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MECHANICAL BEHAVIOR OF BAMBOO FIBER EPOXY COMPOSITES USING XRD

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Abstract- The increasing environmental awareness and the concern over the depletion of the fossil fuels have led to the rapid utilization of the green resources for producing eco- friendly products. Owing to the tremendous use of composite as an engineering material there has been an increasing attention towards the replacement of synthetic fibres in composites by natural plant fibres such as bamboo, jute, sisal, flex, hemp, coir etc. The advantages offered by these natural fibres over the conventional synthetic fibre such as carbon and glass are low density, ease of separation, acceptable specific properties, decrease in the environmental contamination and cost. Moreover, they also cause less wear on the processing equipments and reduce health hazards. Also, the natural fibres can be easily obtained from the plants and their resources; therefore can be a viable alternative for the expensive and non-renewable synthetic fibre. This research work focuses on the recent developments and potential for further improvement of natural fibre reinforced composites. Keeping this in view, the present work has been under taken to develop a polymer matrix composite (epoxy resin as in matrix) using bamboo fibers and to study its characterization and mechanical behaviour. Composites have been prepared with different weight fraction of bamboo fibers. XRD and optical microscope have been used for characterization of composites. Tensile, flexural and hardness test of fabricated composite sample have been carried out. It is concluded that the enhancement of tensile strength, flexural strength and hardness of bamboo fiber epoxy composites depends on fiber concentration and fiber-matrix-adhesion.

Keywords: bamboo fiber; epoxy composite; density; ultimate strength; fracture surface

I. INTRODUCTION AND BACKGROUND

Natural fibre composites is very popular because of its property such as light weight, high specific properties, and environment friendly, non-abrasive, nontoxic, low cost etc. The properties of natural fibers depend mainly on the nature of the plant, locality in which it is grown, age of the plant, and the extraction method used. The physical properties of natural fibres were mainly determined by their chemical and physical composition, such as structure of fibers, cellulose content, angle of fibrils, and cross-section, and by the degree of polymerization. Natural fiber reinforced composites are the best replacement of metals and carbons. Natural fibers can be obtained from plant, animal, minerals. Natural fibres are classified according to their origin wood: hard wood and soft wood; cane grass and reed fibers: bamboo, bagasse, canary grass, rice; leaf: sisal, abaca, pineapple; bast: flex hemp jute kenaf; seed: cotton kapok, rice husk; fruit: coir; wool /hair: lambs hair, goat hair, angora wool, horse hair; silk: tussah silk, spider silk; minerals: asbestos, fibrous brucite, inorganic whiskers.

Due to their variable properties their application is increasing in various fields such as building construction, industry, furniture, electrical device, and daily life application and transportation industry. Natural fibers plays important role in automobile industry as the world is now facing the petroleum crises due to its fossil fuel. Natural fiber reinforced composites having light weight make automobile industry efficient. A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. Flax, Linum usitatissimum or linseed, belongs to the bast fibers. It is grown in temperate regions and is one of the oldest fiber crops in the world. The bast fiber flax is most frequently

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used in the higher value-added textile markets. Nowadays, it is widely used in the composites area the effect of processing parameters [1]. The tensile and flexural properties of bamboo/glass fiber hybrid composite is suitable for highly flexibility & it can be concluded by finding such a value of tensile & flexural strength that the mechanical properties significantly influenced while using bamboo & glass fiber in such layer manner [2]. Flax fiber composites reinforced with polyester resin have been evaluated for thermal degradation and fire resistance [3]. Hemp is notable bast-fiber crop belongs to the Cannabis family. Hemp is currently the subject of a European Union subsidy for non-food agriculture, and a considerable initiative in currently underway for their further development in Europe.

Composites of polypropylene with hemp fibers, which were functionalized by means of melt grafting reactions with glycidyl methacrylate (GMA) and prepared by batch mixing, were examined increased stiffness of the composites as a result of improved fiber–matrix interfacial adhesion [4]. Pickering and co-workers [5–7] they obtained results prove that the mechanical properties of hemp fiber/PP composites remain well preserved, despite the number of reprocessing cycles. The Newtonian viscosity decreases with cycles, indicating a decrease in molecular weight and chain scissions induced by reprocessing. The decrease of fiber length with reprocessing could be another reason for decrease of viscosity. Epoxy resins, which were used as a matrix for hemp fiber reinforced composites, were studied regarding the effect of fiber architecture on the falling weight impact properties [8]. Kunanopparat et al. [9, 10] studied the feasibility of wheat gluten as a matrix for hemp fiber reinforced composites regarding their thermal treatment and plasticization effect on the mechanical properties. Jute is one of the cheapest natural fibers and is currently the bastfiber with the highest production volume.

Bangladesh, India and China provide the best condition for the growth of jute. Mohanty et al. [11] investigated effects and influence of surface modification on the mechanical and biodegradability of jute/Biopol and jute/PA (Poly Amide) composites. Enhancements in tensile strength of more than 50%, 30% in bending strength and 90% in impact strength were observed in the composites and are comparative to values achieved for pure Biopol sheets. Degradation studies showed that after 150 days of compost burial more than 50% weight loss of the jute/Biopol composites occurs. Sisal is an agave (Agave sisalana) and commercially produced in Brazil and East Africa. The global demand for sisal fiber and its products is expected to decline by an annual rate of 2.3% as agricultural twine. The traditional market for fibers continues to be eroded by synthetic substitutes and by the adoption of harvesting technologies that utilizes less or no twine. Zhang et al. [12] developed all plant fiber composites by converting wood flour into thermoplastics using an appropriate benzylation treatment and compounding both discontinuous and continuous sisal fibers to produce composites from renewable resources. epoxy resin was used as a matrix for sisal fiber reinforced composites and examined regarding the influence of fiber orientation on the electrical properties [13],Investigations were also carried out using cement as a matrix for sisal fiber reinforced composites focusing on their cracking micro-mechanisms [14]. Pineapple (Ananascomosus) is a tropical plant native to Brazil. Pineapple leaf fiber is rich in cellulose, relatively inexpensive and abundantly available.

Furthermore, it has the potential for polymer reinforcement. At present pineapple leaf fibers are a waste product of pineapple cultivation and therefore these relatively inexpensive pineapple fiber can be obtained for industrial purposes. Pineapple leaf fiber was reinforced with polycarbonate to produce functional composites [15]. The silane treated modified pineapple leaf fibers composite exhibited the highest tensile and impact strengths. The thermogravimetric analysis showed that the thermal stability of the composites is lower than that of neat polycarbonate resin. In addition, the thermal stability decreased with increasing pineapple leaf fiber content. The thermal conductivity and thermal diffusivity of pineapple leaf fiber reinforced phenol formaldehyde composites were studied using the Transient Plane Source (TPS) technique [16].

II. COMPOSITES CHARACTERISTICS AND METHODOLOGY

A composite material consists of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement or reinforcing material whereas the continuous phase is termed as the matrix. The matrix is usually more ductile and less hard. It holds the dispersed phase and shares a load with it. Matrix is composed of any of the three basic material type i.e. polymers, metals or ceramics. The matrix forms the bulk form or the part or product. The secondary phase embedded in the matrix is a discontinuous phase. It servers to strengthen the composites and improves the overall mechanical properties of the matrix. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them.

The composite properties may be the volume fraction, sum of the properties of the constituents or the constituents may interact in a synergistic way, resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties. The shape of the discontinuous phase (which may by spherical, cylindrical, or rectangular cross- sanctioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix. Concentration, usually measured as volume or weight fraction, determines the contribution of a single constituent to the overall properties of the composites. It is not only the single most important parameter influencing the properties of the composites, but also an easily controllable manufacturing variable used to alter its properties.

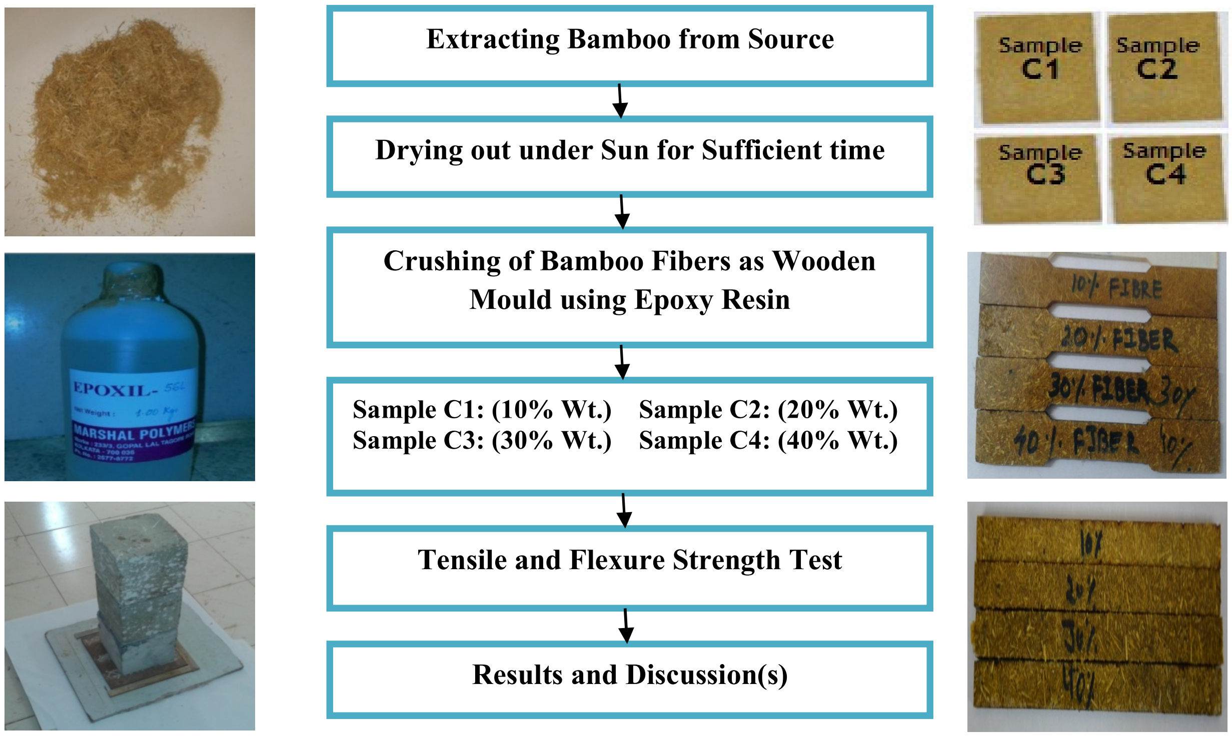


Figure 1: Methodology and Fabrication of Sample(s) for Testing

The methodology of preparing the samples has been shown in figure 1. The tensile test and flexure test is carried at cross head speed of 5 mm/min using universal testing machine to understand its elongations and maximum stress, respectively.

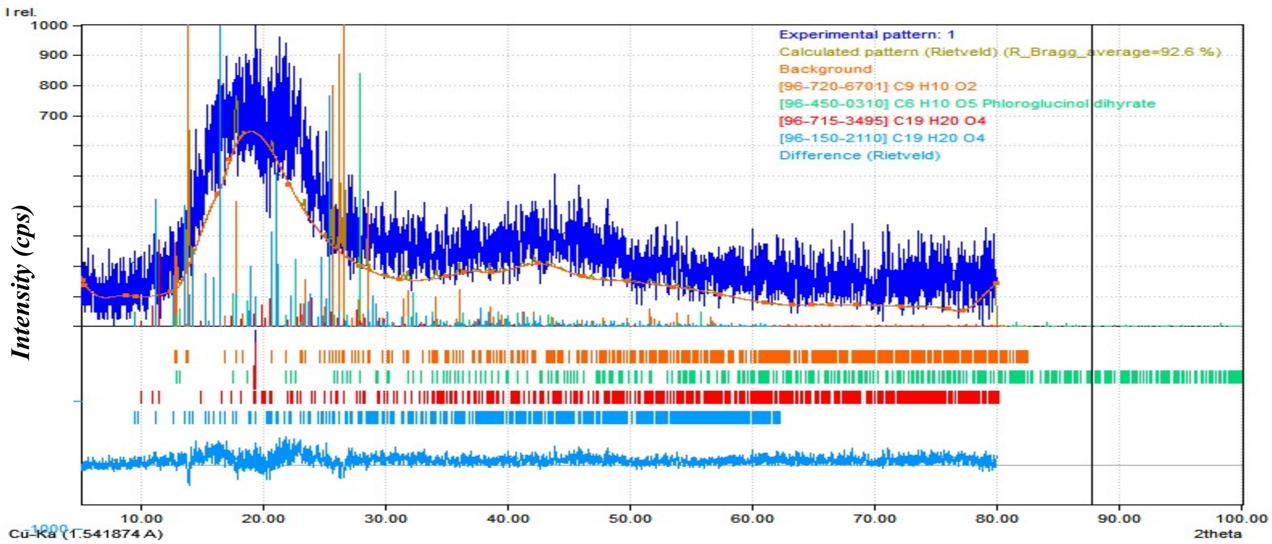
III. RESULTS AND DISCUSSIONS

In this, the physical and mechanical characterization of the class of polymer matrix composites developed for the present investigation. The random oriented bamboo fiber reinforced epoxy resin composites are used and hence, the detail processing of these composites and the tests conducted on them have been described in the previous chapter. The results of various characterization tests are reported here. These include evaluation of tensile strength, flexural strength, has been studied and discussed. It may be mentioned here that both tensile and flexural strengths are important for recommending any composite as a material for structural applications.

[A] Analysis of Epoxy Composite Sample using XRD

The various figures (i.e., Figs. 2, 3, 4, and 5) show the X-ray diffraction pattern of composites sample i.e., C1, C2, C3, and C4, respectively. Due to the absence of any sharp peak in the XRD pattern, it confirms that the sample composites have the amorphous nature. From all these XRD patterns, it is concluded that this analysis have high repeatability of all the samples in nature of amorphous of the composites. The patterns have very broad features consistent with "incoherent scatter" from an amorphous solid. In all figures, it is observed that the X-ray diffraction of bamboo fibers presents the well defined X- ray diffraction peaks for the material.

Material tested is amorphous Spectrum corresponding to the unmodified fibers shows diffraction peaks at the following 2Θ angles: 5º to 80º. The position of these peaks indicates an increase of the inter-planar distance due to the disorder of fibers. Patterns for all materials sample are similar. The intensities of peaks were decreased with the increase of lignin in cellulose. Table 1, 2, 3 and 4 represent the tabulation among the three composite compounds of **$C_9H_{10}O_2$; $C_6H_{10}O_5$;** and **$C_{19}H_{20}O_4$** with their fixed density and obtained the percentage of variation in crystal system of the fibres sample.

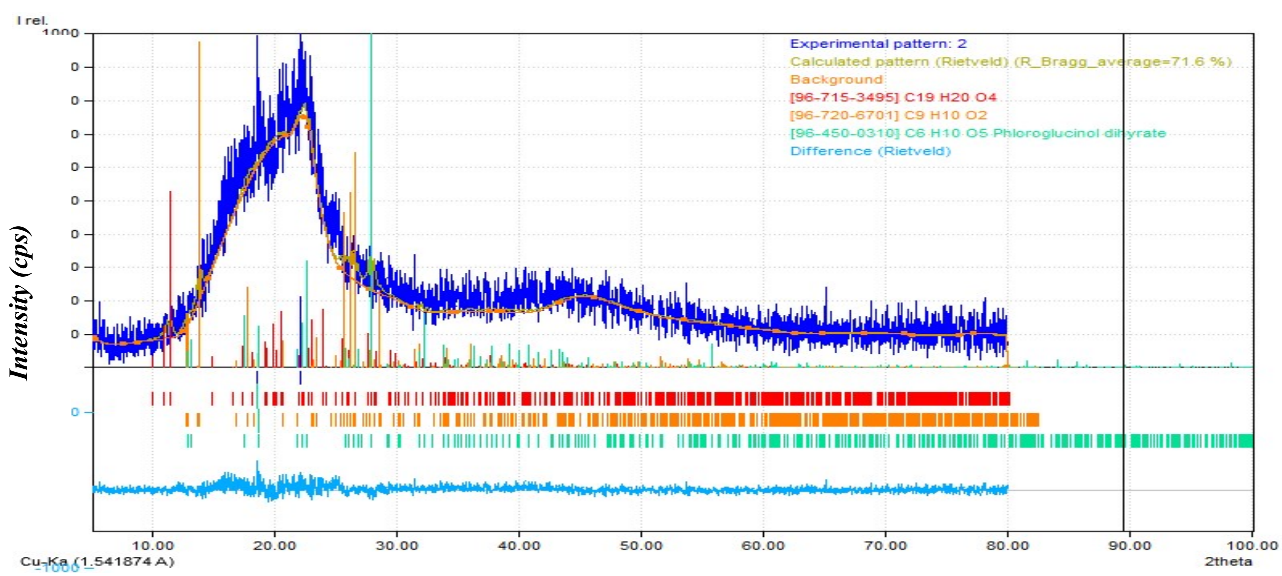


2Theta (2Θ)

Figure 2 XRD images of 10% weight of fiber

Table 1 XRD analysis of Sample C1

SN	Element/ Compound	Intensity Scale Factor	Crystal System	Calculated Density (gm/cc)	Entry No.	Amount (%)
1	$C_9H_{10}O_2$	1.67	monoclinic	1.29	96-200-3632	32.1
2	$C_6H_{10}O_5$	0.84	orthorhombic	1.50	96-450-0310	17.6
3	$C_{19}H_{20}O_4$	0.29	orthorhombic	1.33	96-715-3495	32.5

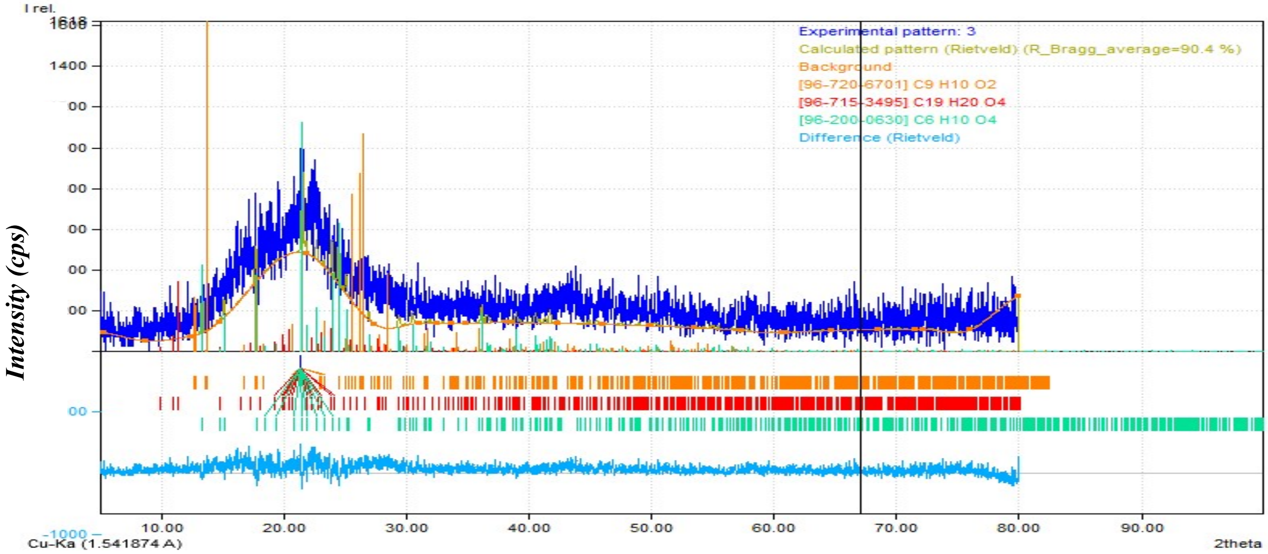


2Theta (2Θ)

Figure 3 XRD images of 20% weight of fiber

Table 2 XRD analysis of Sample C2

SN	Element/ Compound	Intensity Scale Factor	Crystal System	Calculated Density (gm/cc)	Entry No.	Amount (%)
1	$C_9H_{10}O_2$	0.98	monoclinic	1.29	96-720-6701	42.6
2	$C_6H_{10}O_5$	0.84	orthorhombic	1.50	96-450-0310	17.6
3	$C_{19}H_{20}O_4$	1.21	orthorhombic	1.50	96-715-3495	33.7

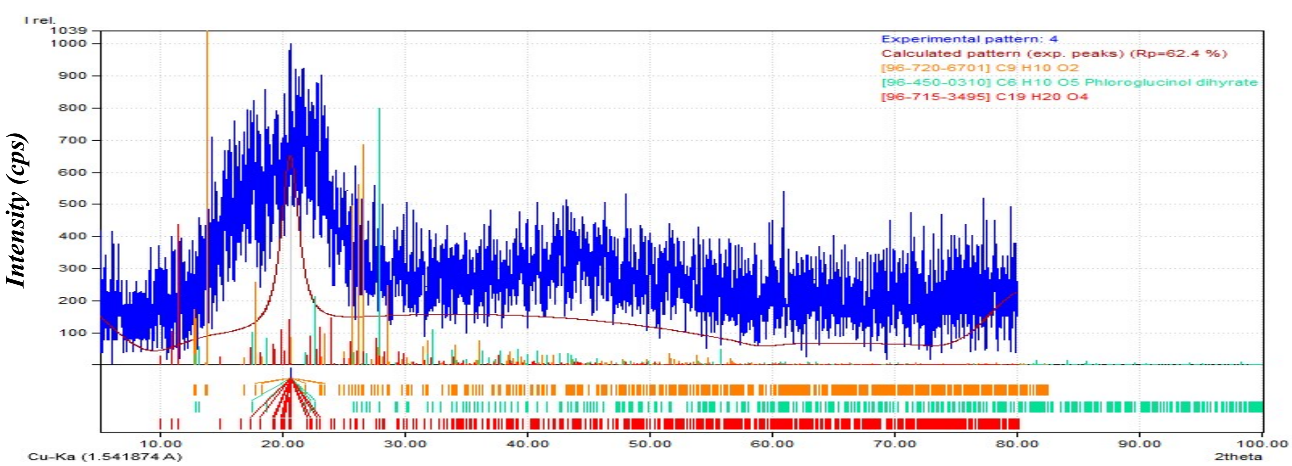


2Theta (2Θ)

Figure 4 XRD images of 30% weight of fiber

Table 3 XRD analysis of Sample C3

SN	Element/ Compound	Intensity Scale Factor	Crystal System	Calculated Density (gm/cc)	Entry No.	Amount (%)
1	$C_9H_{10}O_2$	1.04	monoclinic	1.29	96-720-6701	50.9
2	$C_6H_{10}O_5$	0.80	orthorhombic	1.50	96-450-0310	26.1
3	$C_{19}H_{20}O_4$	0.44	orthorhombic	1.33	96-715-3495	23.0



2Theta (2Θ)

Figure 5 XRD images of 40% weight of fiber

Table 4 XRD analysis of Sample C4

SN	Element/ Compound	Intensity Scale Factor	Crystal System	Calculated Density (gm/cc)	Entry No.	Amount (%)
1	$C_9H_{10}O_2$	1.04	monoclinic	1.29	96-720-6701	50.9
2	$C_6H_{10}O_5$	0.80	orthorhombic	1.50	96-450-0310	26.1
3	$C_{19}H_{20}O_4$	0.44	orthorhombic	1.33	96-715-3495	23.0

[B] Results using Optical Micrograph

The optical microscopy has been carried out using OPTOMECH PP400TE microscope with various magnifications at room temperature. Optical microscopy shows the presence of distinct spherulites when the selected magnification is 5X. The region between spherulite boundaries is amorphous in nature. These supporting the XRD results.

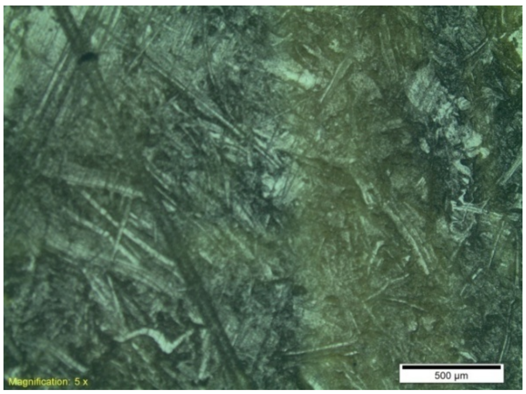


Figure 6 Surface morphology of 10% weight of fiber composites

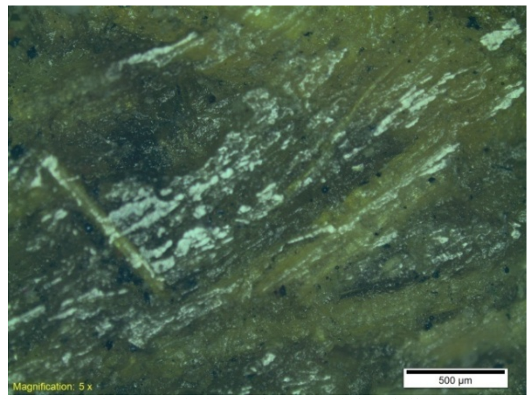


Figure 7 Surface morphology of 20% weight of fiber composites

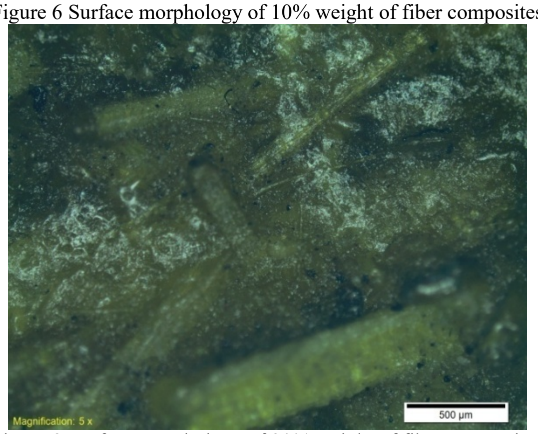


Figure 8 Surface morphology of 30% weight of fiber composites

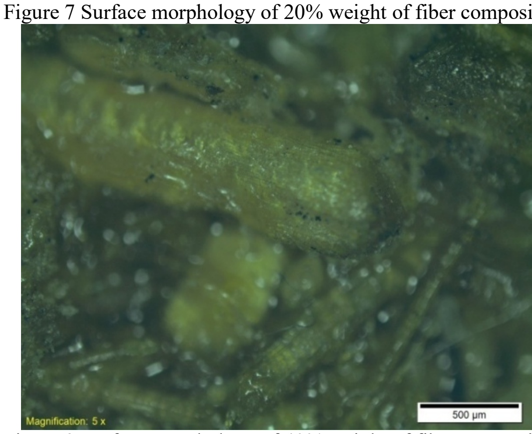


Figure 9 Surface morphology of 40% weight of fiber composites

The microscopic analysis shows the random distribution of the bamboo fibres in all of the considered samples. The randomization becomes less as the weight percentage of the bamboo increases, clearly depicted by Figures 6, 7, 8 and 9. Thus, it can be concluded that the mechanical properties will be more consistent in the case of higher weight percentage of the bamboo fibre composite as compared to their lower percentage counterparts.

Table 5 Sample's Ultimate tensile strength testing

SN	Material	Ultimate Tensile strength (MPa)	Yield Strength	% Elongation
1	C1	21.47	7.94	2.00
2	C2	24.66	9.00	1.90
3	C3	27.29	8.51	2,11
4	C4	19.93	7.43	1.85

The tensile test result has been tabulated for all four sample C1, C2, C3 and C4 in Table 5 and observed the least elongation in sample C4 and highest elongation in sample C3, which indicate that even at high tensile strength, the elongation sustain its quality of firmness. Fig. 10 shows graphically the variation of the sample percentage weight of fiber against the tensile strength.

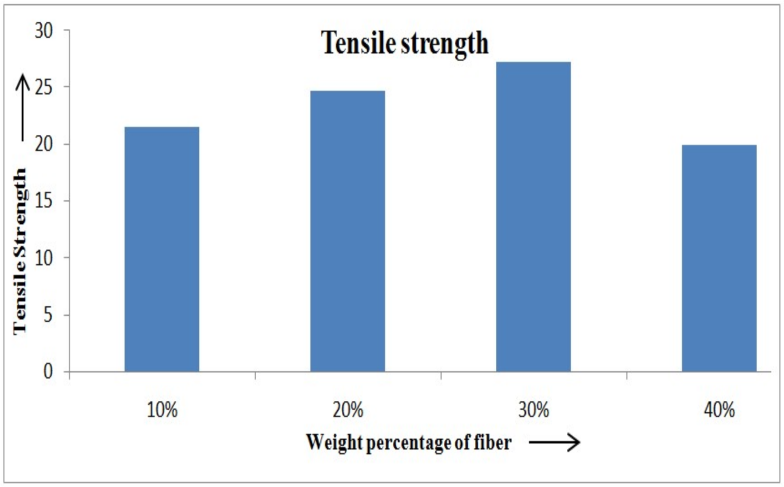


Figure 10 Graph between tensile strength against various percentage weight of fiber

IV. CONCLUSIONS

- Bamboo is a good choice because it is available in many parts of the world and grows very quickly, and is widely unused.
- The successful fabrications of a new class of epoxy based composites reinforced with short bamboo fibers have been done.
- It has been noticed that the mechanical properties of the composites such as tensile strength, flexural strength and etc. of the composites are also greatly influenced by the fiber loading.
- The present investigation revealed that 30wt% fiber loading shows superior tensile strength and flexure strength.

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