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Processing and Mechanical Behaviour of Hybrid Fiber Reinforced Polymer Composite Materials

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ABSTRACT-- *The cutting edge dynamic world can't envision its improvement without getting the idea of progression material composite. Different explores are going on in this field to accomplish the ideal standard. Common fiber fortified polymer composite has a tremendous liking to supplant the composite made up of manufactured fiber. This is essentially a direct result of the focal points like light weight, non-poisonous, non-grating, simple accessibility, minimal effort, and biodegradable properties. The manufactured strands have higher part of the arrangement like elasticity and malleable modulus anyway the particular mechanical properties like explicit tractable modulus and other explicit (properties/explicit gravity) of common fiber provides a delightful outcome for composites when contrasted with engineered fiber based composites. The target of the present examination is to research the mechanical properties of short jute and bamboo fiber strengthened epoxy based composites filled with coconut shell ash. Jute and Bamboo strands with various length and substance are fortified in epoxy sap to create hybrid composite materials. The impact of fiber length and substance on the mechanical bheviour of composites is examined.*

Keywords-- *Jute Fibers, Bamboo Fibers, Matrix, Reinforcement, Mechanical Behaviour*

I. INTRODUCTION

Composite material can be characterized as the material which is made out of at least two particular material on full scale with various properties to shape another material with a property that is totally not quite the same as the individual constituents. The essential period of a composite material is known as a framework having a ceaseless character. As such, framework is a material which goes about as a fastener and holds the filaments in the ideal position accordingly moving the outer burden to fortification. These networks are viewed as not so much hard but rather more flexible. The composite material comprises of a network alongside a fiber with some filler material. The strengthened material can be either engineered or common filaments. In the interest of expanding ecological security, a few common strands strengthened polymer composites (NFPCs) are brought into the aggressive market. NFPCs give a wide scope of focal points over engineered fiber based composites. These focal points incorporate high solidarity to weight proportion, high quality at raised temperatures, high wet blanket protections and high strength [1]. These points of interest can likewise be as their light weight, high solidness and plan adaptability. In NFPCs, the utilized lattices are either thermoset or thermoplastic. Polyester, Epoxy and

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phenolic sap are the regularly utilized thermoset framework though polypropylenes, polyethylene and elastomers involve the enormous scale position in thermoplastic network.

Composite materials can be arranged in view of the sorts of lattice utilized as:-

- The Ceramic Matrix Composites (CMC)
- The Metal Matrix Composites (MMC)
- The Polymer Matrix Composites (PMC)

Among various types of composites, PMC is the most typically used composites, on account of its various positive conditions, for instance, essential gathering rule, insignificant exertion and high caliber. PMCs have two sorts of polymer that have been used as lattice. These are thermoplastics and thermosetting polymer. Thermoplastic polymer is that polymer which are more than once pacified and improved by warming. A couple of instances of thermoplastics are PVC, LDPE and HDPE.

Thermosetting polymer is the polymer which has hard and solidified cross-associated materials. They are not decrease and pliant when they are warmed. Epoxy is the most by and large used thermosetting polymer.

Starting late, the ordinary strands are getting eagerness as stronghold in polymer composites rapidly. The typical fiber used as stronghold from amazingly antiquated as man used grass and straw from beginning of improvement in reinforcing the hinders that are used to impact mud to divider. There are various focal points of typical fiber over standard invigorating material as needs be as low thickness, negligible exertion, updated imperativeness recovery, extraordinary warm properties, satisfactory specific quality and biodegradable [1].
These strands are adequately and copiously available, biodegradable and these central focuses make ordinary fiber surely understood over made fiber, for instance, glass fiber, carbon and other man-made fibers. Ordinary strands are typically happening materials involving cellulose fibrils embedded in lignin arrange.

The structure of some usually utilized common strands is appeared in Table 1.1, based on the wellspring of beginning, regular filaments are portrayed into three orders they are

1. Mineral Fibers
2. Animal Fibers
3. Plant Fibers

Mineral Fibers:

Mineral fibers are the for the most part happening fiber or conceivably adjusted strands obtain from minerals. It has various portrayals they are taking after: Asbestos is the essential by and large happening mineral fiber. The Variations in mineral fiber are the anthophyllite, amphiboles and serpentine. The Ceramic strands are aluminum oxide, glass fibers, boron carbide and silicon carbide. Metal strands merge aluminums fibers.

Creature Fibers:

Animal fiber for the most part incorporates proteins; depictions mohair, fleece, silk, alpaca. Animal hairs are the strands got from animals for example horse hair, Sheep's wool, goat hair, alpaca hair, and so on. Silk fiber is the fibers gathered from dried spit of startling little creatures for the term of the period of planning of spreads. Avian fibers are the strands from flying creatures. Depictions silk from silk worms.

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Plant Fibers:

Plant strands are for the most part contains cellulose: portrayals cotton, flax, jute, ramie, sisal and hemp. Cellulose fibers are utilized as a bit of the produce of paper and material. The plan of these strands is as taking after: Seed fibers are the strands obtain from the seed case and seed for example kapok and cotton. Leaf fibers are the strands get from the leaves for example agave and sisal. Skin strands are the fibers are get from the skin or bast joining the stem of the plant [2].

Table.1.1: Chemical Properties of Natural fibres

Type of Fiber	Lignin (%Wt.)	Hemi-Cellulose (%Wt.)	Cellulose (%Wt.)	Moisture (%Wt.)	Pectin (%Wt.)	Waxes (%Wt.)
Cotton	-	5.75	86 to 91	7.86 to 8.6	0 to 1	0.7
Bamboo	33	0.6	60.9	-	-	-
Flax	2.3	18.7 to 20.7	72	8 to 13	2.4	1.8
Kenaf	8 to 14	21.6	46 to 48	-	3 to 6	-
Jute	13 to 14	13.7 to 20.5	61.5 to 71.6	12.6 to 14.5	0.3	0.6
Hemp	3.8 to 5.8	17.8 to 20.5	70.5 to 74.6	6.3 to 13	0.8	0.9
Ramie	0.7 to 0.8	13.2 to 16.8	68.7 to 77	7.6 to 17.5	1.8	0.4
Coir	401 to 46	0.16 to 0.26	32.5 to 43.7	9	4 to 5	-
Sisal	11 to 15	11 to 15	66.5 to 78.7	10.3 to 22.5	10.6	3
Banana	6	11	63.5 to 64.7	11 to 13	-	-

This strands having higher adaptability than different fibers. In like way, these strands are utilized as a bit of solid yarn, surface, bundling, and paper. By and by a-days, the standard fiber braced polymer composites applications are generally found in vehicle adventures and building industry and where the dimensional security and burden passing on quality under saturated and warm steadfastness conditions is basic. For example, flax fiber based polyolefin are commonly used as a piece of vehicle industry.

In the present investigation, epoxy is as the lattice material. By and large, epoxy has a lustrous appearance with exemplary focal points like great attachment to different materials, great mechanical properties, great electrical protecting properties, great natural and concoction protections and so on [1]. There are various filaments given naturally to the human humankind. In light of the wellspring of source, this normal fiber can be characterized into

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three classes, for example, creature fiber, vegetable fiber and mineral filaments. The point by point characterization of regular strands is done underneath in the Figure 1.1.

In fiber reinforced polymer composite, the fiber used can be of different size [13]. Depending upon the application and the type of possessions to be imparted to the composite, size of fibers are accordingly determined. In fiber reinforced polymer composite, the reinforcing can be either of fibrous or can be non-fibrous. If the fiber used in the composite is derived from the natural resources like animals or plants, then the fiber is said to be natural fiber and the composite is said to be natural fiber reinforced polymer composite.

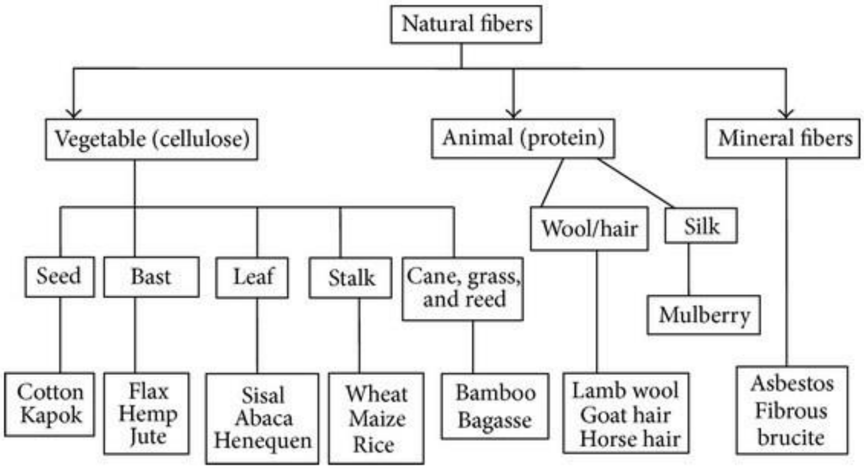

Figure 1.1: Classification of natural fibers based on source of origin

Here, the fiber goes about as a fortification in non-basic inside [3]. Characteristic fiber fortified polymer composites utilized for auxiliary applications, however then for the most part with engineered thermoset grid material which restrict the natural advantages [4, 5]. Properties of few natural fibers are presented in Table 1.2.

Table 1.2: Properties of Natural fibers [3]

Fiber Name	**Density (g/cm^3)**	**Tensile Strength (MPa)**	**Young's Modulus (GPa)**
Sisal	1.4-1.6	508-856	9.5-29
Banana	1.32	528–758	8.3
Cotton	1.6-1.7	288–801	5.6–14
Flax	1.5-1.6	346-1831	28-81
Hemp	1.6	551-1111	59-71
Jute	**1.36–1.47**	**394–801**	**11–56**
Kenaf	46-58	931	21.6
Ramie	1.6	401–939	45–129
E Glass	2.6-2.56	2001-3001	71
Abacca	1.16	401	13

Alfa	0.88	351	13
Bamboo	**0.7-1.2**	**141-231**	**12-18**
Coir	1.3	176	5-7
Pineapple	0.9-1.7	401-628	1.45
Nettle	--	651	39

The main objective of present work is to determine the mechanical properties of hybrid fiber reinforced epoxy composite materials for different orientations. The effect of fiber stacking and the length on mechanical properties like strength, rigidity, flexural quality, affect quality and hardness of composites.

II. LITERATURE SURVEY

Hair is a proteinaceous fiber with a firmly various leveled association of subunits, from the α-keratin chains, by means of middle of the road fibers to the fiber [6]. The uncommon properties of human hair, for example, its extraordinary substance piece, moderate corruption rate, high rigidity, warm protection, flexible recuperation, flaky surface, and one of a kind associations with water and oils, has prompted numerous different employments. Volkin et al. [7] distinguished and portrayed the procedures prompting obliteration of cystine deposits. They analyzed proteins from various species, including those of thermophilic microorganisms living close to the breaking point of water.

Thompson [8] produced a hair-based composite material by controlling a majority of trim lengths of hair to shape a web or tangle of hair, and consolidating said web or tangle of hair with an auxiliary added substance to frame said composite material. Jain et al. [9] examined on hair fiber fortified concrete and presumed that there is colossal augmentation in properties of cement as per the rates of hairs by weight of in concrete. The expansion of human hairs to the solid enhances different properties of solid like elasticity, compressive quality, restricting properties, miniaturized scale breaking control and furthermore increments spalling obstruction. Subsequently human hairs are in relative wealth in nature and are non-degradable gives another time in field of FRC.

Hu et al. [10] considered on Protein-based composite biomaterials which can be framed into an extensive variety of biomaterials with tunable properties, including control of cell reactions. They gave new biomaterials which is an essential need in the field of biomedical science, with guide pertinence to tissue recovery, nano prescription, and ailment medications. Human hair is considered as a waste material in many parts of the world and it is found in civil waste streams which cause various environmental issues. Gupta [11] considered on Human Hair "Waste" and Its Utilization. Through this it has been reasoned that the human hair has countless in regions going from agribusiness to drug to designing ventures. Hernandez et al. [12] contemplated on keratin which is a fiber which is found in hair and quills.

Keratin fiber has a various leveled structure with an exceedingly requested adaptation, is independent from anyone else a biocomposite, result of an expansive development of creature species. Through this it has been reasoned that the keratin strands from chicken quills demonstrates an eco-accommodating material which can be connected in the advancement of green composites. Babu et al. [13] examined on bio-based polymers and presumed that it has generally expanded the consideration because of natural concerns and the acknowledgment that worldwide oil assets are limited.

III. MATERIALS AND METHODOLOGY

The materials that are used in the present work of study are:

a) Epoxy Resin (Matrix)

b) Short Jute & Bamboo Fiber (Reinforcement)

c) Hardener

3.1 Jute fibers:

Jute fiber is prepared from the pseudo stem of jute plant. Jute mainly consists of cellulose, hemi-cellulose and lignin. It has very high tensile strength and highly resistant to rot. It withstands high temperature with minute damage. Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly.

Figure 3.1: Jute Fiber

3.2 Bamboo Fiber:

Bamboo fiber is a cellulosic fiber that is regenerated from bamboo plant. It is a great prospective green fiber with outstanding biodegradable textile material, having strength comparable to conventional glass fibers. Bamboo fiber has various micro-gaps, which make it softer than cotton and increase its moisture absorption. They are elastic, environment friendly and biodegradable.

Figure 3.2: Bamboo Fiber

3.3 Epoxy Polymers:

Polymers are widely employed in our everyday life due to their unique characteristics, such as low density, ease of forming, chemical inertness, low cost and often ductile nature. Polymers are broadly classified into two basic types, namely thermoplastics and thermosets. Each of them has its own individual chemical characteristics based on its molecular structure.

The LY 556 epoxy resin and the corresponding hardener HY-951 are procured from Ciba Geigy Ltd, India (Figure). Table.1 provides some of the important properties of epoxy.

Epoxy is a chemical liquid which used in many apllications. It is based on the structure of epoxide group, a reactive functional group present in all epoxy resins. Epoxy resins [1] may be reacted (cross-linked) either with themselves through catalytic homo polymerization, or with a wide range of co-reactants including poly-functional amines, acids (and acid anhydrides), phenols, alcohols and thiols (usually called mercaptans). These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing.

Figure 3.3: Epoxy Resin

Table 3.1: Properties of Epoxy Resin

Epoxy Resin properties (LY 556)	Value	Units
Density	1.16	g/cm3
Tensile Strength	59	MPa
Young's Modulus	3.76	GPa
Thermal Conductivity	0.363	W/m-k
Coefficient of Thermal Expansion	66	ppm/˚C

3.4 Preparation of Composites

Hybrid laminates of jute and E- glass / coconut shell powder composites were prepared by conventional hand lay-up technique. The layout of fiber for jute and glass was kept at (0°), (0°&90°) and (45°&-45°) orientations are individually used for the different composites. Coconut shell powder was used as the filler material.

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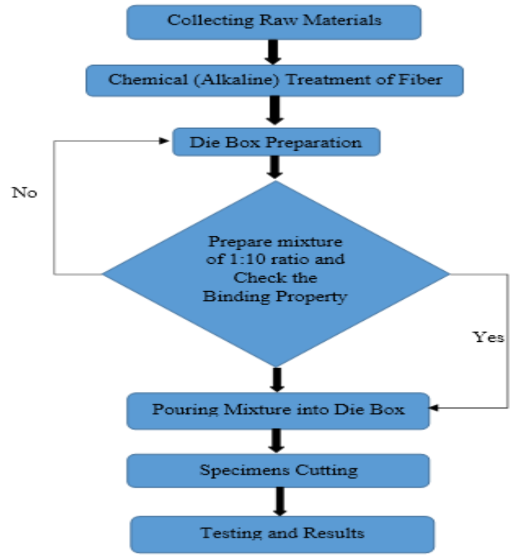

Figure 3.4: Flow Chart for the Process of Preparation of Composite

In this study, the fiber volume fraction is fixed to study the effect of fiber orientation. 30% volume fraction of fiber is used for all the specimens. Different volume fraction (0%, 3%, and 5%) of coconut shell powder is used for the different composites. A GI mould of (200×200×5) mm3 was used for composite fabrication. For quick and easy removal of the composite a mould release sheet is placed on the top and bottom of the GI mould (Figure 3.2 to 3.4). The mould release spray (silicone gel) is also applied to the inner surface of the mould wall to facilitate easy removal of the composite specimen.

A calculated amount of epoxy resin (LY 556) and hardener (HY 951) (of 10:1 by weight) was thoroughly mixed with a mechanical stirrer. After 5 min stirring, some mixture was poured into the mould uniformly, jute fiber mat was placed and then the required amount of epoxy resin was poured over it. The process was continued to fabricate two layers of jute-mat composite. For the hybrid composites two layers of glass and one layer of jute are used.

The glass fiber is kept top and bottom layers. After putting all the layers in the mould, a roller was used to roll over the fiber to remove air bubbles if any present. The mould was then pressed from the top with dead weight to put pressure on the mould. It was kept like that for 24hrs for proper curing.

After 24hrs the mould was removed to take out the composite slab. The same procedure was continued to fabricate hybrid composites with different stacking sequences of jute and glass fiber. In all the fabricated samples, care was taken to keep the thickness as 5mm. Total eighteen composites were prepared. Composite preparation is shown in the figure 3.5. Manufactured composites are shown in the figure 3.6. Total eighteen specimen's compositions are listed in the table 3.2.

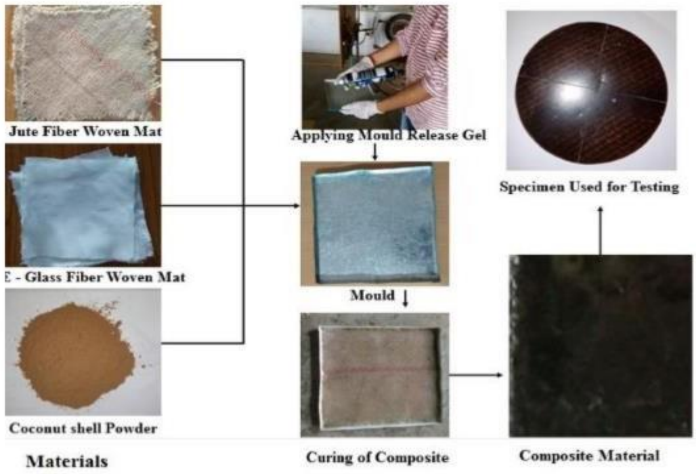

Figure 3.5: Composite Preparation

These composites are prepared as per following the above steps. These composites are considered for further testing. The composites obtained from the preparation are as shown in

0°&90° Orientation

-45° & 45° Orientation

0° Orientation

Figure 3.6: Composites Obtained After Preparation

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The composites are prepared based on below table 3.2. It can describe whether the composites are well prepared while testing. The detailed composition for composites is prepared as per the above table. By using the hand lay-up method, the composites are prepared by following the above composition.

Table.3.2: Detailed Composition of the Composites

Sample No	Orientation	Epoxy percentage	Fiber percentage
1	0^o	70%	30%Jute
2	0^o	67%	30%Jute+3%csp
3	0^o	65%	30%Jute+5%csp
4	0^o	70%	30%Bamboo
5	0^o	67%	30%Bamboo+3%csp
6	0^o	65%	30%Bamboo+5%csp
7	0^o & 90^o	70%	15%Jute+15%Bamboo
8	0^o & 90^o	67%	15%Jute+15%Bamboo+3%csp
9	0^o & 90^o	65%	15%Jute+15%Bamboo+5%csp
10	0^o & 90^o	70%	15%Jute+15%Bamboo+E-glass
11	0^o & 90^o	67%	15%Jute+15%Bamboo+3%csp+E-glass
12	0^o & 90^o	65%	15%Jute+15%Bamboo+5%csp+E-glass
13	45^o & -45^o	70%	15%Jute+15%Bamboo
14	45^o & -45^o	67%	15%Jute+15%Bamboo+3%csp
15	45^o & -45^o	65%	15%Jute+15%Bamboo+5%csp
16	45^o & -45^o	70%	15%Jute+15%Bamboo+E-glass
17	45^o & -45^o	67%	15%Jute+15%Bamboo+3%csp+E-glass
18	45^o & -45^o	65%	15%Jute+15%Bamboo+5%csp+E-glass

3.5 Mechanical Testing of Composites

After the creation of jute/bamboo strengthened epoxy based polymer composite, the example of suitable measurement were set up to complete different tests like rigidity test, flexural quality test, miniaturized scale hardness test and Impact test under ASTM guidelines. The elasticity and flexural quality test were done utilizing howl machine (Figure 3.6.a). Both of these tests are completed on level example. A uniaxial burden is connected to the example in both the bearing of the example, at long last prompting the disappointment of the example after extreme pressure. The ASTM standard test technique for elastic properties of composites has the assignment D 3039-76.

Small scale hardness test was completed by utilizing the instrument named LECO hardness analyzer. The test is normally known as Vicker's Micro hardness test. The example utilized for this situation is likewise of level shape. A precious stone indenter of right pyramid shape with a square base and an edge of 1360 between two inverse appearances are constrained into the material under a heap, F kgf.

Effect quality of a material is characterized as the property of a material by temperance of which the material contradicts it crack under pressure connected at rapid. Effect quality of a polymer composite material is completely identified with its sturdiness in general.

Fig: 3.6 a. Experimental set up of tensile test   b. Specimen for tensile test

c. Loading arrangement for flexural test   d. Experimental setup of impact test

Figure 3.6: a. Experimental set up of tensile test

IV. RESULTS & DISCUSSION

The test results of mechanical behaviour for Bamboo fiber reinforced polymer composites with their different compositions are described below:-

4.1 Mechanical Behaviour of Composites:

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

4.1.1 Effect of fiber length on tensile strength of composites

The tensile strength of a composite material is defined as the resistance offered by the material to get broken under tension. The effect of fiber loading and fiber length on tensile strength of composite is show below in Figure

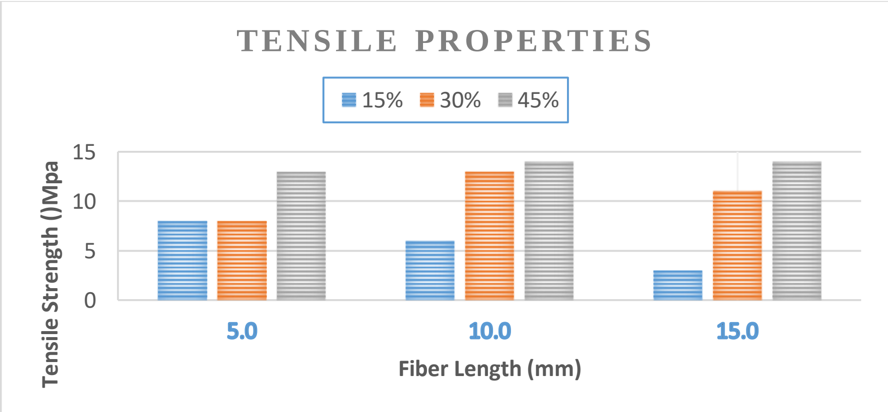

Figure 4.1: Tensile Properties of Bamboo fiber reinforced composites

Elasticity for this situation fluctuates with shifting structure and it is discovered that the quality continues expanding with expanding level of fiber in the composite for every length of fiber. The tractable properties estimated in the present work are very much contrasted and different before agents [12], however the strategy for extraction of bamboo fiber is unique. The tractable modulus shows the overall solidness of a material and would thus be able to be acquired from pressure strain graph [19]. Ideal estimation of rigidity for the composite is observed to be at 45% fiber stacking for every length of fiber. The most elevated an incentive for rigidity is for 45% fiber stacking for a fiber length of 15 mm.

4.1.2 Effect of fiber length on flexural strength of composites

The flexural strength is stated 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 short bamboo fiber loading and fiber length on flexural strength of composites is shown in Figure 4.2.

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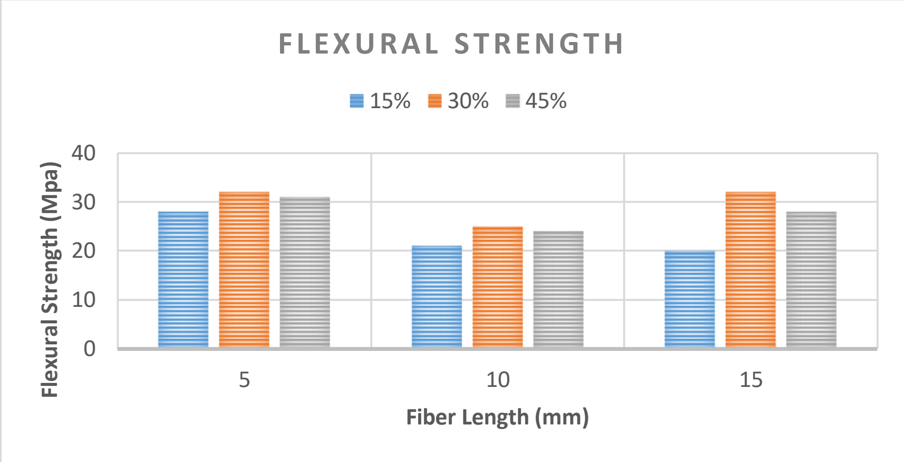

Figure 4.2: Flexural Properties of Bamboo Fiber reinforced composites

4.1.3 Effect of fiber length on impact strength of composites

The 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 short bamboo fiber loading and fiber length on impact strength of composites is shown below in Figure 4.3.

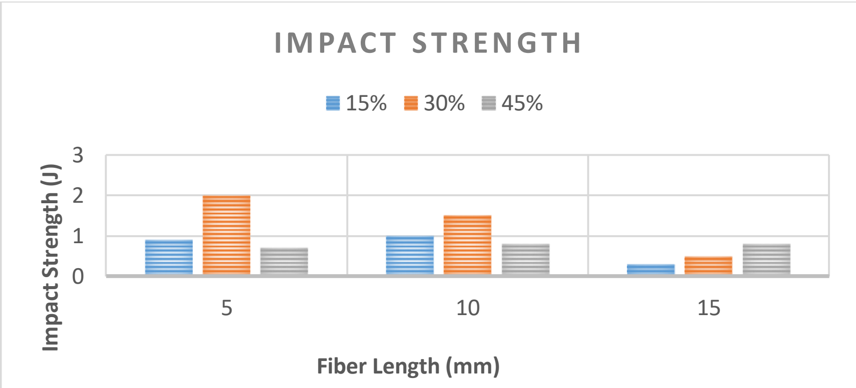

Figure 4.3: Impact Properties of Bamboo Fiber reinforced composites

The diminishing in effect quality or littler variety in quality might be expected to prompt microspaces between the fiber and network polymer, and subsequently causes various smaller scale breaks when effect happens, which incite split proliferation effectively and decline the effect quality of the composites [12, 13].

By and large the effect quality of composite materials increments with the expanding fiber content anyway the lower estimations of effect quality at higher arrangement of fiber might be a direct result of inappropriate attachment between the lattice and the filaments. Higher substance of filaments in composite requires higher framework material however it isn't probably going to be so. Thus all things considered, lattice can't move burden to its filaments

4.1.4 Effect of fiber length on hardness of composite

The surface hardness of composite material is at some point a matter of concern when the composite material so created is experienced for space application. For a given work, the composite material was exposed to Vicker's Hardness test and the accompanying perceptions were made (Figure 4.4).

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From the above figure, it is inferred that the hardness of a short bamboo fiber epoxy based composite increments with the expanding fiber substance and fiber length in a specific way and after that it gradually drops down.

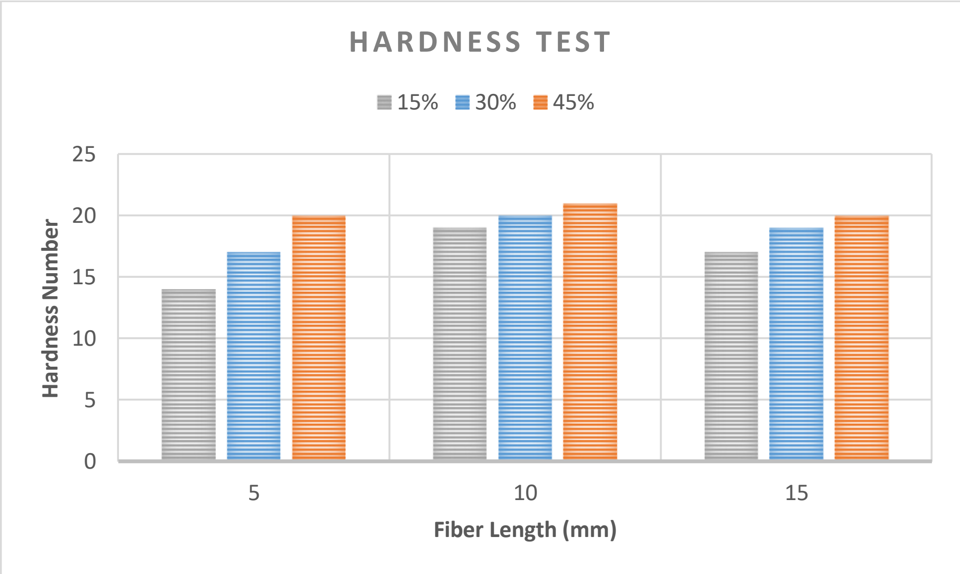

Figure 4.4 : Hardness Properties for Bamboo Fiber reinforced composites

V. CONCLUSIONS

Short bamboo fiber strengthened epoxy based polymer composite was created and its mechanical conduct was examined. The ends drawn from this test examination are as per the following:

i. Epoxy based composite material strengthened with short bamboo filaments have been effectively manufactured.

ii. It has been investigated that the mechanical properties of the composites, for example, elasticity, flexural quality, sway quality and hardness are exceptionally impacted by the size of the strands utilized.

iii. Excess of strands in composite materials break down the mechanical properties of the composite on account of absence of appropriate holding between the network and fiber around their interface. This makes the interruption in exchange of burden the holding filaments. Lower estimations of effect quality and flexural quality at higher sythesis of bamboo strands might be a direct result of this reason.

iv. The present investigation uncovers that effect quality, rigidity and flexural quality increments with expanding substance of fiber in composite materials.

REFERENCES

1. Cao Y., Shibata S., Fukumoto I., (2006). Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments, Composites: Part A 37, pp. 423–429.
2. Naidu, A. Lakshumu, D. Raghuveer, and P. Suman. "Studies on characterization and mechanical behavior of banana peel reinforced epoxy composites." *Int J Sci Eng Res* 4 (2013): 844.

3. Satyanarayana K.G., Sukumaran K., Mukherjee P.S., Pavithran C., Pillai S.G.K., (1990). Natural Fiber-Polymer Composites, Cement and Concrete Composites 12 (2), pp. 117-136.
4. Satyanarayana K.G., Sukumaran K., Kulkarni A.G., Pillai S.G.K., Rohatgi P.K., (1986). Fabrication and Properties of Natural Fiber-Reinforced Polyester Composites, Composites 17(4), pp. 329-333.
5. Mansur M.A., Aziz M. A. (1983), Study of Bamboo-Mesh Reinforced Cement Composites, International Journal of Cement Composites and Lightweight Concrete 5(3), pp.165- 171.
6. Naidua, A. Lakshumu, and D. Nageswara Raob. "Studies on Characterization and Mechanical Behavior of Natural Clay." *Int. J. of Multidisciplinary and Current research* (2013).
7. Naidu, A. Lakshumu, B. Sudarshan, and K. Hari Krishna. "Study on Mechanical Behavior of Groundnut Shell Fiber Reinforced Polymer Metal Matrix Composities." *International Journal of Engineering Research & Technology* (2013).
8. Srinivas, K., A. Lakshumu Naidu, and MVA Raju Bahubalendruni. "A Review on Chemical and Mechanical Properties of Natural Fiber Reinforced Polymer Composites." *International Journal of Performability Engineering* 13.2 (2017): 189.
9. Jain D. and Kothari A. (2012). Hair Fibre Reinforced Concrete, Research Journal of Recent Sciences, Vol. 1, pp.128-133.
10. Naidu, A. Lakshumu, and PSV Ramana Rao. "A Review on Chemical Behaviour of Natural Fiber Composites." *International Journal of Chemical Sciences* 14.4 (2016).
11. Gupta A. (2009), Human Hair “Waste” and Its Utilization: Gaps and Possibilities, International Journal of Refractory Metals & Hard Materials 27, pp. 892–899.
12. Hernandez A.L.M., Santos C.V., (2012). Keratin Fibers from Chicken Feathers: Structure and Advances in Polymer Composites, In: Keratin: Structure, Properties and Applications, Nova Science Publishers, pp.149-211.
13. Naidu, A. Lakshumu, V. Jagadeesh, and MVA Raju Bahubalendruni. "A REVIEW ON CHEMICAL AND PHYSICAL PROPERTIES OF NATURAL FIBER REINFORCED COMPOSITES." *Journal of Advanced Research in Engineering and Technology* 8.1 (2017): 56-68.
14. SUMAN, P., A. LAKSHUMU NAIDU, and PSV RAMANA RAO. "PROCESSING AND MECHANICAL BEHAVIOUR OF HAIR FIBER REINFORCED POLYMER METAL MATRIX COMPOSITES."
15. Rao, D. Venkata, A. Lakshumu Naidu, and Srinivas Kona. "Design and Simulations of Walk Link." *Red* 6000: 603.
16. hin F G , Xian x j , Zheng W P , Yipp M W “Analyses of the mechanical properties and microstructure of bamboo-epoxy composites” journal of material science ,vol 24 , pp- 3483-3490.
17. Lobovikov M, Paudel S, Piazza M, Ren H, Wu J, Non-wood Forest products (18), World Bamboo Resources, A thematic study prepared in the framework of the Global Forest Resources Assessment, Rome, 2007.
18. Suhaily S.S, Khalil H.P.S.A, Nadirah W.O.W & Jawaid M, “Bamboo Based Biocomposites Material, Design and Applications”; pp. 492.
19. Xiao, Y, & Ma, J. Fire Simulation Test and Analysis of Laminated Bamboo Frame Building. Construction and Building Materials. (2012). , 34(0), 257-66.

20. Torres F.G., Diaz R.M., Morphological characterisation of natural fibre reinforced thermoplastics (NFRTP) processed by extrusion, compression and rotational moulding, Polymers and Polymer Composites 12 (8) (2004) pp-705–718.
21. Torres F.G., Aguirre M., Rotational moulding and powder processing of natural fibre reinforced thermoplastics, International Polymer Processing 18 (2) (2003) pp- 204–210.
22. Torres F.G., Ochoa B., Machicao E., Single screw extrusion of natural fibre reinforced thermoplastics (NFRTP), International Polymer Processing 18 (1) (2003) pp- 33–40.
23. Satyanarayana K. G, Sukumaran K, Mukherjee P. S, Pavithran C and Pillai S. G. K, "Natural Fiber-Polymer Composites", Cement and Concrete Composites, 12(2), 1990, pp. 117-136.
24. Lundquist L, Marque B, Hagstrand P. O, Leterrier Y and Månson J. A. E, "Novel Pulp Fiber Reinforced Thermoplastic Composites", Composites Science and Technology, 63(1), 2003, pp. 137-152.
25. Karnani R., Krishnan M., and Narayan R, "Biofiber –reinforced polypropylene composites" Polymer. Engineering and Science, vol 37, (1997)pp- 476.
26. Gassan J. and Bledzki A.K., "Alkali treatment of jute fibers:relationship between structure and mechanical properties" Journal of applied polymer science, (1999).vol 71, pp- 623-629.
27. George J, Bhagawan S.S, and Thomas S, (1998) "Improved interaction in chemically modified pineapple leaf fiber reinforced polyethylene composites" Composite. Interface.5, 201.
28. Bataille P, Richard L, and Sapieha S., "Effect of cellulose fibers in polypropylene composites" Polymer Composite, vol 10, (1989). pp -103-108.