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A Review on Bast Fiber Reinforced Thermosetting Matrix Composite

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ABSTRACT

The development of natural resources occurs due to biodegradability, ecofriendly and good strength to weight ratio in the engineering products. Natural fiber is obtained from various parts of the plant such as bast, leaf, seed, fruit, stalk, grass etc. In the present work take an overview of the characterization of the BF like failure mechanism, manufacturing process & overall properties. It deals with the potential energy absorbed by the natural fiber reinforced composite material. NFRC material replaced the various synthetic fiber. According to the literature survey the various work was carried out on the BF which shows its importance comparatively with the other fiber extract from the plant. BF is used as the reinforcement and thermoset epoxy used as matrix

Keywords : BF, NFRC, Potential Energy, Reinforcement.

I. INTRODUCTION

Synthetic material (carbon, aramid) replaced by the natural fiber due to environmental issue. The research on the natural fiber is carried out throughout the world by the researcher. Polymeric matrix derived from the natural fiber. It may be wood, kenaf, banana, flax, jute, wheat straw, abaca and other fibrous natural fiber and thermoset matrix are used. Wide ranging study carried on jute, kenaf, flax, bamboo, cotton, sugar cane, grass and leaf fibers. It directed extract out from the mineral, plant and animal resources. These fibers able to work in one directional and multidirectional ways which enhance the bearing capacity of the materials. Plant fiber obtained from bast, leaf, fruit, seed, straw. Figure 1 shows the classification of natural fiber.

Gbenga and Ekundayo1 (2019) reviewed about the natural fiber that Natural fiber obtained from the plant, animal, vegetable or through the minerals gives out the hair like structure and also convert into the nonwoven fabric after the spinning or it can transform into the woven cloth or yarn. From the various parts of the plant the vegetable fiber is achieved. Natural fiber obtained from the various resources like plant, animal and minerals. Natural fiber achieved by the different origin which is shown in table 1 In automotive market the use of natural fiber is widely used due to environmental sustainability beneficial for the constructive purpose. Natural fiber comprises with the insulator property due to effectively used in the industry.

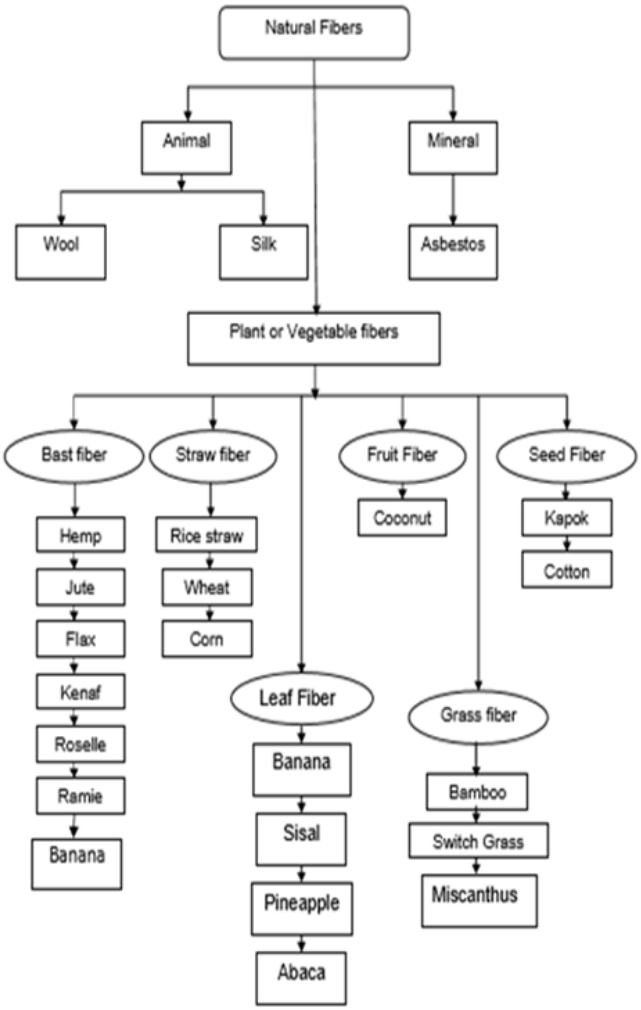

Fig. 1 Classifications of Natural Fibers

There is some chemical composition must be sustaining by the natural fiber which shows its effect during the testing. for instance; during the water absorption test due to the presence of the cellulosic content it allowed the how much water sucked by the material when it is immersed in the water.

Table 1: Fibers and Its Types

Type	General Name	Family Name	Scientific Name
Bast Fibers	Hemp	Cannabaceae	*Cannabis sativa*
	Jute	Tiliaceae	*Corchorus capsularis*
	Flax	Linaceae	*Linum usitatissimum*
	Kenaf	Malvaceae	*Hibiscus cannabinus*
	Roselle	Malvaceae	*Hibiscus sabdariffa*
	Ramie	Urticaceae	*Boehmeria nivea*
Leaf Fibers	Abaka	Musaceae	*Musa textilis*
	Sisal	Agavaceae	*Agave sisalana*
	Henequen	Agavaceae	*Agave fourcroydes*
	Pineapple	Bromeliaceae	*Ananas comosus*
	Banana	Musaceae	*Musa mannii*
Fruit Fibers	Coir	Arecaceae	*Cocos nucifera*
Seed Fibers	Kapok	Bombacaceae	*Ceiba pentandra*
	Cotton	Malvaceae	*Gossypium arboreum*

Fibers are extracted from different parts of the plant:

- Seed fiber
- Bast fiber
- Leaf fiber
- Stalk fiber
- Crane, grass and reed

1.1. Bast fiber

collected from the inner bank or it could be obtained from the surrounding the stem of the plant. Higher tensile strength achieved by these fibers comparatively the other natural fiber. Consequently, these fibers used for packaging and durable yarn. E.g. hemp, kenaf, flax, jute, ramie etc. some of the bast fiber are discussed.

Flax

The biological name of the flax is name of Flax is linum usitatissmum. such a bast fiber which is used in development of the natural fiber, oil production and non-textile industries. It does not obtain from the roots or the capsular and seeds while it is obtained from the inner parts of the stem. Stem length is approx. 600 to 1000mm. In shows the flax plant and flax fiber after extraction and harvesting. back structure provided by the epidermis and cuticle on the outside due to requirement of decortications. Bundle of the fiber covered by the back structure.

Kenaf

Kenaf is a wild plant which grown up in the warm season, short day commonly occur in tropical and sub-tropical places like Asia and Africa. Around 4000 BC kenaf has been cultivated for the production of food and fiber by the extraction process. It has exclusive property that it contains long bast about 35% of stalk dry weight. It does not contain the hollow core instead of that it long bast with short core.it belong to the malvaceae family significant play a important role in the horticulture. In 4-5 months kenaf grown up to 4-6 m height. In a year 6000 to 10, 000 Kg/hrs. dry weighted kenaf fiber produced.

Jute

The biological name of the jute fiber is Corchorus capsularis and Corchorus olitorius. Corchorus capsularis refers the white jute and Corchorus olitorius refer the dark jute. It is also obtained from the bast fiber. Quality and other characteristics depend upon the grades of the jute. In the world it achieved the second rank on the basis of cultivation while cotton have the first rank of cultivation. The growth of the jute fiber occurs in the monsoon season and every season growing plant. It achieved 2.5-4.5m height. Basically, it found in Bangladesh, India, Brazil and Indonesia.

Around the 4500 years ago hemp grown up in the china. In central Asia it is annual plant native. Pesticide, fertilization do not require by this fiber. In 12 weeks, the plant grown up to 4m and require warn conditions. Fine hemp obtained after retting which have light colored and lustrous and strong bast fiber. According the method of preparation its color and cleanliness depend. More non fibrous matter contains by the lower grade which is dark cream in color. In Italy, large amount of hemp produced.

1.2. Leaf fiber

It is obtained by leaf of the plant also termed as hard fiber. Some of having long length which must be from 1-4m but some having shorter length as comparative other like pineapple and banana. Large amount of cellulose comprises while low amount of lignin. Due to the length its property varies comparatively wood.

Sisal

It is easily growing fiber which easily produced all over India.it is not seasoned crop. Input cost is too low and extraction of this fiber achieved through retting process. It takes 15-21 days for extraction of fiber. from the pitch of the plant it is extracted. Industrial, automobile, geotextile, packaging etc.

Pineapple

This fiber also known as pina and espanol. It is whiter, softer and ivory color and having high luster. These fibers are easily washable and dried foe industrial purpose.basically it use in the fabrication of traditional dresses.

Thermoset Matrix

Comprise with more than one dimensional structure and sustain up to its elevated temperature and exhibit high melting point. It has tendency to regain its qualities during cooling, softening the material at its elevated temperature. Thermoset undergo the conventional compress techniques for molding the composite. Thermoset matrix divided into three categories

- Epoxy
- Phenolic polyamide resin
- polyester

Epoxy resin matrix used in manufacturing of filament wound with molding prepress. They are sensibly stable to chemical occurrences and are outstanding adherents having gradual shrinkage throughout

curing and no release of volatile gases. These advantages, though, use of epoxies somewhat exclusive. Similarly, they cannot be predictable further than a temperature of 140ºC.

Polyester resins are widely used and quite accessible due to low in price and easily available. It stored at room temperature for a very long period of time (months or few times for year also). The curing is done due to addition of catalyst into the resin. It used for the industrial, structural and various automobile parts.

Aromatic polyamides are widely used for structural application due to long duration exposure characteristics of the composite material. It is the composite of advanced matrices with the composite of fiber.

All the above material used for the formation of hybrid composite material.It is the multifunctional material which formed by the discrete material provide appropriate characteristics. Composite have cohesive structure formed by one or more compatible material having different composition or same in physical nature by Chandramohan and D & .K. Marimuthu and K (2011). The definition of the composite material given by the various researchers is as follows:

Normally composite is combination of the reinforcement (natural fiber) and matrix (polymers or ceramics). Reinforcement holds by the matrix which improves overall efficiency of the material. Newly combine material provide better efficiency than its individual constituents by Vinayraj and K G (2016). According to Jartiz and A.E (1965) composite have the multifunctional material which contain the discrete material. It contains the cohesive structure which formed by two or various companionable materials.

Kelly and A (1965) told about the composite that it spread out the stresses which improve the capability of the material due to the combination of the two or more material. It has wider significance due to its resistance to some desirable property, better strength and different from others. Berghezan and A (1966) stated that the composites are multifactorial materials which vary from alloys due individual components hold their uniqueness but transformed into the composite for its advantage only of their features and not of their inadequacies", in order to attain a better-quality material.

II. LITERATURE REVIEW

Mai and Y.M (2000) investigated on the latest structural materials require the light weight, high strength and lower cost. Generally strong materials are impenetrable and light material have less weight. In order to attain high asset and less heaviness, they prepared compound materials. In the manufacturing of the Compound materials glass fiber used as base materials. Different specimen is prepared by four dissimilar specimens with sisal stuff, banana stuff, and titanium oxide powder and coconut fiber. Polyester resin used as the bonding material.

Sapuan and S.M, Sahari and J (2000) has estimated the development and assets of natural fiber reinforced decomposable polymer compounds. They have capability to biodegrade and attuned with the environment. Investigators have discovered the manufacture and qualities of bio composites wherever the polymer matrices are imitative from the renewable resources like TPS, PLA.

Hema and P (2008) have studied about the classification of the natural fiber reinforced composite. Glass fibers have high tensile and flexural strength comparatively with the natural fibers. Sisal, pineapple, date palm is used as the natural fiber. In this the theoretical approach is also considered for calculating the tensile, impact and flexural strength by using different formula.

Singh and Jai Inder Preet (2017) has conceded study on the development of the green composite material. Rice husk, wheat husk, banana, jute, sisal, flax, kenaf is used as fiber and epoxy resin, polycratic acid, polypropylene, starch is used as matrix. With the natural fiber and matrix partially biodegradable and green composite are prepared. Aspect ratio, percentage elongation, specific young modulus, surface treatment of fiber is responsible factor for the mechanical properties of the green composite materials. It is used in the automotive parts like seat cover, floor panels, trunk floor, glove box etc.

Urendra kumar komal (2017) used nettle and grewiaoptiva as a natural fiber, polypropylene used as matrix. Three different composition are used nettle and polypropylene, grewia optive and polypropylene, grewiaoptive, nettle and polypropylene. Compression molding is used for manufacturing of natural fiber reinforced composite material. Tensile strength and flexural strength of polypropylene and grewiaoptive is higher than the polypropylene and nettle.

Saradava and Biren J (2016) has studied about the hemp fiber and polyester resin with different composition. Six different composition is prepared according to the weight fraction. Tensile strength and flexural strength increased with the composition of 10% fiber and 90% resin. On the ANSYS the analysis of the composite material can be performed. Sheet rollup method is replaced the hand layup technique. Natural hemp polyester composite has tendency to replace the manmade material which is non-biodegradable.

Korniejenko and K (2018) studied industrial waste like fly ash and biodegradable materials can produce the good mechanical properties and it shows the optimistic impact strength. The natural fiber comprises with the low density, specific weight to strength ratio, economical, all these properties makes it better than the synthetic composite material.

Gopal and p (2017) researched on the water absorbing behavior on the jute fiber mat. The jute and glass fiber mat is used as the natural fiber and epoxy resin with coconut shell powder is used as a matrix. Stacking sequence [0/90] s and [2/90]3s is used. It shows that the water absorption in jute mat with coconut shell powder is moderate than the glass mat.

Srinivasan and V. S (2014) investigate about the shear strength of the hybrid kenaf flax composite is better than the mono kenaf and flax composite material. he also investigated the flexural strength through scanning electron microscopy images in which cracking of the material analyzed on the 100 resolution. The variation of flexural strength finds out through the load verses displacement graph in between the GKFRP, GFFRP and GKFFRP composite material.

Sharba (2013) researched that woven kenaf is better than the glass due its substantial static strength and fatigue strength in bidirectional plane. Hand layup technique used for the fabrication of the composite the specimen is cut according the ASTM standards. Woven kenaf possessed the bidirectional property which improve the sustainability of the material.

Mohaiman and Jet (2008) had investigated the various mechanical testing like flexural, tensile, fully reversed fatigue and compression testing on the kenaf fiber material at different alignment. Coefficient of fatigue degradation of composite enhanced by hybridizations of the unidirectional and woven Kenaf fiber. The hybridization of the kenaf with glass in 30:70 weight ratios provides the good mechanical properties comparatively other hybridization of the kenaf and glass in weight ratio. Static and fatigue strength improved by the woven kenaf hybrid composite with the low weight and ecofriendly.

Sanjay and M. R. (2016) studied that hybridization of the glass in the jute and kenaf enhanced the mechanical properties by decreasing the voids.

Hybridization of the E-glass jute/kenaf with epoxy matrix reduces the moisture absorption of the composite. There is one analysis done by the researcher by comparing the tensile test of hybridized jute glass (JF) and hybridized kenaf glass (KG). Hybridized kenaf glass having more tensile strength than the hybridized jute glass. From the SEM analysis it is observed that the failure of material obtained.

Dhirhi Namrata (2015) investigated about the cultivation of natural fiber flax material in which he finds out that the flax material possessed the higher potential than the cotton fiber. The best growth of the flax fiber obtained under traditional farming process. It used as woven and non-woven end uses. It lies in bast fiber category which is also known as soft fiber or skin fiber.

Pandey and Pankaj (2016) searched that hybridized hemp agave and flax have the improved water absorption and hardness due to the addition of the glass fiber than the unhybridized hemp and glass fiber composite. The void content is affected by the incompatibility of material with the PU resin. The same amount of flexural strength achieved by the alone flax and the hybridized flax and hemp agave material. Hardness of the composite material increased due to the hybridization of the flax with the hemp agave material due to addition of the glass fiber.

Madeva Naik and Santosh (2017) researched about the Damping test of the sisal, flax and epoxy. Fast frequency technique analyzer (FFTA) is used for measuring the damping factor, mode shape and natural frequency. Hand layup technique used for the fabrication of the composite material. natural frequency is high due to the presence of excess flax comparatively other composite. The natural frequency of 10% flax with sisal combination is high as compared to the 5% flax with sisal natural fiber reinforced composite.

R Kalagi and Ganesh (2017) find put that those material which having low frequency material able to replace the glass fiber which is not completely biodegradable by the combination of sisal and flax in appropriate ratio. He go through the testing of natural frequency at the different mode shape. In mode 1 bending, in mode 2, twisting, in mode 3 double bending and in mode 4 combination of bending and twisting both occur.

Mangala Gouramma Saichandu (2015) investigates about the mechanical characterization of the flax and sisal hybrid composite material. hand layup manufacturing technique used for development of the hybrid composite material. The various test like tensile test, compression test, flexural test, hardness test and damping testing performed by the researcher so that the strength of the composite material obtained. It is observed during the testing is that the mechanical characteristics of the material enhanced due to the presence of the flax.

Madhusudhan and T (2016) studied the mechanical behavior of the hybrid composite material (jute & rubber) by using the epoxy matrix. He deals with the different type of hybrid composite produced by mixing of different type of natural fiber (sisal and glass fiber, jute and glass fiber, natural rubber and glass fiber) and the epoxy matrix. The properties of hybrid composite material are discussed in this paper. The performance of the composite material enhanced by adding the filler material. silicon carbide used as a filler material for improving the properties of the material. hybrid composite used as some best alternatives for the synthetic polymer composite material.

Elaya perumal and A (2014) on the hybrid composite material in which hybrid composite prepared with the jute and two different type of matrix polyester and epoxy. There is comparatively studied performed on the jute polyester and jute epoxy which shows the result that the jute epoxy sustains the better

mechanical characteristics than the jute polyester. Manufacturing time period require for jute polyester is low than the jute epoxy hybrid composite material. jute-epoxy possess the better tensile strength and flexural strength than the than the jute-polyester. The application of the jute- epoxy is seen in the automotive parts rather than the jute-polyester.

Chumsamrong and P (2014) studied that the flexural properties effected by the addition of the salinized sisal fiber. If the amount of fiber increased, then the flexural modulus is increased and blend in shape. Development seen by the composite in the form of the flexural modulus due to salinized sisal fiber constituents comparatively with the balkanized sisal fiber. From all of the composite the epoxy resin and blend attain more flexural strength than the other composite material. GNDR/epoxy composite have the higher flexural modulus by the addition of the fiber content.

Fernando and Wypych (2012) find out that the effect of the epoxy matrix which possessed the lack of thermal properties and good mechanical properties. Epoxy matrix have low boiling point; it starts burn out at slightly high temperature. Thermal property total is completely affecting the fracture of the composite, from protecting these types of disadvantages the composite mixed with the LDH. LDH behave as fire resistive material which increased the life cycle of the composite. So, therefore the epoxy matrix problem resolved.

III. MANUFACTURING TECHNIQUE

Hybrid composite material developed through the different manufacturing technique, which having different procedure and parameters.

1) Vacuum Bag Molding (VBM)

In the vacuum molding method, the flexible film used which prevent from the atmospheric condition like air and enclose the part. Vacuum bag used for vacuum creation and that compressed by the atmospheric pressure. A sheet of material or tube shape structure followed by the vacuum bag. Total part of the system must be placed at a single placed when the tube-shaped structure used for the manufacturing process. This bag divided into two parts lower and upper mold; upper mold consists of flexible membrane while the lower mold comprises with the rigid structure. Reusable silicone material used for the upper mold which is flexible in nature or extruded polymer film. Curing start after sealing the part with the vacuum (vacuum drawn by using vacuum bag). This process occurs in the presence of the ambient temperature or elevated temperature and atmospheric pressure occur at the vacuum bag. For removing the vacuum, a vacuum pump is used. The venture vacuum and air compressor are play a vital role for the sucking of vacuum from the system.

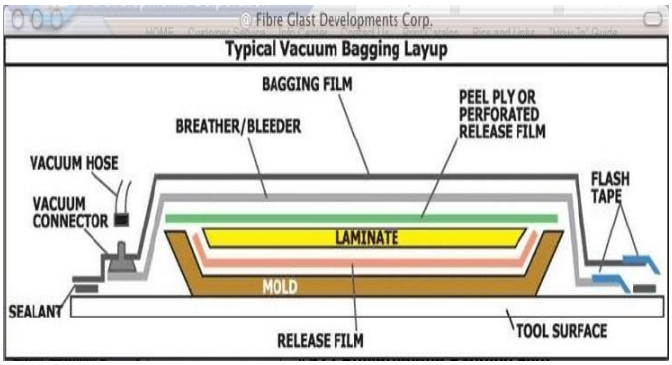

Fig. 1. Vacuum bag molding

During the cure or hardening process strong rubber coated material or polymer film used for the compression. A single application only single layer of the mold is used for the laminate the whole of the manufacturing system. Vacuum pump (which having nipple like structure) used for extracting the air from the tube-shaped vacuum bag due to this uniform pressure seems one atmospheric pressure, holding the parts properly though adhesive cures. The system must be comprising with the following activities like which provide accelerate curing.

- Oven must be temperature controlled
- Water immersion
- Oil bath
- Gently heated

This method is used for the industrial purpose also. Vacuum bag molding generally used for manufacturing the glass fiber and epoxy resin matrices prepare the laminate type structure.

Pressure Bag Molding (PBM)

This method works somewhat like vacuum bag molding (VBM) process and it is somewhat like its name. There is appropriate combination of the solid female and flexible mold. Female mold undergoes with the reinforcement process by using the required matrix material for joining the fabrics or fiber formed the laminates (layup). A proper amount of resin is placed over the fiber by the brush and after that clamped in the male flexible mold into the machine. Steam or heated compressed air contained by the flexible male membrane. After that solid female membrane also start heated. The excess matrices exert out into the atmosphere along with the stocked air. It can be performed by the unskilled labor, generally used in the production of the helmets because it is cheaper. 20-45 minutes are the cycle time acquired by the helmet, if the molds heated then no further curing required.

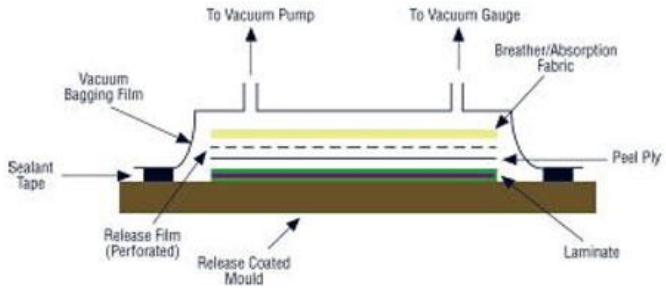

Fig. 2 : Pressure Bag Molding (PBM)

Hand Layup Technique

The simplest manufacturing process is hand layup technique. It required minimum infrastructure for the fabrication process. This manufacturing techniques is quite simple. Initially a releasing gel is applied onto the surface of the mold surface so that the evading of the sticking can performed. Proper surface finishing obtained by the using the plastic sheet at the top and bottom parts of the mould, so that finished sheet must be obtained with the good surface finish. Reinforcement cut into different size like chopped strand mat or woven mat with the different dimension and after that the it used into the molding process takes place. The thermoset matrix (presence in the form of liquid) is prepared with the proper proportion of resin and hardener (which work as curing agent) and sprayed onto the surface of the mat or fiber which is already present in the mold. During the preparation of the matrix i.e. mixing of the resin with the hardener go through the exothermic reaction, heat evolution occurs. Brush is used for the spreading of matrix onto the mold surface. After that another layer of the mat or fiber is applied on to the first layer of mat which is completely wetted with the thermoset matrix. Excess polymer and trapped air removed by roller pressing with a mild pressure from the mat polymer. Uniform movement of the roller occur during this process. The repletion of this process shown continuously until unless the required stacked sheet not obtained. When all the layers are placed, a plastic sheet placed on the mat or fiber. Above the mat or fiber release gel is squirted on the innermost surface of the mold plate which is at the upper mold. The upper mold helped in applying the pressure on the stacking layer of the material and above that a required pressure applied onto the mold. This curing of the material takes place at room temperature.

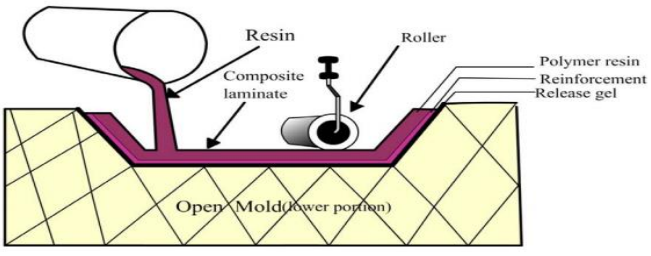

Fig 3. Hand lay-up Technique

IV.CONCLUSION

Bast fiber reinforced thermosetting matrix composite material developed high quality product with good specific strength to weight ratio. low density, high specific tensile strength etc. properties must be attained.

- Tensile strength of pineapple and sisal epoxy hybrid composite material is 8.7% lower than the kenaf, sisal epoxy and 3.53% lower than pineapple kenaf epoxy reinforced hybrid composite material because of bast fiber (kenaf) have high mechanical properties, low density relatively leaf fiber (pineapple and sisal) [28].
- flax have high specific tensile strength, stiffness due to that 24.09% tensile strength increased in the flax, pineapple and epoxy composite material than the pineapple, sisal and epoxy hybrid composite material [29].
- 9.33% increase in tensile strength of jute epoxy (22.82 N/mm^2) than the Sisal epoxy (20.69 N/mm^2) hybrid composite material. while combination of jute, sisal and epoxy produced the 26.93 N/mm^2 tensile strength [30].
- 18.48% increase in impact strength of jute epoxy (3.160 J/mm^2) than the Sisal epoxy (2.576 J/mm^2) hybrid composite material. while combination of jute, sisal and epoxy produced the 4.732 J/mm^2 tensile strength [30].

V. APPLICATION

Bast fiber used in different field like industrial, textile, automobile, building construction, green composite technology etc. in the production of racing bicycle flax, hemp used with epoxy matrix, manufactured by the Museeuw Bikes. Green wall panel formed by the combination of 50% recycled resin, reinforced with flax (25%) and E-glass (25%) roving.

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