International Journal of Engineering Research
Volume No.3 Issue No: Special 1, pp: 187-194
ISSN:2319-6890)(online),2347-5013(print)
22nd March 2014

# Mechanical Properties Evalution of Bamboo Fiber Reinforced Composite Materials

**S.sreenivasulu[1], Dr. A chennakeshava Reddy[2]**
[1]Department of Mechanical Engineering, RGMCET, Nandyal- 518501,
[2]Professor in Department of Mechanical Engineering, JNTUCE, Hyderabad
***Corresponding author:*** *e-mail:srinivas019@gmail.com*

**ABSTRACT:**
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.

In this the 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: polymeric composites, bamboo fiber**

## INTRODUCTION

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.

The dynamic mechanical analysis of banana fiber reinforced polyester composites was carried out between the phases determine the dynamic mechanical properties of the composite(3). Short bamboo fiber reinforced polycarbonate toughened epoxy composites are developed using varied fiber lengths. The variation of tensile strength with varied fiber length has been studied. The optimum length of fiber is found in this experimental study. also showed good chemical resistance to some acids, Theses composites alkalis and solvents. An experimental investigation was conducted on cement mortar reinforced with woven bamboo mesh in a manner similar to Ferro cement. The main parameter of the study was the volume fraction of bamboo and its surface treatment. The effect of casting pressure was also included. The results of the tests conducted in direct tension, flexure and impact are presented and discussed.(6). A critical review of the literature on the various aspects of natural fibres and bio composites with a particular reference to chemical modifications is presented in this paper. A notable disadvantage of natural fibers is their polarity which makes it incompatible with hydrophobic matrix. This incompatibility results in poor interfacial bonding between the fibers and the matrix. This in turn leads to impaired mechanical properties of the composites (4).

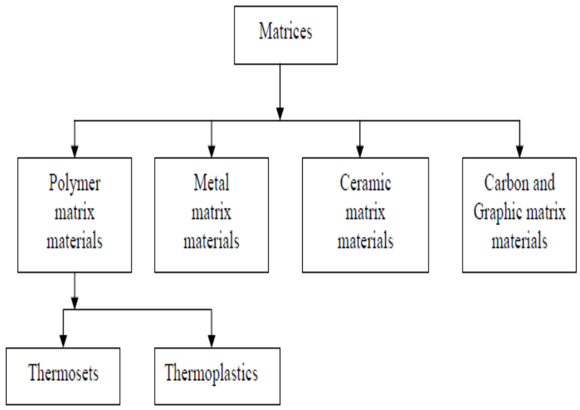


Fig1

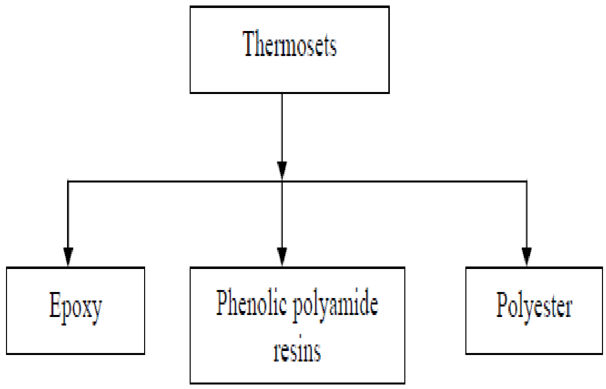


Fig 2

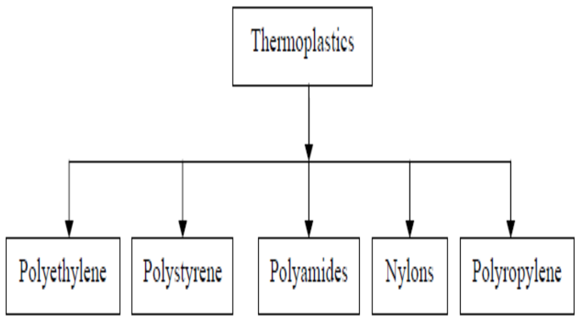


Fig 3

Fig 1, 2,3 Cassification of Matrix, Thermoset, Thermoplastics

**Material 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 the reinforcing 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 since ancient times. The bamboo used for this work is collected from the local source. This is one of the predominant species of bamboo in Andhra Pradesh, Orissa, Uttar Pradesh, Madhya Pradesh and Western Ghats in India. 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. The average thickness of each bamboo fiber is about 2 mm. Table 1 shows short bamboo fiber properties

**Table1. Properties of bamboo fiber**

| Properties | Values |
|---|---|
| Tensile strength(Mpa) | 140-230 |
| Young's modulus(GPa) | 11-17 |
| Elongation at break (%) | ~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.

**MATRIX MATERIAL**

Unsaturated Polyester Resin is taken as the matrix material Polyester is a 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 widest range 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

**MANUFACTURING PROCESSES**

The most commonly used manufacturing processes are introduced. Although many variants on these techniques exist, this overview gives a good indication of production possibilities.

**Hand lay-up technique**

The fibers, usually mats, are cut and placed in a mould, see figure 4 .The resin is applied by rollers. One option is to cure while using a vacuum bag, then it's called vacuum bagging. By applying vacuum, excess air is removed and the atmospheric pressure exerts pressure to compact the composite. Thermosets commonly product is the boat hull. The advantages are the high flexibility and the simplicity of the process and the cheap tooling. The long production time, the labour intensive character and poor possibilities for automation are considered to be disadvantages.

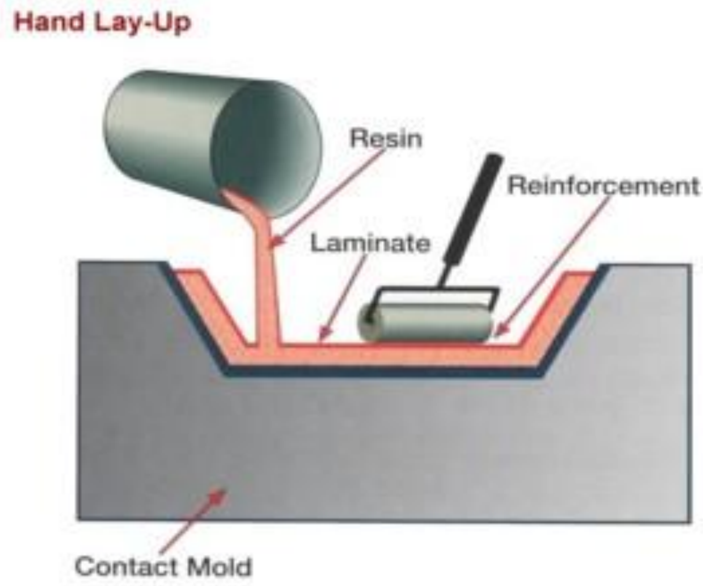


**Fig 4. Hand lay-up technique**

**Resin injection techniques**

The chopped fiber are placed inside a mould. In case of Resin Transfer Moulding(RTM), this mould consists of two solid parts, see figure 5, whereas with vacuum injection a single solid mould and a foil are used tube connects the mould with a supply of liquid resin, which is pumped or transferred through the mould, impregnating the fibers. After curing the mould is opened and the product is removed. The big advantage is the capability of rapid manufacture of large, complex, high-performance structures, such as the frames presented.

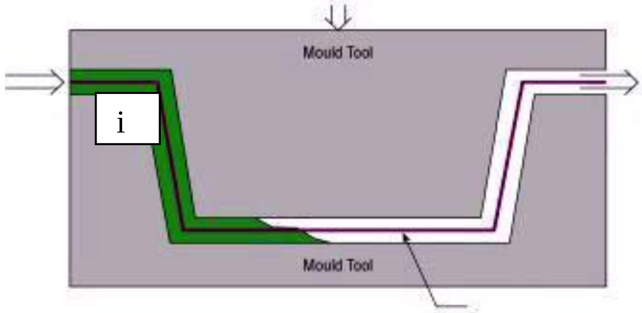

**Fig 5.** RTM

**Hot press methods**

Composite pre-forms (already mixed resin and fibers) are inserted in a mould and are cured using pressure and heat. With injection moulding, resin granules and short fibers are mixed and transported to the mould by a spindle, see figure 6. In this way very complex product, like housings of telephones, TV's, cameras and keyboard parts can be made. With sheet moulding reinforced mats are placed in a press, see figure. Various other hot press methods exist.

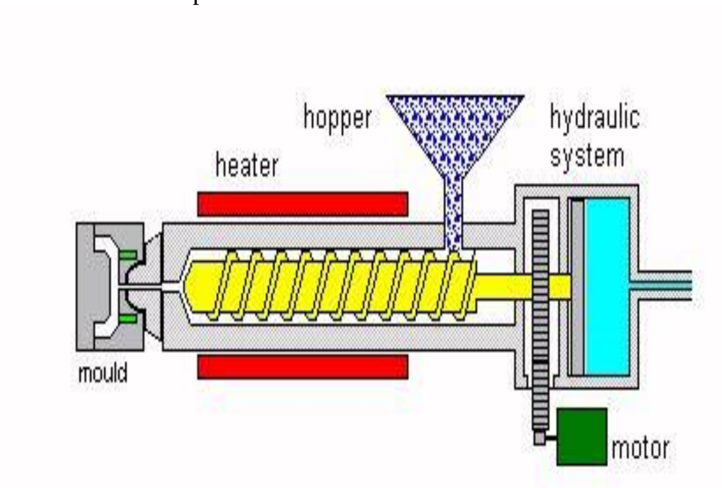


**Fig 6. Injection moulding technique**

**Filament winding**

Filament winding is a process in which continuous fibers or tows are wound over a rotating mandrel, see figure 7. They can be resin-impregnated before, during or after placement. The advantages of filament winding are the repetitiveness of an accurate fibre placement, the use of continuous fibers resulting in high strength and the possibility to construct rather large structures. The disadvantages are the requirement of a removable mandrel (not with all applications) and the hard to define outer surface. A typical product is a LPG container.

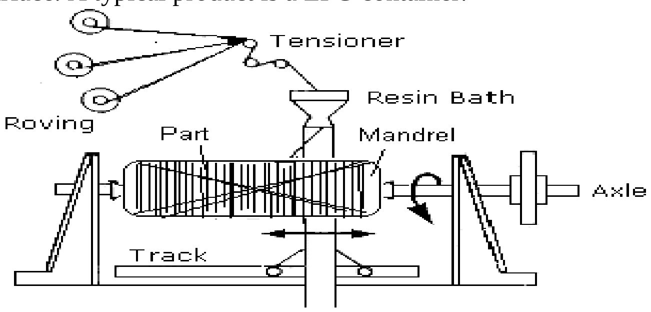


Fig 7. Filament winding

**Pultrusion**

Pultrusion is a continuous process to manufacture composite profiles at any length. The impregnated fibers are pulled through a hole (the heated mandrel), which is shaped according to the desired cross-section of the product, see figure 8. The resulting profile is shaped until the resin is dry. The advantages are the manufacturing of thin-wall shapes of "endless" length large variety in cross-sectional shape and the possibility for a high degree of automation. Disadvantage is the restriction to one cross-section, shape variation in transverse direction is not possible.

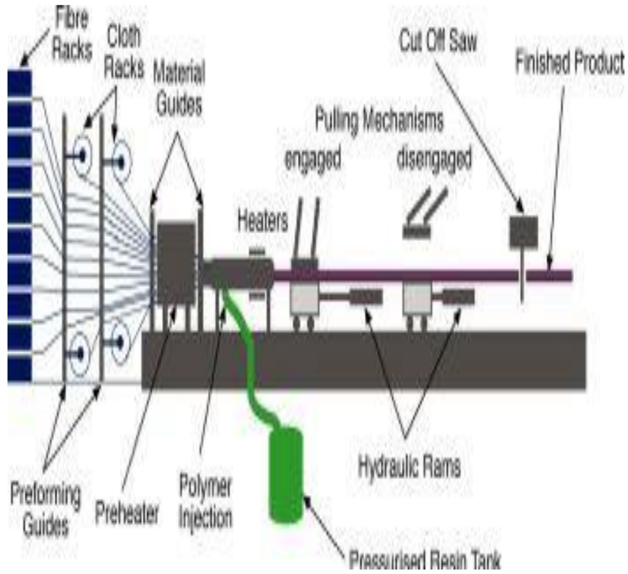


Fig 8. Pultrusion process

**PREPARATION OF MOULD**

A glass molding box with 150mm X 150mm X 3mm mold cavity was used for making the composite and a plain glass is used to cover the mould.

**COMPOSITE FABRICATION**

In this study, short bamboo fiber is taken as reinforcement is collected from local sources. The polyester resin, the catalyst(mekp) and accelerator cobalt napthenate are supplied by Ecmas Resin suppliers,$Al_2O_3$ powders are obtained from the laboratory in a range of 80-100 µm here for Composite fabrication Hand lay-up technique is employed. A Glass mould having dimensions of 150*150*3 mm is used for composite fabrication. The short bamboo fiber and $Al_2O_3$ particulates are mixed with polyester resin by the simple mechanical stirring and the mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The composite samples of four different compositions (PB-1 to PB-3), in which no particulate filler is used. The other composite samples PBA-1 to PBA-3 are prepared in four different percentages of alumina particulates (0wt%, 5wt%, 10wt% and 15wt% of alumina) is used keeping bamboo fiber at a fixed percentages (i.e. 45wt%). A releasing agent (Ethanol) is used to facilitate easy removal of the composite from the mould after curing. The entrapped air bubbles (if any) are removed carefully with a sliding roller and the mould is closed for curing at a temperature of 40°C for 24 h at a constant pressure of $10kg/cm^2$. After curing, the specimens of suitable dimension are cut for mechanical tests. The composition of the composites prepared for this study is listed in Table 2. The composite samples with different compositions are shown in figure 9

**.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%) |

**Fig.9 Samples prepared for tests**

**TESTS PERFORMED**

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

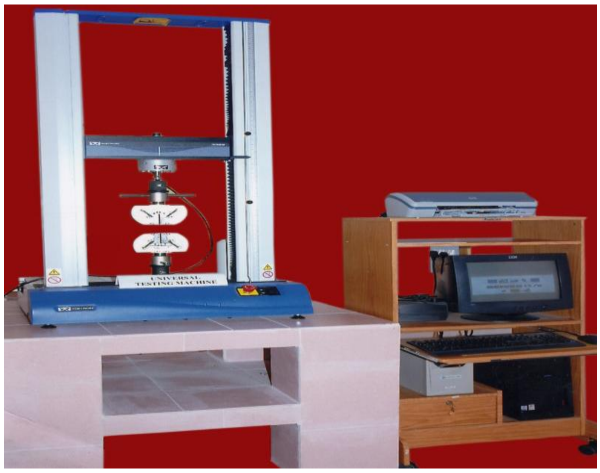

**Fig.10. Universal Testing Machine**

**Tensile Test**

The tension test was performed on all the three samples as per ASTM D3039-76 test standards. The tension test is generally performed on flat specimens. A uniaxial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 150 mm specimens with fibers parallel to the loading direction should be 20 mm wide . Ultimate tensile strength is the force required to fracture a material. The tensile strength can be experimentally determined by the given formula.

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

The ultimate tensile strength $p_{max}$ can be determined by the stress strain graph. The unit used for tensile strength is $N/m^2$. According to ASTMD 3039-76 the tensile test specimen dimensions are 150mm X 20mm X 3mm as shown in the fig 11. The test speed was maintained 5mm/min, at a temperature $22^oC$ and humidity 50%.

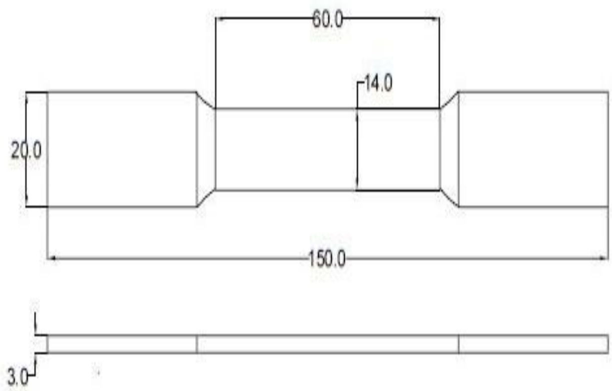


**Fig. 11. Specimen dimensions according to ASTM standards**

**Fig.12. Specimen before Tensile Test**

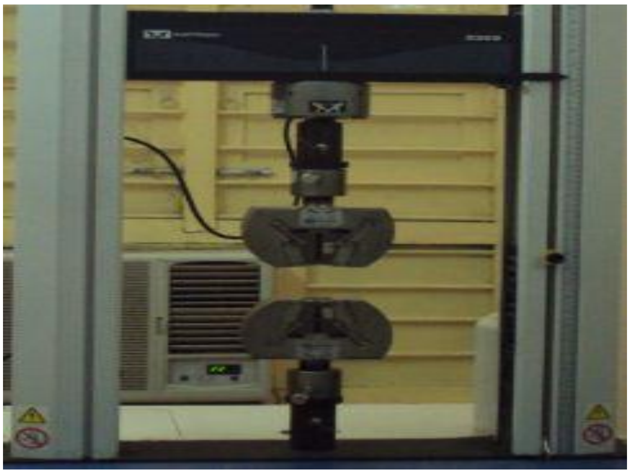

**Fig. 13. Grip components for Tensile Test**

**Fig.14. Specimen after Tensile Test**

**Flexural Test**

The strength of material in bending, expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. Flexural strength was determined using three point simply supported bending equipment. In a conventional test, flexural strength expressed in Mpa.

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

Where p = the load applied to a sample of test, in Newton
l= specimen length in mm
b = specimen width in mm
d = specimen thickness in mm

Flexural strength was determined using universal testing machine equipment. The specimen are prepared as per ASTMD790-03, the test speed was maintained at 5mm/min, at a temperature 22˚C and humidity 50%.In each case three samples were taken and average value is reported. According to ASTMD 790-03 the flexural test specimen dimensions are 150mm X 20mm X 3mm as shown in the fig.15.

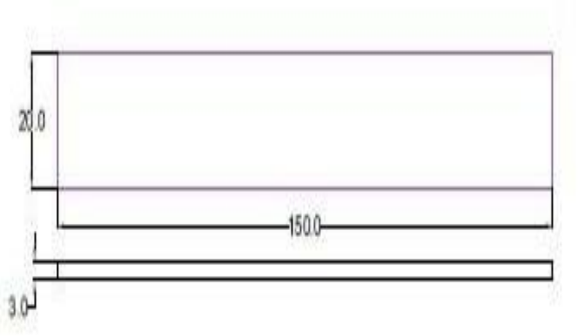


**Fig.15. Specimen for Flexural Strength**

**Fig.16. Specimen before Flexural Test**

**Fig .17. Grip Components for Flexural Test**

**Fig.18. Specimen after Flexural Test**

International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3 Issue No: Special 1, pp: 187-194 22nd March 2014

Results & 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 45wt% of fiber loading the composites show better mechanical properties as compared to others

**Table3.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 19.As the weight fraction of fiber increases in the composites up to 45 wt%, the tensile strength of composite is increases up to 15.601MPa. 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.

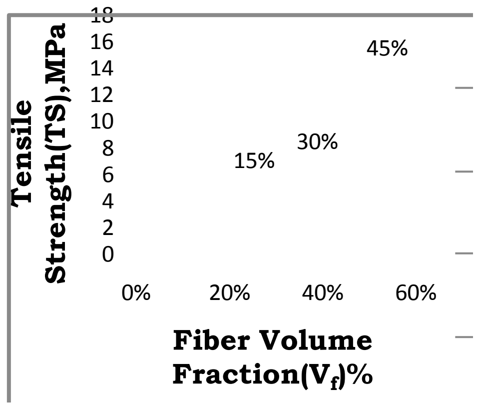


**Fig.19. Effect of fiber volume fraction on tensile strength of composites**

**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 20. the flexural strength increased by the increase of fiber loading up to 30wt%. For instance, flexural strength of bamboo-polyester composite is increased from 29.38Mpa to 38.98Mpa i.e up to 30wt% and then decreased from 38.989MPa to 26.226Mpa i.e. up to 45wt% respectively (Figure 20). It is also observed from Figure 20 that a linearly increasing trend up to a certain value of fiber loading (30wt%) and suddenly drops due to failure of specimens and the arrest points correspond to breakage and pull out of individual fibers from the resin matrix. This is due to higher flexural stiffness of bamboo composite and the improved adhesion between the matrix and the fiber. The effect of weight fraction of fiber on mean flexural strength for other fiber reinforced composites in comparison to bamboo composites are more. This decrease is attributed to the inability of the fiber, irregularly shaped, to support stresses transferred from the polymer matrix and poor interfacial bonding generates partially spaces between fiber and matrix material and as a result generates weak structure. As flexural strength is one of the important mechanical properties of the composites. For a composite to be used as the structural application it must possess higher flexural strength.

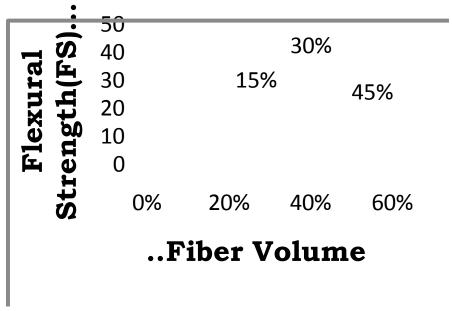


**Fig.20. Effect of fiber volume fraction on flexural strength of composites**

**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 45wt% of fiber volume fraction the composites show better mechanical properties as compared to others.

**Table4. Mechanical properties of the composites with filler**

International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3 Issue No: Special 1, pp: 187-194 22nd March 2014

| 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 tensile strength of the composites**

The influence of filler content on tensile strength of composites is shown in Figure 21..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 (15wt %) in the matrix. The significant variation of tensile 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. Generally, modulus reflects the performance of both fiber and matrix interface material to transfer the elastic deformation in the case of small strains without interface fracture. Therefore, it is not surprising that the tensile modulus is less sensitive to the variation of interfacial adhesion than the tensile strength which is strongly associated with interfacial failure behavior. The increase in tensile strength is due to the crosslinking network formation between the fibers and the filler filled polymer matrix.

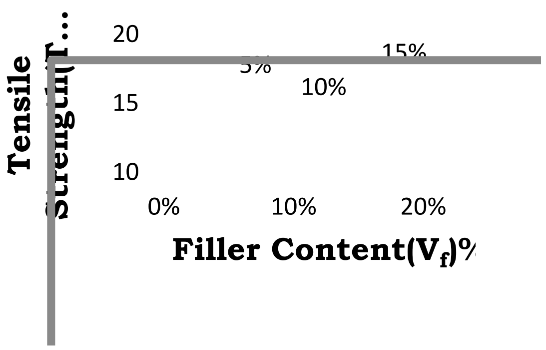


**Fig 21. Effect of filler content on tensile strength of the composites**

**Effect of filler content on flexural strength of the composites**

The influence of filler content on flexural strength of composites is shown in Figure. 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 10wt % 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. The decreases in mechanical strengths of the 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.

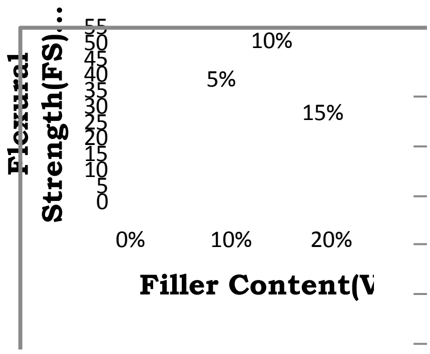


**Fig.22 Effect of filler content on flexural strength of the composites**

## Conclusions

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 ($V_f$) up to 45% of bamboo fiber.
4. Flexural strength of the composite material without filler increase with increase in fiber volume fraction ($V_f$) 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. Possible use 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.

## REFERENCES

i. Geethamma VG, Kalaprasad G, Gabriel G, Sabu T. Dynamic mechanical behavior of short coir fiber reinforced natural rubber composites. Composites 2005; 36:1499–506.
ii. Laly A. Pothana, Zachariah Oommenb, and Thomas S, "Dynamic Mechanical Analysis of Banana Fiber Reinforced Polyester Composites", Composites Science and Technology, 63(2), 2003, pp. 283-293.
iii. Pothan L. A, Thomas S and Neelakantan, "Short Banana Fiber Reinforced Polyester Composites: Mechanical, Failure and Aging Characteristics", Journal of Reinforced Plastics and Composites, 16(8), 1997, pp. 744-765.
iv. John M.J. and Anandjiwala R.D., (2008). Recent Developments in Chemical Modification and Characterization of Natural Fiber-Reinforced Composites,Polymer Composites, 29(2), pp.187-207.

v. Mohanty K, Misra M and Drzal L. T, (2005) Natural Fibers, Biopolymers and Biocomposites, Boca Raton, FL, CRC Press, Taylor & Francis Group, 2005, pp. 875.

vi. Mansur M. A and Aziz M. A, "Study of Bamboo-Mesh Reinforced Cement Composites" Int. Cement Composites and Lightweight Concrete", 5(3), 1983, pp. 171-185.