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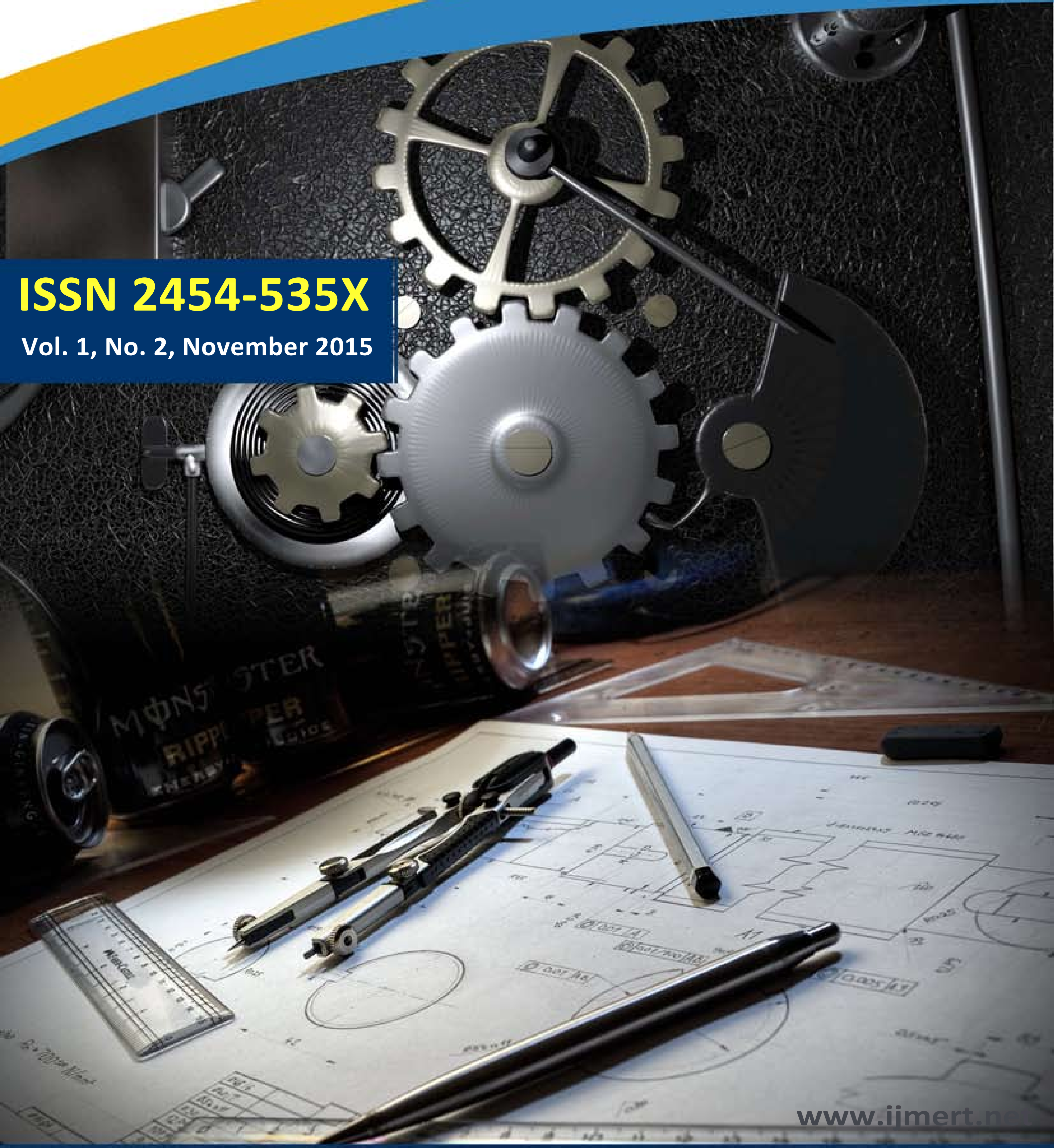

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*Research Paper*

# DESIGN AND ANALYSIS OF SHORT BAMBOO FIBER REINFORCED COMPOSITE MATERIALS

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Many of our modern technologies demand materials with unusual combination of properties such as high strength to weight ratio, high stiffness, high corrosion resistance, high fatigue strength, high dimensional stability, etc., these can't be met by the conventional metal alloys. Polymeric materials reinforced with synthetic fiber such as glass, carbon and aramid provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials, i.e., wood, concrete, and steel. Despite these advantages the widespread use of synthetic fiber-reinforced polymer composite has tendency to decline because of their high-initial costs, their use in non-efficient structural forms and most importantly their adverse environmental impact. On the other hand, the increase interest in the natural fibers as reinforcement in polymers to substitute conventional synthetic fiber in some structural applications has become one of the main concerns to study the potential of using natural fiber as reinforcement for polymers. In this project work, an attempt has been made to explore the potential utilization of short bamboo fiber reinforced polyester composites. Therefore, the present project work is to evaluate the Mechanical properties such as Tensile Strength (TS), Flexural Strength (FS) of short bamboo fiber reinforced composites with and without Alumina ($Al_2O_3$) as a reinforced material.

Keywords: Composite materials, Bamboo fiber, Resin injection techniques, Hot press method

## INTRODUCTION

### Composites

A composite is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material (fiber, Kevlar and whiskers). The advantage of composite materials over conventional materials are largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material as

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reinforcement imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load.

## CONSTITUENTS OF COMPOSITES

The constituents or materials that make up the composites are resins, fillers, additives and reinforcements (e.g., fibers).

### Polymer Matrix Materials

The matrix is an important constituent in composites. Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications. The polymer matrix materials are mainly classified in to two types. They are Thermo sets and Thermoplastics. Figure 1 helps to classify matrices.

The classifications of Thermoses are shown in Figure 2.

## OBJECTIVES OF THE PROJECT WORK

The objectives of the project are outlined below.

Figure 1: Classification of Matrices

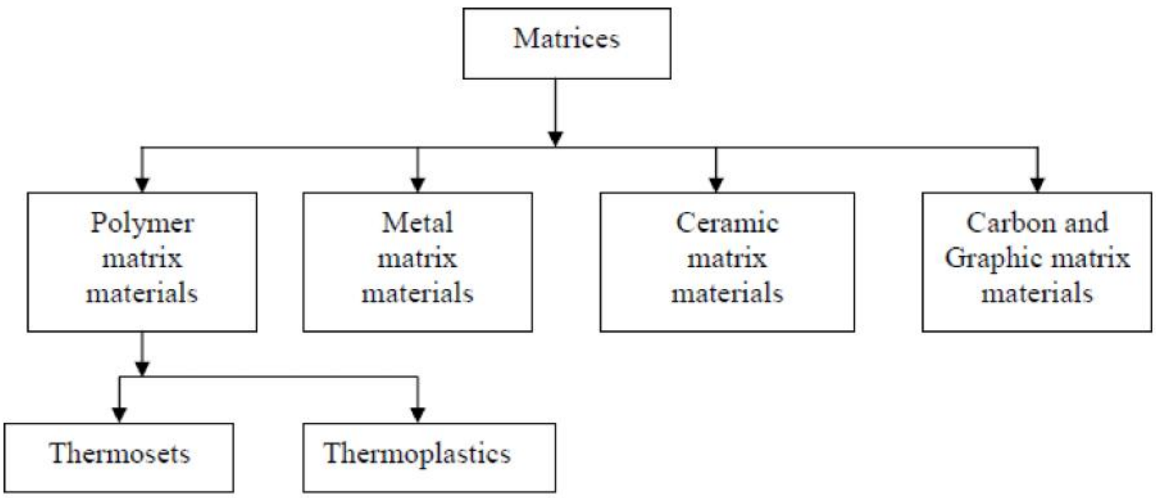
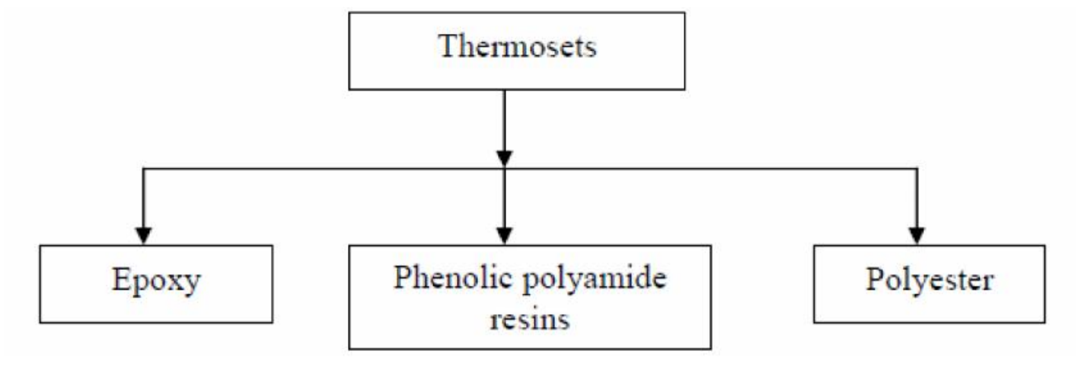


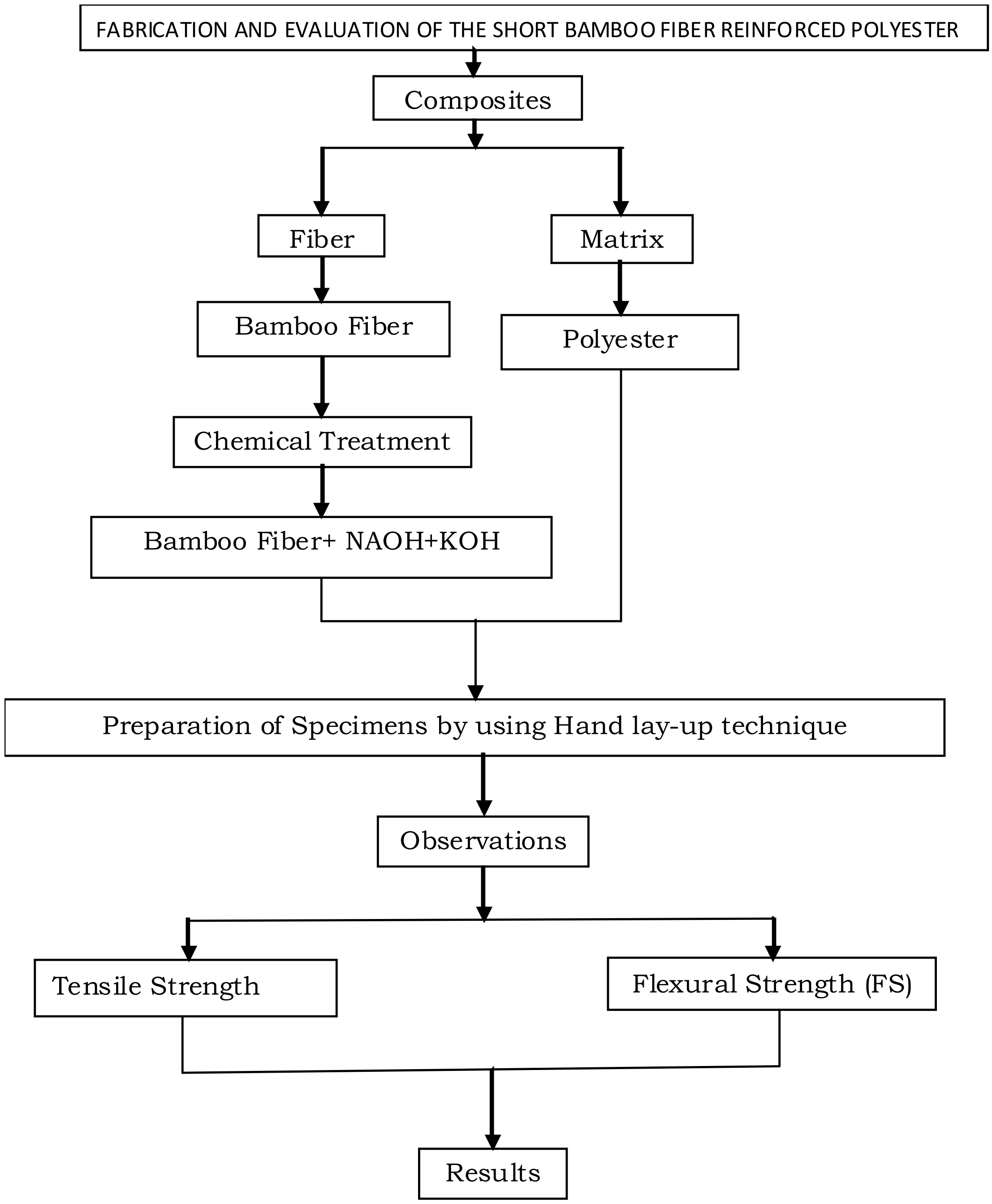

Figure 2: Classification of Thermosets



- Fabrication of unfilled and alumina filled short bamboo fiber reinforced Polyester composites.
- Evaluation of mechanical properties of both unfilled and particulate filled Composites such as Tensile Strength (TS) and Flexural Strength (FS).

The processing of scheme of investigation is shown in Figure 3.

Figure 3: Scheme of Investigation



## MATERIALS AND METHODS

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used in this work are

1. Short Bamboo fiber
2. Polyester resin
3. Alumina (Al2O3) filler material

### Bamboo Fiber

Fiber is there in forcing phase of a composite material. In the present project work, short bamboo fiber is taken as the reinforcement in the polyester matrix to fabricate composites. In general, bamboo is available everywhere around the world and is an abundant natural resource. It has been a conventional construction material in ancient times. The bamboo used for this work is collected from the local source. Bamboo is an orthotropic material with high strength along axial and low strength transversal to its fibers. The structure of bamboo itself is a composite material, consisting of long and aligned cellulose fibers immersed in a ligneous matrix. In this work, short bamboo fiber is used as the reinforcement in the composites. Average thickness of each bamboo fiber is about 2 mm. Table 1 shows short bamboo fiber properties.

Table 1: Properties of Bamboo Fiber

| Properties | Values |
|---|---|
| Tensile strength (Mpa) | 140-230 |
| Young's modulus (GPa) | 11-17 |
| Elongation atbreak (%) | ~2 |
| Density (g/cm^3) | 0.6-1.1 |

### Applications of Bamboo Fiber

Roof construction, Car Dashboard, Rope, Making sheet, Paint brush, Upholstered furniture, Geo-textile, Bamboo cycle etc.

### Chemical Treatment

The structure of bamboo itself is a composite material, consisting of long and aligned cellulose fibers immersed in aligneous matrix. The bamboo fiber has the highest percentage of lignin which makes the fiber very stiffer when compare to other natural fiber. This can be attributed to the fact that the lignin helps provide the plant tissue and the individual cells with compressive strength and also stiffness to the cell wall of the fiber where it protect the carbohydrate from the chemical and physical damage. The lignin content also influences the structure; properties, flexibility, hydrolysis rate and high lignin content it appear to be finer and also more flexible.

In this investigation, the bamboo fibers are chemically treated with two different types of chemicals namely Sodium Hydroxide (NaoH) and Potassium Hydroxide (KoH) at 3 moles of concentration in 100ml of distilled water, then the beaker boiled for few minutes and the fiber is dried in sunlight for 10-12 days. The purpose of chemical treatment is to remove the moisture content present in the bamboo fiber and to increase the tensile strength of bamboo fiber.

### Matrix Material

Unsaturated Polyester Resin is taken as the matrix material Polyester is at Thermoset material, Polyesters and other resins in liquid form contain monomers (consisting of simple molecules),which convert into polymers (complex cross-linked molecules) when the resin is cured. The resulting solid is called thermosets, which is tough, hard, insoluble and infusible. The property of infusibility distinguishes thermosets from the thermoplastics. Cure and polymerization refer to the chemical reactions that solidify the resin. Curing is accomplished by heat, pressure and by addition of curing agents at room temperature.

Polyesters can be cured at atmospheric pressures and also at ambient temperatures. Polyester matrices have been in use for the longest period in the wide strange of structures. Polyesters cure with the addition of a catalyst (usually a peroxide) resulting in an exothermic reaction, which can be initiated at room temperature. However, Polyesters are widely used due to the following advantages.

- Low cost,
- Good handling characteristics,
- Low viscosity and versatility,
- Good mechanical strength,
- Good electrical properties,
- Good heat resistance,
- Cold and hot molding,
- Flame resistant with fire proof additive, and
- Max Sustainable temperature is 120 °C (250 °F).

The choice of Unsaturated Polyester to be the matrix could be the answer to counter the weakness of natural fiber. Polyester has very low moisture absorption level and cloud solve the fast degradation problems of natural fiber, thus improving the natural fiber's performance in environment. Polyester also possess good tensile strength compared to other thermoset polymer and it is suitable to fulfills the objective of this project.

Table 2: Designation of Composites

| Samples | Compositions |
|---|---|
| PB-1 | Polyester + Bamboo Fiber (15 wt%) |
| PB-2 | Polyester + Bamboo Fiber (30 wt%) |
| PB-3 | Polyester + Bamboo Fiber (45 wt%) |
| PBA-1 | Polyester + Bamboo Fiber (45 wt%) + Alumina (0 wt%) |
| PBA-2 | Polyester + Bamboo Fiber (45 wt%) + Alumina (5 wt%) |
| PBA-3 | Polyester + Bamboo Fiber (45 wt%) + Alumina (10 wt%) |
| PBA-4 | Polyester + Bamboo Fiber (45 wt%) + Alumina (15 wt%) |

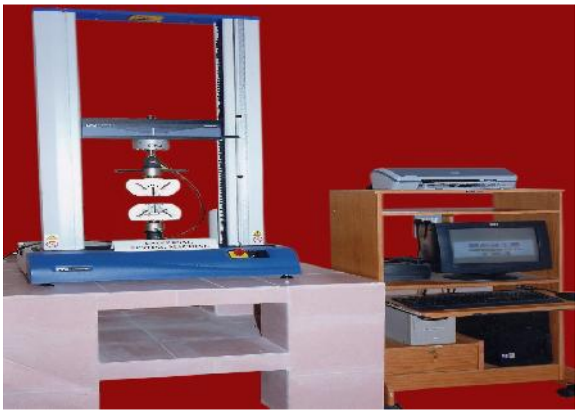
## TESTSPERFORMED

The prepared specimens of suitable dimensions are cut using by machine (according to ASTM standards) for physical characterization. On thus fabricated specimens following tests are performed.

- Tensile strength characteristics.
- Flexural strength characteristics.

Tensile test is performed on a Universal Testing Machine

Figure 4: Universal Testing Machine



$$\text{Tensile strength} = \frac{\text{Maximum tensile load applied}}{\text{Original cross section area}} = \frac{p_{max}}{A}$$

### Flexural Test

$$F.S = \frac{3lp}{2bd^2}$$

## RESULTS AND DISCUSSION

This chapter presents the results of mechanical properties of short bamboo fiber reinforced polyester composites. This chapter consisting of two parts, in the first part the results of mechanical behavior of short bamboo fiber reinforced polyester composites without filler and in the second part mechanical behavior of alumina filled bamboo fiber reinforced polyester composites is presented.

**Part-1:** Bamboo Fiber Reinforced Polyester Composites without Filler

### Mechanical Characteristics of Composites Without Filler

The mechanical properties of the short bamboo fiber reinforced polyester composites with different fiber loading under this investigation are presented in Table 3. It is evident from the Table 3 that at 45 wt% of fiber loading the composites show better mechanical properties as compared to others.

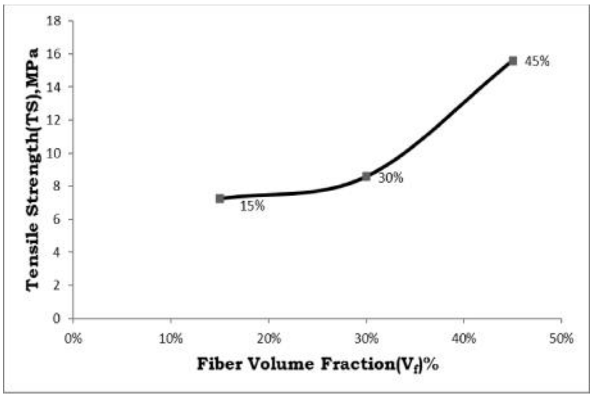
Table 3: Mechanical Properties of the Composites Without Filler

| Composites | Tensile Strength (MPa) | Flexural Strength (MPa) |
|---|---|---|
| PB-1 | 7.241 | 29.381 |
| PB-2 | 8.587 | 38.989 |
| PB-3 | 15.601 | 26.226 |

### Effect of Fiber Volume Fraction on Tensile Strength of Composites

The effect of weight fraction of fiber on the tensile strength of the composite is shown in Figure 5. Asthe weight fraction of fiber increases in the composites up to 45 wt%, the tensile strength of composite is increases up to 15.601 MPa. The tensile properties measured in the present work are well compared with various earlier investigators, though the method of extraction of bamboo fiber is different.

Figure 5: Effect of Fiber Volume Fraction on Tensile Strength of Composites




### Effect of Fiber Volume Fraction on Flexural Strength of Composites

Figure shows the effect of fiber loading on flexural strength of composites. Adversely, as shown in Figure 6, the flexural strength increased by the increase of fiber loading up to 30 wt%. For instance, flexural strength of bamboo-polyester composite is increased from 29.38 Mpa to 38.98 Mpa up to 30 wt% and then decreased from 38.989 MPa to 26.226 Mpa, i.e., upto 45 wt% respectively (Figure 6). It is also observed from Figure 6 that a linearly increasing trend up to a certain value of fiber loading (30 wt%) and suddenly drops due to failure of specimens and the

Figure 6: Effect of Fiber Volume Fraction on Flexural Strength of Composites

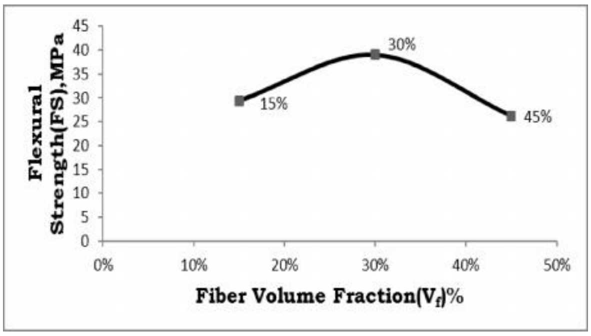
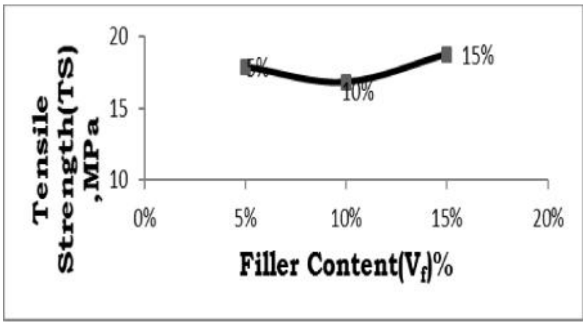



Figure 7: Effect of Filler Content on Tensile Strength of the Composites




arrest points correspond to breakage and pullout of individual fibers from the resin matrix. For a composite to be used as the structural application it must possess higher flexural strength.

**Part-2:** Alumina Filled Bamboo Fiber Reinforced Polyester Composites

### Mechanical Characteristics of Composites with Filler

The mechanical properties of alumina filled bamboo fiber polyester composites with different fiber volume fraction are presented in Table 4. It is evident from the Table 4 that at 45 wt% of fiber volume fraction the composites show better mechanical properties as compared to others.

### Effect of Filler Content on Tensile Strength of the Composites

The influence of filler content on tensile strength of composites is shown in Figure 7. In this the bamboo fiber reinforcement is maintained 45% and alumina is added as filler with different proportions. It can be seen that the tensile properties have become distinctly improved with the incorporation of alumina particles (15 wt %) in the matrix. The increase in tensile strength is due to the cross linking network formation between the fibers and the filler filled polymer matrix.

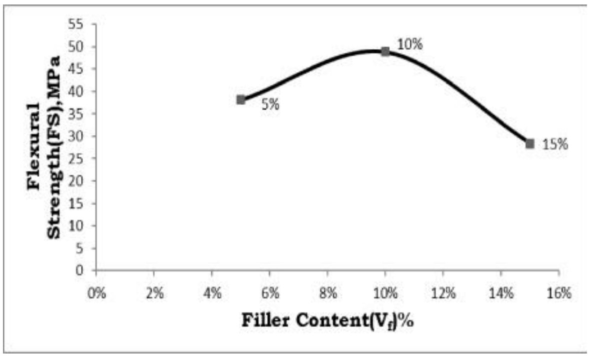
Table 4: Mechanical Properties of the Composites with Filler

| Composites | Tensile Strength (MPa) | Flexural Strength (MPa) |
|---|---|---|
| PBA-1 | 17.883 | 38.109 |
| PBA-2 | 16.861 | 45.848 |
| PBA-3 | 18.767 | 28.448 |

### Effect of Filler Content on Flexural Strength of the Composites

The influence of filler content on flexural strength of composites is shown in Figure 8. In this the bamboo fiber reinforcement is maintained 45% and alumina is added as filler with different proportions. It can be seen that the flexural properties have become distinctly improved with the incorporation of alumina particles up to 10 wt% in the matrix. The significant variation of flexural strength for different systems indicates fiber alignment is not the only factor which affects mechanical performance; interfacial adhesion and the bamboo fiber influences polyester matrix properties also have a significant effect. The variation of flexural strength of the composites with filler content is shown in Figure 8. The decreases in mechanical strengths of the

Figure 8: Effect of Filler Content on Flexural Strength of the Composites




composites are probably caused by an incompatibility of the alumina particles and the polyester matrix with bamboo fiber, leading to poor interfacial bonding. However, it also depends on other factors such as the size and shape of the filler taken in the composites.

## CONCLUSION

The experimental investigation on the effect of fiber loading and filler content on mechanical behavior of short bamboo fiber reinforced polyester composites leads to the following conclusions obtained from this study are as follows:

1. The successful fabrications of a new class of polyester based composites reinforced with short bamboo fibers have been done.
2. It has been observed that the Mechanical properties of the composite such as Tensile Strength (TS) and Flexural Strength (FS) are greatly influenced by the fiber volume fraction.
3. Tensile strength of the composite material without filler increases with the increase in fiber Volume fraction (Vf) up to 45% of bamboo fiber.
4. Flexural strength of the composite material without filler increase with increase in fiber Volume fraction (Vf) up to 30% of bamboo fiber and then decreases slightly.
5. Tensile strength of the composite material with filler increases with the increase in filler content by keeping 45% of bamboo fiber constant.
6. Flexural strength of the composite material with filler increase with increase in filler content up to 30% by keeping 45% of bamboo fiber constant and then decreases slightly.
7. Possibleuse of bamboo fiber reinforced composites such as pipes carrying coal dust, industrial fans, desert structures, low cost housing, etc. However, this study can be further extended in future to new types of composites using other potential natural fibers/fillers and the resulting experimental findings can be similarly analyzed.

## SCOPE FOR FUTURE WORK

- There is a very wide scope for future scholars to explore this area of research.
- This work can be further extended to study other aspects of such composites like effect of fiber content, fiber orientation, loading pattern, fiber treatment on mechanical behavior of bamboo based polymer composites and the resulting experimental findings can be similarly analyzed The study leaves wide scope for feature investigation.
- Characterization can also be done on SEM (Scanning Electronic Microscope), TEM (Transmission Electronic microscopy), DSC (Differential Scanning Calorimetry) and TGA (Thermo Gravi Metric Analysis). It

can be extend to produce newer composite, by placing them in different orientation, by changing the manufacturing method.

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