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Replacement of Synthetic Fiber with Eco Friendly Natural Fiber As Rein Forcement in Composite Materials and Compare Their Properties

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Abstract: Polymers are serving to a maximum extent, but they are also posing environmental problems due to their non-judicious usage. The main problem with most of the polymers is their non- degradable nature which can pollute the environment to an alarming rate. Simultaneously lot of research to develop polymer composites with natural fiber reinforcements is being carried out in various laboratories and research institutes. Natural fibers are biodegradable and can replace the polymer society. In this project, composite materials will be developed for different fiber volume fractions with synthetic fiber and natural fiber as reinforcement. These two developed composites will be compared for tensile, compression, impact and flexural tests. Based on the values obtained in these tests it is expected that the natural fiber composite values may come closer to the values of the synthetic fiber. Thus the aim of the project is to replace the synthetic fiber composite with natural fiber composite, which will be cheaper, widely available, abundant and very much eco-friendly, when compared to synthetic fibers.

Keyword: Fiber orientation, Epoxy resin composites, Glass fiber, laminated polymer composites.

I. 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). By definition, composite materials consist of two or more constituents with physically separable phases. However, only when the composite phase materials have notably different physical properties it is recognized as being a composite material. Composites are materials that comprise strong load carrying material (knownas reinforcement) imbedded in weaker material (known as matrix).Reinforcement provides strength and rigidity, helping to support structuralload. The matrix or binder maintains the position andorientation of the reinforcement. Significantly, constituents of the compositesretain their individual, physical and chemical properties; yet together theyproduce a combination of qualities which individual constituents would beincapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

II. OBJECTIVES OF THE PROJECT WORK

The objectives of the project are outlined below.

To develop glass fiber reinforced composites and bamboo fiber reinforced composites with different fiber lengths and fiber volume fractions.
To study the effect of fiber length (L_f) and fiber volume fraction (V_f) on mechanical behavior of glass fiber as well as bamboo fiber reinforced composites.
Evaluation of mechanical properties such as tensile strength (TS), flexural strength (FS) and impact strength (IS) for both glass fiber composites and bamboo fiber composites.
To develop a mathematical model to predict mechanical properties of the above mentioned composites like tensile strength (TS), flexural strength (FS) and impact strength (IS) from experimental results using response surface methodology (RSM).
Compare the test results between glass fiber composites and bamboo fiber composites and checking for the replacement of glass fiber with bamboo fiber in composites as reinforcement.
The processing of scheme of investigation is shown in figures 2.1 and 2.2

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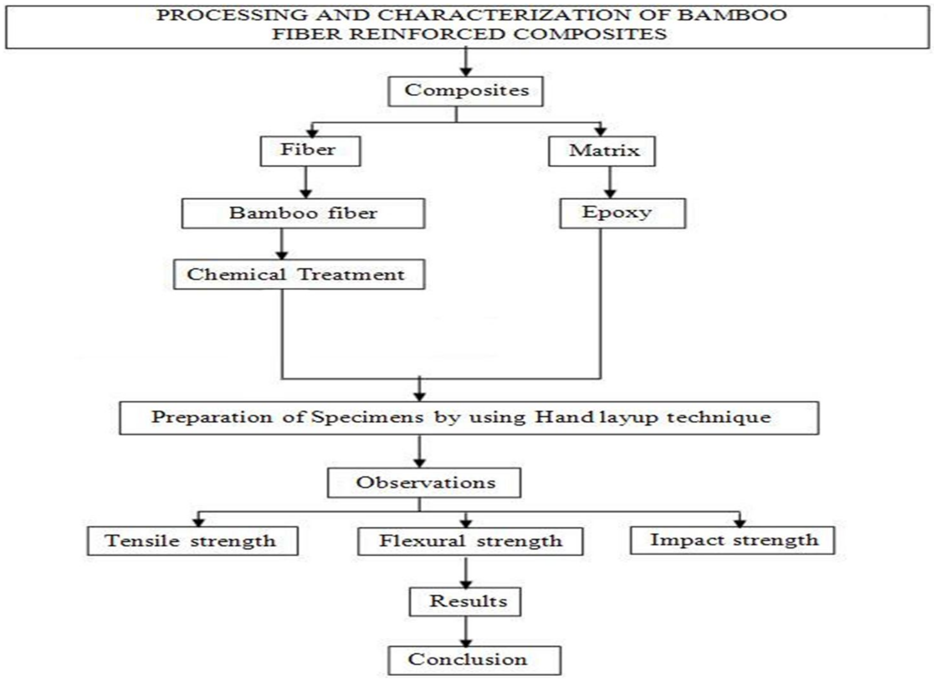

Fig.2.1 Scheme of Investigation in the case of Bamboo fiber

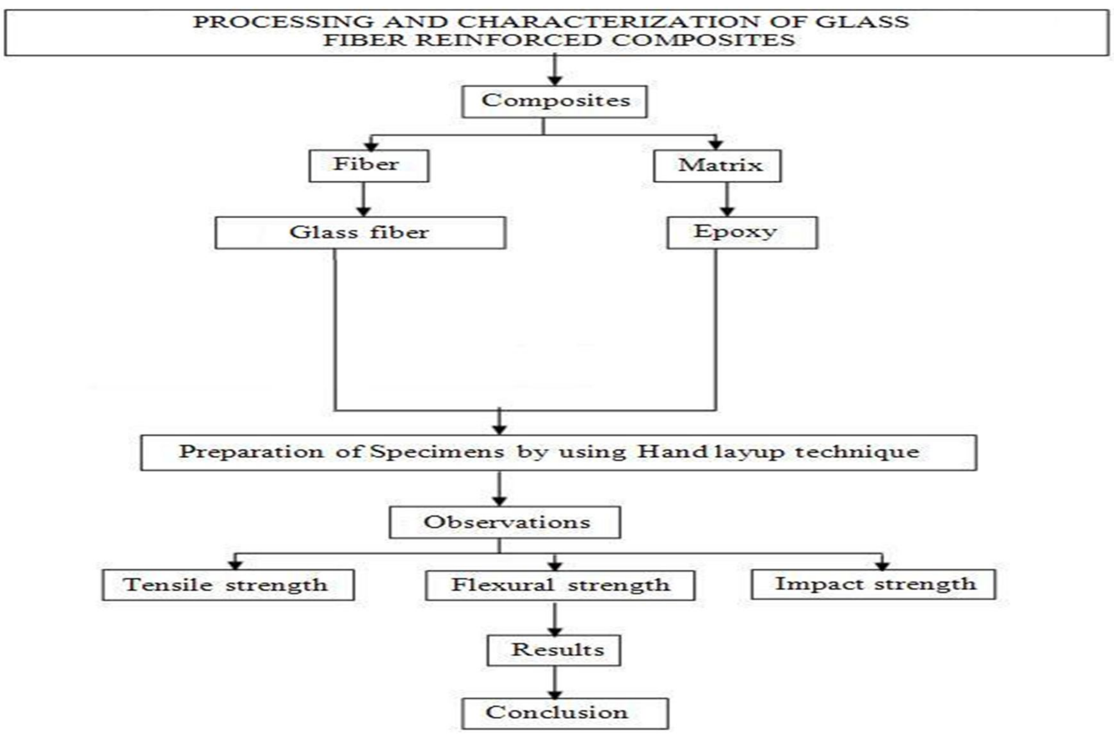

Fig.2.2 Scheme of Investigation in the case of Glass fiber

III. MATERIAL AND METHODS

In order to study the performance of composites, it is necessary to test them for mechanical properties, such as tensile, flexural and impact. The performance of the composites depends on their properties. In this chapter, the materials used and the methods followed for the processing of composites are presented.

A. Materials

1) Fiber Reinforcement: In the present work, two fibers were used as the reinforcements.

a) Bamboo Fiber: Fiber is the reinforcing phase of a composite material. In the present project work, short fiber bamboo taken as the reinforcement to fabricate the composites. In general, bamboo is available and is 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. The structure of bamboo itself is a composite material, consisting of long and aligned cellulose fibers immersed in a ligneous matrix.

b) Glass Fiber: The glass fibers (chopped form) have been procured from company. Good tensile and compressive strength and stiffness, good electrical properties and relatively low cost, but impact resistance relatively poor. E-glass is the most common from of reinforcing fiber used to fabricate the composites. The density of the glass fiber is 1.7gm/cc.

2) Matrix: In the present work, Araldite LY 556 is used as the matrix. This resin was developed by ECMOS Corporation Ltd, and is bought at SREE COMPOSITES, Hyderabad, India. Its corresponding hardener is Aradur HY 951. Resin & Hardener should be mixed uniformly in the ratio 10:1 until they form a Homogenous mixture. Resin and hardener provides a low viscosity, solvent free room temperature curing laminating system. This inexpensive resin is mainly used in making parts of automobiles, domestic articles and sports goods.

3) Chemical Reagents

a) Mould Releasing Agent: The bottom and side-walls of the mold were coated with aqueous solution of polyvinyl alcohol (PVA) and hard wax. Polyvinyl alcohol (PVA) acts as a good mold-releasing agent whereas the hard wax will give the good finish for the composite.

b) Chemical Treatment: The structure of bamboo itself is a composite material, consisting of long and aligned cellulose fibers immersed in a ligneous matrix. The bamboo fiber has the highest percentage of lignin which makes the fiber very stiffer when compared to the other natural fiber. This can be attributed to the fact that the lignin helps to 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. In this investigation, the bamboo fibers were soaked in 1% NaOH solution for 30 min to remove any greasy material, hemi-cellulose etc., washed thoroughly in distilled water, and dried under the sun for 2 weeks. The purpose of chemical treatment is to increase the strength of bamboo fiber.

B. Methods

1) Fabrication: In order to make the specimens for mechanical strength testing, sheets are prepared by taking matrix and fiber in the open moulds. This system can be processed by different methods like injection, hand lay-up, winding and pressure moulding etc. Some of the fabrication techniques are as follows: In the present work Hand lay-up technique is used for making test specimens.

Hand layup method

Resin injection technique

Automatic injection moulding

Hot press methods

Filament winding

Pultrusion

a) Hand Layup Method: Hand lay-up technique is the simplest polymer-processing technique. Fibers can be laid onto a mould by hand and the resin is sprayed or brushed on. Frequently, the resin and fibers (chopped) are sprayed together onto the mould surface. The deposited layer is densified with roller as shown in the figure 3.1. Curing may be done at room temperature or at a moderately high temperature in an oven.

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Fig 3.1 Hand lay-up technique

2) Preparation of Mould and Test Specimens: In the present work glass moulds are used to prepare glass fiber reinforced composites as well as bamboo fiber reinforced composites. A glass mould of 180mm x 180mm x 3 mm (length x width x thickness) is used to prepare sheets and specimens for tensile, flexural and impact test. The specimens for test were prepared as per ASTM specifications. The specimen dimensions were presented in Table 4.1.

The tensile test specimens with dimensions 150mm x 15mm x3mm are cut as described else where. The flexural test specimens with dimensions 100mm x10mm x3mm are cut as per ASTMD5943-96 specifications from sheet 200mm x200mmx 3mm. The impact test specimens with dimensions 122mm x 11mm x 3 mm are cut as per ASTM D 256-88 specifications from a sheet of 180mm x 180mm x 3mm.

Test	ASTM standard	Specimen Dimensions (mm)	Crosshead Speed (mm/min)
Tensile	ASTM D 3039-76	150 X 15 X 3	5
Flexural	ASTM D5943-96	100 X10 X 3	2
Impact	ASTM 256-88	122 X 11 X 3	Sudden force

TABLE 1. SPECIMEN DIMENSIONS FOR DIFFERENT MECHANICAL TESTING

3) Composite Fabrication: In this study, the matrix material used for the fabrication of glass fiber reinforced composites and bamboo fiber reinforced composites is epoxy. The bamboo fiber is collected from the local sources. The bamboo fibers are chemically treated with NaOH solution at the concentration mentioned above as it will give the best strength at that particular concentration. The purpose of chemical treatment is to increase the strength of the fiber. As a result the bonding strength also increases. After the chemical treatment, the bamboo fibers are allowed to dry for 2 weeks under the sun. Then they are cut into 3, 5 and 7 mm lengths as shown in the figure.

Figure 3.2 Chopped Bamboo fibers in 5 and 7mm lengths.

Now weigh the bamboo fiber of particular length & matrix of different volume fractions i.e. (30, 40 and 50%). After weighing the above raw materials they are reinforced in random orientation into the Epoxy and mixed uniformly and are poured in the glass mould. Before pouring the materials, the glass mould is to be prepared by applying white wax on it and allowed to dry for 20 minutes as shown in the fig 4.

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Figure 3.3 .Glass mould while applying wax.

Later PVA is applied and is allowed to dry for 20 minutes at room temperature until a thin layer is formed on the surface of the glass mould. After pouring the mixture of bamboo fiber and epoxy on the mould, it is adjusted to distribute the material throughout the mould uniformly as shown in figure 3.4. A roller is taken and is rolled on the surface of the mould to level the surface and remove the excess content of the material by keeping an OHP sheet in between roller and mould as shown in figure 5.

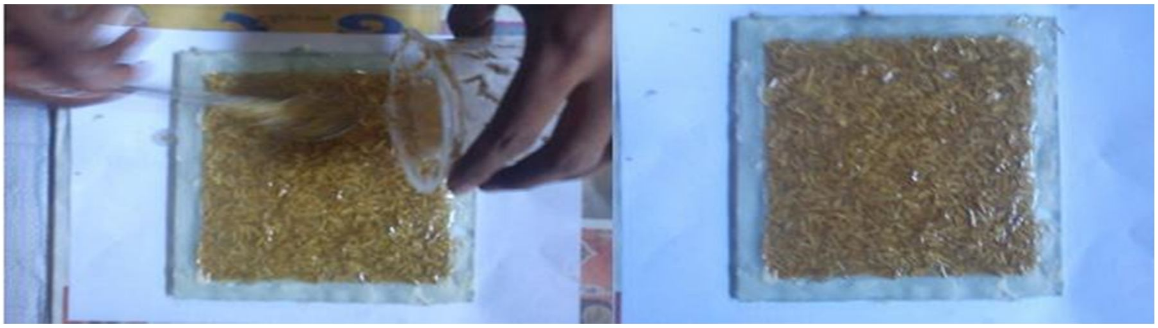


Figure 3.4 . Pouring the Bamboo Epoxy mixture on the glass mould.

Figure 3.5 . Rolling on the surface of the specimen with a roller by keeping OHP sheet.

After that the glass plate is kept on the OHP sheet to cover the mould completely and is kept under some weight so as not to disturb the arrangement as it should be kept for about 24 hours without disturbing the arrangement. After 24 hours, the upper glass plate is removed and the mould is kept in the oven for 20 minutes under 55-60^{0}C to melt the releasing agent applied before pouring the material on the glass mould. The melting of the releasing agent helps to remove the composite material very easily. After getting the specimen, it is allowed to stay in oven at 65^{0}C up to 24 hours for curing. This is known as heat treatment for the specimens in order to increase their strength. Care should be taken to avoid the air gaps in the mould while preparing these specimens.
This procedure is repeated for the other two fiber lengths of Bamboo fiber for different fiber volume fractions to form the following total number of specimens.

Specimen No.	Fiber volume fraction (V_f)%	Fiber length (L_f) in mm
1	30	3
2	30	5
3	30	7
4	40	3
5	40	5
6	40	7
7	50	3
8	50	5
9	50	7

Table 2 Total number of Bamboo composite Specimens with different combinations of V_f and L_f

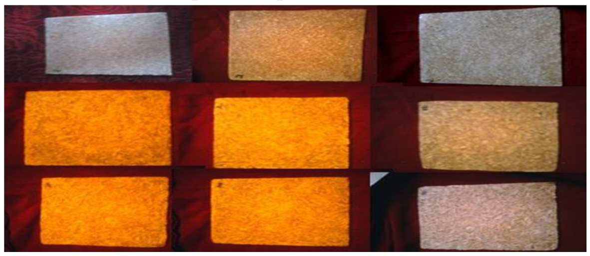


Figure 3.6 Bamboo fiber specimens

The same procedure is repeated taking glass fiber as reinforcing material. Glass fiber does not require any chemical treatment as it is a synthetic fiber. The following are the total number of composite specimens shown in the table 3.3 in which glass fiber is taken as the reinforcement.

Specimen No.	Fiber volume fraction (V_f)%	Fiber length (L_f) in mm
1	30	3
2	30	5
3	30	7
4	40	3
5	40	5
6	40	7
7	50	3
8	50	5
9	50	7

Table 3. Total number of Glass composite Specimens with different combinations of V_f and L_f

IV. EXPERIMENTAL

A. Material Properties Testing

In order to know the performance of the composites made in the present work, the following tests are conducted.

- Tensile test
- Flexural test
- Impact test

The flexural test and tensile tests are conducted using Instron Universal Testing Machine (model 3369) shown in Figure 4.8. Impact strength test was conducted using Izod Impact tester.

A. Tensile Test

Tensile strength is a measure of strength and ductility of the material. Ultimate tensile strength is the force required to fracture a material. The tensile properties of the composites are determined by employing an Instron make 3369 model Universal Testing Machine as shown in figure 3.8. Tensile testing provides useful data such as ultimate tensile strength and elongation at break. These properties indicate the materials behavior under loading in tension. The test is conducted as per ASTM D3039-76 specifications. The cross-head speed is maintained at 5mm/min. In each case, two specimens are tested and the average value is recorded.

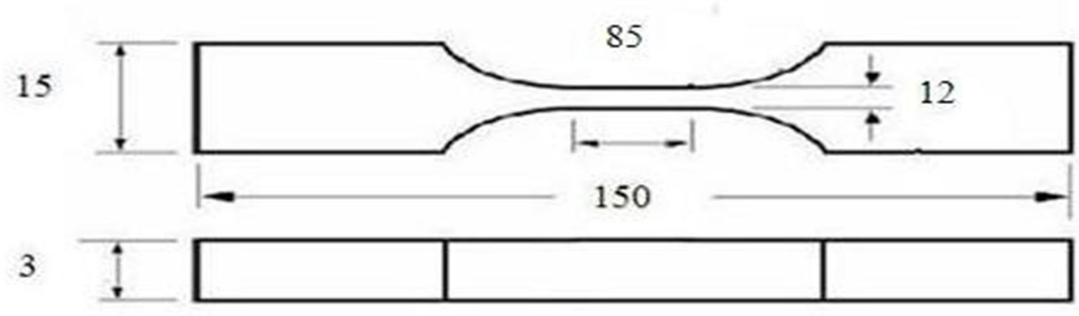


Fig 4.1 Dimensions of Test specimen for tensile test

Fig 4.2 Specimen before Tensile Test

Fig 4.3Specimen after Tensile Test

B. Flexural Test

The strength of material in bending, expressed as the stress on the outer most fibers of a bent test specimen, at the instant of failure is defined as the flexural strength. The flexural properties of the matrix and the composites are determined using Universal Testing Machine. Here 3 Point bending method is conducted. In this method, a bar of rectangular cross-section rests on two supports and load is applied by means of a loading nose midway between the supports as shown in the figure 3.15. The test is conducted as per the ASTMD 5943-96 specifications. The cross-head speed is maintained at 5mm/min. In each case, two specimens are tested and the average value is recorded.

Fig 4.4 Dimensions of Test specimen for Flexural Test

Fig 4.5 Specimen before Flexural Test

Fig 4.6 Specimen before impact test

C. Design Of Experiments Via Taguchi Method

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors affecting a process and the output of that process.

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr. Genichi Taguchi of Japan who maintained that variation. Therefore, poor quality in a process affects not only the manufacturer but also society. It allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Analysis of variance on the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic. The most important stage in the design of experiment lies in the selection of the control factors. The mechanical behavior of polymer composites reveals that parameters viz., fiber length and fiber volume fraction etc largely influence the mechanical behavior of polymer composites. The impact of two such parameters are studied using L9 (3^2) orthogonal design.

D. Comparison Of The Experimental Values And Predicted Values Of The Mechanical Properties Of Both Bamboo And Glass Fiber Reinforced Composites

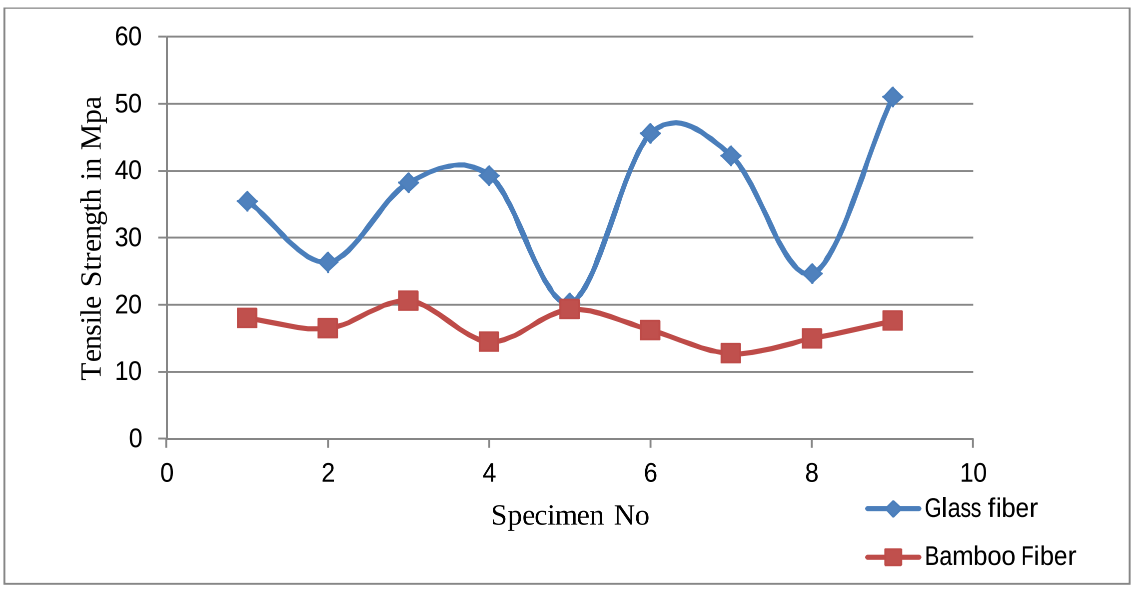
The results predicted by RSM model were compared with the experimental result values and graphs are drawn as shown in the following Graphs

Experiment No.	Fiber volume fraction (V_f)%	Fiber length (L_f) in mm	Experimental Values	Predicted Values
1	30	3	35.572	38.0636
2	30	5	26.418	21.2736
3	30	7	38.301	40.9538
4	40	3	39.362	38.2076
5	40	5	20.322	22.9532
6	40	7	45.646	44.1692
7	50	3	42.261	40.9238

E. Comparison Of Results Between Glass Fiber Composites And Bamboo Fiber Composites

The results for both glass as well as bamboo fiber composites are discussed earlier and are compared with the predicted values in the previous chapter. Here the comparison is made between the mechanical properties of glass fiber reinforced composite and bamboo fiber reinforced composite materials.

1) *Comparison of Tensile Strength:* From the results it is observed that the Tensile strengths for glass fiber reinforced composites are very much high when compared to bamboo fiber reinforced composites as shown in the graph 6.1.



Graph 1 Graph between glass and bamboo fiber specimens comparing their Tensile strengths

From the graph, it can be clearly observed that the tensile strengths for glass fiber reinforced composites are very higher than the bamboo fiber reinforced composites. The maximum TS for glass fiber is observed to be 51Mpa for specimen 9(i.e., V_f=50% and L_f = 7mm) and the minimum TS is observed as 20Mpa for specimen 5 (i.e., V_f=40% and L_f = 5mm). Where as for bamboo fiber, the maximum TS is observed as 20Mpa at specimen 5 and minimum TS is observed to be 12Mpa at specimen 7 (i.e., V_f=50% and L_f = 3mm). The bamboo fiber curve is touching the glass fiber curve at 20Mpa. It means the tensilestrength of specimen 5 (bamboo) is getting very close to the tensile strength of specimen 5 (glass). Except at this point, the bamboo curve is no where touching the glass curve.

2) *Comparison of Flexural Strength:* From the results it is observed that the Flexural strengths for glass fiber reinforced composites are very much high when compared to bamboo fiber reinforced composites as shown in the Graph 6.2.

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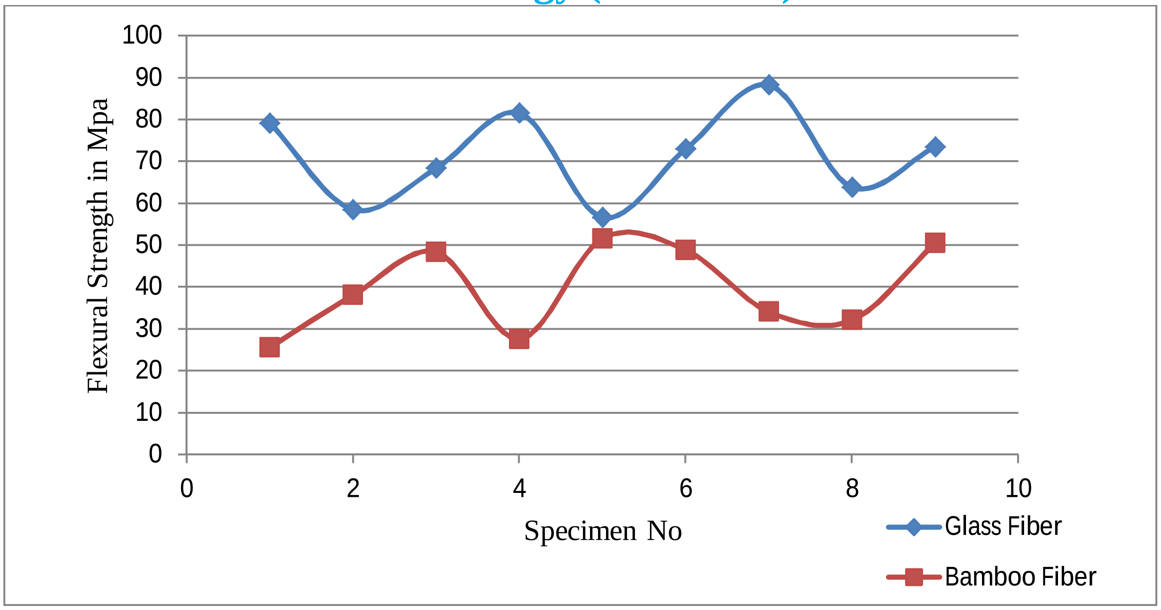

Graph6.2Graph between glass and bamboo fiber specimens comparing their Flexural strengths

From the graph, it can be clearly observed that the Flexural strengths of glass fiber reinforced composites are very higher than the bamboo fiber reinforced composites. The maximum FS for glass fiber is observed to be 88Mpa for specimen 7(i.e., V_f=50% and L_f = 3mm) and the minimum FS is observed as 56Mpa for specimen 5 (i.e., V_f=40% and L_f = 5mm). Where as for bamboo fiber, the maximum FS is observed as 51Mpa at specimen 5 and minimum FS is observed to be 25Mpa at specimen 1 (i.e., V_f=50% and L_f = 3mm). The bamboo fiber curve is not touching the glass fiber curve. The flexural strength of specimen 5 (bamboo) is getting close near to the flexural strength of specimen 5 (glass).

V. CONCLUSION

By comparing the results between glass fiber and bamboo fiber reinforced composites, and by observing the graphs and results in the previous chapters, it is concluded as follows:

A. The mechanical properties like Tensile strength (TS), Flexural Strength (FS) and Impact Strength (IT) for glass fiber reinforced composites are same equal to the bamboo fiber reinforced composites at particular fiber volume fraction and fiber length.

B. However for tensile and impact strengths, the values of bamboo fiber specimen number 5 (i.e., at V_f =40%, L_f = 5mm) are same as that of the values of glass fiber specimen number 5. Also for Flexural strength, the value of bamboo fiber specimen number 5 (i.e., at V_f =40%, L_f = 5mm) is very close to that of the value of glass fiber specimen number 5.

C. Therefore it is observed that the glass fiber can be replaced with the bamboo fiber at particular composition when the fiber volume fraction (V_f)=40% and fiber length (L_f)= 5mm.

D. This suggests that the bamboo fiber composites have the potential to replace glass in some applications that do not require very high load bearing capabilities

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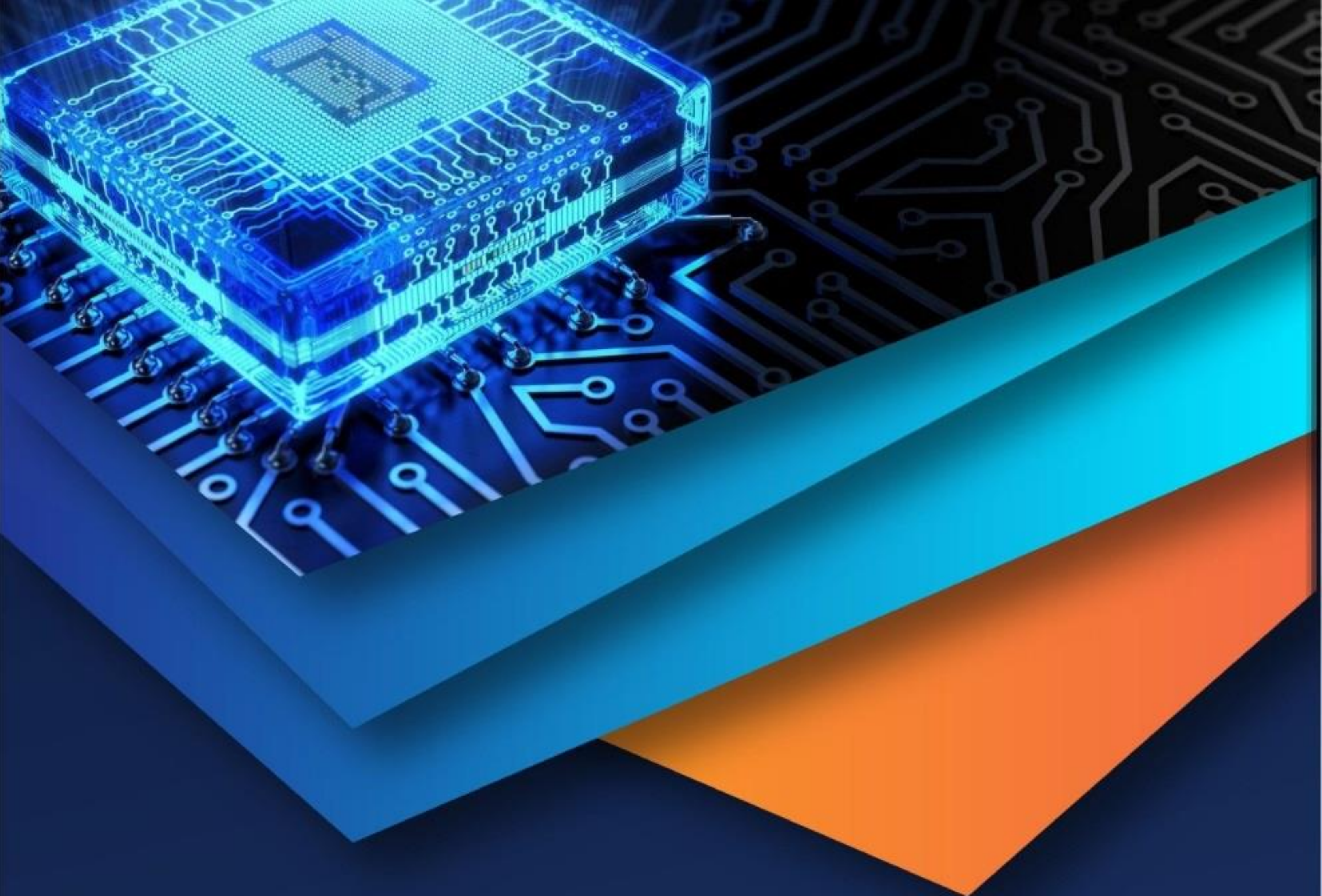

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