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Development and Investigation of Mechanical Behaviour of Bamboo Based Fiber Composites

Mr.Vikram.S Yendhe[1], Mr. Nilesh B. Landge[2], Mr. Manoj B. Thorat[3]
[1,2,3]*Mechanical Engineering,P.Dr.V.V.P Institute of Technology & Engineering(Polytechnic), Loni.*

Abstract*: *The modern dynamic world can't imagine its development without bringing the concept of advancement in material composite. Various researches are going on in this field to achieve the desired standard. Natural fiber reinforced polymer composite has a huge affinity to replace the composite made up of synthetic fiber. This is primarily because of the advantages like light weight, non-toxic, non-abrasive, easy availability, low cost, and biodegradable properties. The synthetic fibers have higher end of mechanical properties like tensile strength and tensile modulus however the specific mechanical properties like specific tensile modulus and other specific properties (properties/specific gravity) of natural fiber gives a satisfying result for composites as compared to synthetic fiber based composites. The objective of the present study is to investigate the mechanical behaviour of short bamboo fiber reinforced epoxy based composites. Bamboo fibers with different length and contents are reinforced in epoxy resin to fabricate composite materials. The effect of fiber length and content on the mechanical behaviour of composites is studied.
Keywords*: *Bamboo fibres, Biocomposites, Tensile Strength, Flexural Strength, Impact Strength.

I. INTRODUCTION

In the demand of increasing environmental security, several natural fibers reinforced polymer composites (NFPCs) are brought into the competitive market. These advantages include high strength to weight ratio, high strength at elevated temperatures, high creep resistances and high toughness, Bamboo can be used in a different form to synthesize a composite product. Bamboo shows the mechanical properties which are analogous to that of wood. Bamboo shows better mechanical properties as compared to fibers such as sisal, banana, vakka etc Bamboo can be used in a different form to synthesize a composite product. These can be either in a form of a long strip, whole bamboo, sections, and short bamboo fibers. The selection of their fiber kind depends upon the property to be imparted in the composite. Longer bamboo strips are used in making structural composite that is used in automobile roofings, shorter bamboo fibers are used in making of medium density fiber board, ply bamboo are made up of bamboo veneer and medium sized bamboo flake can be used for making of bamboo flake board. Studies are going on to determine the feasibility of using bamboo for reinforcing concrete with flat symmetric structure decisions and smooth surface from a combination of bamboo, bamboo strips and wood veneer particles that play an important role as new material and is used for concrete formwork. Although bamboo finds its wide application in various fields but their use in polymer matrix composites are very rare. The natural fiber used in the present study is short bamboo fiber due to many reasons. Bamboos are the largest members of the grass family. It is a long fleshy plant which technically comes under grass family but the appearance is never like grass. It is soft towards the centre and hard towards its periphery. Bamboo is mostly grown in tropical countries and is naturally occurring composites. Bamboos are largely used for the purpose like housing, forestry, agro-forestry, agricultural activities, utensils and weapons. It is mainly planted in Asian countries and constitutes about 65% of the total bamboo resources found in the world. The mechanical behaviour of the NFPCs are mostly influenced by the large number of parameters like volume fraction of fibers, fibers length, fibers aspect ratio, fiber-matrix adhesion, fiber orientation, and stress transfer at the interface. Hence to improve the overall mechanical behaviour of the composites. Objective of the present research work are Fabrication of a new class of epoxy based composites reinforced with short bamboo fibers, Evaluation of mechanical properties such as flexural strength, impact strength, tensile strength and micro-hardness etc and to study the influence of fiber lengths and fiber content on mechanical behaviour of short bamboo fiber reinforced epoxy based composites.

II. MATERIALS AND METHODS

This paper deals with the materials that are used in the present study and the methods by which these materials are processed. The materials that are used in the present concern of study are:
Epoxy Resin
Short Bamboo Fiber
Hardener

A. Preparation of Composites

Dry bamboo fibers were bought from the local market, in the form of long strip with an average width of about 10mm. The fibers were then further left to be died for a week. After a week, the fibers of three different lengths i.e. 4mm, 7mm and 10mm and a width of approx. 3mm were cut manually. Epoxy Resin and the hardener (HY 951) were supplied by Ciba Geigy India Ltd. A wooden mould having a dimension of 200 × 200 × 40 mm3 was used for composite fabrication. Composites with three different wt.% (10wt.%, , 20wt.% and 30wt.% of fiber with length of 4mm, 7mm and 10mm was taken for the composite fabrication. The weighed epoxy and hardener is first manually stirred with a glass rod followed with an addition of weighed fiber. The fiber and epoxy resin is thoroughly stirred to make sure there is no air bubble trapped in the mixture. The mixture was then poured on a relieving sheet which was already placed in a mould. The mixture was uniformly distributed over the inner surface of the mould and then closed by another relieving sheet on its top. The mould was then closed and a constant dead load of 50 kg was put on the mould for the for the purpose of curing to enhance the mixture to take the desired shape of mould. The load was left for 24 hours and then released. The composite thus obtained was further allowed to be cured in air for another 24 hours.

Fig.1. fabricated short bamboo fiber reinforced composite.

The various composition of short bamboo fiber reinforced epoxy based composites and their designation is presented below in Table 1A

Table 1. Composition and designation of fiber reinforced composites

Composites	Composition
C-1	Epoxy(90wt%)+Short bamboo fiber of length 4mm (10wt%)
C-2	Epoxy(80wt%)+Short bamboo fiber of length 4mm (20wt%)
C-3	Epoxy(70wt%)+Short bamboo fiber of length 4mm (30wt%)
C-4	Epoxy(90wt%)+Short bamboo fiber of length 7mm (10wt%)
C-5	Epoxy(80wt%)+Short bamboo fiber of length 7mm (20wt%)
C-6	Epoxy(70wt%)+Short bamboo fiber of length 7mm (30wt%)
C-7	Epoxy(90wt%)+Short bamboo fiber of length 10mm (10wt%)
C-8	Epoxy(80wt%)+Short bamboo fiber of length 10mm (20wt%)
C-9	Epoxy(70wt%)+Short bamboo fiber of length 10mm (30wt%)

B. Mechanical Testing Of Composites

After the fabrication of bamboo reinforced epoxy based polymer composite, the sample of appropriate dimension were prepared to carry out various tests like tensile strength test, flexural strength test, micro hardness test and Impact test under ASTM standards. The tensile strength and flexural strength test were carried out using instrument TINIUS OLSEN H10KS (Figure 2)Both of these tests are carried out on flat specimen.

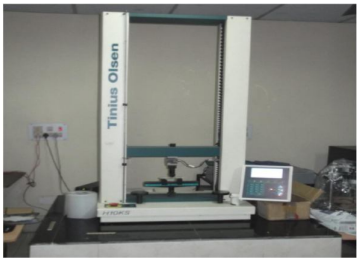

Fig 2. Experimental set up for tensile and flexural test

A uniaxial load is applied to the specimen in both the direction of the specimen, finally leading to the failure of the specimen after ultimate stress. The ASTM standard test method for tensile properties of composites has the designation D 3039-76.Micro hardness test was carried out by using the instrument named LECO hardness tester. The test is commonly known as Vicker's Micro hardness test. The specimen used in this case is also of flat shape. A diamond indenter of right pyramid shape with a square base and an angle of 1360 between two opposite faces are forced into the material under a load, F kgf. After indentations (rhombus shape) produced by the indenter on the specimen, both the diagonals are measured and hardness value is thus calculated. The load considered in the present study is 0.1 kgf. The instrument is shown below in the Figure 3

Figure 3 LECO Micro hardness tester

Impact strength of a material is defined as the property of a material by virtue of which the material opposes it fracture under stress applied at high speed. Impact strength of a polymer composite material is entirely related to its toughness as a whole. The instrument used for impact test in present study is Izod Impact Tester as shown in Figure.4.

Figure 4. Izod Impact tester

III.MECHANICAL PROPERTIES OF COMPOSITES: RESULT AND DISCUSSIONS

This section presents the various results obtained from various tests carried out in the present study. The mechanical behaviour of short bamboo fiber reinforced polymer composites with their various compositions are described here:

A. Mechanical Characteristics Of Composites

Mechanical properties of bamboo reinforced epoxy based composites such as tensile strength, flexural strength, impact strength and hardness number with their varying composition are tabulated below.

1) Effect Of Fiber Parameters On Tensile Strength Of Composites: Tensile strength of a material is defined as the resistance offered by the material to get broken under tension. Effect of fiber loading and fiber length on tensile strength of composite is show below in Figure 5.

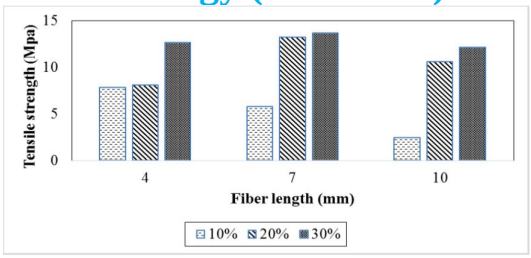

Figure 5. Effect of fiber parameters on tensile strength of composite

Tensile strength in this case varies with varying composition and it is found that the strength goes on increasing with increasing percentage of fiber in the composite for each length of fiber. 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. The tensile modulus indicates the relative stiffness of a material and can thus be obtained from stress strain diagram. Optimum value of tensile strength for the composite is found to be at 30% fiber loading for each length of fiber. The highest value for tensile strength is for 30% fiber loading for a fiber length of 7 mm.

2) *Effect Of Fiber Parameters On Flexural Strength Of Composites:* Flexural strength is defined as the ability of a composite by virtue of which it opposes the deformation likely to be imparted to it under the application of load. The effect of fiber loading and fiber length on flexural strength of composites is shown in Figure 6.

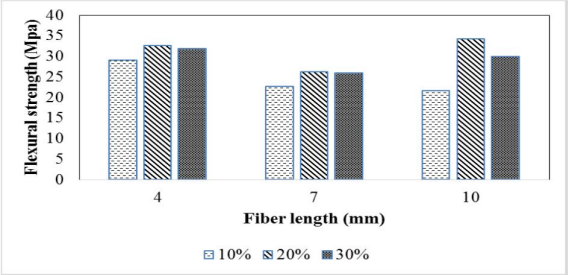

Figure 6. Effect of fiber parameters on flexural strength of composite

The test uses a flat specimen of rectangular cross section where the load is gradually applied with a speed of 1mm per minute until the specimen fails at the given load. The test is accompanied by three point bend test. Flexural strength for bamboo reinforced polymer composite increases with increasing fiber loading and then decreases. The same results comply for fiber length as well. The linearly increasing trend of flexural strength with increasing fiber contents suggests that the bonding between the fibers and the matrix is relatively good. The lower value of flexural strength at higher fiber content may be because of insufficient matrix in the composite which could not be able to transfer the load to the fibers. The effect of weight fraction of fibre on mean flexural strength for other fibre reinforced composites in comparison to bamboo composites are more. According to Ismail et al. and Yao and Li 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.

3) *Effect Of Fiber Parameters On Impact Strength Of Composites:* Impact strength refers to a shock absorbing capacity of composite material. This is entirely related to a toughness of the composite material. The effect of fiber loading and fiber length on impact strength of composites is shown below in. Figure 7**.** Effect of fiber parameters on impact strength of composites is shown below in Figure 7.

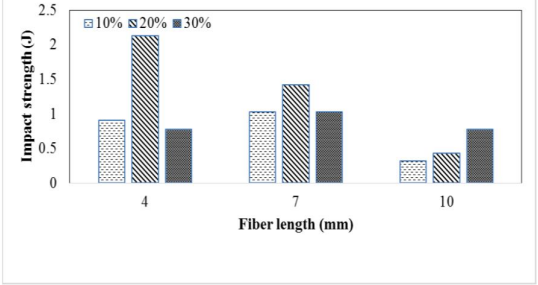

Figure 7. Effect of fibre parameters on impact strength of composites

The decrease in impact strength or smaller variation in strength may be due to induce microspaces between the fiber and matrix polymer, and as a result causes numerous micro-cracks when impact occurs, which induce crack propagation easily and decrease the impact strength of the composites. Generally the impact strength of composite materials increases with the increasing fiber content however the lower values of impact strength at higher composition of fiber may be because of improper adhesion between the matrix and the fibers. Higher content of fibers in composite requires higher matrix material but it is not likely to be so. Hence it is more likely that matrix is not able to transfer load to its fibers.

4) Effect Of Fiber Parameters On Hardness Of Composite : Surface hardness of composite material is sometime a matter of concern when the composite material so produced is encountered for space application.

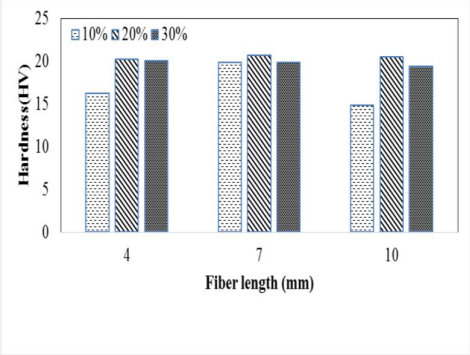

Figure 8. Effect of fiber parameters on hardness of composite

For a given work, the composite material was subjected to Vicker's Hardness test and the following observations were made (Figure 8.). From the figure, it is concluded that the hardness of a short bamboo fiber epoxy based composite increases with the increasing fiber content and fiber length up to a certain point and then it slowly drops down.

IV. CONCLUSION

Short bamboo fiber reinforced epoxy based polymer composite was fabricated and its mechanical behaviour was studied. The conclusions drawn from this experimental investigation are as follows:

Epoxy based composite material reinforced with short bamboo fibers have been successfully fabricated.

It has been explored that the mechanical properties of the composites such as tensile strength, flexural strength, impact strength and hardness are highly influenced by the size of the fibers used.

Excess of fibers in composite materials deteriorate the mechanical properties of the composite because of lack of proper bonding between the matrix and fiber around their interface. This causes the disruption in transfer of load to the bonding fibers. Lower values of impact strength and flexural strength at higher composition of bamboo fibers may be because of this reason.

The present study reveals that impact strength, tensile strength and flexural strength increases with increasing content of fiber in composite materials.

A. Scope For Future Work

This area of research can be extended to other varying size of bamboo fibers which may be in form of flake, whole bamboo, sections, strips etc. in order to achieve the desired mechanical properties in composite materials. Presently, epoxy, reinforced with bamboo and hemp with saw dust as a filler material is hot topic of research and is used to fabricate an eco-friendly helmet which can be a substitute for synthetic helmets. This fabrication includes compression molding technique. Further research in the field of bamboo composites can be extended to the fabrication of eco-friendly tyres by converting the bamboo fibers into its carbon black and then treating it with the thermoplastic resin.

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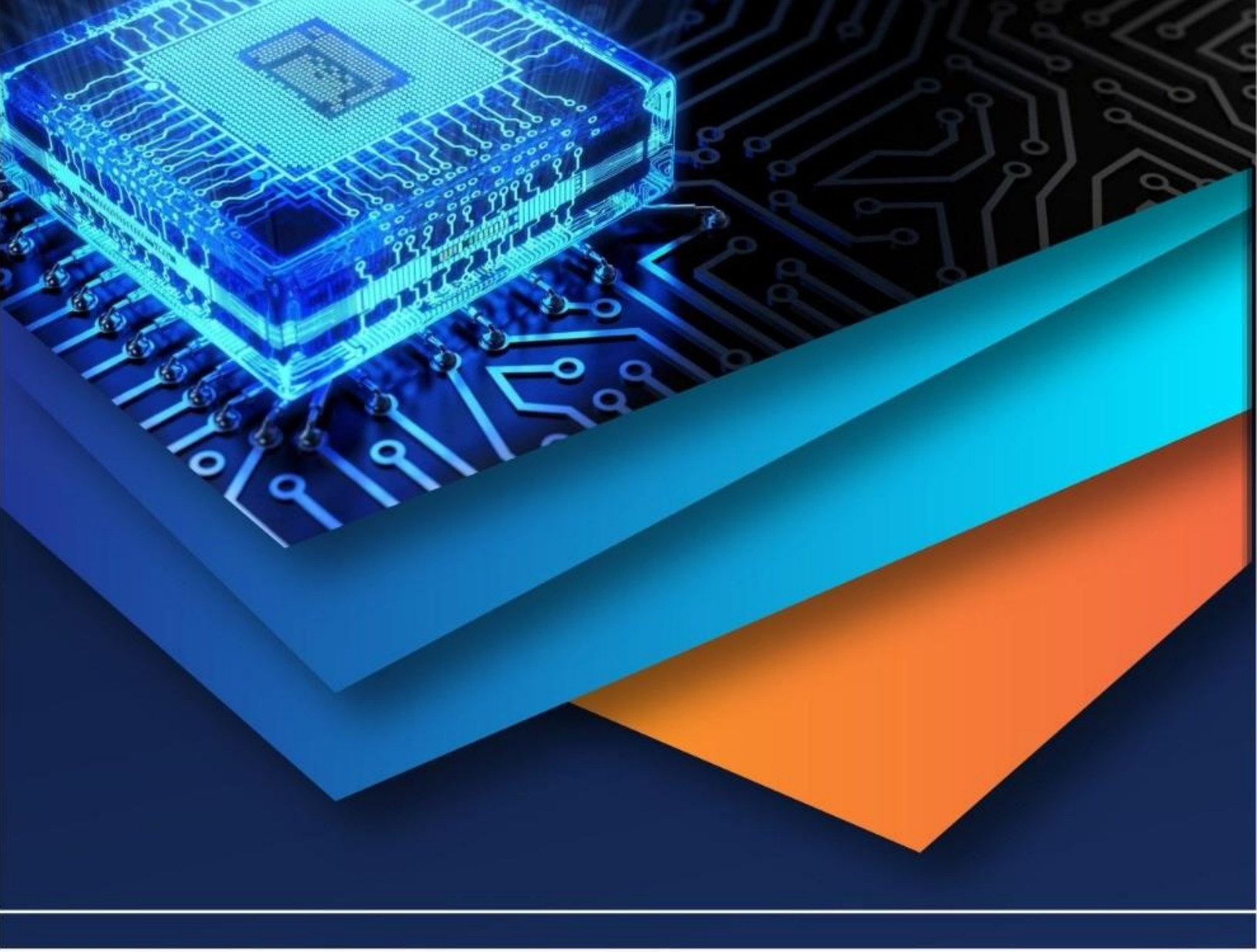

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