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Mechanical Properties of Chemically Treated Luffa Aegyptiaca Fiber Reinforced Epoxy Matrix Composites

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Abstract: *In recent year natural fiber composite material place a major role in aerospace and automobile industries. Natural fibers such as flax, hemp, kenaf and jute are derived from renewable resources and consequently are perceived as environmentally friendly materials. Natural fibers are reported to have advantages of lower cost and better stiffness per unit weight compared to other materials. In this project the natural fiber is Luffa aegyptiaca Fibers are alkaline treated and dried out in sunlight. The various wt % of discontinued fibers are laminated with epoxy resin and the laminates are prepared by hand layup process. The Mechanical properties of natural fiber composites such as tensile, compressive, impact and flexural strength has founded and compared. Then, SiO_2 nano particles synthesized in sol-gel method and they are induced with epoxy to improve the certain mechanical property of the composite material. Most major automobile manufacturers are currently using natural fiber Composites for different parts inside and outside cars and buses. Such as dash board ceilings, seat filling, door trim, door cladding. Consumer and industrial uses include flowerpots and lawn furniture.*

Keywords: Luffa Aegyptiaca Fiber; epoxy resin; mechanical properties; SiO_2 nano particles; NaOH solution.

1. Introduction

India, endowed with an abundant availability of natural fiber such as jute, coir, sisal, pineapple, ramie, bamboo, banana has focused on the development of natural fiber composite primarily to explore value added application avenues. The natural fiber composite can be very cost effective material especially for building and construction industry panels, fals ceiling partition board, packing, automobile, railway coach interior and storage devices. The development in composite material after meeting the challenges of aerospace sector have cascaded down for creating

domestic and industrial application. Composites, with light-weight, high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional material like metals, wood etc, here the natural fiber is Luffa aegyptiaca [1].

Loofa is derived from the cucumber and marrow family and originates from America Luffa cylindrica commonly called sponge gourd, loofa, vegetable sponge, bath sponge or dish cloth gourd, is a member of cucurbitaceous family. Loofa sponge is a lignocelluloses material composed mainly of Cellulose, hemicelluloses and lignin the fibers are composed of 60% cellulose, 30% hemicellulose and 10% lignin .The fruits of L. cylindrica are smooth and cylindrical shaped .mature Luffa sponge will produce at least 30 seeds. Some will produce many more .L. cylindrica has alternate and palmate leaves comprising petiole. The leaf is 13 and 30 cm in length and width respectively and has the acute-end lobe. It is hairless and has serrated edges. The flower of L. cylindrica is yellow and blooms on August-September. Fruit is green and has a large cylinder-like shape. The outside of the fruit has vertical lines and a reticulate develops inside of the flesh. L. cylindrica grows about 12 cm long. The stem is green and pentagonal and grows climbing other physical solid. The loofa sponge is cultivated, unlike the sponge produced with cellulose that is extracted from trees. The plant is cultivated in many countries, including Brazil, where its cultivation has an increasing economic importance [2][3].

Generally, L. cylindrica can be used in virtually all areas. Factors such as high surface area per volume, strong and durable structure, low specific gravity which makes it light and reasonable cost are characteristics of loofa making it a suitable alternative for use as a packing medium. Young fruits are edible and matured fibers are generally used in washing ships and decks and manufacturing slippers or baskets and used as shoes mats, The fibrous vascular system inside the fruit after separating from the skin, flesh and seeds, can be used as a bathroom sponge, as a component of shock absorbers, as a sound proof linings, as a utensils cleaning sponge, as packing materials, for making crafts, as filters in factories and as a part of soles of shoes They also can be used for cleaning floors or cars without scratching. They can also be recycled into mats or pillows when they finally wear down [4][8].

Luffa aegyptiaca is an annual vine that quickly covers any support it finds. When it finds no support it crawls along the ground. The leaves are large and lobed with silvery spots on the top. The yellow, striking flowers measuring 5-7.5 cm in diameter and have five petals. The fruits are green, up to 60 cm long and 7.5 cm in diameter. They are cylindrical and smooth and slightly wider at the tip. The young fruits are small and look like cucumber. The fiber is treated in a chemical solution to remove the dead cell in the raw fiber. Natural fibers as composite reinforcements have grown in recent years. A survey of recent literature shows a significant increase in the number of articles and patents relating to the use of natural fibers. Attempts have been made by other researchers for the preparation of hybrid composites of natural fiber and synthetic fiber to improve the mechanical properties of the composites [5].

The natural fibers have attracted substantial importance as a potential structural material. The attractive plus point of natural fibers in terms of industrial usage has made its availability more demanding Keeping this in view the present work has been undertaken to develop a polymer matrix composite (epoxy resin) using luffa sponge fiber as reinforcement and to study its mechanical properties and performance. The composites are prepared with 30% volume fraction of fibers [6].

Usually the fiber reinforcement is done to obtain high strength and high modulus. Hence it is necessary for the fiber to possess higher modulus than the matrix material. So the load is transferred to the fiber from the matrix more effectively. Fiber reinforced composites are popularly being used in many industrial applications because of their high specific strength & stiffness. Due to their excellent structural performance these composites are gaining potential also in tribological applications. The physical properties of natural fibers are mainly determined by the chemical & physical composition, such as structure of fibers' cellulose content, angle of fibrils, cross section and by the degree of polymerization. Only a few characteristics values but especially the specific mechanical properties can reach the compensable values of traditional fibers [7].

The application of natural fibers as reinforcing materials in composite materials require as just for glass fiber reinforced composites, a strong adhesion between the fiber and the matrix regardless of whether a traditional polymer(thermoplastic or thermosetting) matrix, a biodegradable polymer matrix or cement is used. The
mechanical and other physical properties of the composites are generally dependent on the fiber content, which also determines the possible amount of coupling agents in the composite. An important property of natural fibers to be used as reinforcements is their availability in large quantities. Nowadays natural fibers are very fast replacing the traditional manmade fibers as Reinforcements they have several advantages over manmade fibers. A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties [8][10][11]. The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to 50volume percent) due to processing difficulties and brittleness [9].

A fiber has a length that is much greater than its diameter. The length-to-diameter (l/d) ratio is known as the aspect ratio and can vary greatly. Continuous fibers have long aspect ratios, while discontinuous fibers have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth and helical winding, while examples of discontinuous reinforcements are chopped fibers and random mat. Continuous-fiber composites are often made into laminates by stacking single sheets of continuous fibers in different orientations to obtain the desired strength and stiffness properties with fiber volumes as high as 60 to70 percent. Fibers produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fiber, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibers have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii. Typical fibers include glass, aramid, and carbon, which may be continuous or discontinuous. The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low Strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. The matrix (continuous phase) performs Several critical functions, including maintaining the fibers in the proper orientation and spacing and protecting them from abrasion and the environment.

In polymer and metal matrix composites that form a strong bond between the fiber and the matrix, the matrix transmits loads from the matrix to the fibers through shear loading at the interface. In ceramic matrix composites, the objective is often to increase the toughness rather than the strength and stiffness; therefore, a low interfacial strength bond is desirable. The type and quantity of the reinforcement determine the final properties. The highest strength and modulus are obtained with continuous-fiber composites. There is a practical limit of about 70 volume percent reinforcement that can be added to form a composite. At higher percentages, there is too little matrix to support the fibers effectively. In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force. The demands on matrices are many. They may need to temperature variations, be conductors or resistors of electricity, have moisture sensitivity etc. This may offer weight advantages, ease of handling and other merits which may also become

applicable depending on the purpose for which matrices are chosen. Solids that accommodate stress to incorporate other constituents provide strong bonds for the reinforcing phase are potential matrix materials. A few inorganic materials, polymers and metals have found. These materials remain elastic till failure occurs and show decreased failure strain, when loaded in tension and compression.

Composites cannot be made from constituents with divergent linear expansion characteristics. The interface is the area of contact between the reinforcement and the matrix materials. In some cases, the region is a distinct added phase. Whenever there is interphase, there has to be two interphases between each side of the interphase and its adjoint constituent. Some composites provide interphases when surfaces dissimilar constituents interact with each other. Choice of fabrication method depends on matrix properties and the effect of matrix on properties of reinforcements. One of the prime considerations in the selection and fabrication of composites is that the constituents should be chemically inert non-reactive.

2. Materials and methods

2.1 Polymer Matrix Materials

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications. Two main kinds of polymers are thermosets and thermoplastics. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the chopped fiber composites form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins [10].

2.2 Fiber treatment

The natural fiber luffa aegyptiaca is cut in to two half to remove the inner rough portion of the dry fruit. The fiber is washed with water and NaOH solution to remove the contaminants and adhering dirt. Thereafter, they were air dried for 72h at room temperature, and then Fiber were placed in packets, preserved in polyethylene bags and stored. After the storage period, fiber was cut in angle such a way that the fiber are not in straight, it is cut in to 6cm lengths [7].

2.3 Fiber treated with water

The fiber is treated with water for 30 min. then it is dried in room temperature around 25-32 degree Celsius and then Fiber were placed in packets, preserved in polyethylene bags.

2.4 Fiber treated with NaOH

The fibers were soaked in a 2 % NaOH solution at 28°C. The fibers were kept immersed in the NaOH solution for periods of 20min, 40min and 1 hr. The treated fibers were then washed several times with distilled water. Any traces of NaOH, remaining on the fiber surface, were neutralized with 2 % sulfuric acid during 10 min. The fibers were washed again with distilled water until obtaining a pH = 7. Subsequently, the fibers were dried at 30-45°C for 6 hours. The weight loss after treatment was measured accordingly. The fiber is treated with NaOH for 40 min. the color changes from yellow to brown then it is dried in room temperature around 25-32 degree Celsius and then Fiber were placed in packets, preserved in polyethylene bags [11].

2.5 Cutting of fiber

The natural fiber luffa aegyptiaca is cut in to small strips and then it is arranged discontinues in the steel plate. The fiber was cut in angle such a way that the fiber are not in straight, it is cut in to 6cm lengths. The luffa fiber is dried in sunlight and then the fiber is cut in short around 6cm long ,the fiber is arranged in discontinuous manner in the plate and the fiber is arranged in layer by layer to reach the thickness up to 3mm [12].

2.6 Fabrication of composite material

The fiber is taken and arranged in discontinuous method in the steel plate and it is

compressed by the help of bolt. After 15min the bolt are released and the mat form fiber is taken carefully without any damage. The fiber are arranged in such a way that there is no gap in-between the Fiber, If there is any gap in the fiber arrangement the resin is filled by the gap so the strength may reduce .so closely arrange the fiber. Measure the weight of the fiber using weighing scale. Then 1:5 of resin and hardener is added and mixed in the jar. 1%fiber and 5% resin and hardener Then the steel plate was cleaned with acetone and wax is applied in the inner side of the plate finally resin is poured and steel plate was compressed by tighten the bolt and nut. After 24hr, the bolt was released and the laminates are taken carefully without any damage.

2.7 Experimentation

Sol-gel method was used for the preparation of silica nanoparticles. These SiO_2 particles were synthesized by hydrolyzing TEOS in a mixture of ethanol, water, ammonia and surfactant. TEOS, ethanol and ammonia were used as silica precursor, common solvent and catalyst, respectively. For each experiments, 30 ml ethanol, 40 ml de ionized water,60 ml TEOS added to the reaction container and stirred for 2hr for homogeneity. Then ammonium hydroxide was added drop wise to the mixture to control the pH of the reaction mixture. Upon addition of ammonia, the reaction mixture remained clear for some time and slowly turned turbid due to the formation of silica. The reaction was completed in 4h. The resulting white powder was dried overnight at 80°C and then calcinated for a period of 3h at 500°C. The reaction was also performed without surfactants for comparative studies of particle size of silica nanoparticles. Process flow chart is shown in Fig 1.

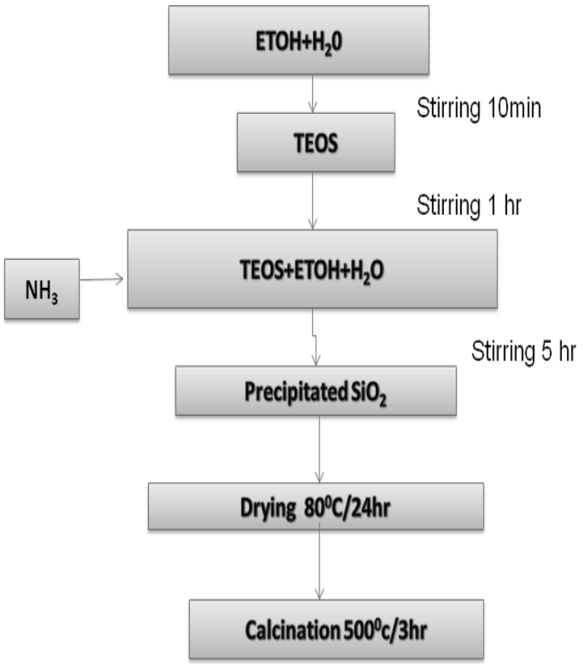

Fig 1. Process flow chart

2.8 Characterization of silica nanoparticles

Morphologies of the samples were examined using PhilipsCM12, 80 kV transmission electron microscopy (TEM) system while the particle size was measured using analysis DocuVersion 3.2 image processing software. The average particle size and statistical parameters were determined based on the measurement of more than 300 particles from the TEM micrographs. The term particle size used in this paper refers to the average diameter of the silica particles. An average diameter was measured for particles which are almost spherical. Fourier transformed infrared (FTIR) analysis was conducted on the silica samples using Perkin-Elmer 2000 FT-IR spectrometer. All the samples were preheated at 110 ◦C for overnight prior to the Analysis. Specifications of samples are shown in Table 1.

Table 1. Specifications of samples

Specification	Specimen 1	Specimen 2	Specimen 3
Weight of the fiber (g)	50	100	100

Weight of the resin (g)	250	500	300
Weight of the hardener	25	50	30
Volume of the plate (cm^3)	187.5	187.5	187.5
Density (g/cm^3)	0.2666	0.533	0.533
SiO_2 (g)	-	-	3

2.9 Effect of TEOS

The formation of homogenous, monodispersed nanometer silica particles highly depends on the reaction conditions. The concentration of nuclei/primary particles present in the system. At initial supersaturated solution, nucleation will take place and will induce the formation of primary particles (induction Period).Aggregation of primary particles results in the formation of more stable secondary particles. After the induction period, any primary particles or nuclei that form will dissolve and re-precipitate on the growing secondary particles through Ostwald ripening mechanism.

The process will continue until all the primary particles consumed or until a stable condition is achieved. The effect of TEOS concentrations on particle size, yield and size distribution (SD) of the silica particles. At fixed $[NH_3]$ = 0.08 mol/l and $[H_2O]$ = 0.04 mol/l, particle size increased with the increase in [TEOS] until 0.80 mol/l whereby the size starts to stabilize at 90 nm. This phenomenon strongly suggests that the increase in the particle size is attributed to the increase in concentration of primary particles at the induction period, i.e. [primary particles] $\propto$ [TEOS]. At [TEOS] > 0.80 mol/l, ammonia becomes the limiting reactant and results in an inefficient hydrolysis and condensation reactions. As a result, the product yield drops.

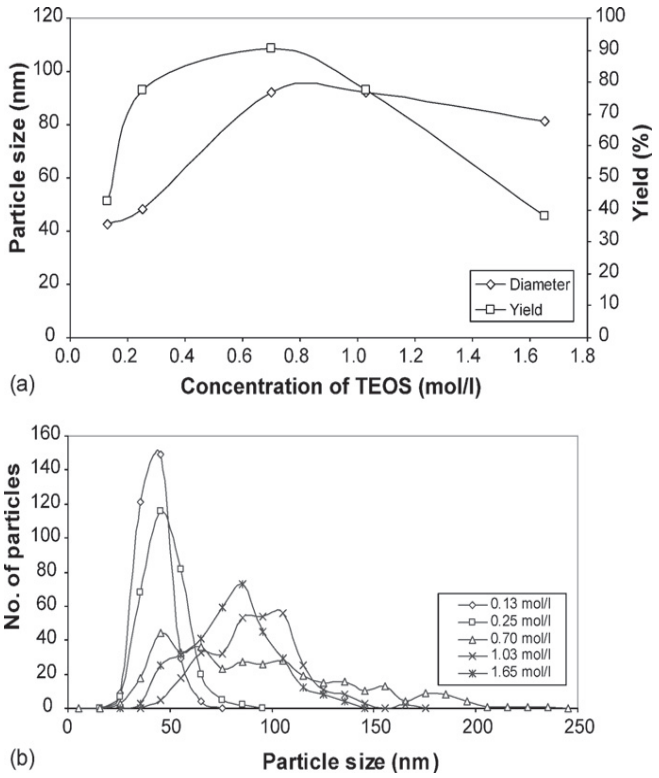

Fig 2.a) Particle size and yield for various Concentration of TEOS. b) No. of particles for various Particle size.

Effect of TEOS concentration on (a) particle size and yield, and (b)size distributions of silica prepared at fixed initial concentrations of NH_3 (2.18 mol/l) and H_2O (1.09 mol/l).

3. Results and discussions

3.1 Compressive Test

The compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally. It is shown in Table 2.

Table 2. Compressive strength for natural fiber composite without sio_2 nano particles

Sample	Area (cm)	Breaking load (kN)	Compressive strength (N/mm^2)
1	13.58×13.69	14.62	79
2	14.6×13.76	13.7	68

3	14.2×13.65	13.34	66

Table 3. Compressive strength for natural fiber composite with sio_2 nano particles

Sample	Area (cm)	Breaking load (kN)	Compressive strength (N/mm^2)
1	13.83 X 13.90	15.66	81
2	13.58X13.62	14.68	78
3	13.62X13.83	15.28	79

Compressive strength is increases, when sio_2 is nano particles is added with natural fiber composite. It is shown in Table 3.

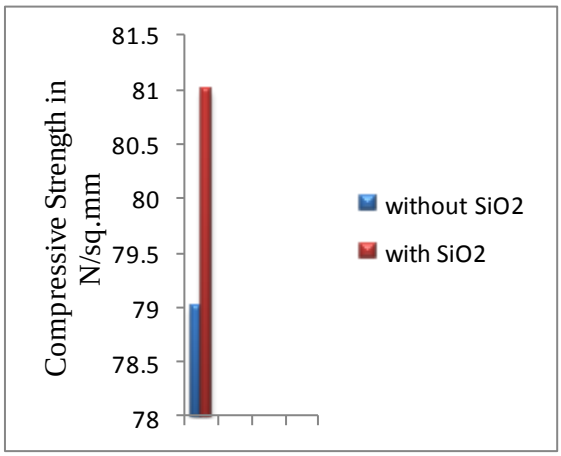

Fig 3. Comparison of Compressive strength

Fig 3. shows the compressive strength of the luffa fiber is 79 N/mm^2 to increase the strength, SiO_2 Nano particles are added in the composite material and the the composite board are tested.after testing the strength is improved as 81 N/mm^2.

3.2 Impact test

The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. It is shown in Table 4. Natural fiber composite with sio_2 nano particles laminates is tested. In which, 14.20 mm width, 5.63 mm thickness is observe more impact strength. It is mentioned in Table 5.

Table 4. Impact strength for natural fiber composite without sio_2 nano particles

Sample	Width (mm)	Thickness (mm)	Energy (J)
1	13.84	4.51	0.8
2	14.32	4.54	0.7
3	14.52	4.58	0.6

Table 5. Impact strength for natural fiber composite with sio_2 nano particles

Sample	Width (mm)	Thickness (mm)	Energy (J)
1	14.20	5.63	0.9
2	13.20	5.30	0.7
3	14.02	5.41	0.8

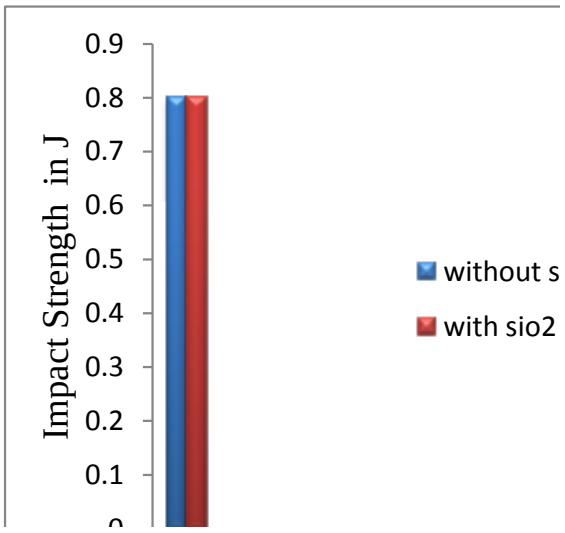

Fig 4. Comparison of Impact strength

Fig 4. shows while comparing the properties of a natural fiber composite material with SiO_2 nano particles, there is no change in impact strength the impact strength we attained is 0.8 Joule.

3.3 Tensile test

Intuitively, we know that a "simple" tensile test is the most fundamental of all mechanical property tests. It tells us how strong and how stiff a material is, and for most essentially isotropic materials, such as metals, the tensile properties are a good indicator of the overall mechanical response. While we should realize that with composites we cannot make a similar inference about other mechanical properties, such as compression and shear, from tensile information, our conditioned response is to try to do so. As a result, there is always an interest in tensile testing.

Generally, the strongest material in a class is usually the most difficult to test for tensile properties. Composite materials are no exception, and the axial loading of a unidirectional composite presents the greatest challenge. (It is debatable whether one should even attempt a tensile test on a unidirectional composite, given the difficulties encountered, but that is a topic for another time.[1] See end note.) This discussion will concentrate on developing a method to meet this challenge, assuming that we then will be able to test other laminates successfully using similar, or simpler, techniques. The greatest challenge is gripping the unidirectional composite specimen without introducing unacceptable stress concentrations. Typically, grips are clamped onto the specimen ends, thus transferring the applied tensile force via shear at the specimen surfaces into tensile stresses within the specimen. Assuming that the composite is strong, the required clamping forces can become significant. The issue then is how to minimize these required clamping forces, and/or keep them from degrading the measured tensile strength of the specimen. It is mentioned in Table 6.

Table 6. Tensile strength for natural fiber composite without sio_2 nano particles

Sample	Width (mm)	Thickness (mm)	Breaking load (kN)	Tensile strength (N/mm^2)	Tensile modulus (kN/mm^2)
1	25.65	6.10	2.62	13	3.284
2	25.80	6.12	2.51	13	3.425
3	25.75	6.15	2.56	12	3.822

Table 7. Tensile strength for natural fiber composite with sio_2 nano particles

Sample	Width (mm)	Thickness (mm)	Breaking load (kN)	Tensile strength (N/mm^2)	Tensile modulus (kN/mm^2)
1	25.65	6.10	2.62	13	3.284
2	25.80	6.12	2.51	13	3.425
3	25.75	6.11	2.58	13	3.333

Table 7 says, the tensile test is done on the luffa composite board the width of the board is 25.65mm and the thickness is 6.10 mm and the load applied is 2.62 KN then the tensile strength is attained 13 N/mm^2.

The tensile strength of the luffa fiber is 13 N/mm^2 to increase the tensile strength 3% of SiO_2 Nano particles are added in the composite material and the the composite board are tested.after testing the tensile strength is improved as 14 N/mm^2. It is shown in Fig 5.

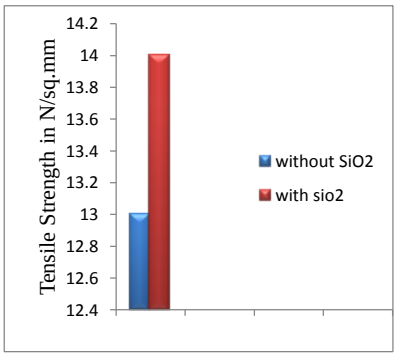

Fig 5. Comparison of Tensile strength

3.4 Flexural test

The flexural strength of a material is defined as its ability to resist deformation under load. For materials that deform significantly but do not break, the load at yield, typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yield strength. The test beam is under compressive stress at the concave surface and tensile stress at the convex surface. It is mentioned in Table 8.

Table 8. Flexural strength for natural fiber composite without sio_2 nano particles

Sample	Width (mm)	Thickness (mm)	Breaking load (kN)	Flexural strength (N/mm^2)
1	13.4	6.12	197.875	28.975
2	13.2	6.17	182.305	27.120
3	12.8	6.22	163.215	24.157

Table 9. Flexural strength for natural fiber composite with sio_2 nano particles

Sample	Width (mm)	Thickness (mm)	Breaking load (kN)	Flexural strength (N/mm^2)
1	13.42	5.42	76.86	28.958
2	13.25	5.63	75.52	27.153
3	13.35	5.67	76.38	28.654

The flexural test is done on the luffa composite board the width of the board is 13.42mm and the thickness is 5.42 mm and the load applied is 76.86N then the flexural strength is attained 13 N/mm^2. It is mentioned in Table 9.

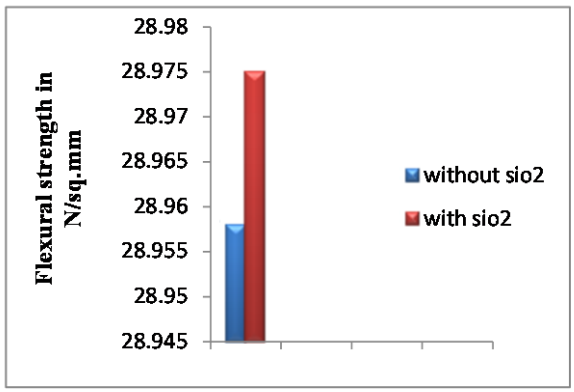

Fig 6. Comparison of Flexural strength

The flexural strength also slightly improved the flexural strength of the luffa fiber composite material is28.975 N/mm^2 and after adding nano particles we get28.958 N/mm^2. It is shown in Fig 6.

4. Conclusion

The alkali treatment of fibers luffa improves the quality of the fiber/matrix interface. The results showed that both NaOH concentrations used and time treatment has a significant effect on the mechanical properties of luffa fibers reinforced composites. . However, the treatment of fibers over a prolonged period makes the fibers stiffer and more brittle. The mechanical properties of luffa fiber increased upto2% while infusion of SiO_2 nano particles. The results of this study suggest that luffa fibers are comparable to

other natural fibers used as reinforcement in polymer matrices. They are completely suitable for use as reinforcement in composites. The natural fiber composite materials are fabricated by hand layup process. Composites use different parts on automobile accessories, such as dash board ceilings, seat filling, door trim, door cladding. Consumer and industrial uses include flowerpots, lawn furniture, office supplies, picture frames, plastic lumber, industrial flooring, pallets, boat hull and which can use in lightweight military helmet.

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