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Abstract: In this paper, tensile behaviour of the natural fiber composites such as the areca nut composites and the sunn hemp composites were determined. The fibers were arranged in different orientations such as the uniaxial, biaxial and the criss-cross arrangements. For both the types of fiber composites, specimens were made with and without the incorporation of E-glass fibers. Comparisons were done on the basis of fiber orientation, E-glass fibers incorporation and the type of natural fiber used. Initially, the fibers were treated with alkali, i.e. Sodium hydroxide (NaOH) in order to get better bonding at the fiber-matrix interface. The conventional hand lay-up technique followed by the soft compression molding technique was carried out for fabricating the composite specimens. It was inferred from the results that the tensile strength was more for uniaxial arrangement and the least for biaxial arrangement in case of both the fibers. Further, for both the fibers, E-glass fiber incorporation increased the tensile strength as compared to the non-incorporated E-glass fiber composites. Also, sunn hemp composites showed better tensile strength than areca nut composites. The research suggested that the areca nut and sunn hemp composites were assets to many potential applications that did not require very high load bearing capabilities. These examined composites can be considered as very reliable materials for fabrication of lightweight materials used in automobile industry, packaging materials, medical field, etc.

Keywords- Areca Nut; Sunn Hemp; Composite; Uniaxial; Biaxial; Criss-cross; Specimen; E-glass Fiber; Alkali; Matrix; Hand Lay-up Technique; Compression Molding Technique; Tensile Strength

I. INTRODUCTION

Natural fibers are substances which are derived from organic matter such as plants and animals. These materials can be greatly elongated and can be spun into valuable items such as threads, ropes and filaments. These are used to make fabrics by virtue of operations like weaving, knitting, etc. and hence are essential to the society. Natural fiber has the following advantages-

• It has low specific weight that results in higher specific strength and stiffness than glass.

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- It is a renewable resource and very little energy is required in its production.
- It can be produced very cheaply.
- Its processing is user-friendly as no wear of tooling and no skin irritation occur.
- It has good thermal as well as insulating properties.

Along with these advantages, natural fibers are also used to form composites. Natural fiber composites are being used since a century. These composites have their applications in aerospace, architecture, automotive field, infrastructure, etc. The increased and productive use of natural fibers is now decreasing the dependency on the synthetic fibers and hence ultimately decreasing the greenhouse emissions [1]. Natural fibers are biodegradable and have the capability to replace non-biodegradable materials such as High Density Polyethene (HDPE). Various reasons are low cost, low density and high specific properties characteristics. The petroleum-based synthetic fiber, HDPE, resins have caused vital damage both ecologically and environmentally due to their non-biodegradable nature. The increase in the mechanical properties ranges of natural fibers is between 3 and 43%, for flexural strength and a 339% increase in the stiffness values as compared to the stiffness of the HDPE matrix [2]. Some more researches on natural fibers such as Kenaf fibers have also shown that these fiber composites have a potential to replace automotive panels [3]. During the last decade, many researches have been carried out on natural fibers so as to find a substitute for the glass fiber. The natural fiber composites are emerging rapidly and can potentially substitute metals and ceramics [4].Since the covalent bonds are formed between fiber matrixes which results in improved chemical properties of fiber composite [5]. The motivation for these researches are weight saving, lower raw material prices and the ecological advantages because of the biodegradable nature of natural fibers. Fiber loading is an important criterion in deciding the strength and stiffness of the natural fiber composites [6]. Areca fiber reinforced with various polymers can also be used for small load carrying applications [7]. At the same time; various shortcomings of the natural fibers have to be solved in order to be competitive with the glass fiber. Natural fibers are often treated with chemicals in order to increase the fiber-matrix interface adhesion and mechanical properties [8]. One serious disadvantage related to natural fibers is their strong polar character. This leads to incompatibility with most of the polymer matrices [9].



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Further, even the generation of micro voids between the fiber and the matrix greatly influences the tensile property; hence minute precautions have to be taken while preparing natural fiber composites which can lead the overall process to be time consuming [10].

Natural fibers can be extracted from various sources such as banana, sugarcane, areca nut, sunn hemp, jute, pineapple, etc. In this paper our major concern will be areca nut fruit fiber and sunn hemp fiber. Areca nut is most commonly called as supari in many regions of north India. It is the fruit of the Areca palm tree (Areca catechu). This fruit is a native of Malaysia and grows broadly across Asia, especially in countries like Taiwan and India. The fibrous part of the fruit is the husk through which areca nut fibers are extracted. It is a renewable fiber [11]. These fibers are mainly constituted of hemicelluloses which are present in 35-64.8% of the total quantity [12] .These fibers are suitable for lightweight composites because of their low density and good aspect ratio. An interesting research has been done according to which it is shown that the moisture content of the areca nut fruit increases as the fruit ripens [13]. For dimensional stability, dried areca nut fibers are preferred over the ripened areca nut because of low moisture and water uptake of the former [14]. Each individual thread of areca nut fiber has extended hair like structures coming out which are known as trichomes. These surface extensions help to improve the adhesive strength at the fiber interface, and hence improve the strength of the composites [15]. Further the incorporation of glass fibers along with these fibers have known to increase the impact energy of the composites [16].

Another category of natural fibers is the sunn hemp fiber. Sunn hemp (Crotalaria juncea L.) is one the oldest fiber yielding crop used in textiles. The fibers are extracted from the outer bark of the plant stem. According to some researches done in the past, these fibers are used to make pulp and paper. These fibers have high strength because of high cellulose content and low micro fibril angel [17]. These fibers are off-white in colour and have very good flexural as well as tensile properties. These fibers are suitable for polymer reinforcement without the loss of materials' biodegradability. It has been observed that silane treatment of the sunn hemp fiber increases the weight and tensile strength of the fiber, however a loss in density is observed [18]. Some additives such as lignin is known to improve the tensile strength, of the sunn hemp composites, if added in a considerable amount [19]. Further on increasing fiber length and composition of sunn hemp fiber in the composites, tensile strength is observed to be increasing significantly [20].

Natural fiber composites are often reinforced with glass fibers for improving their mechanical properties and even vice versa. Glass fibers have further classifications; however, E-glass fiber is our major concern. Some of the advantages of glass fibers are-

• These fibers are light weight and extremely strong.

• These fibers are very less brittle as due to their thin structure, good ductile properties are observed.

- These fibers have high surface area to weight ratio.
- These fibers are very good thermal insulators.

• Glass is having amorphous structure; hence properties are the same along the fiber as well as across the fiber.

Glass fiber has been observed to increase the tensile properties of natural fiber composites such as the sunn hemp composites. The tensile strength increases as the content of the glass fiber increases in the composite [21].

In this paper, tensile strength of the areca nut composites and the sunn hemp composites are found and compared, separately. The fibers are arranged in different orientations such as uniaxial, biaxial and criss-cross orientations. The composites are made in two ways. For both the types of fiber-composites, in half of the specimens, E-glass fiber is incorporated while the other half does not have any E-glass fiber incorporation. Tensile test is performed on all the varieties of specimens and comparisons are made on the basis of orientations, E-glass fiber incorporation and the type of natural fiber.

II. MATERIALS

Two types of glass fibers are used-Uniaxial glass fiber and biaxial glass fiber. The uniaxial glass fiber made of 360 g/m2 with a diameter of $5 - 10 \mu \text{m}$ and biaxial glass fiber made of 360 g/m2 with a diameter of $5 - 10 \mu \text{m}$ has been utilized. The matrix system employed is a moderate viscous epoxy resin (LY556) and a room temperature cured polyamine hardener (HY951). Natural fibers used are Areca nut fruit fiber (husk) and Sunn hemp fiber. All the chemicals and fibers are obtained from Ciba Geigy India Ltd. All the fibers used in this research work are shown in figure 1.



Figure 1. Fibers used in the research

III. METHODS

A. Alkali treatment of fibers

First the areca nut and the sunn hemp fibers are treated with 0.5% NaOH solution (sodium hydroxide).

About 500 grams of each areca nut and sunn fibers are treated in one liter solution 0.5% NaOH solution. The fibers are kept in the alkaline solution for about 10 minutes at room temperature as shown in figure 2(a). The alkali treated fibers are then washed with distilled water.



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Then fibers are kept for drying at room temperature at a humidity of 70% for around 72 hours to ensure effective drying as shown in figure 2(b).

Composites with alkali treated fibers have better mechanical properties to composites containing untreated fibers. It is also found that the mechanical properties do not improve significantly when the fiber surface is treated with high silane concentrations.



Figure 2. (a) Alkali treatment of fiber; (b) Drying of fibers

B. Preparation of mold

To make composite specimens, a molding box is prepared from the low density fiber board with dimensions of cavity according to the ASTM standards- D638 and D790, as shown in figure 3.



Figure 3. (a) Dimensions of Tensile test mold according to ASTM standard (D638); (b) Final mold prepared

C. Preparation of composites

Steps involved in preparing the areca nut-epoxy as well as the sunn hemp-epoxy composites are shown in the form of a flow chart in figure 5-

- The cleaned and treated fibers are arranged in a randomly distributed manner, so they are twisted evenly to form uniform threads.
- In order to fabricate the fiber composites, all the fibers are cut according to the dimension of ASTM D638 mould.
- For the purpose of minimizing the fiber pullout, mixture of Epoxy-Hardener in the ratio of 10:1(v/v) is added to the fiber composite, which also improves the interfacial adhesion strength of the fiber.
- Fiber composites are prepared using a traditional hand lay-up technique, followed by a soft compression molding technique. The composites prepared are shown in figure 4(a).

- a) Natural fiber –epoxy reinforced resin (without glass fiber)
- In these composites, the natural fiber and the epoxy layers are arranged in an alternate manner, starting with the epoxy layer first.
- This results in 6 layers of epoxy and 5 layers of natural fibers. Hence the overall ratio of epoxy and fiber in the composite becomes 35:65 (v/v), as shown in Table-I.
 - For uniaxial arrangement of fibers, in every layer of natural fiber, 6 threads are arranged along the length of the composite.

Table- I: Detailed compositions of the composites

S. No.	Composite type	Epoxy (% v/v)	Natura l fiber (% v/v)	Glass fiber (% v/v)
1	Natural fiber-epoxy reinforced resin (without glass fiber)	35	65	0
2	Natural fiber-epoxy-glass fiber reinforced resin (with glass fiber)	45	45	10

- In case of biaxial arrangement of fibers, the threads are cut into pieces of varying width which just fits the width of the mould of varying width along the length. Around 55-65 pieces are arranged perpendicular to the length of the mould in each layer.
- For criss-cross arrangement of fibers, the threads are cut into pieces in the same way as for biaxial arrangement, except they are arranged at an angle of 45 degrees with the width of the mold. Around 60-70 pieces are arranged in each layer.

Natural fiber-epoxy-glass fiber reinforced resin

- In these composites, the natural fiber and the epoxy layers and the E-glass fibers are arranged in an alternate manner, starting with the epoxy layer first.
- This result in 6 layers of epoxy, 3 layers of natural fiber and 2 layers of glass fiber in all three orientations, resulting in the epoxy and total fiber ratio in the mold cavity to be 45:55 (v/v) for each case, as shown in Table-1.
- For uniaxial arrangement of fibers, in every layer of natural fiber, 6 threads are arranged along the length of the composite. E-glass fiber used is uniaxial.
- In case of biaxial arrangement of fibers, the threads are cut into pieces of varying width which just fits the width of the mould of varying width along the length. Around 55-65 pieces are arranged perpendicular to the length of the mould in each layer. E-glass fiber used is biaxial.
- For criss-cross arrangement of fibers, the threads are cut into pieces in the same way as for biaxial arrangement, except they are arranged at an angle of 45 degrees with the width of the mold. Around 60-70 pieces are arranged in each layer. E-glass fiber used is biaxial.



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• Post curing duration is 30 days for the composite specimens at room temperature. This is done prior to preparing specimens, as shown in figure 4 (b), and performing mechanical tests.



Figure 4. (a) Areca nut and sunn hemp composites; (b) Specimens prepared from the composites for



II. EXPERIMENTAL PROCEDURE

- 1. The tensile test is carried out on Digital tensile testing machine TFT-50KN C, as shown in figure 6, for the specimens prepared as per the ASTM D638 standard.
- 2. The specimens were securely clamped by the top and bottom grips attached to the tensile testing machine as shown in the figure 6.
- 3. During the tension test grips are moved apart at constant rate of 10mm/min to stretch the specimen.
- 4. The gage length of the ASTM D638 standard specimen was 50mm for 165mm long specimen.
- 5. The force on the specimen and its displacement is continuously monitored and graph is plotted until the specimen fails.
- 6. The specimen was cut in two pieces, after critical load applied on the specimen, shown in figure 6. Table-II

Retrieval Number F8322088619/2019©BEIESP DOI: 10.35940/ijeat.F8322.088619 Journal Website: <u>www.ijeat.org</u> provides details about the specifications of the tensile testing machine.



Figure 6. (a) Tensile test setup; (b) Tensile testing machine (TFT-50KN C); (c) Specimen after testing

(Courtesy: Metal forming lab, VIT, Vellore)

Table- II: Tensile Testing Machine Specifications

Equipment name	Digital Tensile testing machine	
Model	TFT- 50KN C	
Max. Capacity	500N	
Ranges least counts	0.025N	
Least count for displacement (Elongation)	0.01mm	
Grip separation Min. and Max.	25 to 900 mm	
Supplier	Herenba Instruments and engineers, Chennai	

III. RESULTS AND DISCUSSIONS

The load-displacement curves for the areca nut and sunn hemp composites both glass incorporated and not incorporated are obtained from digital tensile testing machine and are shown in the following figures 7-12.

The maximum stress corresponds to the maximum load. The tensile strength is defined as the maximum stress on the stress-displacement curve. Hence more the value of maximum load more is the tensile strength. The value of the maximum load is the highest in case of glass incorporated fiber composites for areca nut fiber, as the highest value of stress in case of Areca nut-epoxy-glass fiber reinforced composite(uniaxial fiber arrangement) is 57.1466 MPa and for Areca nut- epoxy reinforced fiber composite(uniaxial fiber arrangement) is 25.9733 MPa. There is a similar scenario in case of sunn hemp fiber as the maximum stress value for Sunn hemp-epoxy-glass

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fiber reinforced composite (uniaxial fiber arrangement) is 61.9200 MPa and for Sunn hemp fiber reinforced composite (uniaxial fiber arrangement) is 30.0266 MPa.



Figure 7. (a) Areca nut-epoxy reinforced fiber composite (uniaxial fiber arrangement); (b) Areca nut-epoxy-glass fiber reinforced composite (uniaxial fiber arrangement)

The load displacement curve shows the linear relationship of load and displacement over the application of quasi-static load rate of 10mm/min. From the above graph it is observed that Sunn hemp fiber composites have better tensile strength than the areca nut fiber composites, as the value of Areca nutepoxy reinforced fiber composite(biaxial fiber arrangement) is 12.7466 MPa and for Sunn hemp-epoxy reinforced fiber composite(biaxial fiber arrangement) is 18.4000 MPa, respectively., Similarly maximum stress values for Areca nut-epoxy-glass fiber reinforced composite(biaxial fiber arrangement) is 22.5006 MPa and for sunn hemp-epoxy-glass fiber reinforced composite(biaxial fiber arrangement) is 29.0133 MPa, respectively.

A. Comparison on the basis of incorporation of glass fiber in composites

E-glass incorporated fiber composites have better tensile strength than plain fiber composites. The epoxy: fiber ratio is 45:55 (v/v) in case of areca nut-epoxy-glass fiber reinforced composite(uniaxial fiber arrangement), areca nut-epoxy-glass fiber reinforced composite(biaxial fiber arrangement) and areca nut-epoxy-glass fiber reinforced composite(criss-cross fiber arrangement) which is more than areca nut- epoxy reinforced fiber composite(uniaxial fiber arrangement), areca nut- epoxy reinforced fiber composite(biaxial fiber arrangement) and areca nut- epoxy reinforced fiber composite(criss-cross fiber arrangement), respectively, which is 35:65 (v/v). From the graph it is evident that maximum load values for Areca nut-epoxy reinforced composite (biaxial fiber arrangement) is 1688 N for Areca nut -epoxy-glass fiber reinforced and composite(biaxial fiber arrangement) is 956 N, respectively. Hence former has higher tensile strength. There is a similar pattern observed in Sunn hemp composites in which the glass fiber incorporation increases the tensile strength. The better adhesion in the matrix leads to better reinforcement effect. More is the amount of epoxy, better is the adhesion effect. This leads to desirable distribution of the fibers in the matrix and the voids between the fibers are also bridged effectively. Stress distribution is favorable due to the presence of glass fiber which results in better strength.



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Figure 8. (a) Sunn hemp-epoxy reinforced fiber composite (uniaxial fiber arrangement) ;(b) Sunn hemp-epoxy-glass fiber reinforced composite(uniaxial fiber arrangement)



Figure 9. (a) Areca nut- epoxy reinforced fiber composite (biaxial fiber arrangement); (b) Areca nut-epoxy-glass fibe reinforced composite (biaxial fiber arrangement)

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Figure 10. (a) Sunn hemp-epoxy reinforced fiber composite (biaxial fiber arrangement); (b) Sunn hemp-epoxy-glass fiber reinforced composite (biaxial fiber arrangement)



Figure 11. (a)Areca nut- epoxy reinforced fiber composite (criss-cross fiber arrangement); (b) Areca nut-epoxy-glass fiber reinforced composite (criss-cross fiber arrangement)



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Figure 12. (a) Sunn hemp-epoxy reinforced fiber composite (criss-cross fiber arrangement); (b) Sunn hemp-epoxy-glass fiber reinforced composite (criss-cross fiber arrangement)

The variations in the load-displacement relationship indicate the change in tensile strength of the composites on glass fiber incorporation and change in orientation of the fibers. From almost all the above figures, the values for areca nut- epoxy reinforced fiber composite(uniaxial fiber arrangement), areca nut- epoxy reinforced fiber composite(biaxial fiber arrangement) and areca nutepoxy reinforced fiber composite(criss-cross fiber arrangement) are 25.9733 MPa, 12.7466 MPa and 16.5333 MPa, respectively. Hence, it is observed that the highest value of maximum stresses is the most in case of uniaxial arrangement followed by criss-cross and biaxial.

B. Comparison on the basis of orientation of fibers

For the areca nut fiber composites and sunn hemp fiber composites (glass incorporated and plain both), tensile strength of the uniaxial orientation is the most while it is least for biaxial orientation. Criss-cross orientation has moderate tensile strength. This is due to the better interface bonding of the fiber-matrix interface due to greater compatibility as compare to the criss-cross and biaxial arrangement. This leads to uniform stress distribution in the composites and hence results in high tensile strength. Table-III gives the experimental values obtained after performing the tensile tests on the composite specimens.

S. No.	Specimen label	Maximum load (N)	Maximum Tensile stress (MPa)
	Areca nut- epoxy		
	composite(uniaxial		
1	fiber arrangement)	1948	25.9733
	Areca nut- epoxy reinforced fiber		
	composite(biaxial		
2	fiber arrangement)	956	12.7466
	Areca nut- epoxy reinforced fiber		
3	composite(criss-cross fiber arrangement)	1240	16.5333
4	Areca nut-epoxy-glass fiber reinforced composite(uniaxial fiber arrangement)	4286	57.1466
	Areca nut-epoxy-glass fiber reinforced composite(biaxial		
5	fiber arrangement)	1688	22.5066

Table- III: Summary of experimental results of tensile test



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6	Areca nut-epoxy-glass fiber reinforced composite(criss-cross fiber arrangement)	1836	24.48
7	Sunn hemp-epoxy reinforced fiber composite(uniaxial fiber arrangement)	2252	30.0266
8	Sunn hemp-epoxy reinforced fiber composite(biaxial fiber arrangement)	1380	18.4

9	Sunn hemp-epoxy reinforced fiber composite(criss-cross fiber arrangement)	1700	22.6666	
10	Sunn hemp-epoxy-glass fiber reinforced composite(uniaxial fiber arrangement)	4644	61.9200	
11	Sunn hemp-epoxy-glass fiber reinforced composite(biaxial fiber arrangement)	2176	29.0133	
12	Sunn hemp-epoxy-glass fiber reinforced composite(criss-cross fiber arrangement)	2285	30.4666	The
Mea	n	2199.25	29.3233	e test

was carried out on digital tensile testing machine for the specimens made as per the ASTM D638 standard. From figure 13, it is clearly seen that Areca-epoxy-Glass fiber reinforced uniaxially oriented composite exhibit the maximum tensile strength of 57.1466 N/mm2 over 25.9733 N/mm2 showed by Areca-epoxy reinforced composite. The uniaxially oriented fiber composite showed better result as compared to biaxial and criss-cross orientation. The tensile strength for Areca-epoxy reinforced composite was found out to decrease by 50.92% and 36.34% with respect to biaxial and criss-cross orientations respectively, when compared with uniaxially oriented fiber composite.

From figure 14, it is evident that uniaxially oriented Sunn hemp fiber composite showed the better result. Sunn hemp-epoxy-glass fiber reinforced uniaxially





oriented composite showed the maximum tensile strength of 61.9200 N/mm2.The tensile strength of sunn

Retrieval Number F8322088619/2019©BEIESP DOI: 10.35940/ijeat.F8322.088619 Journal Website: www.ijeat.org hemp-epoxy reinforced fiber composite(uniaxial fiber arrangement) was estimated to increase by 63.18% and 32.47% as compared to sunn hemp-epoxy reinforced fiber composite(biaxial fiber arrangement) and sunn hemp-epoxy reinforced fiber composite(criss-cross fiber arrangement), respectively.



Figure 14. Comparison of tensile stresses of different sunn hemp composites

IV. CONCLUSION

The tensile strength of areca nut fiber and sunn hemp fibre reinforced with only epoxy and both epoxy and glass fibers have been investigated for the specimens prepared as per the ASTM D638 standard. it is evident that fibers treated with alkali sodium hydroxide (NaOH) exhibits better mechanical properties as it enhance bonding at the fiber-matrix interface .It was observed that sunn hemp composites have more tensile than the areca nut composites. This is because of the fine structure of the sunn hemp fiber which helps in the better reinforcement of the fiber-matrix when compared with the areca composites. Orientation-wise uniaxial arrangement is having the maximum tensile strength. Also glass fiber incorporation in the composites enhances the tensile strength of the composites. There is a percentage increase of 120.02% in the tensile strength when areca nut-epoxy reinforced composite with incorporation of glass fiber(uniaxial fiber arrangement) is compared with areca nut- epoxy reinforced fiber composite without incorporation of glass fiber(uniaxial fiber arrangement). On the other hand, there is 106.21% increase in the tensile strength when sunn hemp-epoxy-glass fiber reinforced composite (uniaxial fiber arrangement) is compared with sunn hemp-epoxy reinforced fiber composite (uniaxial fiber arrangement). Addition of glass fibre in the fiber composite exhibits superior mechanical properties is evident from the research. These fiber composites have found their applications in almost every filed where there is no involvement of high load bearings, such as medical field, packaging industry, etc. and the developed composites can be the alternative material for an automotive applications.





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