix, and filler cross-linking.

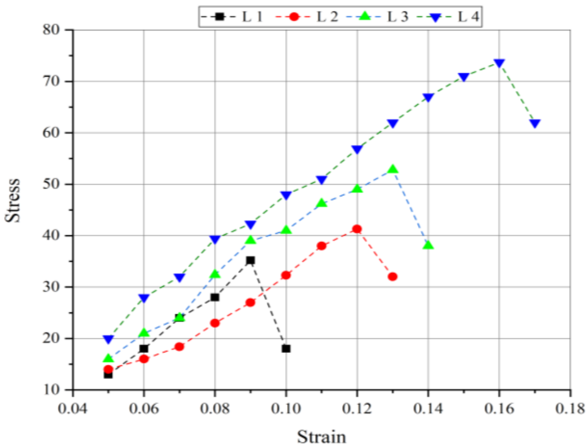


Fig. 3. Stress-Strain curves for all laminates

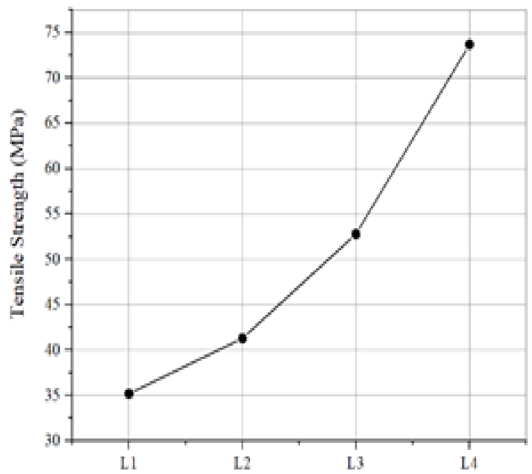


Fig. 4. Tensile properties of laminate

3.2 Flexural Test

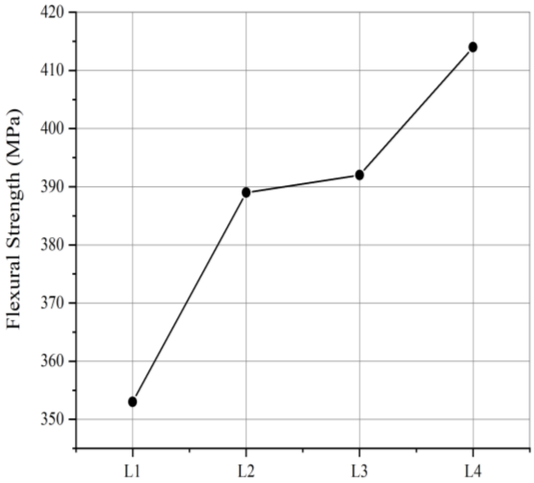


Fig. 5. Flexural strength of fabricated laminates

3.3 Hardness Test

A hardness test was performed with a load of 100 kg-Force for a duration of 20 seconds. The composites' hardness was calculated by computing the mean value at random points on the surface, taking into consideration randomly oriented fibres and particles. The hardness values of the composites are displayed in Figure 6. The observed hardness values of pure bamboo-epoxy composites were 53.3 RHN, which is lower in quality compared to the other laminates. SiC increases the toughness of bamboo epoxy composites (S. Biswas, 2012). L4 laminates which is a hybrid composite shows maximum hardness value of 82 RHN. The SiC filled laminates have higher hardness, this is because the gaps between matrix and fiber interface are filled the filler materials, thereby creating denser structure which reasons for better hardness property.

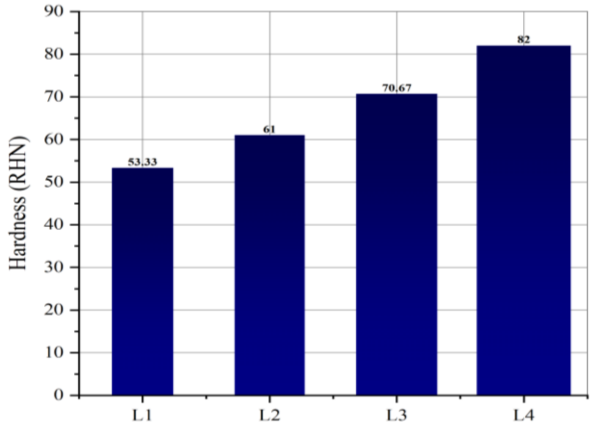


Fig. 6. Hardness values of all laminates

3.4. Water Absorption Test

The water test was performed by submerging the specimens in distilled water at ambient temperature. The samples periodically taken out from the beaker and wiping out the surface, then the composites weighed at the regular intervals of 24, 48, 72 and 96 hours. Measuring the weight difference between the dry and wet samples determined the composites' water absorption rate.

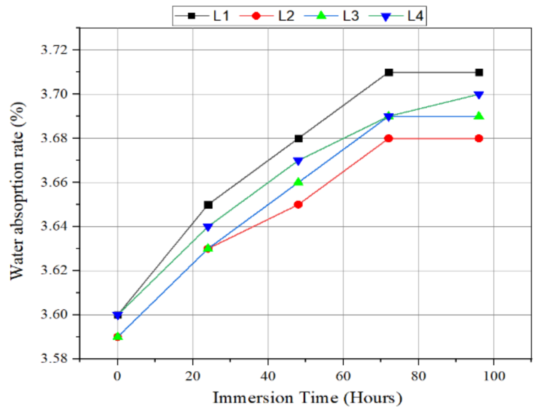
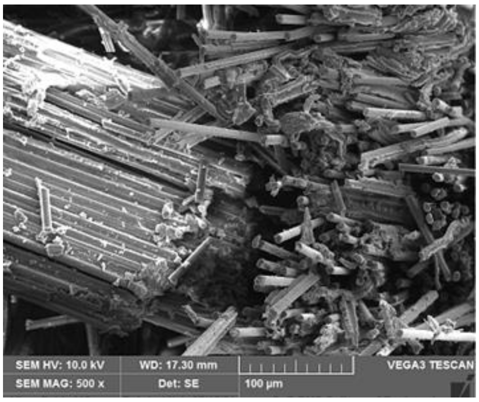


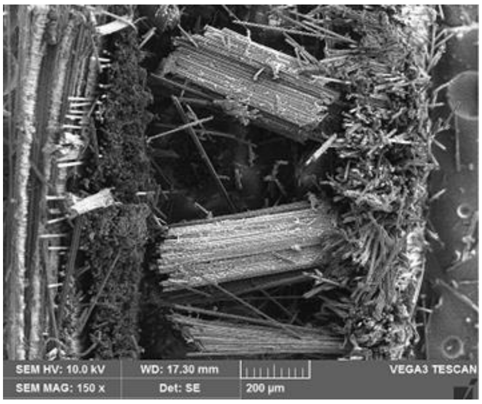
Fig. 7. Water absorption curve for laminates

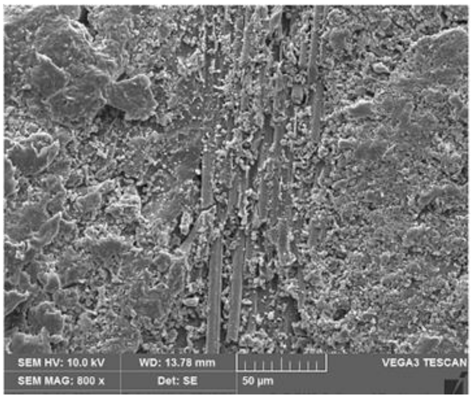
Figure 7 displays the rate at which water is absorbed by all composite samples. The water absorption is initially high and then gradually decreases over time. The highest rate of water absorption was recorded for the L1 laminate, which consists of a pure bamboo-epoxy composite. Lignin and hemicellulose increase hydrophilicity in untreated bamboo composites, causing more water absorption (Kushwah et.al., 2010). Although hemicelluloses are primarily accountable for water absorption, noncrystalline cellulose and lignin also plays a key role. The water absorption rate of L4 laminates which consists of carbon fibres and SiC particulates found comparable to that of L1 laminates.

3.5. Microstructure of the Composites

Figure 8 (a-d) illustrates a scanning electron microscope examination of natural fibre composite laminates and the combination of natural fibre with synthetic fibre and particulates. Figure 7a illustrates the phenomenon of fibre extraction from the matrix phase caused by insufficient adhesion between the resin and the bamboo fibre (S. Biswas, 2012) & (Souza, J et.al., 2019).







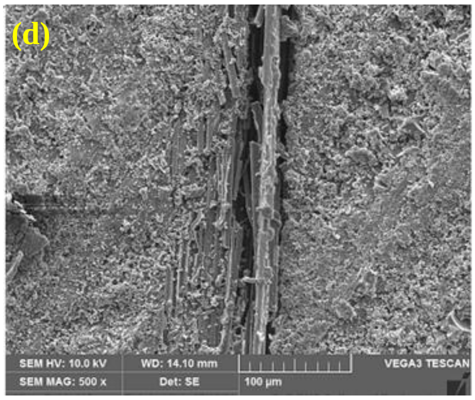


Fig 8. SEM images of composites comprised of (a) Bamboo Fiber, (b) Bamboo Fiber with SiC, (c) Bamboo fiber with Carbon Fiber, (d)Bamboo fiber with Carbon Fiber and SiC

It also clearly demonstrates the existence of cavities in the specimen. Voids could be eliminated by adopting better procedures during composite processing, such as a vacuum bagging system. However, because of its cost-effectiveness, the hand lay-up technique was utilized. The observations demonstrate the presence of a gap between the fibre and the matrix, due to impacts of the processing conditions. Figure 8 (c-d) shows that the interfacial adhesion of the fibre and the matrix is still good, indicating that the fibre surface is rougher and the matrix contour is closer to the fiber's surface. Because of the existence of SiC and Carbon fibres, the integrity of the fibre and resin surfaces improved.

4 CONCLUSIONS

Epoxy-based polymer composites reinforced with bamboo, carbon, and SiC particle fillers were tested for mechanical characteristics. The following are the experimental findings.

- Bamboo Fibre reinforced epoxy composites have been successfully produced by handlyaup method.
- Carbon fibres reinforcement and Sic Particulate fillers significanlty affected the mechanical propertis of bamboo-epoxy composites.
- Tensile and flexural strength of bamboo epoxy composites have been improved effectively with carbon fibre and SiC particulates. Tensile strength of L4 laminate found 70.7% higher compared to L1 laminate, a pure bamboo epoxy composites. Where as the flexural strength of L4 laminate was 15.9% higher to that of L1 laminates.
- Microhardness test reveals that addition of carbon fibres and Sic particulates made

- composite surface more harder compared pure bamboo epoxy composites.
- Water absorption rate is effectively higher in pure bamboo epoxy composites compared to that of bamboo epoxy composites with synthetic fibres and SiC particulates.

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