© 2019 IJSRSET | Volume 6 | Issue 3 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology
DOI : 10.32628/IJSRSET196334

Mechanical Characterization of Flax and Bamboo (BFBF) Mat Reinforced Epoxy Hybrid Composite

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ABSTRACT

Hybrid composite materials are the great potential for engineering material in many applications. Hybrid polymer composite material offers the designer to obtain the required properties in a controlled considerable extent by the choice of fibers and matrix. The properties are tailored in the material by selecting different kinds of fiber incorporated in the same resin matrix. In the present investigation, the mechanical properties of Bamboo and flax mat reinforced epoxy hybrid composite were studied.The hand lay-up technique was adopted for the fabrication of hybrid composite materials. The mechanical properties such as hardness, tensile strength, tensile modulus, impact strength, water absorption of the hybrid composites were determined as per ASTM standards.The mechanical properties were improved as the fibers reinforcement content increased in the matrix material.SEM observation reports the fracture behavior of composite material.

Keywords : Hybrid composite, Hand layup technique, ASTM standards.

I. INTRODUCTION

Composites are multi-functional materials consisting of two or more chemically distinct constituents, on a macro-scale, having a distinct interface separating them. More than one discontinuous phases are embedded in a continuous phase to form a hybrid composite. The discontinuous phase is usually harder and stronger than the continuous phase and it is called the hybrid reinforcement and the continuous phase is termed the matrix. The matrix material can be classified into metallic, polymeric and ceramic. Recently, the polymer matrix composites have been widely used for many applications like automotive parts, airplanes interior parts, household appliances and construction materials [1]. The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are derived from plants or some other living species, they are called natural fibers. The environmental issues have resulted in considerable interest in the development of new composite materials with addition of more than one reinforcement that are biodegradable resources, such as natural fibers as low-cost and environment-friendly alternative for synthetic fibers[2]. The hybrid fibers in the composites can withstand higher load compared to single-fiber reinforcements in different direction based on the reinforcement, and the surrounding matrix keeps them in the desired location and orientation, acting as a higher load transfer medium between them[3]. The increased environmental consciousness is promoting the use of eco-friendly fibers, extracted from plants, vegetables, minerals and animals instead of synthetic fibers [4]. Automobile sector has various applications of NFRP composites to manufacture different parts such as door panels, headliners, package trays, dashboards and interior parts of vehicle [5]. In recent years, the use of flax fibers as reinforcement in composites has gained popularity due to an increasing requirement for developing sustainable materials. Flax fibers are cost effective and offer specific mechanical properties comparable to those of synthetic fillers. Composites made of flax fibers with thermoplastic, thermoset, and biodegradable matrices have exhibited good mechanical properties [6]. The mechanical properties of composite materials depend on many factors, which include fiber length, shape, size, composition, orientation and distribution, as well as volume fraction, mechanical properties of the polymer matrix, manufacturing techniques and adhesion or connection between the fibers and the matrix [7]. Fiberglass has been used since the 1930s and it is most commonly used in reinforcing polymer matrix composites. One of the main causes of mechanical properties loss in composites reinforced with fiberglass is their susceptibility to moisture absorption [8]. Hybrid composites with different stacking sequences of glass /carbon , carbon/basalt , jute/glass on the mechanical loadings significantly affected the properties of the laminates[9]. However, glass-reinforced plastics exhibit shortcomings such as their relatively high fiber density (approximately 40% higher than natural fibers), difficulty onto machine, and poor recycling properties, not to mention the potential health hazards posed by glass-fiber particulate. An ecological evaluation, or eco-balance, of natural-fiber mat as compared to glass-fiber mat offers another perspective. The energy consumption to produce a flax-fiber mat (9.55 MJ/kg), including cultivation, harvesting, and fiber separation, amounts to approximately 17% of the energy to produce a glass-fiber mat (54.7 MJ/kg) [10]. Natural fibers such as flax, hemp, and jute can be used as reinforcement for thermoset or thermoplastic polymers instead of synthetic fibers. Thermoplastic material currently dominates as matrixes for natural fibers are polypropylene and polyethylene, while thermosets, such as phenolic and polyesters, are common matrixes. Both thermosets and thermoplastics are attractive as matrix materials for composites as a result of large numbers of components being involved such as base resin, curing agents, catalysts, flowing agents, and hardeners that make the formulation complicated in thermoset composites [11].

II. EXPERIMENTAL

Natural Fibre and Matrix

flax and bamboo mat were supplied by Compact Buying Services, Faridabad, Haryana. Bi-directional mats of these fibers have been used for fabrication of bio - composites. Epoxy resin and hardener was supplied by Excellence Resins, Meerut, UP.

Bamboo Fiber:

Bamboos include some of the fastest-growing plants in the world due to a unique rhizome-dependent system. Certain species of bamboo can grow 91 cm (36 in) with in a 24-hour period, at a rate of almost 4 cm (1.6 in) an hour (a growth around 1 mm every 90 seconds, or 1 inch every 40 minutes). Giant bamboos are the largest members of the grass family. Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia and East Asia, being used for building materials, as a food source, and as a versatile raw product. Bamboo has a higher specific compressive strength than wood, brick or concrete, and a specific tensile strength that rivals steel. Density of bamboo fibre is 1.1gm / cm3[12].

Flax Fiber:

Flax (*Linum usitatissimum*),also known as common flax or linseed, is a member of the genus *Linum* in the family Linaceae. It is a food and fiber crop cultivated in cooler regions of the world. Textiles made from flax are known in the Western countries as linen, and traditionally used for bed sheets, underclothes, and table linen. Its oil is known as linseed oil. In addition to referring to the plant itself, the word "flax" may refer to the unspun fibers of the flax plant. The plant species is known only as a cultivated plant, and appears to have been domesticated just once from the wild species *Linum bienne*, called pale flax. Density of flax fibre is 1.5gm /cm³ [13].

Fig.1 – Bamboo Mat(0^0 / 90^0 orientation)

Fig.2 – Flax Mat(0^0 / 90^0 orientation)

Fiber name	Cellulose [wt%]	Lignin [wt%]	Hemi-cellulose [wt%]
Abaca	56–63	7–9	20–25
Bamboo	26–43	1–31	30
Banana	83	5	–
Coir	37	42	–
Cotton	82.7–91	–	3
Curauá	73.6	7.5	9.9
Flax	64.1–71.9	2–2.2	64.1–71.9
Hemp	70.2–74.4	3.7–5.7	17.9–22.4

Fiber name	Density [g cm^{-3}]	Diameter [μm]	Tensile strength [MPa]
Abaca	1.5	–	400
Bamboo	1.1	240–330	500
Banana	1.35	50–250	600
Coconut	1.15	100–450	500
Coir	1.2	–	175
Cotton	1.6	–	287–597
Curauá	1.4	170	158–729
Flax	1.5	–	800–1 500
Hemp	1.48	–	550–900

Epoxy Resin

Araldite LY 556 is manufactured by Huntsman Advanced Materials having the following outstanding properties has been used as the matrix material. Epoxy Resin was purchased from Excellence Resins, Meerut, UP. Epoxy shows long open time , high shear, peel strength, easy to apply, electrically insulating, good resistance to static and dynamic loads.

Hardener

Hardener is a curing agent for epoxy resin. Epoxy resins require a hardener to initiate curing. It is also called the catalyst, the substance that hardens the adhesive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determine the final characteristics and suitability of the epoxy coating for a given environment. Optimum levels of a hardener are used to formulate epoxy coatings. The ratio differs from product to product. The use of an improper hardener may result in an under catalyzed or over catalyzed product. In the present work hardener (HY951) is used. This has a viscosity of 10-20MPa at 25ºc.

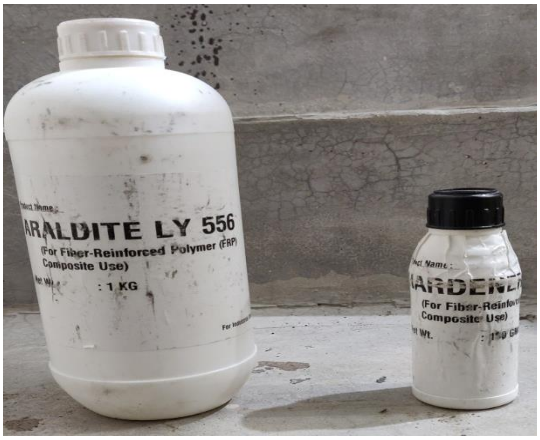

Fig. 4 – Epoxy and Hardener

Processing

Hybrid composites were fabricated with the help of detachable closed mold of mild steel using hand lay-up technique. The silica gel was applied to the inner surface of mold plates to avoid sticking of polymer with the steel plates during curing.

Fig. 5 – Mould

Fig. 6 – Roller

Fig. 7- Wooden Frame

Fig. 8- Composite Processing

The matrix was prepared by proper mixing of epoxy resin of Araldite LY556 grade and hardener HY951in proportion of 10:1as per manufacturer (Huntsman). Epoxy resin and hardener were properly mixed to reduce the air bubbles present in the liquid of resin and hardener. A wooden frame of dimension (250*260*5) was prepared. Flax and bamboo mat were washed with 10 % Sodium Hydroxide (NaOH) solution for 30 min and was cleaned with normal water until normal pH was attained .Now these fibers were dried by keeping them in sunlight for 8-10 hours The liquid matrix was then uniformly spread on the inner surface of the mold and the resin was rolled by the steel roller to achieve the equal thickness of resin layer over the surface of the mold. Fiber mats were cut in equal size as of Frame cavity and placed over the layer of resin. Roller was again rolled over to remove any air bubble trapped within the layer. This process was repeated again and again till the pre-decided specifications. For each type of developed composite, the weight fraction of fiber was 28%. Load is applied with the help of C- Clamp . Composite is left for curing for 48 hours at room temp with humidity 55%.

Final Composite Sheet is shown in Fig. 9 &10 a

Fig. 9- Final Sheet (Top View

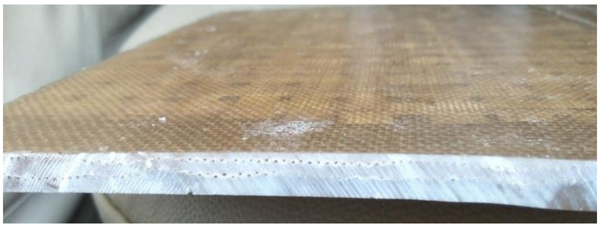

Fig. 10- Final Sheet (Side View)

FLAX MAT
BAMBOO MAT
FLAX MAT
BAMBOO MAT

Fig 10 (b) systemic view of hybrid composite

III. TESTING AND RESULT

(1) Tensile Test

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. Specimens were prepared as per ASTM D 638[15].
Tensile test was performed on UTM manufactured by INSTRO ,USA , Working range : max. 100 kN ,accuracy: +_ 0.66%

Fig 11- Universal Testing Machine

Fig 12- Clamped Specimen

Fig.13(a)- Tensile Specimen before Fracture

Fig.13(b) – Tensile Specimen after Fracture

Average value obtained of tensile Stress-strain curve are shown in fig. 13c.

- Young modulus= 2.24GPa,
- Elongation= 1.35,
- Ultimate stress = 56MPa

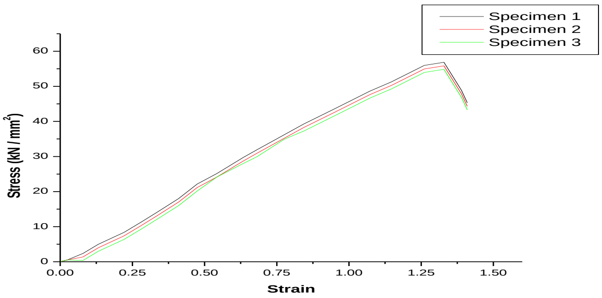

Fig.13(c) tensile stress-strain curve of hybrid composite

(2) Impact Test

The Izod test is has become the standard testing procedure for comparing the impact resistances of plastics. While being the standard for plastics it is also used on other materials.The Izod test is most commonly used to evaluate the relative toughness or impact toughness of materials and as such is often used in quality control applications where it is a fast and economical test. It is used more as a comparative test rather than a definitive test. This is also in part due to the fact that the values do not relate accurately to the impact strength of moulded parts or actual components under actual operational conditions.

The Pendulum is mounted on antifriction bearings. It has two starting positions, the upper one for Charpy and the lower one for Izod testing. On release, the pendulum swing down to break the specimen and the energy absorbed in doing so is measured as the difference between the height of drop before rupture & height of raise after rupture of the test specimen. To obtain the impact strength Izod test is performed as per ASTM D256.

Test was performed on Izod & Charpy Impact Tester With Notch Cutter manufactured by Tinius Olsen ,USA with a Accuracy of +_ 0.0015 Joule[16].

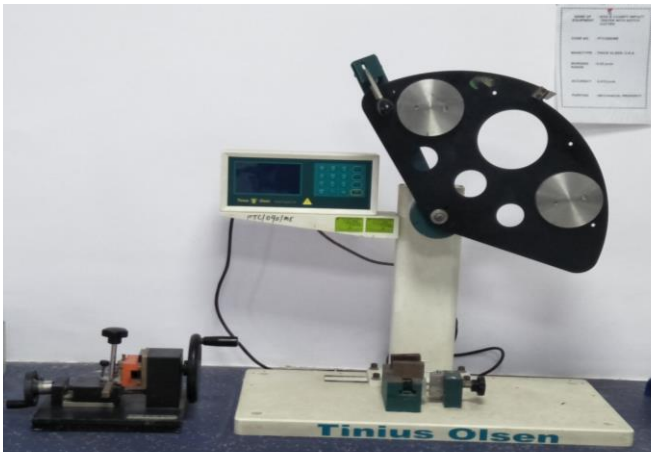

Fig.14- Impact Testing Machine

Fig.15 a Specimen Before Fracture

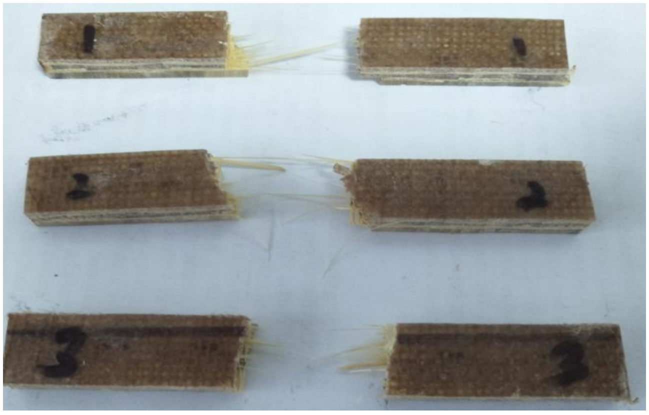

Fig.15b Specimen after Fracture

The mean value impact strength of this hybrid composite material is found to be 28.5 kJ/m^2

(3) Hardness Test

Hardness test is performed on Digitally hardness testing machine with model RBHT, M scale, 100 kgf load capacity,1/4” ball indenter.

The hardness value on M scale of hybrid composite is 62.5 (Mean Value) as shown in fig. 17 is more than hardness value of natural fibres hybrid composite.

Fig. 16 – Digital Hardness testing Machine

Fig.17 – Hardness Test Reading

(4) Water Absorption Test

Hybrid composite after fabrication are machined into required dimension as per ASTM standard D5229.The moisture absorption test was conducted in three different media like sea water, purified water and Bore well water .These different water was taken in same proportion in different beaker. sea water, and Bore well water was purchase from supplier, known weight of composite specimen are immersed in different water for specific period and the moisture absorbed is noted by weighing the specimen. Specimen of moisture absorption test under water and weighing balance machine , least count is 0.01g are shown in figure 18a-18d. Water absorption test is conducted for 48 hours at room temperature 22°C and 55% humidity. Figure 19 shows the graph of water absorption versus time.

Fig.18(a) –Sea Water (PH-8.2)

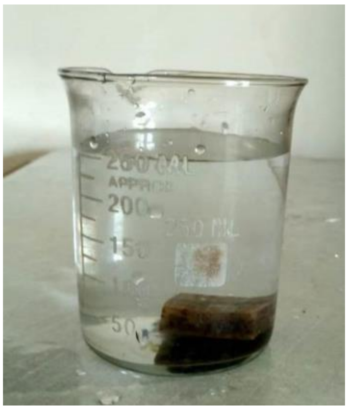

Fig.18(b)-Purified Water (PH-8.5)

Fig.18(c)-Borewell Water(PH-7.4)

Fig.18(d)- Weighing Balance

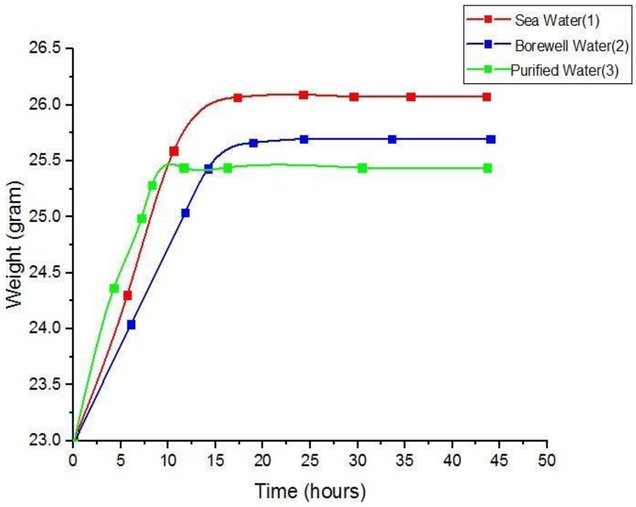

Fig.19- Water Absorption curve

(5) SEM (Scanning Electron Microscopy)

SEM images were taken on JSM 6490 which is an instrument which may be used both under low & high vacuums depending on the nature of the specimens. Low vacuum with low kV (energy) provides the user the longer duration for scanning the material, the organic specimens, before it is charged. The instrument has been coupled with an optional accessory, viz., EDS 133, EV Dry Detector (INCAx-act) of OXFORD instruments, UK, which has enhanced the application range in a manner that any metal associated with the biological material or in isolation or in the form of alloy may be identified and also quantified.

Fig.20 - SEM model JSM 6490

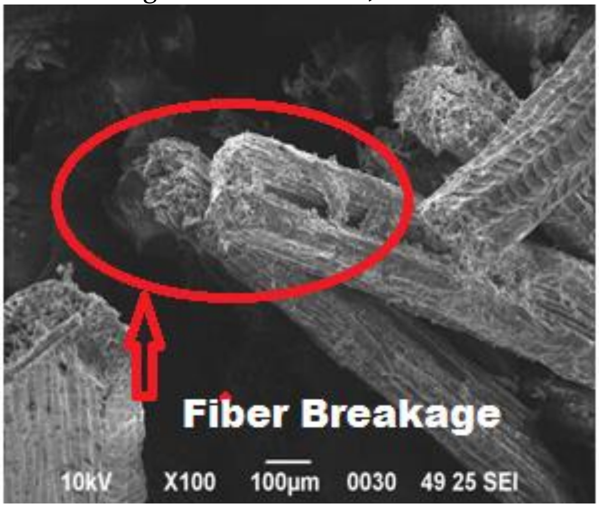

Fig.21(a)

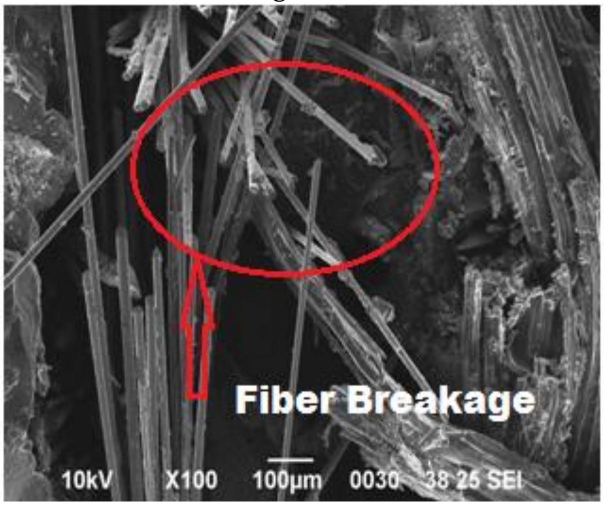

Fig.21(b)

The SEM micrographs for composite fracture are shown in Fig 21 (a-c). In general fibers are pull out , detachment of reinforced fibres can be seen . The fracture mechanism , based on morphology achieved , appears to involve both fibre pull out and fibre breaking as well as crack of matrix.

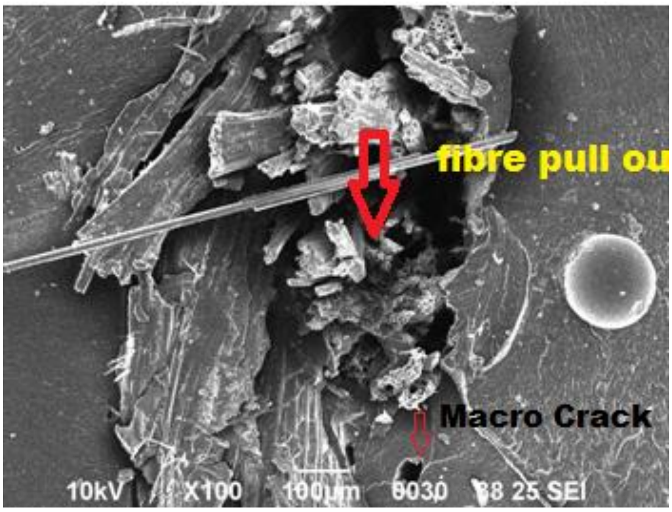

Fig.21(c)

II. CONCLUSION

1. There is improvement in tensile strength of hybrid composite by adding bamboo mat and flax mat reinforced in epoxy. Tensile Strength increases of BFBF hybrid composite (56 MPa) which is higher as plain epoxy (22MPa) and BGBG hybrid composite (45MPa).
2. The impact strength of BFBF hybrid Composite is 28.5 kJ/m^2 which is higher as compared to plain epoxy.
3. On M-scale the hardness reading is 62.5 which shows that BFBF composite will resist s a localized plastic deformation induced by either mechanical indentation or abrasion.
4. Water absorption test shows some water uptake due to cellulose content of natural fibre.
5. Moisture absorption is higher in sea water, lower in purified water and bore-well water between them in hybrid composite specimen.
6. The fracture mechanism, based on morphology achieved, appears to involve both fiber pull out and fiber breaking as well as micro-crack of matrix.

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Cite this article as :

Ravi Shukla, Dharmendra Kumar Singh, A. K. Srivastava, "Mechanical Characterization of Flax and Bamboo (BFBF) Mat Reinforced Epoxy Hybrid Composite", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 6 Issue 3, pp. 113-122, May-June 2019.

Journal URL : http://ijsrset.com/IJSRSET196334