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Mechanical Behaviour of Palm Fiber (Palmyra Spout) – Basalt Fiber - Hybrid Composites

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Abstract: ***In general the natural fibers are taken out from the sources of animals and plants. In recent days the natural fibers play an important role in engineering applications like automotive, aerospace and marine industries due to abundant availability, less in cost and zero percentage environment harmless in nature. In this paper the investigation of various mechanical properties of hybrid reinforced composite (Palm fiber Basalt S-glass fiber) is been done on the fabricated samples. The different mechanical property includes tensile, hardness and impact tests etc... The fabrication comprises three layers of Palm and Basalt fibers outer laminated by two layers of S-glass fibers using injection molding method. From the various testing and investigation against the test sample it is been concluded that the fibers in the hybrid set took a major role in determining the important mechanical properties. Thus the fibers present in the hybrid composite increases the strength, stiffness and weight ratio of the composite materials. The various forms and structural analysis of the hybrid composite material are processed by using scanning electron microscope for attaining the better results and application basis.***

Keywords:Natural palm and Basalt fibers, glass fibers, Composite Fabrication, Injection moulding, Mechanical properties.

I. INTRODUCTION

In recent days the synthetic fibers are replaced by natural fibers because of cheap in cost, less in weight, density, high specific strength and eco friendly nature. In synthetic fiber composites the resins are combined together with hardener such as thermoplastic or thermosetting plastics. The applications of synthetic fiber composites are very few because of the higher in material cost and methods for manufacture is difficult in nature. Generally the natural fibers are extracted naturally from plant and animals in elongated form. Plant fibers include cotton, stem (or bast) fibers such as Basalt and hemp, leaf fibers such as palm and coconut. Wool, hair and secretions, such as silk are the bi products of animals. The application of natural fiber reinforced composites exists many possibilities since the number of applications is rapidly growing within many engineering fields.

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Industries such as packaging, automobile and construction but natural fiber composite is also finding its way into sport, aerospace and in electronic industries, this is mainly due to their advantages compared to synthetic fibers.

The hybrid reinforced natural fiber composite is suitable for n number of application and designs. The main reason for choosing the composite materials in recent development weight reduction, more effective than conventional materials used. Composite means joining of two or more different materials together and gives the best result against the various load tests. Comparatively the composite shows the better result than the mono material used.

Different layers are built up together in the composite materials called phases and the outer phase called reinforcing phase which gives the additional strength, stiffness and hardness to the composites. In major part of composite a reinforcement layer will be given into the outer surface of the composite materials to protect and also for additional strength purposes. Different types of reinforcing materials used for manufacturing the composites based on their respective applications. Normally glass base reinforced polymer gives better results comparatively.

The aspect ratio (Length to Diameter) for continuous fiber will be more than the discontinuous fiber. Also the continuous fiber will have better orientation, thus selection of continuous fiber in composite material produce best results in all aspects.

The continuous fibers are arranged in the form sheets one over the other and give laminate structure. The different orientation given into the fiber alignments for obtaining the expected level of strength, stiffness and hardness values in the ranges of 70 to 80% to fiber composites. In addition to that the laminate also protects the natural fiber considerably. The fiber was treated with alkali solution and distilled water for improving the tensile and flexural properties of the natural fibers.

Through this investigation, palm fiber, glass Basalt fiber hybrid composites are made into combinational unidirectional and bi-directional cross arrangements. The different mechanical based properties like tensile, flexural and impact strength are calculated under different working conditions.

II. EXPERIMENTAL DETAILS

MATERIALS USED

A) PALM FIBER

The palm fiber (Borassus flabellifer) is a natural fiber obtained from various portions of palm tree which is found in abundance in the southern parts of India. The palm fibers are composite material designed by nature,

the fibers are basically a rigid, crystalline cellulose micro fibril- reinforced amorphous lignin and/or with hemi cellulosic matrix. Most plant fibers are composed of cellulose, hemi cellulose, lignin, waxes and some water soluble compounds. Normally the fiber consists of 5-20% lignin, 60-80% cellulose, and up to 20% moisture. The fibers from various parts of the palm tree were extracted either by retting process or mechanical processing or hand processing. The fibers were cleaned with water after soaking for two weeks, further dried in natural sunlight to remove moisture content and long uniform fibers obtained. Generally the fibers are extracted from the different parts of palm tree. (palm leaf sheath, fruit, leaf stalks and petioler)

Through research experimental the palm fruit fiber has good mechanical properties like specific strength, tensile strength and hardness etc.

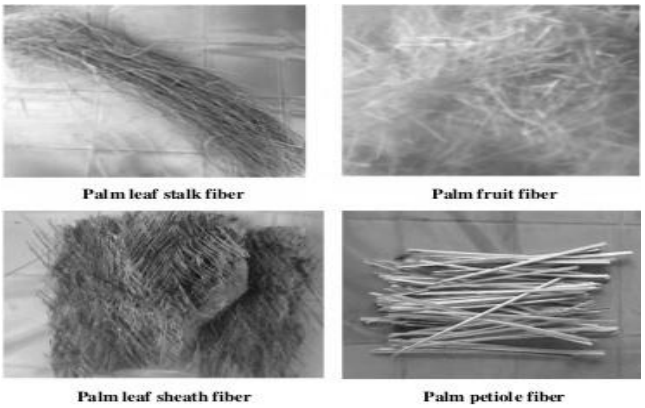

Figure 1. Extracted fibers from various parts of palm tree

B) BASALT FIBER

From lava core of igneous rock the basalt is layered from which the fibers are extracted. The temperature require to extract the basalt fiber is around 1500°C. The basalt fiber is extracted in same method as used for glass fiber. The main composition of basalt fiber is pyroxene, minerals plagioclase, and olivine. This fiber has more effective in physical, chemical as well as mechanical properties. Through the various reference sections it is noted that the basalt fiber gives the best results over various mechanical tests, so this fiber is chosen for various combination of composite applications.

C) GLASS FIBER

Glass fibers are majorly used in polymer matrix composites due to its good mechanical properties. This material gives additional strength and stiffness to the composite material and also it acts as protective cum super finish layer to the composites. Basically the glasses are differentiated with many grades for the reinforcement purposes. S grade glass has better combination in reinforcement composite fibers and gives best results in various mechanical properties as compared with other grades of glasses.

The S glass are produced with a higher level of silica content than other grade glass fibers, S-glass fibers gives the best level in physical properties including high tensile and compressive strength, high temperature resistance, and improved impact resistance values.

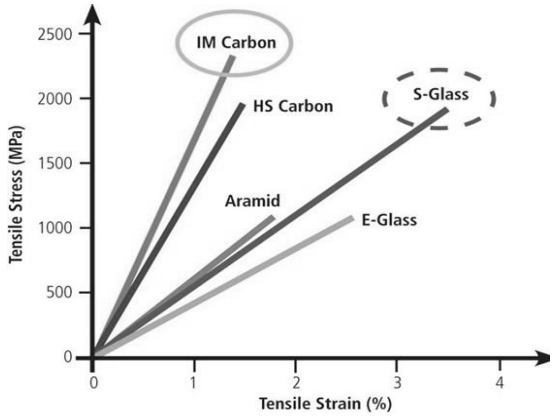

Figure.2 Tensile Properties of various types of fibers

The S glass reinforcement layers are coated into the upper and lower surface of the composite material for protection and additional strength reasons. A bonding glue contains epoxy resins mixed up with hardener in the mixing ratio of 10:1 is used to stick the S glass reinforcement into the composite layers.

From the fig.2 it is observed that S-glass fiber gives the best results among other types of glass fibers and thus it is selected for this evaluation test for obtaining the better results.

IMPORTANT PROPERTIES OF FIBERS ARE GIVEN BELOW:

Fiber	Physical properties			
	Density (g/cm^2)	Elongation (%)	Tensile strength (Mpa)	Youngs modulus (Gpa)
Palm leaf	1-1.2	2-4.50	97-196	2.50-5.40
Palm fruit	1.09	28	423	6-8
Basalt	2.7	3.13	484	89
S-Glass	2.46	2.5-3.7	4890	70-73

Table 1. Various properties of fibers

D) GLASS FIBER REINFORCED POLYMER (GRP):

GRP is made up of very fine fibers of glass and it is very light weight in nature. The main advantage of using the glass fiber in the composite based applications are, it reduces the weight considerably, it gives additional strength to the composites and acts as protective layer for the composite material due to strength and robustness. For this all reasons the GRP is widely used in many composite applications as reinforcement.

E) ADDITIVES:

The main reason for adding the additives in the manufacturing of fibers are due to the bonding and hardening factors. Resins mixed up with hardening agent gives better bonding strength. Therefore the Epoxy resin is mixed up with hardener here to obtain better bonding strength between the fiber layers to form a composite. Epoxy LY558 resin and HY932 hardener are mixed up together and heat them at temperature of 65°C for better bonding purposes.

In this experimental work optimal level of ratio 10: 1 is chosen for the better results.

F) MANUFACTURING METHOD:

The composite is manufactured by basic hand layup method for this experimental work. The Hand lay-up process is like a molding process, the continuous fibers (palm and basalt) are placed inside the mould along with mat structure the epoxy resins mixed up with the hardener is applied over the surface of the fibers gradually by layers. The roller will be used to make this composite much stronger and linear throughout the end space. GRP is given as next layer coating followed by this process. Similarly a combination of seven layers to be prepared by the same procedure. (3 layer Palm / Basalt and 4Layer GRP). In this experimental work, 3 different combinations of composites are prepared and tested for various levels to obtain the best results. The composite combinations are taken into three sets in the experimental work as discussed below.

Set I composite contains Palm fiber arranged at 45˚ to each other in all the 3 layers which resembles inclined orientation. Set II composite contains basalt fiber similar to Set I. Set III contains both the Palm and Basalt fibers.

In every layers, both fibers are inclined at 45degree in the layer (45degree orientation) for obtain extreme level of stiffness to the composite material against various tests.

Table 2. Arrangement of fibers and GRP

SET I	SET II	SET III
GRP	GRP	GRP
PALM	BASALT	PALM
GRP	GRP	GRP
PALM	BASALT	BASALT
GRP	GRP	GRP
PALM	BASALT	PALM
GRP	GRP	GRP

III. SAMPLE TESTING

A) TENSILE TEST:

The mechanical testing of samples is much important in the composite manufacturing because it decides the conclusion and applications of the respective one. The specimen is prepared according to the standards which are shown in the figure 3. The fabrication and all process for the composite sample preparations are explained in the previous section. With the help of Universal testing machine major test (Tensile properties) results is been taken accordingly. All the three set of samples were tested against the tensile properties and the readings is noted for the respective hybrid composites.

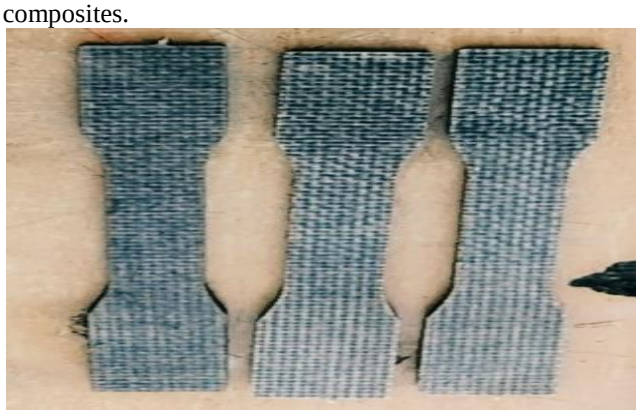

Figure.3 Fabricated composite sample for tensile test

B) FLEXURAL TEST:

With the help of the same Universal testing machine the flexural test is been conducted in three point bending method for obtain the results in ASTM standards as shown in figure 4. The load is applied progressively, at certain level of load applied the specimen tends to break, that load should be noted for the reference as breaking load. The load and displacements are noted and the graph is plotted for load vs. displacement. The fabricated specimen is shown in figure 5.

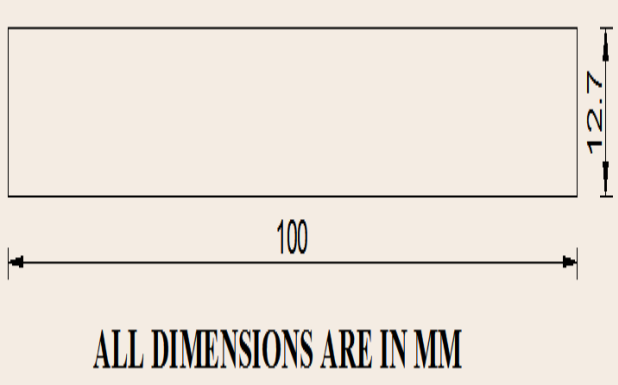

Figure.4 Flexural test specimen

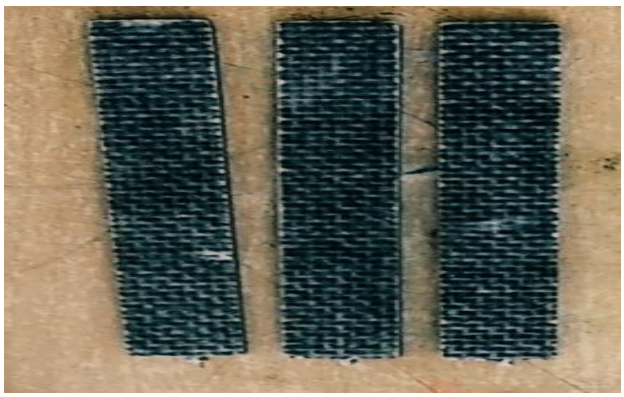

Figure.5 Flexural test specimen

C) IMPACT TEST:

For all the three sets the impact test are performed in the ASTM standards and the values are noted down. With the aid of water jet maching process the cut is been made into the samples as shown in the figure 6. In the charpy test the pendulum drop will cause the force to break the sample and the amount of energy absorbed by the each samples through the charpy test is taken down.

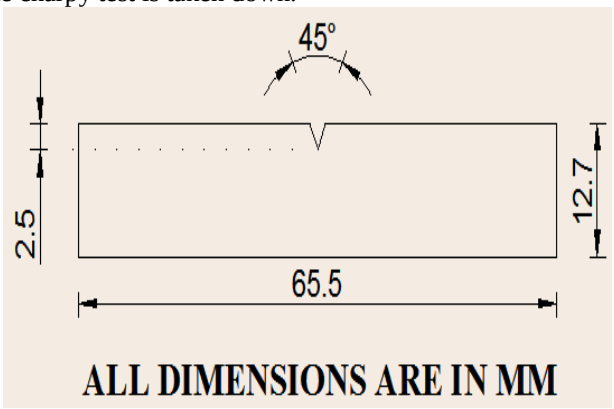

Figure.6 Impact test specimen

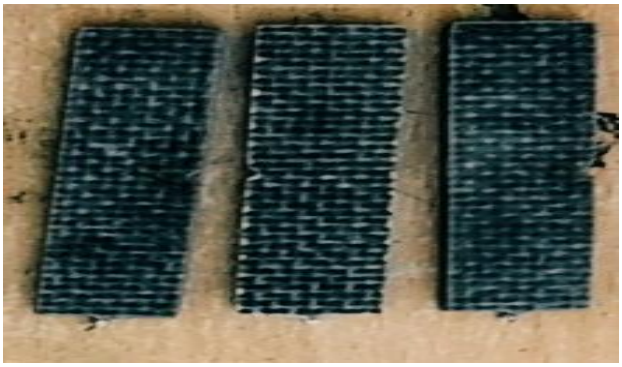

Figure.7 Impact test specimen

D) HARDNESS TEST

The Rockwell hardness testing machine is used for obtaining the hardness vale for each set of hybrid composite sample. In this testing also the ASTM standards were followed to get the results accurately. With three trails the samples are tested and the values is been taken down.

IV. RESULTS AND DISCUSSION

A. TENSILE TEST RESULT

The hybrid composite sample sets were tested on a universal testing machine and the various tensile properties of the specimens are taken down. The figure 8 shows the ratio between stress and strain for all the three sample sets. From the graphical value it is been observed that the set 3 will give the better results that is, the sample which contains the palm fiber and basalt fiber arranged in 45° coated with GRP. In this sample only more amount of load is absorbed compared to the other sample sets. (Maximum stress of 110 N/mm2 with a maximum strain of 6.5). Moreover, it is also noted that composite 1 which contains palm fiber alone withstand maximum of 95 N/ mm2 with a strain of 5.8. This is because of better density of palm fiber as compared to basalt fiber. Composite 2 which contains basalt alone shows poor tensile behavior while compared with other composite.

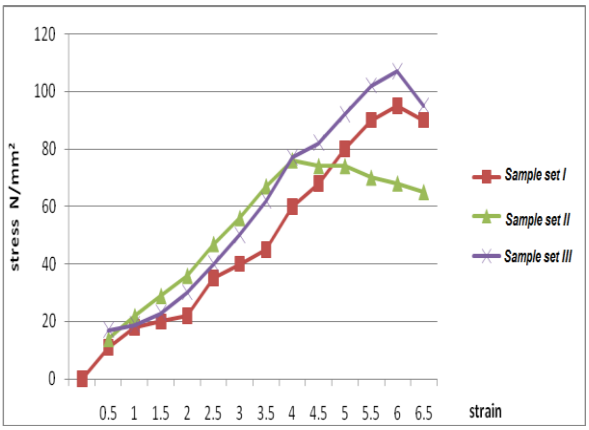

Figure 8. Tensile test result

B. FLEXURAL TEST RESULT

The flexural test and the readings were noted down by using the standard universal testing machine. The various behavior of the hybrid composite such as break load, displacement and strength is measured. The load displacement curve was drawn as shown in the figure 9 for all the three composite samples. From the figure 9 it is observed that the displacement is directly proportional to the load applied on the samples. From the graphical value it is been observed that the hybrid composite sample set 3 will have more strength compared with other sets. The sample set 3 will give 25% more strengthen than the other two sets that is, it is withstanding high amount of load compared to the other sample. Once the maximum load is reached a decreasing level is occurred due the breaking pull point as shown in the graph as shown in figure.

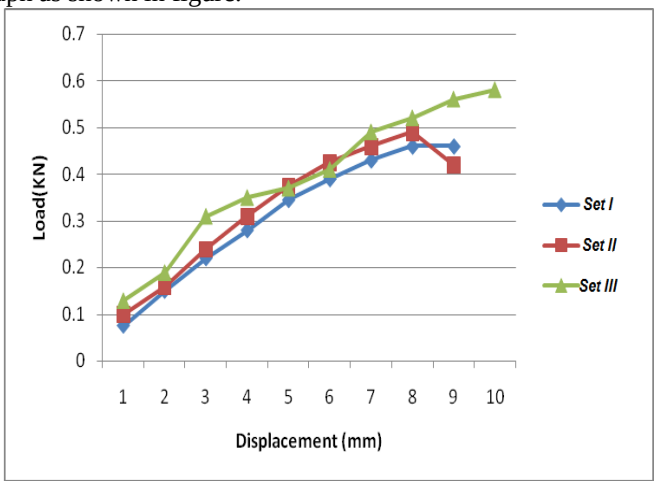

Figure 9. Flexural test result

C. IMPACT TEST RESULT

From the table the impact test is listed as shown in the table number three. The maximum amount of energy absorbed by the hybrid composite sample set 3 will have more than the other two sets. The higher amount of energy absorbed by set 3 is due the presence of both palm and basalt fiber coated with GPF. The palm fiber have the capability of absorbing energy as more compared to basalt and hence this combination sample set will have more effect against the load applied. Figure 10 shows the detailed results of impact test.

TABLE 3. IMPACT TEST RESULT

Name of composite	Trial 1	Trial 2	Trial 3	Energy Absorbed in J (Average)
Set I	7	8	11	7
Set II	8	8	12	11
Set III	6	11	3	12

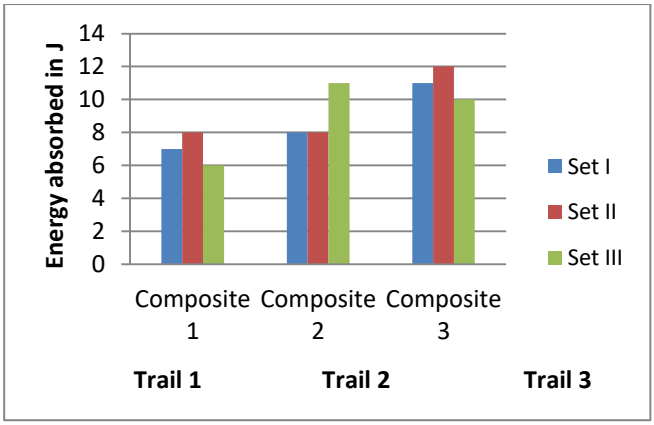

Figure 10. impact test result

D. RESULT OF HARDNESS TEST

The hybrid composite test sample set I, II and III are tested under the standard hardness testing equipment called Rockwell Hardness Testing Machine. From the observed values noted in table 4 shows the hardness value of each sample sets. It is noted that from table 4, the composite sample set 1 show more hardness than the other two sample set 2 and 3. Due to the palm fiber strength and flexibility, the test sample 1 will give more hardness than the other two sample sets 2 and 3.

TABLE 4. HARDNESS TEST VALUES

Name of Composite	Trial 1	Trial 2	Trial 3	Hardness (Avg Value)
Set I	34	57	22	37.67
Set II	30	39	34	34.33
Set III	16	29	21	22

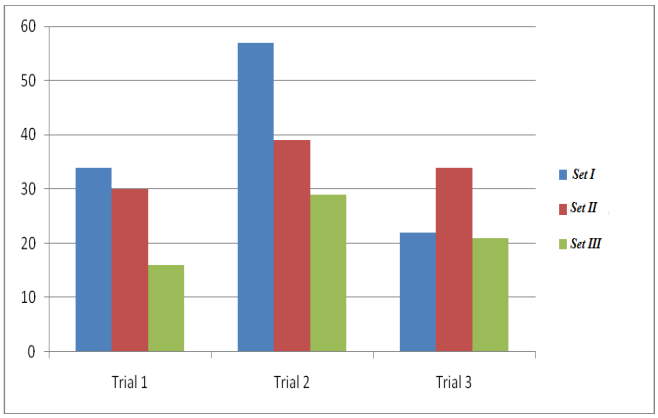

Figure 11. Hardness Test Result

V. STRUCTURAL ANALYSIS

The structural analysis of each test sample set is carried out to the study the internal structure of all the 3 sample sets. Fig 12 shows internal structure of tensile tested over test sample set 1, in which fiber pullout is observed. This is occurred due to improper curing time given during fabrication of composite.

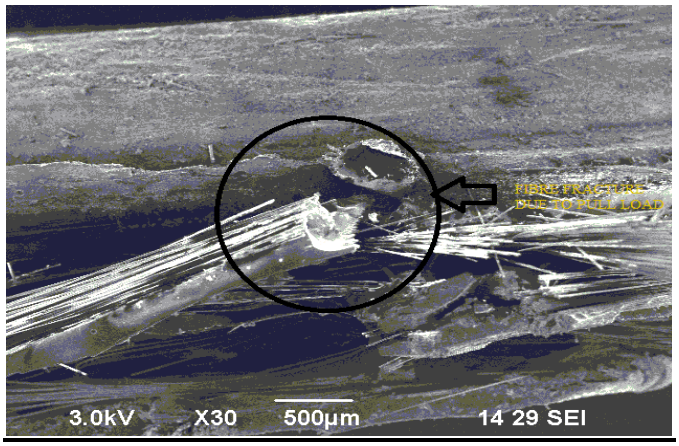

Figure 12. Tensile tested sample set 1

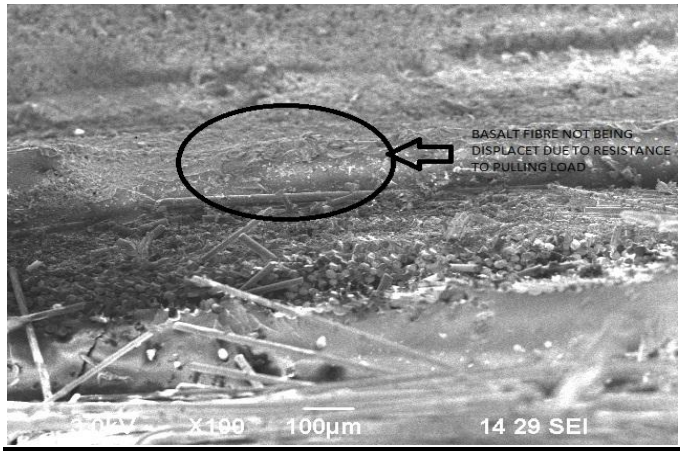

Figure 13. Flexural test on sample set 1

From figure 13 it is observed that basalt fibers are not being displaced due to resistance of pulling load. Due to this reason in discussion it is concluded as the combination of basalt with palm gives better results

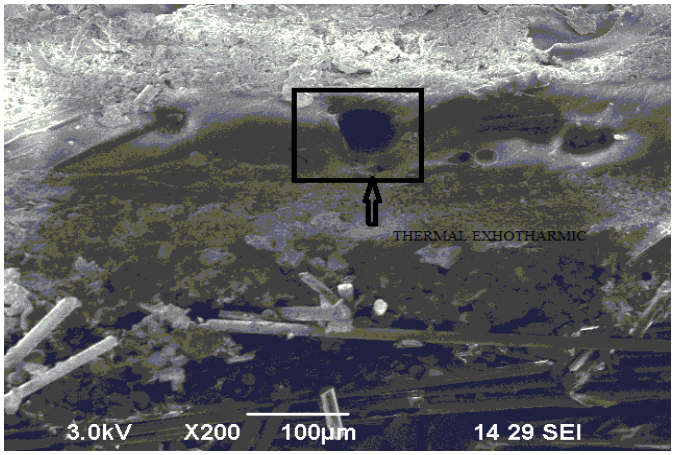

Figure 14. Tensile test on sample set 1

From fig 14 and 15, it is observed that, thermal exothermic formed on laminate which is due to intermediate movement of fibers in laminate while applying load during tensile and flexural test.

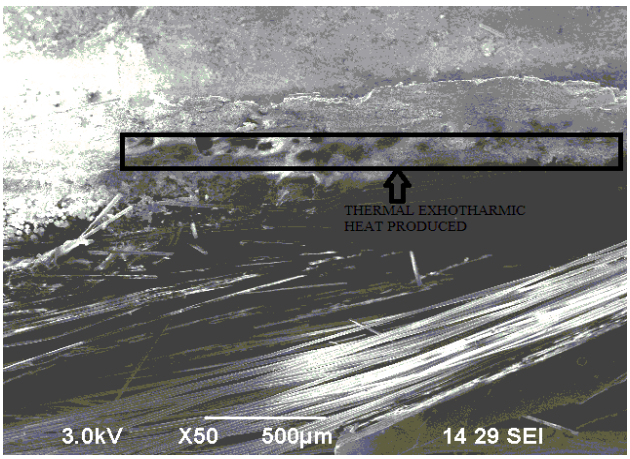

Figure 15. Flexural test on sample set 1

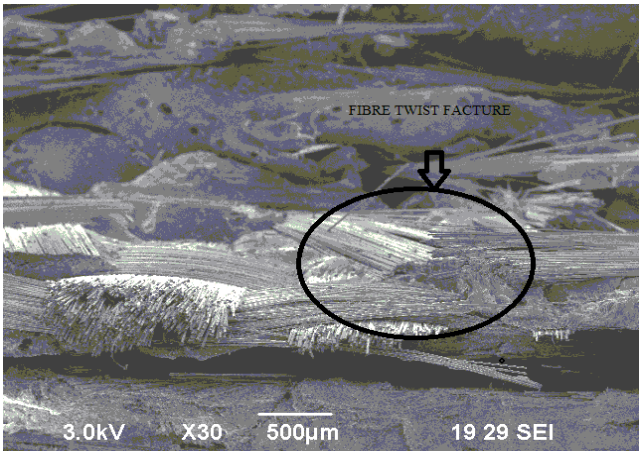

Figure 16. Tensile test on sample set 2

From the above figure 16 it is noted that the fibers are fractured intermediately and twisted into helical form at certain part. Also there is some failure at the glass fiber area provided in it as shown in figure 17. The twisted fiber fracture occurs since, the crack propagation initiated between solidified resin and palm fiber.

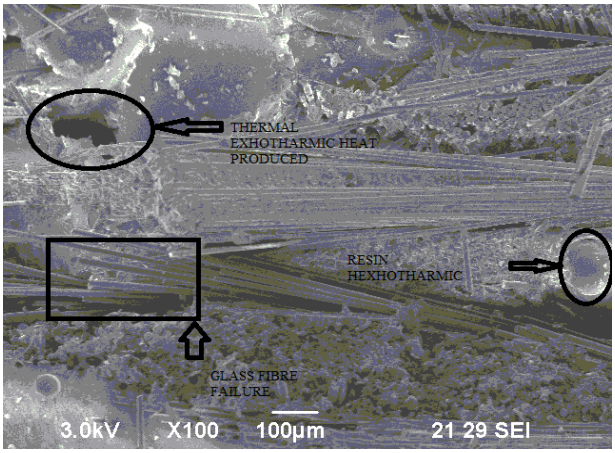

Figure 17. Tensile test on sample set 2

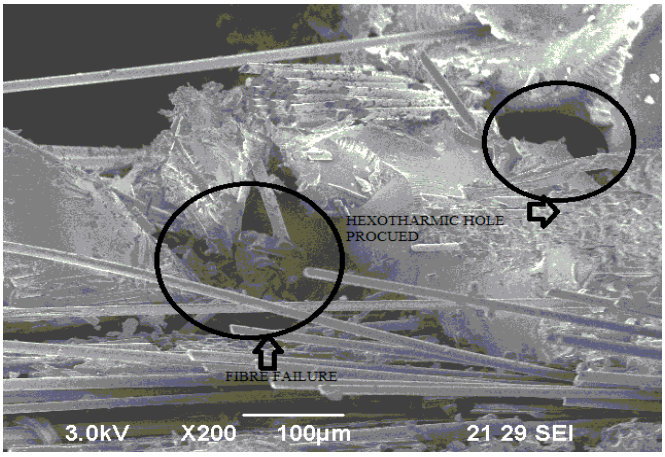

Figure 18. Tensile test on sample set 3

The failure in the fiber and holes are observed in the sample set 3 as shown in the figure 8. At the time of testing the samples, a rupture in sample sets is formed. From figure 19 it is observed that a failure due to the overload.

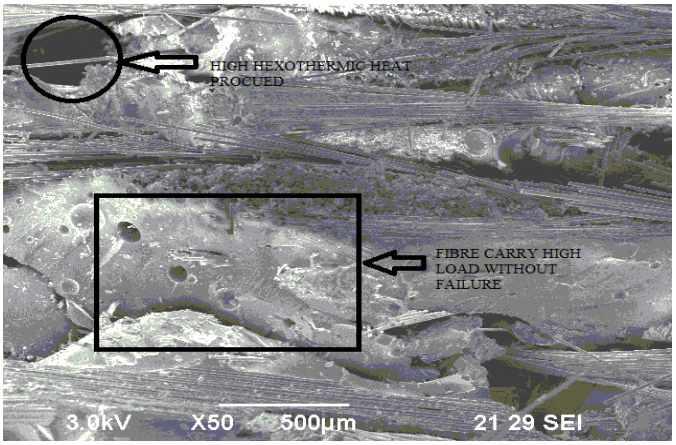

Figure 19. Impact test on sample set 3

VI. CONCLUSION

Through this experimental investigation, the hybrid composite were fabricated with palm fiber and basalt fiber as reinforcement while glass fiber reinforced polymer as covering layer. The basic manual method of hand layup process was used for manufacturing the composite at ambient temperature. The different major mechanical properties like tensile, shear and impact strengths of fabricated composite were perceived and the following conclusions were obtained.

- The composite sample set 3 withstands a maximum stress of 110 N/mm^2 and a strain of 6.5. Moreover, it is also noted that composite sample set 1 which contains palm fiber alone withstand maximum 95 N/ mm^2 with a strain rate of 5.8. This is because better density of palm fiber as compared to basalt fiber.
- The hybrid composite test sample set 3 withstands more loads and undergoes maximum displacement than the test sample set 1 and 2. Set 3 could withstand load of 25% higher than the sample set 2 and 29% higher than sample set1.
- The hybrid composite test sample set 3 intakes more amount of energy through the load applied. Therefore sample set 3 will absorbs more amount energy compared with other sample set 2 and 3 respectively. This is due to the presence of linear continuous palm and basalt fiber arranged at 45^o stacked with glass coating given in the composite 3.

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