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Test Analysis and Mechanical Properties of Sisal and Glass Fiber Composites for Manufacturing of Wind Turbine Blades

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***Abstract*—To replace the synthetic fiber, great demand has raised to seek natural fiber as a composite material which needs innovation. Sisal as a composite one is more attractive than others which have enormous strength. The present work is a culmination of mechanical properties of sisal reinforce with epoxy for the production of small wind turbine blades. Sisal polymer composite became more attractive due to their high specific strength, light weight, biodegradability. The research shows that mechanical properties such as tensile test and bend test with different arrangement of layers. The compression, flexure, tensile strength, peak load, yield stress, load at break and percentage of elongation are evaluated by using UTM-TUE-400(C) machine, as per the ASTM D790 and ASTM D638 standardized tests. It is evidently seen that the sisal and its performance could be used as a proper substitute to glass fiber or synthetic fiber.**

***Index terms** - Natural fiber, composite materials, sisal fiber, tensile strength and wind turbine blades.*

I. INTRODUCTION

Due to the depletion of natural resources the composite one plays a major role which is of great demand; since it is scarce. As the synthetic fiber has become critical due to its environmental pollution, the need for bio-fiber has gained momentum. The availability of natural fiber is abundance and they are very inexpensive when compared to other advance manmade fibers. As the natural fiber possess specific acceptable properties with less wear and tear and low density with low cost of production which will lead to low energy consumption also. Since natural fibers have low thickness, bio-degradable and recyclable, they ought to be represented more at present prudently. The strength and stiffness are added advantages for sisal and it is renewable also. Plant fibers, mineral fibers and animal fibers are the three categories classified as of now.

A. Plant Fibers

Plant fibers for instance, cotton, jute, bamboo, flax, ramie, hemp, coir and sisal consist of cellulose and they have variety of application. Seed fibers such as cotton and kapok also included as plant fiber.

These fibers normally have superior tensile properties for this reason; they have wide range of utility as packaging material etc. To add more, fruit fibers like banana, pine-apple and coconut fibers have various utilities. Stalk fiber are yet another variety is from the stalk of rice, bamboo, wheat and barley.

Leaf fibers are normally from leaf such as agave and sisal. Skin fiber is also obtained from the bast and skins of a plant have potential in their contribution.

B. *Mineral Fibers:*

From minerals also we get fibers which is a prevalent one. Asbestos one among all and it is a different category. Fibers are those which are getting from minerals. These are naturally happening fiber or somewhat changed fiber. It has different classifications they are taking after: Asbestos is the main characteristically happening mineral fiber.

Serpentine, amphiboles and anthophyllite are the varieties in it. These are filaments from glass fiber, aluminum oxide and boron carbide and these filaments provide us aluminums strand.

C. *Animal Fibers:*

The main component of animal fiber is protein (example silk, alpaca, mohair, downy etc.). Hair strands for example are from sheep's downy, goat hair, horse hair etc.

Silk fiber is from dry saliva of cocoons. Apart from these avian strands obtained from fowls are also considered as animal fiber. These fibers are used as structural drives which is eco-friendly.

To consider the dimensional constancy under moisture, the load bearing and high thermal conditions are of utmost important.

II. MATERIALS USED

Sisal fiber saves the way as a green composite for its suitability commonly known as sisalana produced commercially nowadays is a yield from its rosettes. The usages of sisal have already been enlightened by various industries worldwide. The strength and durability have also been taken into consideration; the duration of crop and its potential yield have also been mentioned in the study.

A member of agave family, Sisal is fully bio-degradable, abundantly available in the regions of India and it is grown commercially nowadays.

Next to Cotton, Jute is such an important fiber on account of its versatility and its bio-degradable nature. Textile industries tapped the benefits of jute. It has low thermal conduction and easily de-compostable, we can reap the benefits of jute by using it in wood industries.

Deforestation to some extent is curtailed by plantation of jute which is eco-friendly and it is recyclable also. As jute as the low properties of low conductivity, it could be used as a good insulation to help, mitigation of skin allergy.

Sisal Fiber

Fig. 1: a) Sisal plant; b) Sisal fibers; c) Sisal fabric

Jute Fiber

Fig.2: a) White jute; b) Tossa jute; c) Jute fabric

Jute has its own ability to blend with others and this particular quality has enormous potential to face increase in demand. The blending quality of jute enhances the possibility of wooden industries to improve their capability .Commercially it can also be treated flame proofing agent. Fiber shedding is a major disadvantage in jute. When jute is wet, it loses its strength. In humid climate microbial attack is bound to take place on it. The advantage of jute is that it reduces the brittleness and stiffness. Its affinity towards natural dyes is most appreciable.

Banana Fiber

Fig. 3: a) Banana plant; b) Banana fibers; c) Banana fabric

Banana fiber with a ligno-cellulosic content has a good mechanical property. So far it has not been properly utilized. Efforts are on to have more innovations on it. As a fruit, it is meant for eating only. Starch is extracted from it.

C. Glass Fabric and Mesh

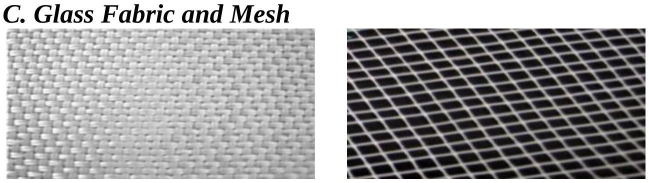

Fig. 4 : a) Glass Fabric; b) Mesh

Glass is the most common of all reinforcing fibres for Polymeric (plastic) Matrix Composites (PMCs). The principal advantages of glass fibre are low cost, high tensile strength, high chemical resistance and excellent insulating properties. The two types of glass fibers commonly used in the fibers reinforced plastics industries are E-glass and S-glass.

III. PREPARATION METHODS

For the investigation carried out, synthetic fiber namely E-Glass fiber with density has been used. Apart from that, three natural fibers namely Sisal, Jute and Banana have been used for fabricating the composite.

Epoxy Resin LY556 and Hardener HY951 have been used as resin material, with Teflon sheet is used for molding purpose. Mold used in this work is made of well-seasoned teak wood of 320mm X 320mm X 3mm dimension with five beadings.

The fabrication of the composite material was carried out through the hand lay-up technique. The top, bottom surfaces of the mold and the walls are coated with remover and allowed to dry. The functions of top and bottom plates are to cover, compress the fibre after the epoxy is applied, and also to avoid the debris from entering into the composite parts during the curing time.

- The top surface of the teak table was cleaned with acetone (Thinner) to remove dirt and wax was applied on surface. This wax was acting as a releasing agent.
- A mixture of resin (LY556) and Hardener (HY951) in the ratio of 100:10 and one coat of this mixture was applied on the surface.
- Different combination of layers one above the other was made in between layers the mixture of resin and hardener was applied subsequently to the required orientation
- By applying peel ply (an optional layer of fabric) placed between the composite parts to release film.
- The peel ply was used to give texture to the part's surface or to protect it from contaminants during the vacuum bagging process.
- Above peel ply surface, mat was applied.
- Finally sealing of the surface using vacuum bag and sealant was done. Entire system of arrangement was kept in vacuum of 680 mm Hg for 3 hours.

The Natural and glass fiber composite plates are as shown in the Fig. 5.

Fig. 5: Natural and glass fiber composite plates

IV. MECHANICAL TEST

A. Tensile Test

Composite plates were cut into various sizes according to our requirement fulfilling the standard task of ASTMD638 for the purpose of tensile test to gauge the length and dimensions. When it is tested after its fracture, the testing process gets over and the tensile force is recorded, gauge length and its elongation is also recorded for assessment.

B. Flexure Test

By bending the material, the test determines the strength. The crack formed on the outer surface has been inspected to access the elasticity which offers varieties of configuration. To determine the accurate reproducible result ASTMD790 standard is followed.

V. RESULTS AND DISCUSSION

The Tensile and flexure test was conducted in universal testing machine (TUE - 400 (C)) at advanced metallurgical laboratory in Bangalore.

Twelve different composite materials are tested and their results will be discussed in below graphs. The thickness of the material is 2.7mm and the width is 25.9mm.

A. Natural Fiber and Composites

In fig. 6 the material is tested for tensile test. In this, Pure Jute fabric 4 layers are used. In peak load the material is damaged at 3.52 KN and the yield stress is obtained at 38.80 N/mm^2. The percentage of elongation is 0.20%.

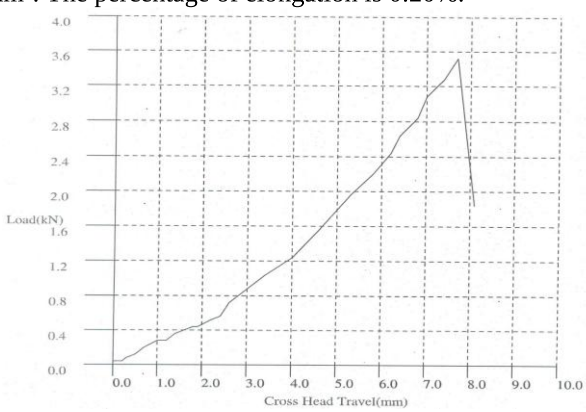

Fig. 6 Pure Jute 4 layers (Tensile)

In fig. 7 the material is tested for bend test. In this, pure jute fabric 4 layers are used. In peak load, the material is damaged at 12.24 kg and the compression strength is obtained at 00.15kg/mm^2.

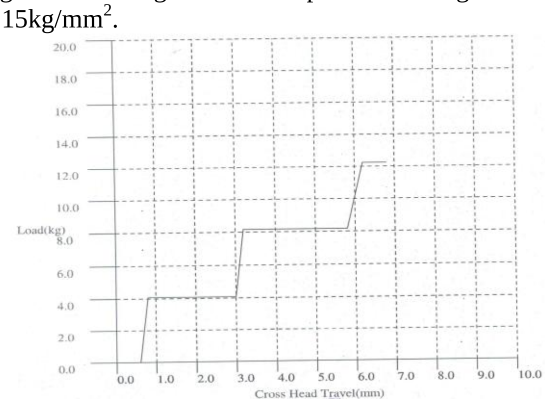

Fig. 7 Pure Jute (4) Layers (**B**end)

In fig. 8 the material is tested for tensile test. In this, pure banana fabric 7 layers are used. In peak load the material is damaged at 3.96 KN and the yield stress is obtained at 44.23 N/mm^2. The percentage of elongation is 5.02%.

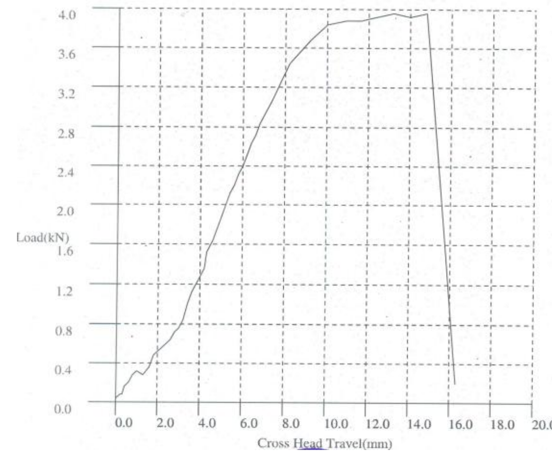

Fig. 8 Pure banana 7 layers (Tensile)

In fig. 9 the material is tested for bend test. In this, pure banana fabric 7 layers are used. In peak load, the material is damaged at 28.55 kg and the compression strength is obtained at 00.34kg/mm^2.

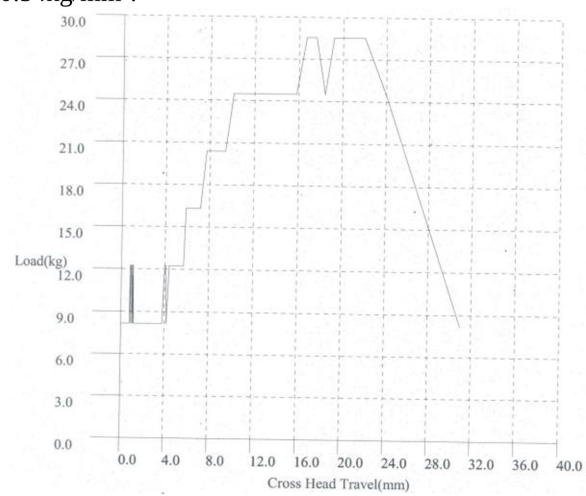

Fig. 9 Pure banana 7 layers (Bend)

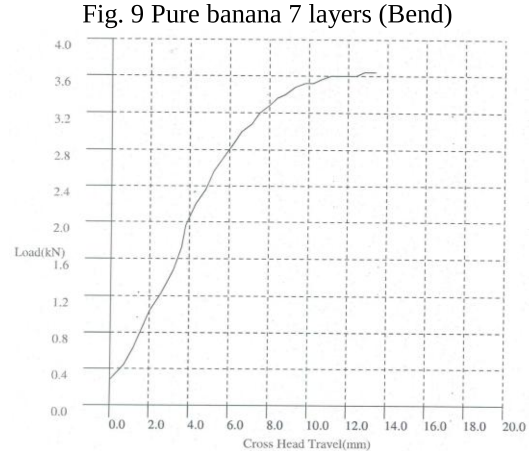

Fig. 10 Pure sisal 7 layers (Tensile)

In fig. 10 the material is tested for tensile test. In this, pure sisal fabric 7 layers are used. In peak load the material is damaged at 3.64 KN and the yield stress is obtained at 40.77 N/mm^2. The percentage of elongation is 3.04%.

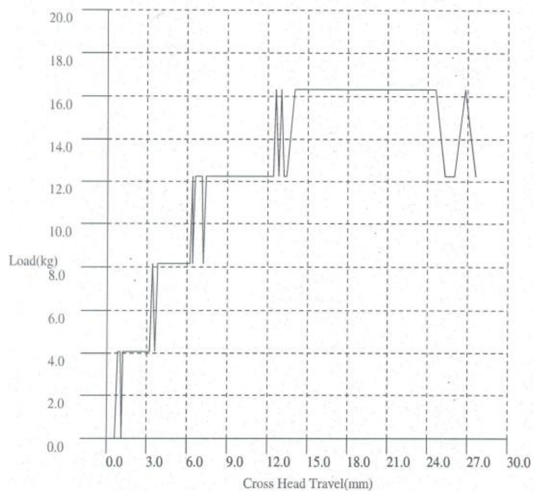

Fig. 11 Pure sisal 7 layers (bend)

In fig. 11 the material is tested for bend test. In this, pure sisal fabric 7 layers are used. In peak load, the material is damaged at 16.32 kg and the compression strength is obtained at 00.23kg/mm^2.

In fig. 12 the material is tested for tensile test. In this test, combination of both sisal fabric and jute fabric (sisal (3) + Jute (2)) layers is used. In peak load the material is damaged at 2.84 KN and the yield stress is obtained at 32.89 N/mm^2. The percentage of elongation is 3.14%.

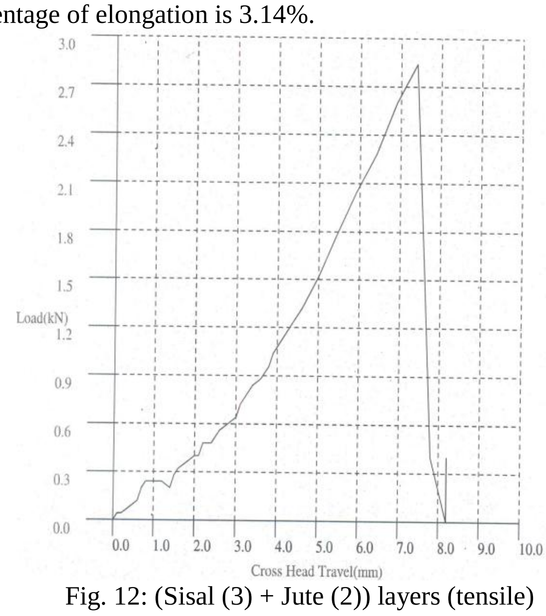

Fig. 12: (Sisal (3) + Jute (2)) layers (tensile)

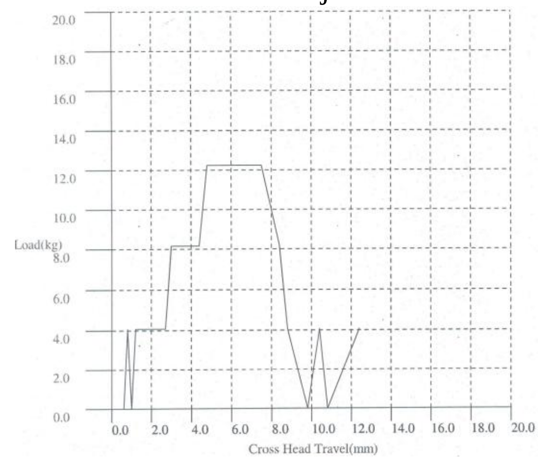

Fig. 13: (Sisal (3) + Jute (2)) layers (bend)

In fig. 13 the material is tested for bend test. In this test, combination of both sisal fabric and jute fabric (sisal (3) + Jute (2)) layers with the thickness of 3.0mm is used.

In peak load, the material is damaged at 12.24 kg and the compression strength is obtained at 00.15kg/mm^2.In fig. 14 the material is tested for tensile test. In this test, combination of both sisal fabric and banana fabric (sisal (4) + banana (3)) layers is used.

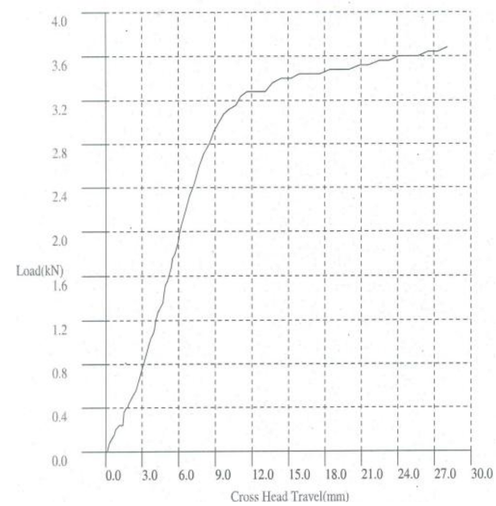

Fig. 14: (Sisal (4) + Banana (3)) layers (Tensile)

In peak load the material is damaged at 3.68 KN and the yield stress is obtained at 43.82 N/mm^2. The percentage of elongation is 7.68%.In fig. 15 the material is tested for bend test. In this test, test, combination of both sisal fabric and banana fabric (sisal (4) + banana (3)) layers is tested. In peak load, the material is damaged at 16.32 kg and the compression strength is obtained at 00.23kg/mm^2.

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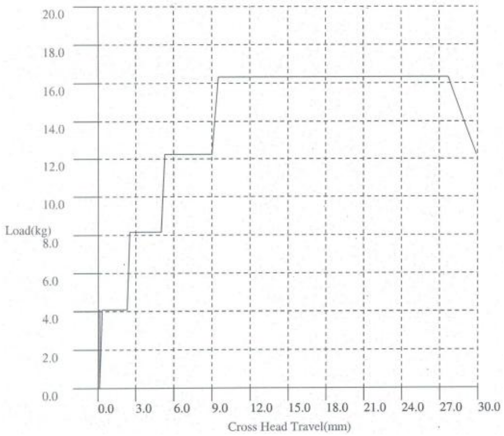

Fig. 15: (Sisal (4) + Banana (3)) layers (bend)

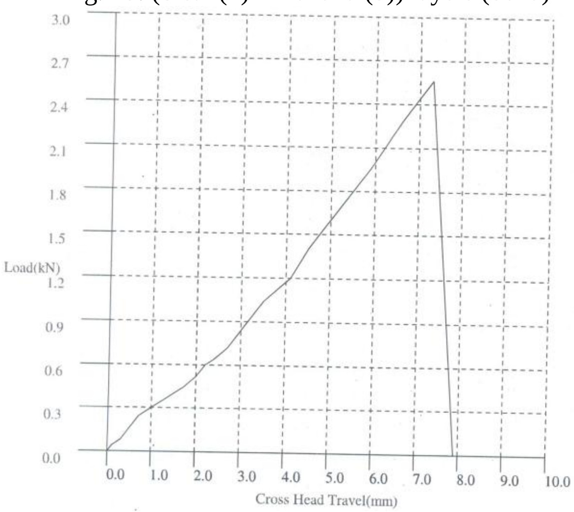

Fig. 16 (Sisal (2) + Jute (2) + banana (1)) Layers (tensile)

In fig. 16 the material is tested for tensile test. In this test, combination of all three fabrics of sisal, jute and banana (Sisal (2) + Jute (2) + banana (1)) layers are used.

In peak load the material is damaged at 2.56 KN and the yield stress is obtained at 32.26 N/mm^2. The percentage of elongation is 0.84%.

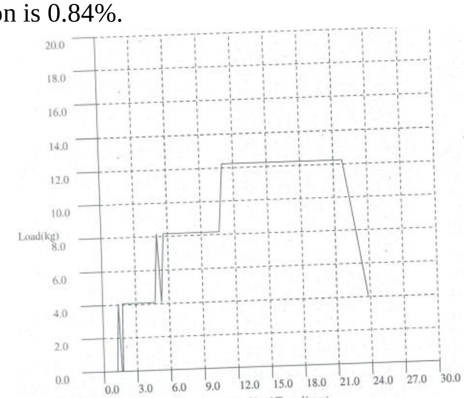

Fig. 17 Sisal (2) + Jute (2) + banana (1) Layers (bend)

In fig. 17 the material is tested for bend test. In this test, the combination of all three fabrics (Sisal (2) + Jute (2) + banana (1)) layers is used. In peak load, the material is damaged at 12.24 kg and the compression strength is obtained at 00.17kg/mm^2.

B. Glass Fiber and Composites

In fig. 18 the material was tested for tensile test. In this (sisal (4) + fiber (2)) layers is tested. In peak load the material is damaged at 11.24 KN and the yield stress is obtained at 144.14 N/mm^2. The percentage of elongation is 0.24%.

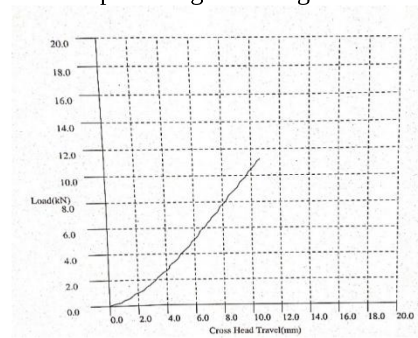

Fig. 18: (Sisal (4) + fiber (2)) layers (tensile)

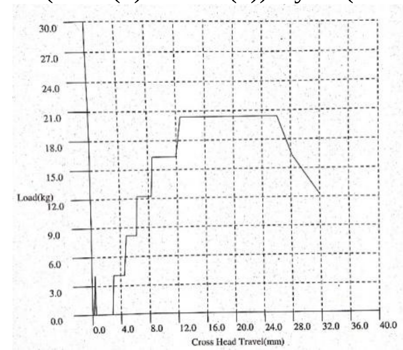

Fig. 19: (Sisal (4) + fiber (2)) layers (bend)

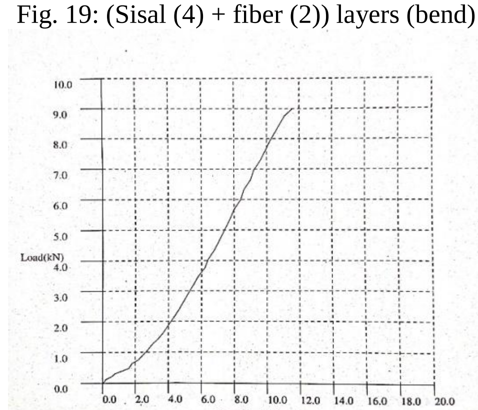

Fig. 20: (Sisal (3) + 950gsm (2)) layers 2.6mm (tensile)

In fig. 19 the material was tested for bend test. In this (sisal (4) + fiber (2)) layers is tested. In peak load the material is damaged at 20.38 kg and the compression strength is obtained at 0.29 kg/mm^2.

In fig. 20 the material was tested for tensile test. In this (sisal (3) + 950gsm (2)) layers 2.6mm is tested. In peak load, the material is damaged at 9KN and the yield stress is obtained at 118.63N/mm^2. The percentage of elongation is 1.70%.In fig. 21 the material was tested for bend test. In this (sisal (3) + 950gsm (2)) layers 2.6mm is tested. In peak load, the material is damaged at 24.47 kg and the compression strength is obtained at 0.35 kg/mm^2.

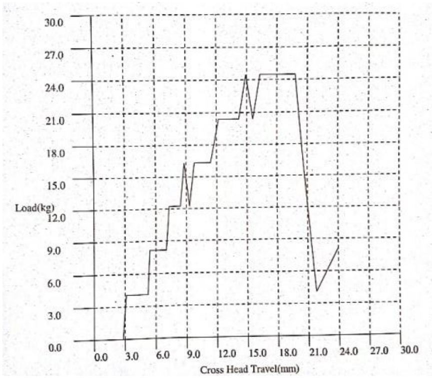

Fig. 21: (Sisal (3) + 950gsm (2)) layers 2.6mm (bend)

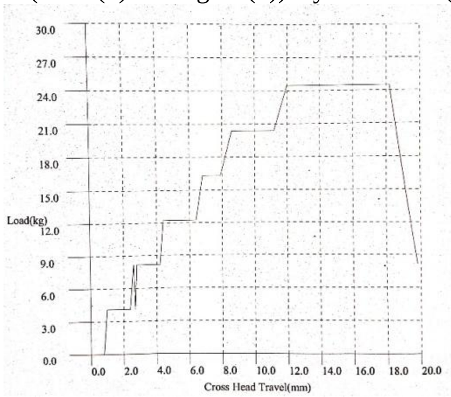

Fig. 22: (Sisal (4) + 800gsm (2)) layers (tensile)

In fig. 22 the material was tested for tensile test. In this (sisal (4) + 800gsm (2)) is tested. In peak load, the material is damaged at 8.08 KN and the yield stress is obtained at 114.01N/mm^2. The percentage of elongation is 2.00 %.

In fig. 23 the material was tested for bend test. In this (sisal (4) + 800gsm (2)) layer is tested. In peak load, the material is damaged at 24.47 kg and the compression strength is obtained at 0.38 kg/mm^2.

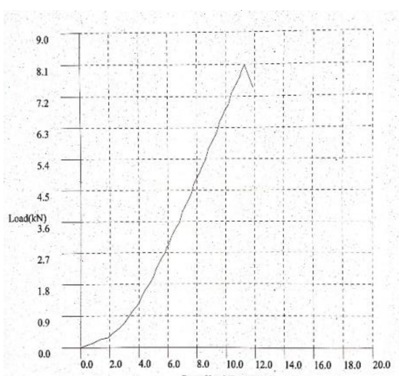

Fig. 23: (Sisal (4) + 800gsm (2)) (4+2) layers (bend)

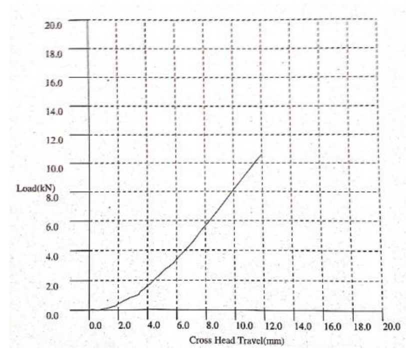

Fig. 24: (Sisal (4) +GF08 (3)) layer 3.7mm (tensile)

In fig. 24 the material was tested for tensile test. In this (sisal (4) +GF08 (3)) layer 3.7mm is tested. In peak load, the material is damaged at 10.60 KN and the yield stress is obtained at 97.95 N/mm^2. The percentage of elongation is 0.40 %.

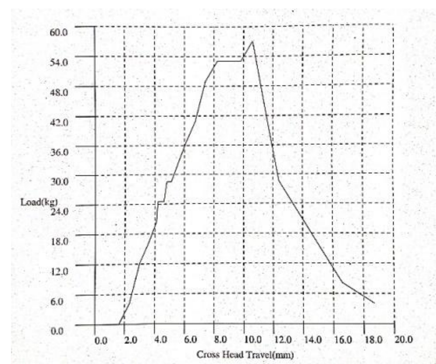

Fig 25: (Sisal (4) +GF08 (3)) layer 3.7mm (bend)

In fig. 25 the material was tested for bend test. In this (sisal (4) + 800gsm (2)) layer is tested. In peak load, the material is damaged at 57.10 kg and the compression strength is obtained at 0.58 kg/mm^2.

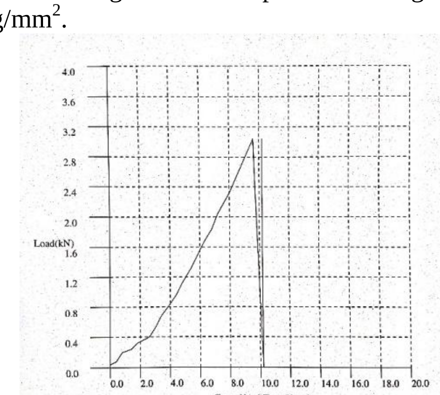

Fig. 26: (Sisal (5) + mesh (4)) layer 3.5mm (tensile)

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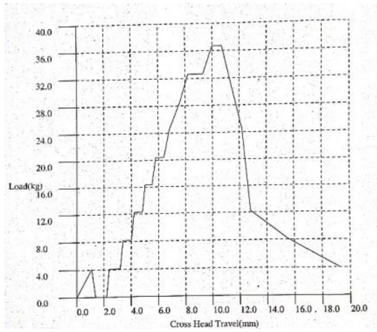

Fig. 27: (Sisal (5) + mesh (4)) layer 3.5mm (bend)

In fig. 26 the material was tested for tensile test. In this (sisal (5) + mesh (4)) layer 3.5mm is tested. In peak load, the material is damaged at 3.04 KN and the yield stress is obtained at 28.13 N/mm^2. The percentage of elongation is 0.84 %.

In fig. 27, the material was tested for bend test. In this (sisal (5) + mesh (4)) layer, 3.5mm layer is tested. In peak load, the material is damaged at 36.71 kg and the compression strength is obtained at 0.39 kg/mm^2

In fig. 28 the material was tested for tensile test. In this (sisal (5) + mesh (3)) layer 3.5mm is tested. In peak load, the material is damaged at 2.80 KN and the yield stress is obtained at 27.18 N/mm^2.

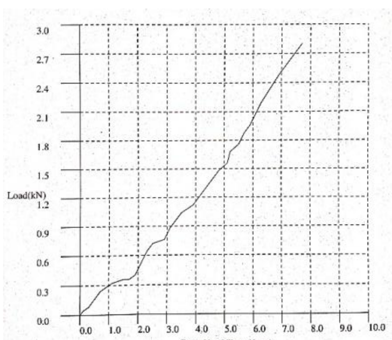

Fig. 28: (Sisal (5) + mesh (3)) layer 3.5mm (tensile)

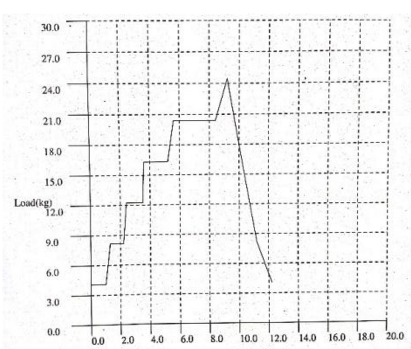

Fig. 29: (Sisal (5) + mesh (3)) layer 3.5mm (bend)

In fig.29 the material was tested for bend test. In this (sisal (5) + mesh (3)) layer, 3.5mm layer is tested. In peak load, the material is damaged at 24.45 kg and the compression strength is obtained at 0.27kg/mm^2

C. Comparison Analysis

In Fig. 30 shows the comparison graph for tensile strength of natural fiber plates. The comparison graph for elongation is as shown in Fig. 31.

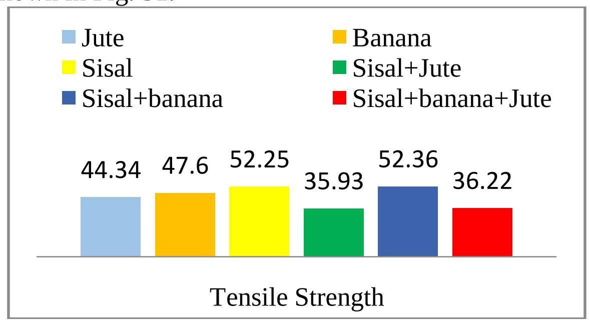

Fig. 30: Comparison graph for Tensile Strength

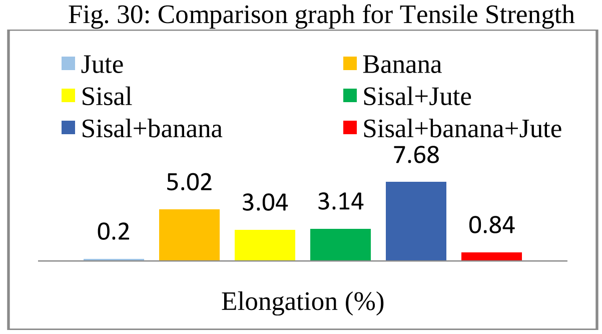

Fig. 31: Comparison graph for Elongation

In Fig 32 shows the comparison graph for tensile strength and yield stress of glass fiber composite and the comparison graph for compression ratio is shown in Fig. 33.

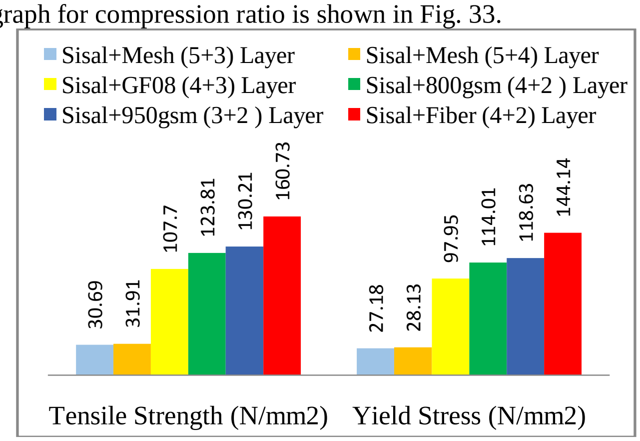

Fig. 32: Comparison graph Tensile Strength and Yield Stress

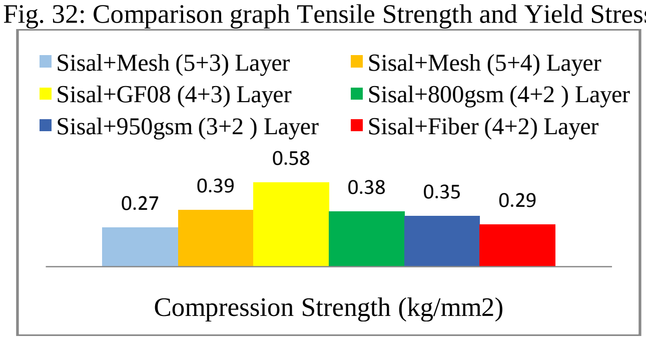

Fig. 33: Comparison graph for Compression strength

VI. CONCLUSION

The natural and glass fiber composites are fabricated and tested successfully with different combination arrangements. During investigation of natural fiber composites, Sisal fiber fabric and banana fiber fabric have good potential as reinforcement in polymer composite and fit a fiddle with their reinforcement composites. Due to low density and high specific properties of these natural composites will be helpful in making very good implementation in the wind turbine blades. As far as the assessment of glass fiber composites comprising the combinations of natural sisal fabric and glass fiber, to ensure that it has the potential as reinforcement composite on account of its high specific properties mixed with its low density. This seems to be good while implementing the same in the wind turbine for its blade preferably for the manufacturer. Various test standards were applied to gauge the accuracy of peak load percentage of elongation such as ASTM D638 and ASTM D790. After comparing all six combinations of sisal and glass fibers in both tensile and bend test results, the composite material (sisal (4) + fiber (2)) layers has high tensile strength is in the range 160.73 N/mm^2 and it is compared in the fig. 16. In addition, the microstructure of the fiber was obtained in the breaking point of tensile and bend test of specimen along with this results, the other interfacial properties like peak load, percentage of elongation, yield load, compression strength of the factures surface of the composite materials are obtained from ASTM D638 and ASTM D790.

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