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Experimental Investigation on Mechanical Behaviour of Rice Straw- Jute – Coconut-Palm Fibres - Reinforced Epoxy Natural Composite Material

Asst. Prof. Gosula Suresh, Research Scholar Manda Ranjith Kumar, M. Keshav Prasad, M. Shiva Kumar, M. Nagesh, Ch. Ranjith Kumar
Department of Mechanical Engineering,
ACE Engineering College,
JNTU, Ghatkesar, Hyderabad.

Abstract- Rice-Straw-jute-Coconut-palm-Fibres is being used as a reinforcement material in the development of reinforced plastics for various engineering applications. Its biodegradability, low cost, and moderate mechanical properties make it a preferable reinforcement material in the development of polymer matrix composites. Therefore, Rice-Straw-jute-Coconut-palm-Fibres reinforced composites have replaced the most widely used synthetic fibre (glass, kevlar) reinforced composites in many applications. In the present experimental endeavor, Natural fibre reinforced composites were prepared using Vacuum bagging process. The effect of the weight percentage of the trio fibre reinforcement was investigated experimentally on the mechanical properties of the developed composites. The mechanical properties were tested using computerized UTM machine as per the ASTM standards. Scanning Electron Microscope (SEM) have been utilized to fully understand the mechanical behaviour of developed composites. The results reveal that, the mechanical properties of Rice-Straw-jute-Coconut-palm-Fibres based composites are substantially improved on account of the addition of the Jute fibre reinforcement. It has also been observed that the significance of the enhancement of the mechanical properties increased as the weight percentage of the Jute fibre reinforcement increased.

Keywords- Natural fibers, Sisal, Jute, Vacuum bagging.

I. INTRODUCTION

Natural fiber is a type of renewable sources and a new generation of reinforcements and supplements for polymerbased materials. The development of natural fiber composite materials or environmentally friendly composites has been a hot topic recently due to the increasing environmental awareness. Natural fibers are one such proficient material which replaces the synthetic materials and its related products for the less weight and energy conservation applications.

The application of natural fiber reinforced polymer composites and natural-based resins for replacing existing synthetic polymer or glass fiber reinforced materials in huge. Automotive and aircrafts industries have been actively developing different kinds of natural fibers, mainly on hemp, flax and sisal and bioresins systems for their interior components. High specific properties with lower prices of natural fiber composites are making it attractive for various applications.

The applications of natural fibers are growing in many sectors such as automobiles, furniture, packing and construction. This is mainly due to their advantages compared to synthetic fibers, i.e. low cost, low weight, less damage to processing equipment, improved surface finish of moulded parts composite, good relative mechanical properties, abundant and renewable resources.

Natural fibers are used in various applications such as building materials, particle boards, insulation boards, human food and animal feed, cosmetics, medicine and for other biopolymers and fine chemicals.

1. Natural Fiber Reinforced Composites:

The interest in natural fibre-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibres are more and more often applied as the 9 reinforcement of composites.

Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites.
The natural fibre-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military

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applications, building and construction industries ceiling paneling, partition boards, packaging, consumer products, etc.

Fig 1. The life cycle of biodegradable natural fibre reinforced composites.

Fig 2. Animal Fibres.

Fig 3. Natural Fibre Plants.

II. LITERATURE REVIEW

Many research papers have contributed to the development of carbon fibre reinforced polymer matrix composites in terms of strength, stiffness, creep, impact and considerable amount of research is been carrying on the secondary properties of the CFRP composites i.e Tensile and bending behaviour and there is huge scope for the composites in adverse conditions like high temperatures, impact and sudden loads and chemical resistance.

These composite materials sometimes depart from their designed specifications as some defects, such as manufacturing defects, cause them to deviate from the expected enhancement in mechanical properties. These manufacturing defects involve misalignment, waviness, and sometimes breakage of fibres, fibre/matrix debonding, delamination, and formation of voids in the matrix of a composite material.

An increase of 1% voids content in composites and leads to a decrease in tensile strength (10–20%), flexural strength (10%), and interlinear shear strength (5–10%), respectively.

It can be eradicated by manipulating the processing parameters of manufacturing processes.Many research papers have contributed to the development of carbon fibre reinforced polymer matrix composites in terms of strength, stiffness, creep, impact and considerable amount of research is been carrying on the secondary properties of the CFRP composites i.e Tensile and bending behaviour and there is huge scope for the composites in adverse conditions like high temperatures, impact and sudden loads and chemical resistance.

1. Study of moisture absorption in natural fiber plastic composites (W. Wang, M. Sain *, P.A. Cooper)-2005
This study led to the following conclusions:
At high fiber loading when fibers are highly connected, the diffusion process is the dominant mechanism; while at low fiber loading close to and below the percolation threshold, the formation of a continuous network is key and hence percolation is the dominant mechanism. The model can be used to estimate the threshold value which can be in turn used to explain moisture absorption and electrical conduction behavior. However, it is still on the preliminary stage; further work is needed to improve the accuracy of its prediction.

- **2. Effect of moisture absorption on the mechanical performance of natural fiber reinforced woven hybrid bio-composites (Vijay Chaudhary, Pramendra Kumar Bajpai & Sachin Maheshwari)-2018**

Percentage of water absorption was almost linear with respect to square root of time and very rapid from 0 to 84 h for all the bio-composite specimens. After that, it reaches its saturation level at 130 h and then became constant. For this duration, maximum percentage of water uptake was 4.5% by jute/hemp/epoxy hybrid composite.

- Results of hardness (Shore-D) values of water immersed bio-composite specimens show that hardness is almost unaffected due to moisture uptake.
- Experimental results have revealed that tensile properties are severely affected due to water absorption. There is a minimum 11% to maximum of around 47% reduction in tensile strength values in different composites due to moisture absorption.
- Tensile modulus is almost half way reduced due to water uptake. A minimum of 40% and maximum 51% reduction in modulus values has been observed in different combinations of developed bio-composites.
- Water absorption up to saturation level has seriously influenced the flexural properties of the developed composites and hybrid composites. A maximum reduction (45%) in flexural strength of water saturated hemp/epoxy composite was recorded. Flexural modulus has also shown a maximum percentage reduction of around 40% due to water absorption.
- There is substantial variation in the percentage reduction in flexural properties for different composites due to reinforcement of different combination of natural fibers.
- Morphology of water saturated composite specimens after tensile and flexural testing has concluded that composite interface has got majorly affected. This is due to hydrophilic nature of natural fibers which absorbs moisture and results in debonding, dislocation and fiber fracture

3. Effect of moisture absorption on the properties of natural fiber reinforced polymer composites: (Awasthi Aditya Bachchan, Partha Pratim Das, Vijay Chaudhary)-2020

- In the present study, a dense review is done on the effect of moisture absorption of natural fibre reinforced polymer composites.
- When developed composite comes in the contact of any moisture, reinforced fiber absorbs the moisture particles due to their hydrophilic nature.
- Moisture absorption decreases the fibre strength. The moisture absorption capacity increase with an increase in fibre content.
- Due to moisture absorption, microcracks get initiated in the fibre. Moisture absorption capacity increase with time, but get saturated after reaching the saturation point, after which it becomes constant.
- Natural fibers absorb more water than synthetic fibers due to which use of epoxy, unsaturated polymer resin gel, AESO, etc. as coating helps in prevention of delamination and decreases water absorption.
- Due to advancement in technology, chemical treatment can be done to reduce the water absorption capacity.

4. Mechanical characteristics of hybrid composites based on flax, jute and glass.(MA Abd El-baky, MAAttia, MMA bdelhaleem and MA Hassan) -2020

- The materials used here are flax, jute and glass fibre.
- Test specimens were fabricated by vacuum bagging process.
- In this investigation tensile, flexural and impact were carried out at room temperature, tensile and flexural test were carried out on UTM(UNIVERSAL TESTING MACHINE).
- Impact testing was carried out on IZOD Impact Testing Machine.
- In this work, composite laminates based on epoxy resin and rein forced with three types of fibre flax, jute and glass were produced by hand layup.

5. Tensile and flexural properties of polymer composites reinforce by flax, jute and sisal (Asma Benkhelladi, Hamdi Laouici & Ali Bouchoucha)

- The influences of type of fibres, such as flax, jute and sisal, the type of chemical treatment and the volume fraction of fibre on the mechanical properties such as tensile strength, tensile modulus, flexural strength and flexural modulus of the composites, were evaluated.
- Mathematical models for mechanical properties were developed using the response surface methodology (RSM). Statistical analysis of the results showed that the mechanical properties are influenced principally by the volume fraction of fibre, then the type of fibres.
- On the opposite side, the type of chemical treatment has a very weak significance effect. Then, the best mechanical proprieties of composites were achieved at the highest volume fraction of fibre and when used the sodium bicarbonate $NaHCO_3$ for treated fibres.
- Finally, the developed hybrid composite exhibited superior properties compared to the previous composites based on individual fibre composites when the fibre content is at 80 wt% of jute and 20 wt% of flax.

6. Fabrication and testing of sisal fibre reinforced polymer composites:
6.1 (Dr. Richard Parnas, Dr. Montgomery Shaw)-2019

- Materials used are sisal Fiber and Polymer Composites.
- Process parameters are Heat Clean the Fabric in the Oven, Stir the Resin Mixture, Vacuum the Resin in the Vacuum Oven, Inject the Resin to the Mold, Mold Curing in the Heat Press.
- Tensile test results shows that the hybrid natural composite has excellent properties under tensile, flexural loading.Charpy Impact setup is employed to perform the impact test.

7. Experimental Investigation of Mechanical behavior of Jute-Flax Based Glass Fiber Reinforced Composite
7.1 (B. Vijaya Ramnath*, C. Elanchezhian, P. V. Nirmal, G. Prem Kumar)-2020

- Materials used are Jute-Flax based fiber composites.S

- These composites are fabricated using hand lay-up technique.
- Epoxy resin alongside with HY951 hardener is used as the binding agent throughout the layer.
- Glass fiber laminates are used on both sides for improving the surface finish and surface hardness. The volumetric fraction is such that one third of total volume is occupied by Jute and Flax fibers done using Rockwell hardness testing machine.

Table 3. Impact properties of composites

Composite specimen	Energy absorbed (J)	Impact strength (J/m)
GFRP+JUTE	13	1181.8
GFRP+JUTE+FLAX	11	1000

7.2 Comparative evaluation on properties of hybrid glass fiber-sisal/jute reinforced epoxy composites:

Natural fibers exhibit superior mechanical properties such as flexibility, stiffness and modulus compared to glass fibers. In the recent days natural fibers such as sisal and jute fibers are replacing the glass and carbon fibers owing to their easy availability and cost. The layer sequence has greater effect on flexural and inter laminar shear properties and placing the GFRP layers at the ends possess good mechanical strength. Sisal/jute fiber composites are environment friendly and user-friendly materials and have very good elastic properties. Yan Li et al studied that sisal fiber is the promising reinforcement because of low density, high specific strength, no health hazards and finding applications in making of ropes, mats, carpets, fancy articles etc.

Tensile properties of palm/jute fiber reinforced polymer hybrid composites are carried out by Jawaid et al. They have prepared hybrid natural fiber composites taking palm fiber as skin and jute as core material. They observed that the tensile properties slightly higher for the jute as skin and palm fiber as core material. Jawaid et al conducted experiment on effect of jute fiber loading on tensile and dynamic mechanical properties of oil palm composites.

They have identified that the tensile properties of jute oil palm fiber hybrid composites are increased substantially with increasing the content of jute fibres loading as compared to oil palm epoxy composites. The strength properties of natural fiber composites are somewhat lower, because of less stiff and typically less brittle. Reinforcing glass fiber into the sisal polypropylene composites enhanced tensile and flexural properties without any effect on tensile and flexural module. In addition to this, adding sisal fiber with glass fiber improves thermal properties and water resistance of the hybrid composites.

III. EXPERIMENTAL MATERIALS

In this experiment, for fabricating the composites specimen Sisal (Agave sisalana), Jute (Corchorus oliotorus) and Palm fibers are used. The raw sisal and jute fibers are collected in the form of residues from Dharmapuri District, Tamil Nadu, and India. The epoxy resin and hardener Tri Ethylene Tetra Amine (TETA) are provided by M/s. Sakthi fiberglass Ltd., Chennai, India. The Glass-Fiber of bi-directional woven mat with 600gsm is used for the fabrication of specimen. The physical properties of the natural fibers are presented in Table

1. Table 1. Physical properties of Natural fibers (Sisal – Jute and palm).

Physical property	Sisal fiber	Jute fiber	Palm fiber
Density (g/cm3)	1.34	1.48	1.21
Tensile strength (KN/mm2)	610-720	410-780	58-203
Stiffness (KN/mm)	30-38	10-30	5-10
Elongation at break (%)	2-31.9	10-23	5-10
Price of raw fiber (Rs/kg)	60-70	40-50	180-230

1. Tensile Properties:

The composite samples are tested in the universal testing machine (UTM) and the stress-strain curve is plotted. The typical graph generated directly from the machine for tensile test for sisal/GFRP is presented in Fig. 1. and for jute/GFRP is presented in Fig. 2.

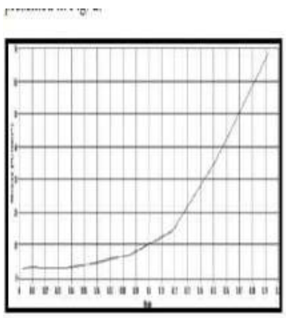

Fig. 1. Stress strain curve for tensile test in sisal/GFRP composite

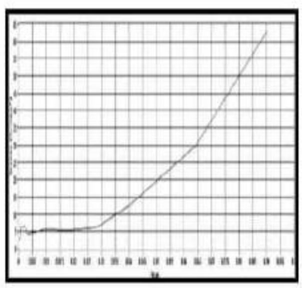

Fig. 2. Stress strain curve for tensile test in jute/GFRP composite

2. Studies on mechanical properties f sisal and jute fibre hybrid sandwich composite: C. Sivakandhan, G. Murali, N. Tamiloli, L. Ravikumar

Epoxy resin (LY556 grade) and hardener (HY951) is taken as the matrix and binder for the sisal and jute fiber combination. The five different kinds of samples of jute/epoxy and sisal fiber/epoxy composite were made with the fiber-matrix weight ratio of 35%. After fabrication, the test specimens were prepared as per in the ASTM standards. The result shows the co-axial tensile strength of jute/epoxy and sisal fiber/epoxy composite the result was increased 32% than sisal epoxy. The tensile, flexural, compression strength and impact of jute fiber/epoxy composites are higher than those of sisal fiber/epoxy composites at the same fiber loading.

Since the present study deals with the manufacturing of hybrid composites, the material for reinforcement is chosen as sisal fiber, and jute fiber due to its suitable mechanical properties and epoxy resin (LY556 grade) and hardener (HY951) is taken as the matrix and binder for the composite. This process carried out with the help of compressive moulding. Work piece prepared in the dimension 300x300x3 mm was used for casting the composite sheet. There are five different kinds of samples were made with the fibre–matrix weight ratio of 35%.The sample is tabulated below the Table 1.

Table 1
Composite sample details.

Sample number	Wt % of jute fiber	Wt % of Sisal fiber	Wt % of Epoxy and Hardener
Sample 1	0	35	65
Sample 2	10	25	65
Sample 3	20	15	65
Sample 4	25	10	65
Sample 5	35	0	65

3. Study of banana and coconut fiber Botanical composition, thermal degradation and textural observations, Bioresource Technology.
(Ketty Bilba, Marie-Ange Arsene, Alex Ouensanga)-2007
Bilba examined Four fibers from banana-trees (leaf, trunk) and coconut-tree (husk, fabric) before their incorporation in cementitious matrices, in order to prepare insulating material for construction. Thermal degradation of these fibers was studied between 200 and 700 °C under nitrogen gas flow. Temperature of pyrolysis was the experimental parameter investigated. The solid residues obtained were analyzed by classical elemental analysis, Fourier Transform Infra Red (FTIR) spectroscopy and were observed by Scanning Electron Microscopy (SEM).

This study has shown (1) the relation between botanical, chemical composition with both localization of fiber in the tree and type of tree; (2) the rapid and preferential decomposition of banana fibers with increasing temperature of pyrolysis and (3) the rough samples are made of hollow fiber.

4. Correlation between the distribution of lignin and pectin and distribution of sorbed metal ions (lead and zinc) on coir (Cocos nucifera L.) Kathrine Conrad, (2008)
Conrad investigates the connection between the distribution of lignin and pectin and the loading of Pb and Zn on coir. The coir consisted mainly of xylem and a fiber sheath. The lignin was evenly distributed in the cell walls of the fiber sheath, but in the xylem, there was no detectable content in the compound middle lamella, and a smaller content of lignin in the secondary walls than in the walls of the fiber sheath.

The only detectable content of pectin in the fiber sheath walls was in the middle lamella, cell corners and extracellular matrix, while in the xylem, the pectin was almost evenly distributed in the wall, with a higher concentration in the middle lamella and cell corners. All cell walls facing the lacuna had a high content of pectin. Simple correlation between the loading of metal ions and the distribution of lignin or pectin, these investigations point at no correlation with lignin and a positive correlation with pectin.

5. Characterization and utilization of natural coconut fibers composites, journal of Materials and Design Wang Wei, Huang GU, (2008).
Wang and Huang had taken a coir fiber stack, characters of the fibers were analyzed. Length of the fibers was in the range between 8 and 337 mm. The fibers amount with the length range of 15-145 mm was 81.95% of all measured fibers. Weight of fibers with the length range of 35- 225 mm accounted for 88.34% of all measurement. The average fineness of the coir fibers was27.94 tex. Longer fibers usually had higher diameters. Composite boards were fabricated by using a heat press machine with the coir fiber as the reinforcement and the rubber as matrix. Tensile strength of the composites was investigated.

6. Prediction of fatigue resistance of short-fiber-reinforced polymers T.M. Dick , P.-Y.B. Jar , J.-J.R. Cheng, (2009)
Dick conduct static and cyclic 4-point bending tests on glass-filled polycarbonate, to collect results for evaluation of a theoretical model on its capability to predict the fatigue life and the residual strength after the cyclic loading The study quantifies the effects of loading conditions, i.e. the stress ratio and the maximum stress level, on the damage development. The paper demonstrates the possibility of expressing each of the model parameters as a function of single variable that is stress ratio, maximum stress level, or a material-dependent constant.

IV. MATERIALS PREFERRED

- Epoxy resin
- Harder
- Paddy Straw fiber
- palm fiber
- Jute fiber
- Coconut fiber

1. Epoxy Resin:
A common starting material for the epoxy resin is Di glycidyl ether of bisphenyl A (DGEBA). In general, the

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tensile modulus, glass transition temperature, and thermal stability as well as chemical resistance are improved with increasing cross-link density, but the strain-to failure and fracture toughness are reduced. Epoxy resin is very commonly used in aerospace structures. Some of the advantages of epoxy resin are Good adherence to metal and glass fibres Curing agents, and modifiers are available Absence of volatile matters during curing Low shrinkage during curing excellent resistance to chemicals and solvents.

2. Making of Reinforcement:
The unidirectional Carbon fibre and Basalt fibre is used as fibre for our laminates and Epoxy resin (LY556) and Hardener (HY951) are mixed in the ratio of 10:1 and used as the matrix for the preparation of laminate in which the weight of the fibre and weight of the matrix in the laminate should be in the ratio of 1:1. The Carbon Fabrics have a density of 200 GSM and thickness of about 0.25mm.

The following steps are followed in mixing of an epoxy and hardener for reinforcement.

- Determine the proper mixing ratio for your application and environmental temperature using the information on the epoxy container and/or technical data sheets.
- Place the clean container on the scale and zero out the scale using the"Tare".
- Add the proper amount of resin to the container. If you pour too much into the container, adjust your calculation to make sure you add the correct amount of hardener to achieve an accurate ratio.

Example: If you measured 475 grams of resin and the ratio by weight of resin to hardener is supposed to be 100:33 PPW (100 parts resin to 33 parts hardener), calculate the amount of hardener by taking 475g x 1.33 = 631.75g total grams when mixed. Or 475g x.33 = 156.75g this will be the total amount of hardener only that would need to be added.

Slowly add the hardener to the same container the resin was measured in until the total weight is 631.75 grams. *Since most digital scales do not measure in fractions of a gram you can round the number(s) up or down to the nearest whole number, i.e. 632.

(a)

(b)
Fig 5. Preparation of Epoxy Resin.

- Mix the materials thoroughly (for large batches, use caution and be aware that greater chemical reactions and faster cures times are likely toresult).
- Stir well, being sure to scrape the sides and bottom of the container. Keep stirring until the mixture is no longer hazy. A few air bubbles arenormal.
- Mixing takes anywhere from a few to several minutes, depending on the viscosity of the material and the size and shape of the container. Cooler temperatures will also result in a longer mixing time. A good rule of thumb is to mix for 2-3 minutes until the mixture is uniform in color and viscosity. Then, when you think you've mixed sufficiently, stir for another 30 seconds, being sure to scrape the sides and bottom of the container. You can also mix using the "two-container method":

Mix in one container and then transfer the contents into a second clean container.

- Use a flat ended mixing stick to reach the inside corners/creases of the initial container to make sure all material are transferred to the second container.
- If using a power mixer or mixing bit, the sides, bottom, and corners of the mixing container should still be scraped periodically to ensure a thorough mix.

Filled epoxies, such as tooling surface coats: When mixing filled epoxies, it is recommended to premix the individual components prior to combining, as heavy particles of the filled materials tend to settle. Mixing times for part A and B combined may need to be increased as much as four times the durations noted in steps above, due to its thick consistency.

3. Palm Fibre:

- Fiber from Date Palm and producing quality yarn from that, has anyone ever imagined?
- For the first time in the world, Egyptian researchers at the Consortium have developed highperformance sustainable textile fibers from date palm by products like fronds, leaves, leaflets, rachis etc. The aim of this study was to extract high-performance fiber from the by products of date palm using a combined alkaline-

mechanical process and to study the identification of physiochemical, morphological and mechanical properties.

Fig 6. Date palm tree and fiber.

3.1 Physical and Mechanical Properties of Date Palm Fiber:

Even this fiber is produced from the byproducts of date palms, deforestation or food crisis will not create any such problems. This particular fiber has certain properties such as- 100% biodegradable and compostable; structurally tensile strength is 5 times higher than steel and same as flax & sisal, thermal insulation properties are higher than carbon fiber. Physical properties of the natural fibers are crucial in determining their quality for various industrial applications as well as natural fiber composites. Mechanical properties of natural fibers are powerfully affected and determined by many necessary variables like structure, micro-fibrillar angle, chemical composition, cell dimensions and defects.

3.2 Some specific characteristics of date palm fiber are mentioned below:

- Length: 20-250 mm
- Diameter: 100-1000 µm
- Density: 0.9-1.2 g/cm3
- Specific Modulus: 7 approx.
- Thermal Conductivity: 0.083 W/m K
- Tensile Strength: 58-203 MPa
- Elongation at Break: 5-10%

3.3 Sources of Date Palm Fibre:

There are more than 140 million date palms in the Middle-East and North Africa. Egypt is currently the largest producer of dates, as are Iran, Saudi Arabia, UAE, Pakistan and Sudan. More than 48.8 million tons of waste is generated every year by pruning date palms for agriculture. So, the production of date palm fiber is currently a big success. Sustainable textile fibers are found in all these countries from date palm byproducts such as fronds, leaves, leaflets, rachis, fruit branches etc.

Fig 7.Palm fibre.

4. Jute Fibre:

Jute is a long, soft, shiny bast fiber that can be spun into coarse, strong threads. It is produced from flowering plants in the genus Corchorus, which is in the mallow family Malvaceae. The primary source of the fiber is Corchorus olitorius, but such fiber is considered inferior to that derived from Corchorus capsularis."Jute" is the name of the plant or fiber used to make burlap, hessian or gunny cloth.

Fig 8. Jute Fibre.

5. Paddy Straw Fiber:

Rice straw fibers have been used as reinforcing fillers in different polymers, tow composites were prepared by using polyvinyl alcohol and polystyrene polymers with different ratio of polymers. The pressed samples were subjected to various electron beam irradiation dose. The results indicated that, flexural strength, impact strength and modulus of elasticity increase with increasing the polymer ratio in the mix composition.

It was found that the water absorption and thickness swelling percentages of rice straw fiber polystyrene composites decrease with increasing the polystyrene content in the same composition, while its values for rice straw polyvinyl alcohol composites improve. These are attributed to hydrophobic and hydrophilic characteristics of the tow composites. The improvement of physico-mechanical properties of both composites with the increase of electron beam irradiation dose are probably attributed to randomly initiated chain reactions, which started by the reactive centers created by electron beam. These observations were confirmed by IR spectrometer and SEM studies.

Fig 9. Paddy straw fibers.

6. Coconut Fiber:
Coconut fibre falls in the category of hard fibre due its high flexural rigidity (1100 mN-mm FAO, 2013) and large diameter (320 µm (100–795 µm)). It possesses highly variable fibre length (183 mm (44–305 mm)), lower modulus (200 cN/tex-m) and tenacity (11.25 cN/tex). Extensibility (21.5%–35%) and specific work of rupture (12.2 cN/tex-m) is very high and an exception in case of lignocellulosic fibres. Lack of inter-fibre cohesiveness in coconut fibres create problem in handling of fibre sheet (sliver). Coconut fibre due to its low length – diameter ratio (650), high coarseness and flexural rigidity – is difficult to spin into finer yarn.

The fibre showed 59.3% instantaneous recovery and 81.5% recovery after 2 h on removal of compressive load on fibre bulk. Lignin content of the fibre is very high (30%–45%) as compared to other lignocellulosic fibre (viz., jute, sisal, flax). Lignin/cellulose ratio of coconut fibre is more or less similar to that of hard wood. XRD reveals bigger crystallite size, presence of large amount of non-cellulose matter and low crystallinity (45%). The lower crystallinity of coconut fibre facilitates absorption of moisture (M. R., 11.7%) and diametrical swelling up to 15%. The apparent hydrophobic nature of coconut fibre may be due to deposition of comparatively more lignin and waxes than cellulosic matter on the fibre surface. Oxygen to carbon (O:C) ratio of raw coconut fibre surface is much lower (0.40) than the O:C ratio of the cellulose, hemicelluloses and pectin which is about 0.83 and is similar to the O:C ratio of lignin (0.35).

Fig 10. Coconut fibre.

The cross-section of coconut fibre is circular and has a spongy view due to presence of a large number of micro-voids. The fibre has outsized central lumens. Probably a very circular cross-section makes the raw coconut fibre lustrous in appearance and imparting high flexural rigidity. High extensibility of the fibre is due to its helical arrangements of micro-fibrils at much higher angle of orientation (45 degrees).

Fig 11. Jute fibre.

FTIR and thermal analysis indicates cellulose and lignin as major components. TGA and NMR reveal higher methyl-aryl ether groups as compared to aromatic groups in lignin of coconut fibre. Treatments causing removal of non-cellulosic materials many times induced higher crystallinity to the fibre than its apparent cellulose content. Ash and fat/wax content are 1.8% and 1.3%, respectively. Electrical resistance (4 Ω-kg/m^2) and microbial resistance of coconut fibre are much higher as compared to other lignocellulosic fibres viz., jute and sisal.

V. PROCEDURE FOR FABRICATION OF FIBRES

- First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface.
- Reinforcement in the form of woven mats are cut as per the mold size and placed at the surface of mold after.

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Fig 12. Cutting of Palm fibre.

Fig 13. Cutting of Jute fibres.

- Then the thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold.
- The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked.
- After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further the same procedure is applied for all the samples separately for sisal alone, jute alone and sisal –jute (50-50%) fibres.

1. Sequence of Fibres:

Jute	Paddy	Coconut	Palm	Paddy	Jute	Coconut
Weight of	JSP -1	JSP -2	JSP -3	JSP-4	JSP-5	JSP-6
Fibre	140	179	153	190	188	145
Epoxy	320	400	400	320	475	420
Hardener	32	40	40	32	47.5	42

2. Hand Lay-Up Process:

A schematic of the HLU process is shown in Fig. 4.4. Production of a composite component is done by manual laying up of reinforcement layers and liquid resin layers in sequence. A roller is used for the compaction and the homogeneous fibre wetting. Then the component is cured under room temperature and it is removed after solidification.

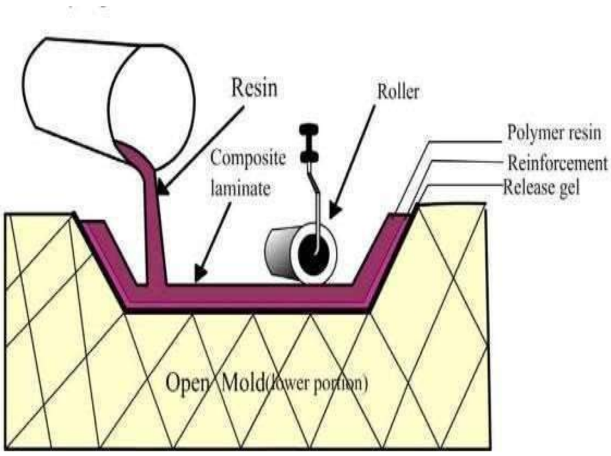


Fig 14. Hand Layup process.

The hand lay-up method, also called the wet lay-up method, is one of the most traditional methods used in the industry. It is a very simple process, where each ply is handled only by hand, and is stacked layer-by-layer up to the desired thickness. Although this method is reliable, it requires a lot of labor, and the procedure requires more time than advanced manufacturing methods. The quality is dependent on the skill of the employee. This method also has a production limit in terms of the complexity of the aircraft. Any materials are suitable for this method, e.g., carbon or glass fibre, and in any kind of form (continuous fibre, chopped fibre, woven, etc.). Brushes and rollers are used in this method to apply the resin and reduce air bubbles.

There is no heat required during the curing process, and it is usually left until cured at room temperature. Several works reported on using the hand lay- up method in the fabrication process. There are also other research works using the hand lay-up method for various types of material. HLU process allows the manufacture of product wide range of applications and geometries with low initial investment.

Despite these advantages, there are several disadvantages which include low reinforcement volume fraction, no uniform quality leading to uneven thickness, and no uniform distribution of reinforcement material and matrix. Being an open mold process, it emits a large volume of styrene which makes the process non environmental friendly. Furthermore, post processing fabrication is more often required which compromises the reliability of the product. Longer production time, lower production rate, and high involvement of skilled labour make the process unsuitable for large scale and complex geometry production forcing the manufacturers to explore the options of closed mold alternatives such as liquid composite molding (LCM) techniques.

3. Vacuum Bagging method:

- Vacuum bagging is a very flexible process for consolidating fibre-reinforced polymer laminates of a wide range of shapes and sizes.
- The composite to be consolidated (e.g. hand lay-up) is placed on a single-sided mould. The material is then covered with an impervious film (the "vacuum bag"), which is sealed around the edge of the part. By evacuating the air between the mould and the vacuum bag using a vacuum pump, the part is consolidated under atmospheric pressure.
- The process is often performed in an oven to assist with the curing of the resin. Because the vacuum bag material can be readily cut to size, it is a very flexible process in terms of the dimensions of the parts that can be consolidated.
- Vacuum bagging adds one atmosphere of pressure to a system. Although the technique is relatively inexpensive and easy to perform, it is worthwhile to understand the principle of atmospheric pressure and how it is measured so that you know if you have a problem with your system.

Fig 15. Vacuum Bagging Process.

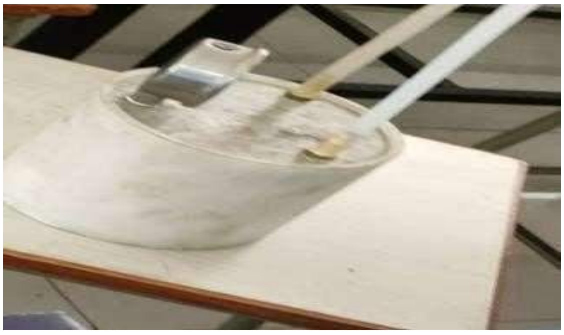
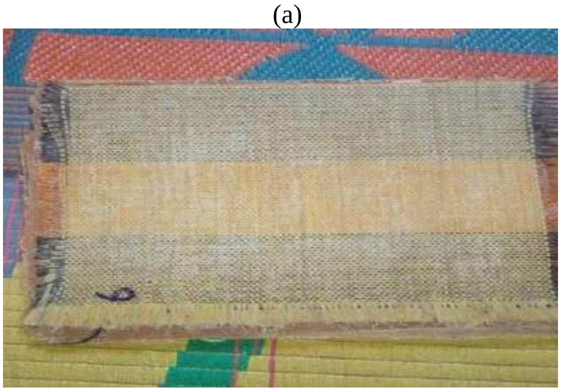


Fig 16. Vacuum Chamber.

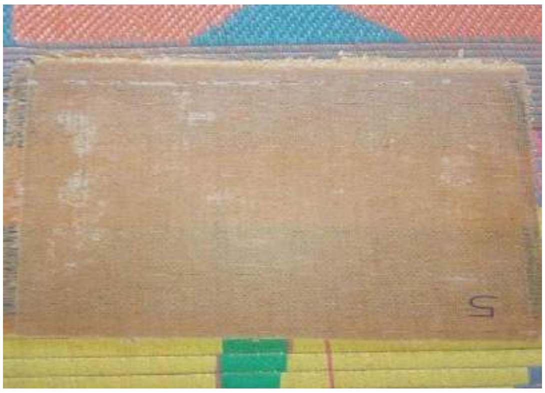
Fig 17. Vacuum Pump.

4. Pictures of Laminated Sheets:

(a)



(b)



(c)

Fig 18. Pictures of Laminated Sheets.

VI. WATER JET MACHINE

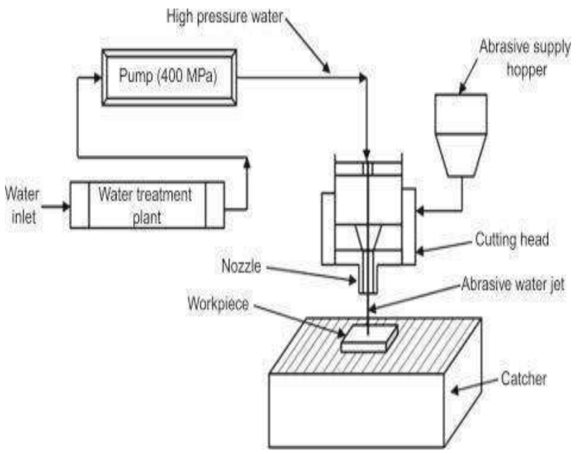


Fig 19. Water Jet machine.

- In WJM, a high velocity jet of pure water (sometimes mixed with stabilizer) is used to erode material.
- Material removal from the workpiece takes place only due to the erosive action of water jet.
- No mixing chamber is desired as abrasive is not mixed with water.
- The jet of water does not possess high power, and thus it cannot be advantageously applied for cutting metals, alloys and ceramics.
- No cost of abrasive is associated with WJM process.
- It is free from the risk of abrasive embedment on the finished surface.

VII. SPECIMEN DIMENSIONS

The specimens are made according to the ASTM Standards and are fabricated.

Table 1. Specimen Dimensions.

Fig 20. Specimen after cutting.

VIII. TESTINGS

1. Moisture Absorption Test:

1.1 Scope: Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption include: type of plastic, additives used, temperature and length of exposure. The data sheds light on the performance of the materials in water or humid environments.

1. 2 Test procedure:

For the water absorption test, the specimens are dried in an oven for a specified time and temperature and then placed in a desiccator to cool. Immediately upon cooling the specimens are weighed. The material is then emerged in water at agreed upon conditions, often 23°C for 24 hours or until equilibrium. Specimens are removed, patted dry with a lint free cloth, and weighed.

1.3 Formula:

Water absorption is expressed as increase in weight percent.

Percent Water Absorption = [(Wet weight - Dry weight)/ Dry weight] x 100

Fig 21. Specimen for Hardness testing.

TESTING	ASTM STANDARDS	DIMENSSIONS (mm)
Flexural test	D790	150 X 15
Tensile test	D3039	250 X 25
Hardness test	D2240	50.8 X 50.8
Moisture absorption test	D5229	100 x 100 x 2
Impact test	D256	80 X 12

Fig 22. Mettler balance.

2. Flexural Testing:

Fig 23. Flexural testing machine.

Flexural tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample.

Unlike a compression test or tensile test, a flexure test does not measure fundamental material properties. When a specimen is placed under flexural loading all three fundamental stresses are present: tensile, compressive and shear and so the flexural properties of a specimen are the result of the combined effect of all three stresses as well as (though to a lesser extent) the geometry of the specimen and the rate the load is applied.

The most common purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural strength is defined as the maximum stress at the outermost fibre on either the compression or tension side of the specimen. Flexural modulus is calculated from the slope of the stress vs. strain deflection curve. These two values can be used to evaluate the sample materials ability to withstand flexural or bending forces.

3. Scanning Electron Microscope:

The surfaces of the raw fish scales and the composite specimens are examined directly by scanning electron microscope JEOL JSM-6480LV. The scales are washed, cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. Similarly the composite samples are mounted on stubs with silver paste. To enhance the conductivity of the samples, a thin film of platinum is vacuum evaporated onto them before the photo micrographs are taken.

Fig 24. Scanning electron microscopy.

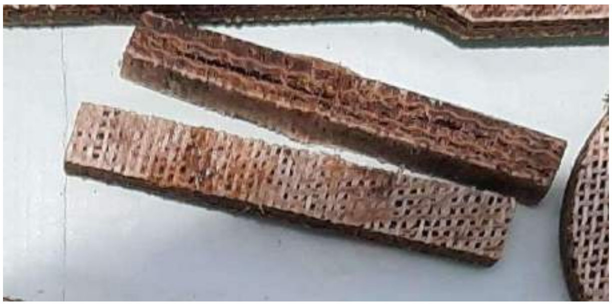


Fig 25. Specimen.

Fig 26. Specimen Samples for Tensile Test.

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4. Hardness Test:
The application of hardness testing enables you to evaluate a material's properties, such as strength, ductility and wear resistance, and so helps you determine whether a material or material treatment is suitable for the purpose you require. The definition of hardness testing is 'a test to determine the resistance a material exhibits to permanent deformation by penetration of another harder material.'

Fig 27. Brinell Hardness Testing Machine.

However, hardness is not a fundamental property of a material. Therefore, when drawing conclusions of a hardness test, you should always evaluate the quantitative value in relation to: The given load on the indenter A specific loading time profile and a specific load duration A specific indenter geometry

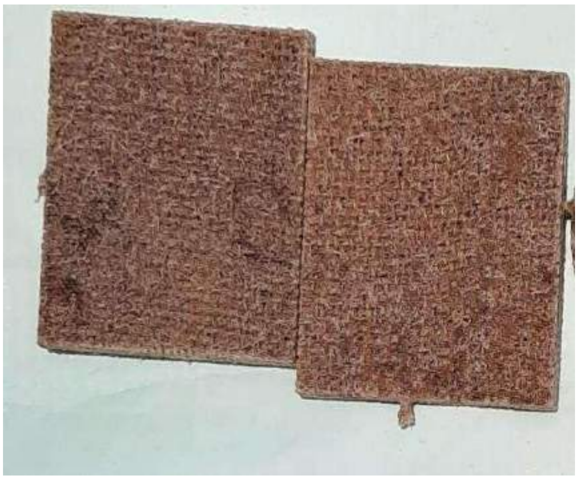

Fig 28. Specimen Sample for Hardness Test.

5. Tensile Test:
A composite specimen is subjected to Tensile testing to measure the force required to break the test specimen and the extent to which the specimen stretches or elongates to that breaking point. The physical properties of materials at a temperature that stimulate intended end user environment.

The most common specimen for ASTM D3039 has a constant rectangular cross section, 25 mm wide and 250 mm long is used to study. Random directional tensile specimens were cut in the longitudinal and transverse direction for tensile test. According to ASTM D 3039 type IV sample the tensile test specimens were carried out, using a tensile testing machine with crosshead speed of 2 mm/min and a gauge length of 150 mm. Three specimens were tested for each set of samples and meant values were tabulated in Table 2.

Name	YP(%YP)_Stress	Max_Stress	Fitted_Strain	Reduc.
Parameters	0.2 %	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
JSP-1	4.51739	34.7125	1.90000	0.02195

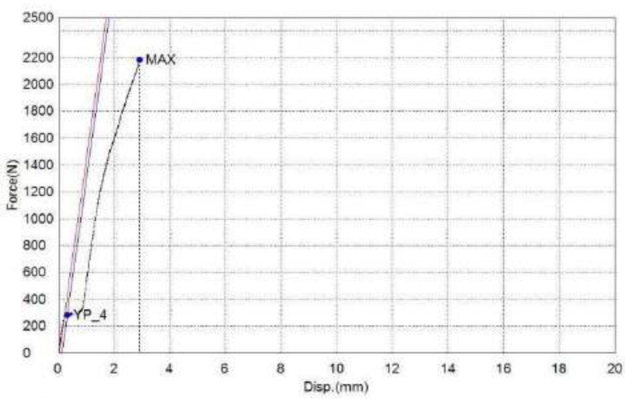

Fig 29. Graph of Tensile test JSP -1.

Name	YP(%YP) Stress	Max Stress	Fitted Strain	Reduc.
Parameters	0.2 %	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
JSP-3	3.36583	19.5304	1.64000	3.36033

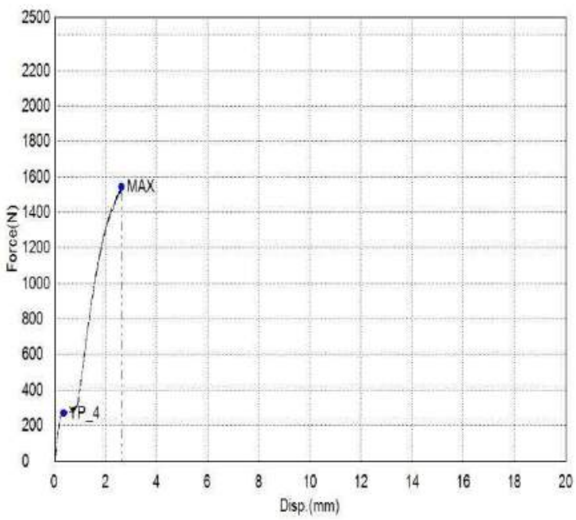

Fig 30. Graph of Tensile test JSP -2.

Name	YP(%YP)_Stress	Max_Stress	Fitted_Strain	Reduc.
Parameters	0.2 %	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
JSP-2	2.66978	23.3303	1.82000	8.99031

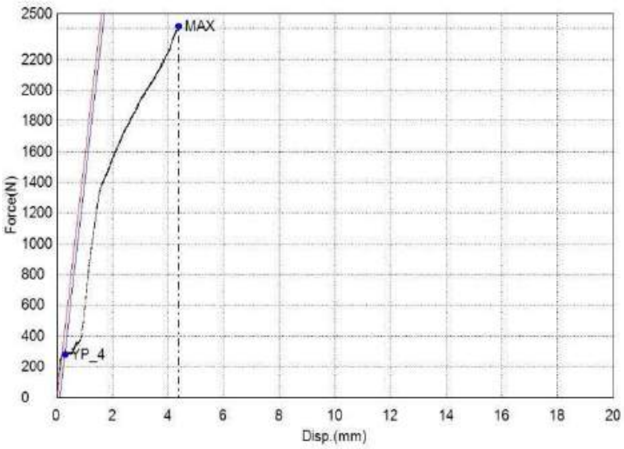

Fig 31. Graph of Tensile test JSP -3.

Name	YP(%YP)_Stress	Max_Stress	Fitted_Strain	Reduc.
Parameters	0.2 %	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
JSP-4	3.42008	22.8161	1.62000	13.1834

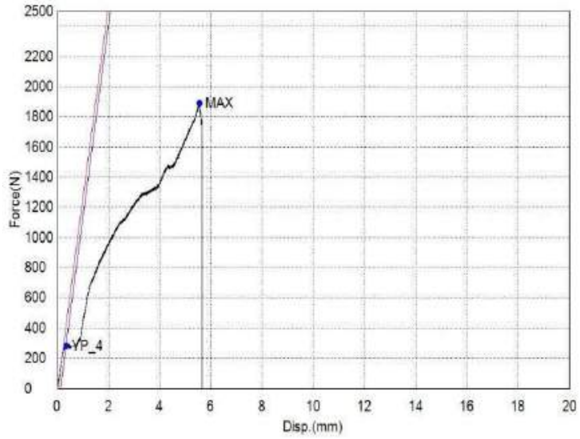

Fig 32. Graph of Tensile test JSP -4

Name	YP(%YP)_Stress	Max_Stress	Fitted_Strain	Reduc.
Parameters	0.2 %	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
JSP-5	5.72313	28.1491	1.50000	1.62968

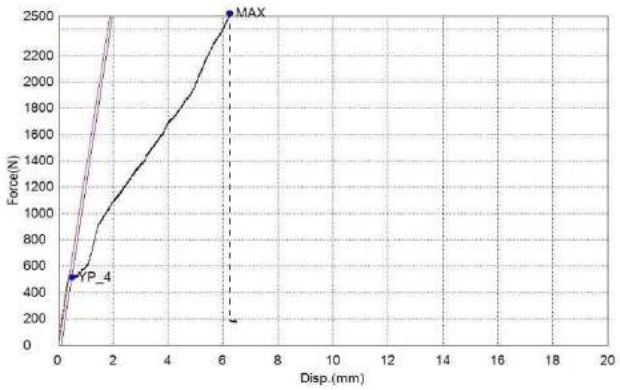

Fig 33. Graph of Tensile test JSP -5

Name	YP(%YP)_Stress	Max_Stress	Fitted_Strain	Reduc.
Parameters	0.2 %	Calc. at Entire Areas		
Unit	N/mm2	N/mm2	%	%
JSP-6	4.22272	31.7325	2.72000	3.35018

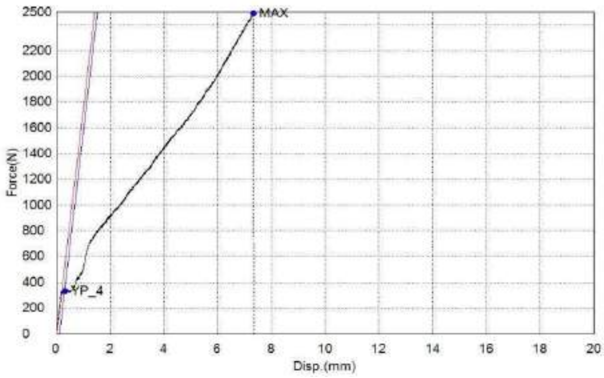

Fig 34. Graph of Tensile test JSP -6.

6. Flexural Test:

The flexural test was performed by the three-point bending method according to ASTM D 790, and a crosshead speed of 2 mm/min. 3-specimens was tested and the averages were calculated. The maximum load was applied in the middle of the specimen, when the specimen was freely supported by a beam. The flexural modules are evaluated from the slope of the initial portion of the load-deflection curve.

The Fig. 2 shows that incorporation of Jute and Sisal fiber at a 35:0 wt% relative weight fraction leads to hybrid composites having a superior flexural strength.The maximum flexural strength of the composite was 56.31 N/mm2 . Flexural strength is nothing but a strength combining the tensile and compressive strengths and deviates with the interfacial shear strength between the fiber and matrix. It was observed from Fig. 2 that the flexural strength and modulus of Jute/Sisal fiber/ epoxy composite increased with increasing jute fiber. If adding sisal fiber will reduce flexural strength.

Name	YP(%FS)_Stress	Break_Force	Max_Stress
Parameters	0.2 %	Sensitivity: 10	Calc. at Entire Areas
Unit	N/mm2	N	N/mm2
JSP-1	9.05236	73.7111	34.2405

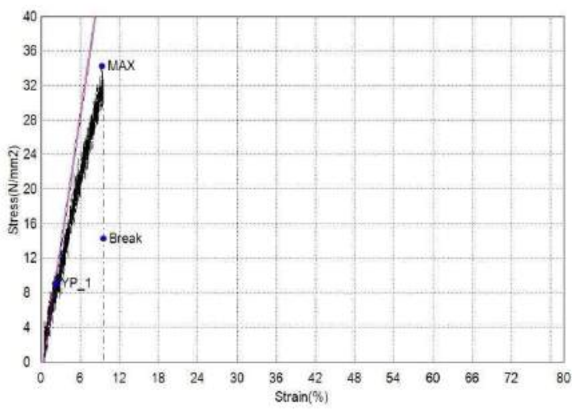

Fig 35. Graph of Flexural test JSP -1

Name	YP(%FS)_Stress	Break_Force	Max_Stress
Parameters	0.2 %	Sensitivity: 10	Calc. at Entire Areas
Unit	N/mm2	N	N/mm2
JSP-2	3.35683	13.6693	7.14269

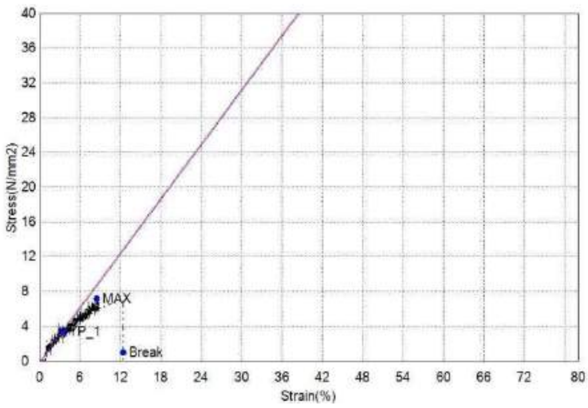

Fig 36. Graph of Flexural test JSP -2

Name	YP(%FS)_Stress	Break_Force	Max_Stress
Parameters	0.2 %	Sensitivity: 10	Calc. at Entire Areas
Unit	N/mm2	N	N/mm2
JSP-3	18.8149	1.82788	26.8317

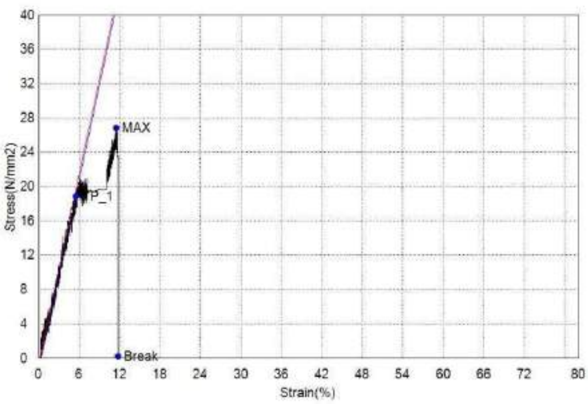

Fig 37. Graph of Flexural test JSP -3.

Name	YP(%FS)_Stress	Break_Force	Max_Stress
Parameters	0.2 %	Sensitivity: 10	Calc. at Entire Areas
Unit	N/mm2	N	N/mm2
JSP-4	1.29220	20.4643	3.19938

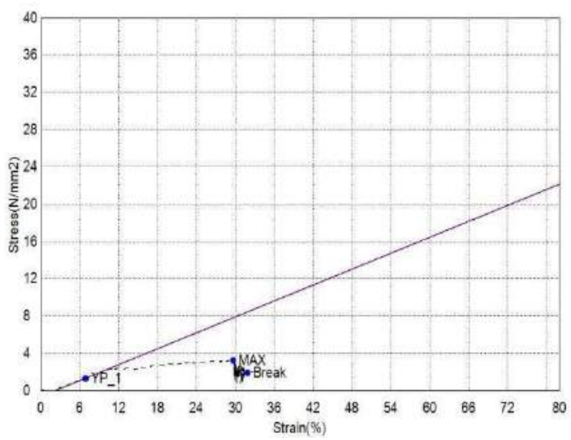

Fig 38. Graph of Flexural test JSP -4.

Name	YP(%FS)_Stress	Break_Force	Max_Stress
Parameters	0.2 %	Sensitivity: 10	Calc. at Entire Areas
Unit	N/mm2	N	N/mm2
JSP-5	8.13404	8.70228	11.6083

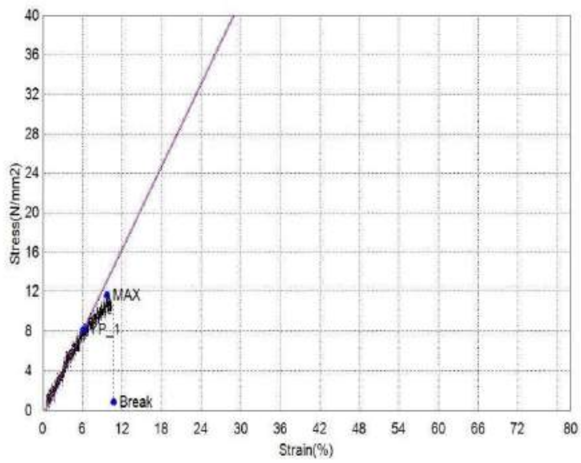

Fig 39. Graph of Flexural test JSP -5.

Name	YP(%FS)_Stress	Break_Force	Max_Stress
Parameters	0.2 %	Sensitivity: 10	Calc. at Entire Areas
Unit	N/mm2	N	N/mm2
JSP-6	5.06539	23.0869	10.2524

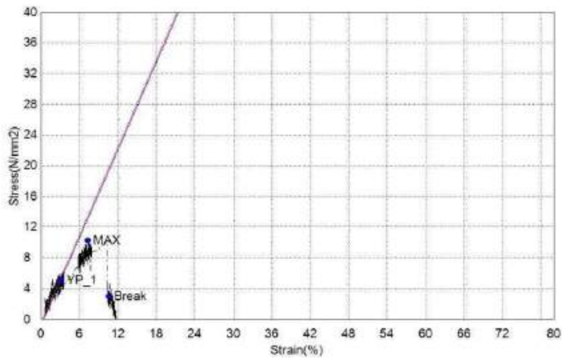

Fig 40. Graph of Flexural test JSP -6.

7. Hardness Test:

JPS-1	86	86	86	86
JPS-2	84	88	86	86
JPS-3	86	84	84	84.6
JPS-4	86	86	88	86.6
JPS-5	84	86	84	84.6
JPS-6	86	86	88	86.6

8. Optical Microstructure:

(a)


(b)
Fig 41. Figures of Optical microstructure.

IX. CONCLUSION

In the present scenario, there has been a rapid attention in research and development in the natural fiber composite field due to its better formability, abundant, renewable, cost-effective and ecofriendly features. This paper exhibits an outline on natural fibers and its composites utilized as a part of different commercial and engineering applications. In this review, many articles were related to applications of natural fiber reinforced polymer composites. It helps to provide details about the potential use of natural fibers and its composite materials, mechanical and physical properties and some of their applications in engineering sectors.

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