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Fabrication, Characterization and Moisture Absorption Analysis of Sponge Fiber-Coir Reinforced Epoxy Resin Hybrid Composite

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Abstract*: Natural fiber reinforced composites are gaining popularity over conventional materials due its low cost, easy accessibility, non toxicity and most important feature - the biodegradability. Since broad varieties of natural fibers are available on earth, hence their merits can be incorporated in one by means of hybridization. Matured sponge gourd, which turns into a net structured fibrous mass on sun drying, is amalgamated with coconut coir as reinforcement along with epoxy resin as matrix material in a composite. The present study was carried out to explore the impact of change in weight percentages of sponge gourd fiber and coir on the mechanical properties and moisture affinity. The alkali treated fibers were turned into composites by dint of Hand Layup technique. The various mechanical properties were evaluated according to ASTM protocol. After the successful conclusion of the experiments, it was found that composite with maximum weight percentage of coir showed superlative tensile and impact strength whereas the composite with highest sponge fibre content showed maximum flexural strength. The composite with equal sponge fiber-coir weight percentage displayed lowest affinity towards moisture.

Keywords: Alkali treated, Hand Layup, Hybridization, Mechanical properties.

I. INTRODUCTION

Exploration and usage of new materials has always been associated with the evolution of human race. Historians have differentiated the era of growth of human race in terms of materials i.e., stone, copper, iron [1]. The first ever use of composite material can be traced around 3400 B.C. in ancient civilization of Mesopotamia where the men gummed the wood strips at different angles to craft plywood. The settlers in the great land of gigantic pyramids, used cartonnage and layers of linen or papyrus soaked in plaster to make the death mask. The Egyptian and Mesopotamia used mixture of mud and straw in construction of strong and durable building. Later in 1200 A.D., the Mongols warriors invented first composite bow by using bamboo, animal tendons and horns, silk along with pine resin. They placed tendons on the outer and sheet of horns in the inner side of bow which was made up of bamboo. The components were secured with pine resin and tied together by silk. These bows were swifter, powerful and accurate than those of rivals and hence it clinched in establishing the supremacy of Genghis Khan’s army. A new era of composites began in 1907 when Belgian-born U.S. chemist Leo Hendrik Baekeland invented Bakelite (Polyoxybenzylmethylenglycolanhydride), one of the first synthetic resins. Bakelite is a thermosetting phenol formaldehyde resin which is prepared from an elimination reaction of phenol from formaldehyde. Baekeland found that the resin was brittle which can be overcome by mixing it with cellulose. The famous automobile company Rolls Royce first commercially started manufacturing gearshift knobs with Bakelite in 1917. In 1930, the American Cyanamid and DuPont invented polyester resins. Simultaneously, Owen-Illinois Glass Company boomed the composite industries by developing a technique for drawing glass into thin strands and then weaving them into a textile fabric. This event gave birth to fiber reinforced polymer industries. The combination of glass fiber and synthetic resin produced lightweight yet strong composite material. Ray Greene Toledo, who had worked in the Owen- Illinois Glass Company, marked a great change in boating world by fabricating a dinghy with glass fiber and synthetic resin. The industries worldwide saw major advancement during the World War II. It brought fiber reinforced polymer from laboratory to actual manufacturing. The composite materials sounded a good replacement of conventional material for aircrafts due to their lightweight. They were also found to be transparent towards radio frequencies and hence they were adapted in sheltering electronic radar equipment (Radomes). Over seven million pound of glass fiber was used in military application in the war. Development of synthetic material provided great advantages over the conventional materials. Apart from being light weight and radiolucent, these materials also possessed exceptional characteristics like corrosion resistance, high tensile strength and extraordinary durability. By the end of World War II, the FRP industries were boosted to the fullest.

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The industries started addressing the other commercial markets. They developed prowess in new manufacturing techniques which allowed them to fabricate variety of materials to address day to day needs of market. The research and development process has never stopped ever since then and in fact researchers are now working with much more enthusiasm to enhance composite materials.

Nowadays synthetic or petroleum based composites have established a significant place in our life. Though these material exhibit lots of extraordinary useful characteristic, it has its own drawbacks. The chiefly used manmade polymers in composites like polyester, nylon, polyethylene, polytetrafluoroethylene, and epoxy resins are extracted from petroleum hydrocarbons. Kevlar is an outstanding material of modern age, finds applications from automobile tires to body armors. It can be used as waterproof material with certain modifications. Nature has limited petroleum reserves. The reserves are rapidly moving towards extinction due to escalating demand. Thus the petroleum or crude oil is also termed as “Liquid Gold” due its high demand and price. The greatest problem of all is their hazardous impact on environment. Considerable amount of toxic waste is produced during extraction, processing and transportation of crude oil. Synthetic polymers cannot be degraded by microorganisms and hence they are categorized as Non Biodegradable material. Researchers have stated that a plastic may take up to 500 years to degrade itself completely. These materials can greatly reduce the fertility of the soil. Certain compounds can also contaminate the water bodies. Ocean acidification is a noxious phenomenon which occurs due to spillage of oil while shipping of the oils from one port to other. The petroleum extraction and its burning raises carbon foot print leading to serious climatic problems like Global Warming, Sea level rise, Acid rain etc. It is has been reported by United Nations that the average global temperature has raised up to 0.85 from 1880 to 2012 and arctic is losing 1.07 x 106 km^2 ice each decade resulting in elevating the sea level due to global warming [21]. It is assumed that the world’s ocean will warm up and the sea level would probably increase by 24-30 cm by 2065 [21].

This has compelled the researchers to develop materials that can not only perform desired functions but are also environment friendly. The natural fibers are appraised in this regard due to their low cost, easy accessibility, non toxicity and most important feature - the biodegradability. The suitability in various engineering application were listed from furniture to automobile sector [9]. Natural fibers can be classified as plant and animal fibers on basis of source of extraction. Particularly in plant fibers, Lignocellulosic fibers are neutral with respect to the emission of CO_2 which can help us to reduce the carbon foot print [2]. Despite having these advantages, natural fiber lacks in strength and resistance towards moisture absorption which is undesirable. The limitation can be overcome by surface treatment of fibers and hybridization of reinforcement in the composites. The process of utilizing more than one type of fiber as reinforcement is called Hybridization of composites. Hybrid composites offer a better combination of properties of constituent fibers [7]. There are various kinds of treatment available for the enhancement of the fiber surfaces such as dynamic ultrasonication, corona discharge or reaction with alkyl ketone dimmers, alkalis, silane-coupling agents etc. which provides significant changes in the fiber surface structure as well as in the surface energy [14]. The chemical modification removes the undesirable surface layers from the fibers, makes the fibers hydrophobic and strengthens the composite system by optimization of interfacial interaction as observed in SEM [8]. This work is an attempt to experimentally investigate the mechanical properties and moisture absorption capacity of a hybrid composite with different weight percentage of sponge gourd fiber and coir as reinforcement and epoxy resin as matrix. The fibers were chemical treated to enhance the fiber surface by removal of undesirable substances. While fabrication of the composites, a 40% constant fiber weight was maintained by varying individual weight percentages of sponge fiber and coir i.e., 30% sponge - 10%coir, 20% sponge- 20% coir and 10% sponge - 30% coir. The tensile, flexural and impact strength of specimens were evaluated according to ASTM standards. The moisture absorption capacity of the specimens was evaluated by exposing them to a distil water environment for 156 hours.

II. LITERATURE SURVEY

Composite materials are made from two or more constituent materials which have significantly different physical or chemical properties and remain discrete and distinct at the macroscopic or microscopic scale within the final product [22]. The materials are such that they harmonize the desirable characteristics together and try to overcome the weakness of the other. The component which carries the load in the composites is known as reinforcement and the component which helps in transmitting the load on the reinforcement is known as matrix. Since reinforcement is that component of the composite which carries the major portion of the load subject on it, hence the selection of reinforcement greatly affects the physical and mechanical properties of the composites. Sponge gourd is an annual herbaceous plant which belongs to the cucurbitaceous family. Sponge Gourd is a tropical fruit which is known by various botanical names such as Luffa aegyptiaca, Cucurbita Luffa and Momordica Cylindrica. The fruit is widely cultivated in Southern Asia and Southeast Asia. It has vine stems and vascular shaped fruit. The young sponge gourd is edible and commonly regarded as a vegetable. Sponge Gourd is also called as Dishrag Gourd or Rag Gourd because when the fruit is fully ripened, it becomes fibrous from inside and is inedible. The dense fibrous structure resembles to a sponge on sun drying. The sundried sponge gourd is used as scrubbing and cleaning sponge for domestic purposes. Commercially, It was used to make the filters for steam and Diesel engine in Japan from 1890 to 1895 [10]. Japan became quickly a large producer of sponge gourd and they were mainly exported to USA before the World War II. 60 % sponge gourds imported by the USA were used in the production of filters and up to 40% in domestic and other industrial applications [10], [11].

The morphology of fractured surface of sponge gourd observed by SEM suggests that the networking of structure restricts the pull of fiber which was found to be responsible for higher mechanical properties [20]. Chemical composition of sponge gourd is shown below in Table I.

Table I. Chemical Composition of Sponge Gourd [13]

Composition	Values
Cellulose	65.69%±3.77%.
Hemicelluloses	19%±3%.
Lignin	12.03%± 2.34%.
Moisture regain	10.81% ±1.34%.
Moisture content	9.74%±1.1%.

The botanical name of coconut is a Cocos Nucifera. It belongs to Arecaceae family. It is widely available in tropics and subtropics region. Coconut flesh and oil are edible. It also finds a great application in cosmetics industries. The densely clubbed fibrous husk over the coconut shell is called coir. It is considered as one of the major secondary products of coconut. Coir is widely used for making ropes, mats and nets. The white coir are obtained from immature coconut whereas brown coir from matured coconut. It is also important to note that coir has high lignin content which holds the composites together but also acts as solidifying agent for the cellulose molecules within wall of the composites cell [5]. Lignin also provides long life to coir by acting as antioxidant against the biological and chemical attacks on the plants [22]. Chemical composition of Coir is shown in Table II.

Table II. Chemical composition of coir [12], [24].

Composition	Values
Water Soluble	5.25%
Pectin and related compounds	3.00%
Hemi – cellulose	0.25%
Lignin	45.84%
Cellulose	43.44%
Ash	2.22%

The matrix is another major constituent of composite whose function is to hold the reinforcement in the craved shape and transfers load to the fibers. It also provides a barrier against adverse environment and protects the surface of the fibers from mechanical abrasion [6]. Currently, the most popular matrices used in composites are polymeric, including thermoplastics and thermosets. Although thermoplastics have the merit of being easily recycled but better mechanical properties are observed with thermosets, such as epoxy resin and polyester [6]. The epoxy resin used in this investigation as matrix is Araldite LY-556. The common name of Araldite LY-556 is Bisphinol-A-Diglycidyl-Ether. The hardener used with the epoxy was HY- 951. It has IUPAC name as NNO-is (2aminoethylethane-1,2diamin). Further it is also worth noting that the epoxy polymer in pristine conditions presents better compatibility and higher tensile and flexural strength than its polyester counterparts [6]. The matrix material Araldite LY-556 and Hardener HY-951 were supplied by Herenba Instruments and Engineers, Chennai, India. The properties of matrix used in the composite are show in table III.

Table III. Properties of Araldite LY-556 [28].

S.No.	Properties	Values
1.	Aspect (visual)	Clear, pale yellow liquid
2.	Epoxy content [eq/kg]	5.30 - 5.45
3.	Viscosity at 25°C [mPa s]	10000-12000
4.	Density at 25°C [g/cm³]	1.15-1.20
5.	Flash Point [°C]	> 200

III. EXPERIMENTAL METHODOLOGY

A. *Material preparation*

The fully developed sponge gourd fruits were collected from the agricultural farms located near Jabalpur, India. The fruit were sundried for two weeks at dry place so that the moisture from the green mass is fully evaporated. The outer skin of green sponge gourd turned into hard and yellowish brown coloured covering after sun drying Fig 1(a). The yellowish brown covering was peeled off and all the seeds from the fibers were removed. The fig 1(b) shows the cylindrical fiber mass which was opened by slitting it from one side. It was turned into mats by cutting off the hard fibrous seed case present in the centre. On the other hand, the broken coconut shells were collected from a temple in Jabalpur, India. The fig 2(a) shows brown coir clubbed on the hard shell of the coconut. The fig 2(b) shows coir which was extracted and sundried for one week in a dry place. The undesirable coarse substances from both the fibers were removed manually. The fibers were then washed thoroughly by tap water to remove the dirt and wax. The fibers were again sundried for one week in open atmosphere at a dry place.

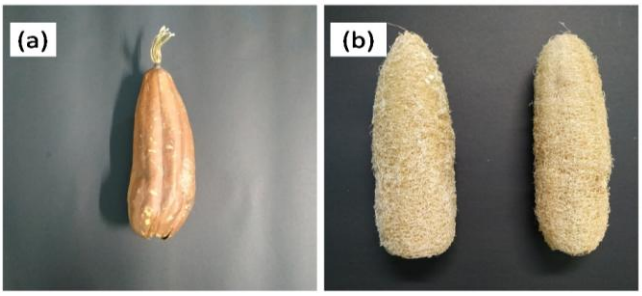

Fig.1 (a) Dry Sponge Gourd (b) Sponge Fibre

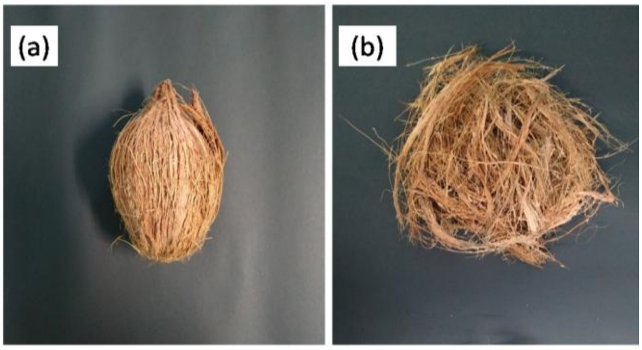

Fig. 2 (a) Brown Coconut (b) Dry Brown Coir

B. *Chemical Treatment*

The presence of hydrogen bonding in network structure of fibers makes them hydrophilic in nature. The affinity towards moisture may reduce the strength of the composite. The drawback can be overcome by Alkaline Treatment. The treatment eradicates hydrogen bonding from the fiber structure and makes them hydrophobic and rough. Another important objective of the chemical treatment is to improve interfacial adhesion between fiber and matrix and surface wet ability of fiber with matrix material [1]. In the present study, both the fibers were treated with 5% Sodium Hydroxide (NaOH) solution for 4 hours at room temperature. After the treatment, the fibers were washed thoroughly with Distilled water to remove the excess sodium hydroxide sticking to them. Finally they were sundried for one week to evaporate all the moisture completely. The fig. 4 and 5 shows the untreated and treated Sponge fiber and coir respectively. The change in the colour and texture of the fiber before and after the treatment can be clearly seen. Thus, preliminary it can be stated that treatment has significantly removed the undesirable substances. The reaction involved in the treatment is shown below [6].

$$\textbf{Fibre} - \textbf{OH} + \textbf{NaOH} \rightarrow \textbf{Fibre} - \textbf{O} - \textbf{Na}^{+} + \textbf{H}_{2} \qquad \ldots (1)$$

During the alkaline treatment of Sponge fibre, the Na^+ ions help in broadening of the pores. The OH groups of cellulose turned into O-Na groups by extension of dimension of cellulose molecule which therefore, expands the pore size [27]. The treatment offers compaction of cellulose molecules by collapsing the lumen [27]. On the other hand, the wax, amorphous hemicelluloses and lignin are removed which prohibits the desired wetting of fiber with matrix. It has been observed the roughness induces in the fibers after treatment promotes better transfer of stresses in the composite.

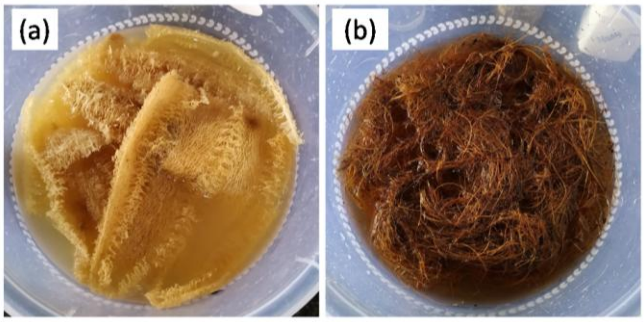

Fig.3 Alkali Treatment (a) Sponge Fibre (b) Coconut Coir

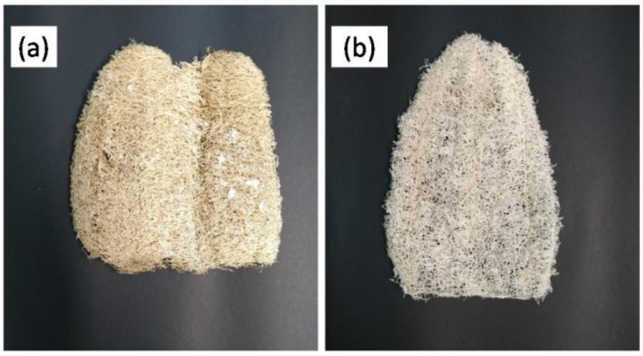

Fig. 4 (a) Untreated Sponge fibre (b) Treated Sponge fibre

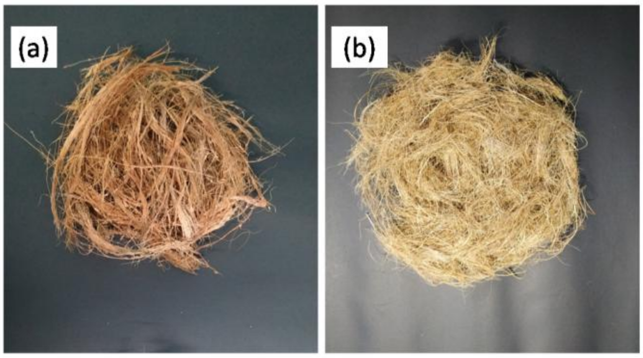

Fig. 5 (a) Untreated Coir (b) Treated Coir

C. *Composite Fabrication:*

A conventional Hand layup method was employed to fabricate the composite. A mould of size 300mm x 300mm was made from wooden planks. The desired thickness of 5mm was maintained by securing blocks of 12mm x 12mm x 5mm at the four corners. Silicon spray was applied at the bottom of the mould for the easy removal of the composite after solidification. The resin was preheated to about 40˚C before adding the cold hardener to simplify the mixing process [28]. The epoxy and hardener were mixed in ratio of 10:1 by weight. Initially a layer of homogenous mixture of resin hardener was applied at the bottom of the mould uniformly. Further mat of Sponge fiber and coir were placed consecutively to achieve the desired composition.

A good amount of mixture of Araldite LY-556 & Hardener HY-951 was applied in between the fibers layers for the proper adhesion. The air bubbles were removed by means of rolling a roller over the fibers layers. A load of 25 kg was kept at the top of closed mould for 24 hours to achieve excellent curing of the composite. During the fabrication, a 40% constant weight of reinforcement was maintained. It is evident from various investigations that 40% fiber weight displayed increase in the strength as compared to the other weight percentages. For instance, it was observed that composite fabricated with Sansevieria trifasciata fiber and epoxy showed improvement in tensile, flexural and impact strengths at 40 % wt fiber content [15].

The analysis of banana and sisal reinforced composites exhibited better mechanical properties at 40% fiber weight against the other weight percentages [16], [17]. The same observation was noticeable in the composite having 40% Sansevieria cylindrical fiber content as reinforcement and polyester as matrix [18], [19]. The study of Luffa and ground nut reinforced hybrid composite also should better performance at 40% than at 30% and 50% fibre content [20]. The table IV provides the detailed composition of composites fabricated for the study.

Table IV. Designation and Com position of Composites

S. No.	Composite	Composition
1.	A	Sponge Fibre (30%wt) + Coir (10%wt)+ Epoxy Resin
2.	B	Sponge Fibre (20%wt) + Coir (20%wt)+ Epoxy Resin
3.	C	Sponge Fibre (10%wt) + Coir (30%wt)+ Epoxy Resin

D. *Material Testing*

Tensile Test: The specimen for tensile strength test was designed as per specifications ASTM D-3039. The test specimen were in shape of dog bone with dimension 140 mm x 15 mm x 6 mm with span length of 42 mm and width of 10 mm. The Amsler Universal testing machine of 10 tonnes capacity was used for performing the test. A uniform strain rate of 2 mm/min was employed.

Three Point Bending Test: The sample for flexural strength test was made as per the specifications ASTM D-790 with dimension of 140 mm x 15 mm x 10 mm. The test was performed on Amsler universal testing machine of 10 tonne capacity. The test specimens were tested using three points bending method and a speed of 2 mm/min was maintained at the crosshead. The flexural strength can be calculated by using the equation.

$$\sigma = \frac{3Fl}{2bt^2} \quad \text{… (2)}$$

Where

σ = Flexural Strength (MPa)

F = Maximum Load applied (N)

l = length of specimen (mm)

b = width of specimen (mm)

t = thickness of specimen (mm)

Impact Test: The impact strength of the composite was examined by using Charpy test. The test specimens for Impact strength were made as per the specifications ASTM E-23 with dimension of 55mm x 10mm x 10 mm. A 'U' notch was made in the middle of the specimen with an angle of 45˚ and depth of 2 mm. The specimens were examined in a Charpy impact testing machine and the energy absorbed (in Joules) by the specimens after the facture were recorded.

Moisture Absorption Test: Moisture Absorption capacity of a test specimen is an important factor which helps to understand the effect of moisture on the composites. It is investigated by preparing the specimen from various composites according to ASTM D-570 standards with dimension of 140 mm x 15mm x 10 mm. The specimens were dried by elevating their temperature up to 40˚C in an oven for about 30 minutes. It is then brought to room temperature and the initial weights were taken. A digital weighing machine was used to measure the weight of the test specimen. The test was accomplished by immersing the specimens in distil water environment for 156 hours. The test specimens were weighed at every 12 hours. The moisture sticking to the specimens was neatly wiped by a clean dry cloth before recording the weights. The weights of specimens were measured within one minute of removal from water bath. The moisture absorption capacity was evaluated by calculating the difference between initial and final weights of the specimens at the interval of 12 hours. The moisture intake capacity is expressed in terms of percentage weight gain [23]. It has been calculated as given below:

$$\%W_g = \frac{W_f - W_i}{W_i} \quad \text{... (3)}$$

Where

W_g = Weight gained by composite

W_i = Initial Weight of the composite before immersion.

W_f = Final weight of the composite after immersion

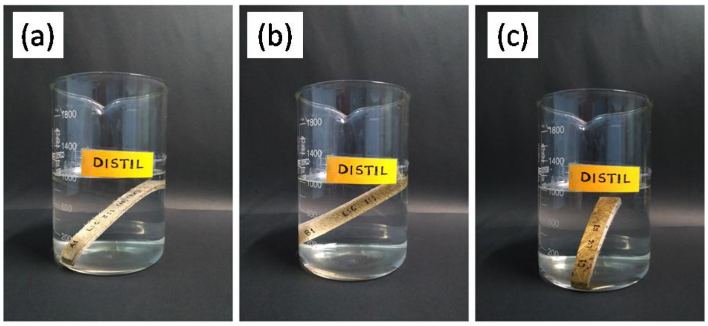

Fig.6 Moistute Absorption of specimens.

IV. RESULT AND DISCUSSION

A. *Tensile Test*

The readings obtained from the tensile test of various specimens A, B and C was recorded and a graph (Fig.9) is plotted as shown below. It is observed that the specimen C having Sponge 10% and Coir 30% by weight respectively showed maximum tensile strength of 23.03 ± 0.66MPa as compare to the specimen A and B. This may be due to the chemical treatment which helped in removing the lignin content.

It favored the enhancement in fiber matrix interaction. Also, Coir has been accounted for having the highest extension at break among common natural fibers, which allows it to absorb strain more than other fibers [3], [4]. The specimen A, consisting Sponge 30% and Coir 10% by weight displayed minimum tensile strength as 16.64 ± 0.42 MPa. The hybrid composite A, showed slight improvement in tensile strength than the composite fabricated with pure short luffa fiber reinforced composite with 30% volume fraction criteria [29]. The lower tensile strength composite can be due to the improper of wet ability sponge with epoxy. The improperly filled sponge network may have provided barrier in the effective stress transfer. The specimen B showed a moderate tensile strength of 21.04 ± 0.85 MPa. The experiment showed increase in tensile strength with increase in the coir.

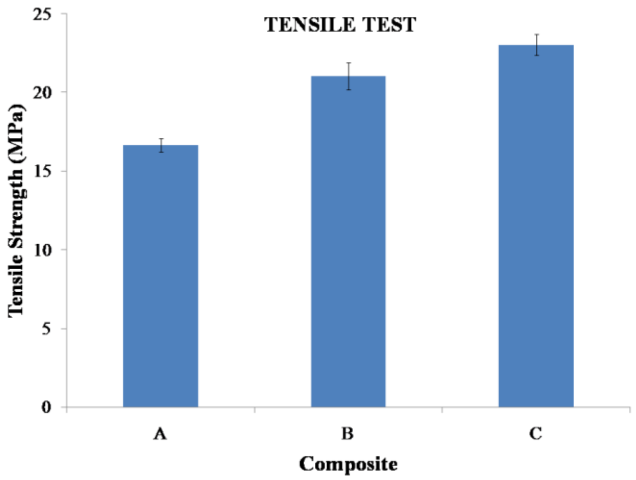

Fig. 7 Tensile Strength of the Composites

B. *Three-Point Bending Test*

Fig. 3 show the variation in flexural strength of composite which ranges from 31.93 ± 0.96 MPa to 43.11 ± 1.84 MPa with respect to varying weight % of Sponge fiber and coconut coir. It is observed that flexural strength increased with increase in weight % of Sponge fiber in the composites. The flexural strength was found to be maximum in the specimen A having composition of 30% Sponge fiber and 10% Coir with 43.11 ± 1.84 MPa. The alkaline treatment enhanced the roughness of fibers and improved fiber matrix compatibility. The specimen having specimen C having composition of 10% Sponge fiber and 30% coir fiber showed low flexural strength of 31.93 ± 0.96. Authors have quoted a range of 23.27 to 42.94 MPa for flexural strength of sodium carbonate and bicarbonate treated coir reinforced composites in their previous investigations [6], [27]. The pull down in flexural strength with increase of coir content may be due to fiber entanglement and agglomeration. The curling of coir leads to poor stress transfer in the composites [25], [26].

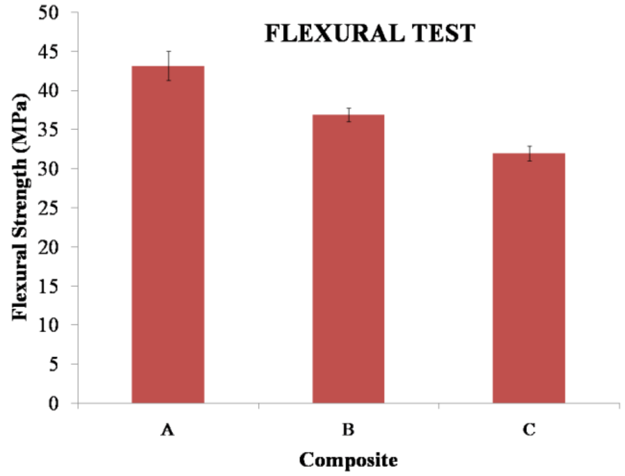

Fig. 8 Flexural Strength of the Composites.

C. *Impact Test*

The impact strength of composites were evaluated through Charpy Impact test standards are presented in.Fig. 4. The figure reveals the effect of variations in weight percentages of fibers on the energy absorbed by various composite specimens during Charpy impact test. It is noticed that the energy absorption of composite improved by increasing the coir content in the composites. The strength sample C having 10% wt sponge and 30% wt coir showed maximum energy absorption of 5.8 ± 0.44 joules. The superlative performance composite C can due to the arbitrary dispersion of coir which created more number of interfaces in regular fashion, thus resulting in complex crack propagation at the matrix fiber interface. It is also observed that the sample A with 30% wt sponge and 10% coir composition requires lower fracture energy of 4.4 ± 0.56 Joules which lowest as compared to other counterparts.

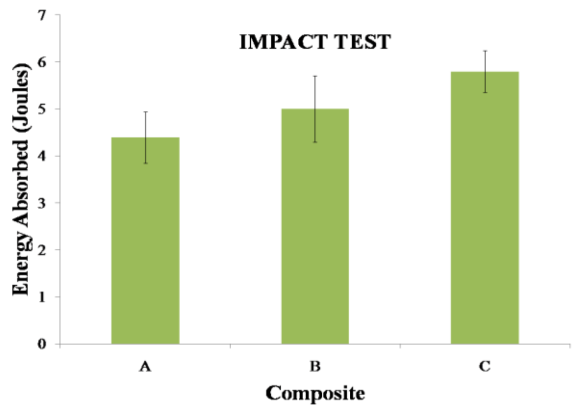

Fig.9 Impact Test of the Composites.

A Sample of five specimens was tested for accuracy. Table V presents the average values obtained for all mechanical tests with respective to the standard deviation.

Table V. Summary of the Mechanical Tests.

Composite	Tensile) Strength (MPa)	Flexural Strength (MPa)	Impact Strength (Joules)
A	16.64 ± 0.42	43.11 ± 1.84	4.4 ± 0.56
B	21.04 ± 0.85	36.84 ± 0.90	5.0 ± 0.71
C	23.03 ± 0.66	31.93 ± 0.96	5.8 ± 0.44

D. *Moisture Absorption Behavior*

Table VI provides information about the initial and final condition of composite after the passage of 156 hours. The weights of composites are shown in grams.

Table VI. Summary of Moisture Absorption Test.

Composite	Composition (wt%)		Initial Weight (Grams)	Final Weight (Grams)	Weight gain (Grams)
	Sponge	Coir			
A	30	10	13.70 ± 0.37	15.79 ± 0.39	2.09 ± 0.02
B	20	20	14.36 ± 0.42	15.81 ± 0.46	1.45 ± 0.04
C	10	30	14.42 ± 0.53	17.34 ± 0.57	2.92 ± 0.04

The moisture absorption behavior of various Sponge - Coir reinforced composites with increase in immersion time is shown in graph fig.10. It is noticeable from the graph that the water absorption in specimen increased with increase in the immersion time. The graph depicts that the specimens evinced saturation near 120 hours and subtle water absorption took place thereafter. It is observed that the sample C with Sponge 10% wt and coir 30% wt showed maximum water absorption with an increase of weight by 2.92 ± 0.04 grams. The sample B with sponge fiber 20%wt and coir 20% wt showed minimum water absorption with an increase of weight by of 1.45 ± 0.04 grams from the initial weight after the completion of the experiment i.e. 156 hours**.**

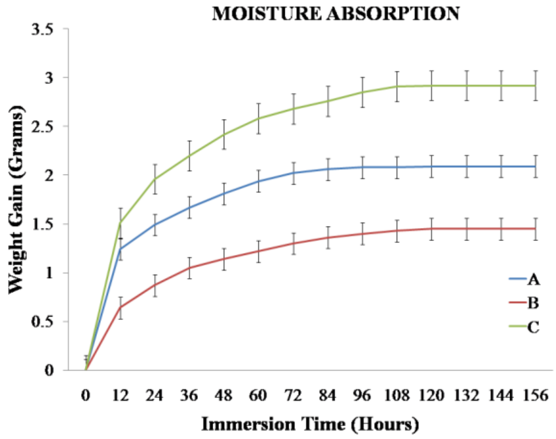

Fig.10 The weight gain by various specimens measured after every 12 hours.

V. CONCLUSION AND FUTURE WORK

The hybrid composite with varying weight % of Sponge fibre and Coir were successfully fabricated by Hand layup technique. The important observations have been noted as follows:

1. The mechanical and moisture affinity were greatly influenced by variation in the reinforcement weight percentage.
2. The tensile strength of the composites was found to be improving with the increase in weight percentage of coir whereas the flexural strength was found to be improving with the increase in weight percentage of sponge fibre.
3. During the Charpy impact test, the maximum energy absorption was displayed by the composite having highest coir content.
4. The fibre entanglement and agglomeration in coir and improper wet ability of sponge fibre were the major reasons for lower strength.
5. The moisture absorption test showed that the moisture affinity increased with the increase in the water bath time. The samples showed little gain in weight after 120 hours. Thus this point can be regarded as saturation point for the composite samples.
6. The moisture affinity was lowest in the composites with equal weight % of sponge fibre and coir.

The present study can be further extended by working on various parameters such as

1. The present study has been carried out using simple and lay-up technique. However, the research work can be extended further by considering other methods of composite fabrication and the effect of manufacturing techniques on the performance of composites can similarly be analyzed.
2. Similarly the impact of other chemical treatments on fiber surface properties can be evaluated to improve the adhesion between fiber and matrix materials.
3. Studying the response of these composites towards the other wear modes such as sliding and abrasion.
4. The stacking sequence of fiber lamina can be analyzed along with incorporation of micro fillers.
5. Cost analysis of these composites to assess their economic viability in industrial applications.

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