International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 9, Issue 2 (MARCH-APRIL 2021), PP. 35-44

A NEW APPLICATION OF NATURAL FIBRE REINFORCED COMPOSITES AND ITS WATER ABSORPTION BEHAVIOUR

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***Abstract*—Environmental perception today encourages empiricism worldwide on the learning of plant or natural fibre reinforced polymer composite and cost efficient alternative to synthetic fibre reinforced composites. The accessibility to natural fibers and simplicity in manufacturing have persuaded researchers to aim for locally existing low cost fibers and to investigate their possibility of reinforcement intensions and up to what extent they can satisfy the essential detailing of superior reinforced polymer composite intended for different application program. Natural fibre represents a superior biodegradable and renewable alternative to the most popular synthetic reinforcement, i.e. glass fibre possessing high mechanical properties and low cost. Regardless the curiosity and environmental request of natural fibers, there usage is restricted to non-bearing uses, because of its lower strength than that of synthetic fibre reinforced polymer composite. The stiffness and strength limitations of bio composites can be chased by operational arrangement by placing the fibers at particular locations to have higher strength performance. Research regarding preparation and properties of polymer matrix composite (PMC) replacing the synthetic fibre with natural fibre like Jute, Sisal, Jute, Bamboo, Pineapple, Bagasse and Kenaf were carried out. Renewable, environmental friendly, low cost, lightweight and high specific mechanical performances are the advantages of these plant fibres over the glass fibre or carbon fibre. Composites are exciting materials which are finding increasing application in transportation, aerospace, defence, communication, sporting, electronics and number of other commercial and consumer products. Composite materials have become one of the fastest growing research and development areas of Material Science because of their high potential. In current years there is swift growth in the arena of fibers, matrix, materials, processing, boundary structure, bonding and their characteristics on the final properties of composites. The technological developments in composite materials help in meeting the global industrial demand for materials with improved performance capabilities.**

Keeping this in view the present work has been under taken to develop a polymer matrix composite (epoxy resin) using Luffa Cylindrica fibre and to study its moisture absorption behavior and mechanical properties. The composite are prepared with different volume fraction (number of layers) of Luffa Cylindrica fibre.

***Index Terms*— Natural Composites, Mechanical testing, Types of composites, Luffa Cylindrica fibre.**

I. INTRODUCTION

The impediments of the polymer framework composites at high temperatures can be overwhelmed by the utilization of metal network composites. These composites are handled by powder metallurgy strategies, by entrance of the liquid metal with the fiber or particulate or by blending particulates with liquid metal. Plasma showering, vapor statement, plasma splashing or electro affidavit pursued by dispersal holding are different strategies for creation. Metal grid composites are finding applications in barrier, aviation, car and electronic bundling. Notwithstanding metal lattice composites, intermetallics, for example, nickel, iron, titanium and niobium aluminides grid composites are additionally being effectively considered for use at raised temperatures.

The study of composites materials is a multifaceted memorandum as it is difficult for any individual to grasp the compound behaviour of many of the current composites. This field provides lot of analytical problems for experimental schedules, theoreticians for research workers and new defiance for designers. Even the technologically advanced fibre glass reinforced plastics in the 1940s require a information of ceramics, glass technology, surface science, polymers, modelling, design and analysis in order to redeem the properties, structure and purpose of the final composite product.

A. NATURAL FIBER COMPOSITES: Initiative in Product Development

The cost effective option to synthetic fibre reinforced composites and the interesting studies of plant or natural fibre inspires the researchers to make advances in the field of composites. Ease in access and built-up simplicity of natural fibre have convinced these researchers to try natural fibres which are available locally and to study their practicability of reinforcement motives. These are also studied to have the information that up to what limit they can fulfil the desired specifications and properties for various uses. Natural fibre

appears as a good renewable and biodegradable substitute to most of the synthetic fibre such as glass fibre.

Vegetables, animal, mineral fibers etc. fall under the area of natural fibre. Generally it is referred as wood and agro based fibre, leaf, stem and seed fibers in the composite engineering. A natural fibre frequently contributes to the structural presentation of plant and they can deliver substantial reinforcement, when used in the production of plastics composites.

Is curtailed to non-bearing applications because of their bring down strength compared to synthetic fibre reinforced polymer complex in malice of the interest and environmental appeal of natural fibers. By the sense of positioning the fibers in particular locations for maximum strength presentation, the limitations in stiffness and strength of bio composites can be succeeded.

Accordingly vast studies on construction and properties of polymer matrix composite (PMC) substituting the synthetic fibre with natural fibre like Jute, Pineapple, Sisal, Kenaf, Bamboo, luffa cylindrica, ipomea carnea and Bagasse were executed [7-12]. Above natural fibers have numerous advantages over the glass fibre or carbon fibre such as renewable, low cost, lightweight, high specific mechanical performance.

B. Applications

1. Automobile industry: For inner and outer parts fibre reinforced plastics are used. These are used in industries because of their advantages over the glass fibre reinforced composites such as cheaper, environment friendly, etc. By these fibers cars according to End-of-Life directive can be developed as the resulting products from these composites can be re-used and do not have to be land filled unlike glass fibre. Because of their softness and non-harsh behaviour unlike glass fibers they are used in interior automotive uses and are having advantages of not injuring the passengers.

2. Packaging industry: In these industries these are used for light weight pallets. Weight reduction is the chief reason for using composite material in place of wood, which saves fuel during transportation.

3. Consumer products: Natural fibre can be used for any injection moulded product. Reduction of plastic use, flame retardancy and re-use. Examples are household appliances like cell phones, refrigerators and computers. They are less vulnerable to fire due to the fibre structure of composite. Also the high fibre loads results in major material cost reduction.

4. Building and construction industry: In these they are used for roofings and instance profiles. Cost reduction, re-use and flame retardancy are the advantages.

C. Luffa cylindrica as a natural fiber

Numbers of potential natural resources are there, which India has in abundance. Most of which comes from the forest and agriculture.

Fig 1.2 (a)

Fig 1.2 (b)

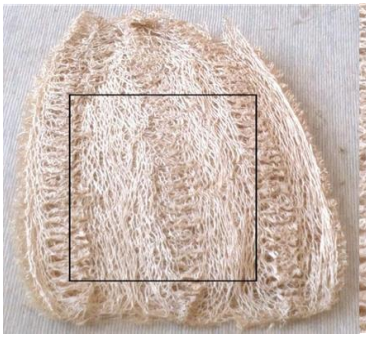

Fig 1.2 (c)

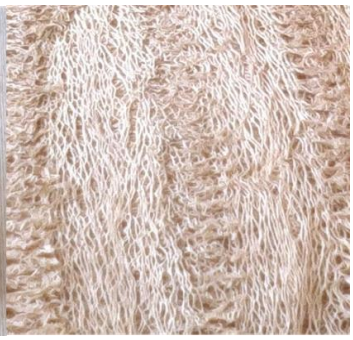

Fig 1.2 (d)

Fig. 1.2 The Luffa cylindrica plant (a), the inner fiber core (b) and the outer core open as a mat (c, d).

Luffa cylindrica, locally called as ‘Sponge-gourds’ is that natural resource whose capability as fiber reinforcement in polymer composite has not been explored to date. The fibrous cords are liable in a multidirectional array resulting in a natural mat in ligneous netting system possess by ‘Sponge gourds’. It comprises 62% cellulose, 20% hemicellulose and 11.2% lignin [1]. The sponge-gourd (Luffa Cylindrica) plant with fruit which belongs to the curcubitacea family is shown in Fig. 1.1(a).

The main objective of this project is to prepare a PMC using luffa fiber as reinforcement and epoxy as matrix material and to study its moisture absorption characteristics under different environmental conditions and then to find its mechanical properties i.e.; tensile and flexural strength. Out of the available manufacturing techniques, we have chosen hand-lay-up method to construct the composite. Then the composites were manufactured by varying the no. of layers of fiber i.e.; single, double and triple layers composite using these techniques. The surface of fracture and worn out samples have

been studied using Scanning Electron Microscope (SEM) to have an idea about the fracture behaviour of the composite.

II. NATURAL FIBERS: SOURCE AND CLASSIFICATION

Growing environmental awareness has activated the researchers worldwide to enhance and utilize materials that are companionable with the environment. In the procedure natural fibers have become suitable options to traditional synthetic or manmade fibers and have the prospective to be used in cheaper, more sustainable and more environment friendly composite materials. Natural organic fibers can be obtained from either animal or plant sources. Most of the useful natural textile fibers are obtained from plant, with the anomaly of wool and silk. All plant fibers comprises of cellulose, whereas protein act as a chief content of fibers of animal origin. Hence, the natural fibers are categorized on the basis of their origin, whereas the plant fibers can be further classified on the basis of plant parts from which the parts are originated. An overview of natural fibers is showed in Figure-2.1 [13].

Normally, plant or vegetable fibers are cast to reinforce polymer matrices and a categorization of vegetable fibers is given in Figure-2.1 [14]. Plant fibers are a renewable resource and have the capability to be recycled. The plant fibers leave slight residue if they are burned for disposal, returning less carbon dioxide (CO2) to the atmosphere than is separated during the plant's growth.

The chief driver for switching natural fibers for glass is that they can be grown with lesser cost than glass. The price of glass fiber is around Rs. 300.0/- per kg and has a density of 2.5 gm/cc. On the other hand, natural fiber costs Rs. 15.0/- to 25.0/- per kg and has a density of 1.2-1.5 gm/cc. As can be seen from Table-2.1 [13], although the modulus is of the same order of magnitude, the tensile strength of natural fibre is considerably lower than the glass fibers. On the other hand, when the specific modulus of natural fibers is measured, the natural fibers show values that are similar to or even better than glass fibers. Material cost savings, suitable to the use of natural fibers and high fiber filling levels, coupled with the benefit of being non-abrasive to the mixing and moulding tools make natural fibers a thrilling outlook. These reimbursement mean natural fibers could be used in many applications, including building, automotive, household appliances, and several other applications.

Table-2.1 Properties of glass and natural fibers

Mechanical Properties	**Fibers**						
	E-glass	**Hemp**	**Flax**	**Jute**	**Sisal**	**Coir**	**Ramie**
Density (gm/cc)	2.25	1.48	1.4	1.46	1.33	1.25	1.5
Tensile Strength (MPa)	2400	550-900	800-1500	400-800	600-700	220	500
Young's Modulus (MPa)	73	70	60-80	10-30	38	6	44
Specific Modulus (MPa)	29	-	26-46	7-21	29	5	2
Failure Strain (%)	3	1.6	1.2-1.6	1.8	2-3	15-25	2
Moisture Absorption (%)	-	8	7	12	11	10	12-17

III. MECHANICAL CHARACTERIZATION OF LUFFA CYLINDRICA FIBRE EPOXY COMPOSITE

A. .Method of Chemical Modification

1) Alkaline Treatment

When it comes to reinforce thermoplastics and thermosets, alkaline treatment is one of the mostly used treatments. In the modification done by the alkaline treatment the disruption of hydrogen bonding in the network structure takes place resulting in increased surface roughness. By using this treatment, certain amount of lignin, wax and oils covering the outer surface wall of the fibre was removed, depolymerizes cellulose and depicts the short length crystallites . Addition of aqueous sodium hydroxide (NaOH) to natural fibre stimulates the ionization of the -OH group to the alkoxide.

$$\textbf{Fiber} - \textbf{OH} + \textbf{NaOH} \rightarrow \textbf{Fiber} - \textbf{O} - \textbf{Na} + H_2O$$

Alkaline treatment has two effects on the fibre:

(1) It increases surface roughness by the disruption of hydrogen bonding resulting in better mechanical linking.
(2) It increases the number of possible reactions sites by increasing the amount of cellulose exposed on the fibre surface.

Subsequently, this treatment has a lasting effect on the mechanical behaviour of flax fibre, especially on the strength and stiffness of the fibre.

For performing this treatment, Firstly the Luffa Cylindrica fibre were kept in a solution containing 5%NaOH at room temperature maintaining a liquor ration of 15:1 for 4hrs. Secondly, the fibers were washed many times with water in order to remove the NaOH sticking to the fibre surface followed by neutralizing with dilute acetic acid and washed with distilled water, so that pH of 7 was maintained. Lastly, the fibers were dried at room temperature for 48hrs followed by oven drying for 6hrs at 100ºC. The alkali reaction between Luffa Cylindrica fibre and NaOH is as follows:

$$\textbf{(Luffa Cylindrica)} - \textbf{OH} + \textbf{NaOH} \leftrightarrow \textbf{(Luffa Cylindrica)} - \textbf{O-Na}^+ + H_2O$$

B. COMPOSITE FABRICATION

For preparation of composite the following materials have been used;

(1) Luffa Cylindrica fiber

(2) Epoxy

(3) Hardener

1) Preparation of Luffa Cylindrica Fiber Mats

Dried Luffa Cylindrica was collected locally. These fibres were then treated with water for 24 hrs in order to remove wax, lignin and oil from the external surface of luffa fibre and then dried at room temperature. After these the fibres were cut with appropriate dimensions (150×140 mm) and then these fibres were kept between two wooden boards followed by pressing it into the bench vice to straighten the fibres.

2) Epoxy Resin

The epoxy resin used in this examination is Araldite LY-556 which chemically belongs to epoxide family. Its common name is Bisphinol-A-Diglycidyl-Ether. The hardener with IUPAC name NNO-bis (2aminoethylethane-1,2diamin) has been used with the epoxy designated as HY 951.

3) Composite preparation

Initially, wooden moulds with dimensions of 140 x 120 × 10 mm3 were prepared for the fabrication. For different number a layer of fibre, epoxy resin and hardener (ratio of 10:1 by weight) with a calculated amount was mixed thoroughly in a glass jar. Figure 3.1(a) illustrates the mould used to construct the composite. Mould release sheet was put over the glass plate and a mould release spray was sprayed over the inner surface of the mould for quick and easy removal of composite. After keeping the mould on a ply board a thin layer of the mixture was poured. Then the fiber lamina was distributed on the mixture. Then again resin was applied over the fiber laminate and the procedure was repeated to get the desired thickness. The remaining mixture was then poured into the mould. Precaution was taken to prevent the air bubbles formation. Then from the top pressure was applied and the mould was kept at room temperature for 72 hrs. During application of pressure some amount of mixture of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing of composite sheets. After 72 hrs the samples were taken out of the mould. Figure 3.2 (a, b) shows the photograph of the composite specimen cut for further experimentation.

Figure- 3.1 Mould used for fabrication of the composite

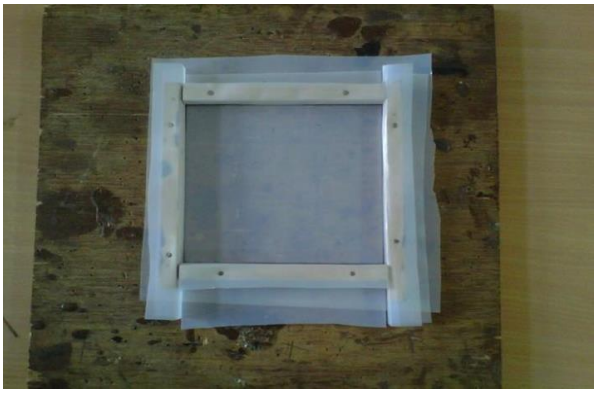

Figure-3.2 (a) Flexural test samples

Figure-3.2 (b) Tensile test samples

C. STUDY OF ENVIRONMENTAL EFFECT

To study the effect of environmental conditions on performance of Luffa Cylindrica fiber epoxy composite, the composite sample with both untreated and chemically treated fibers were subjected to various environments such as:

(1) Saline treatment
(2) Distil treatment

1) Moisture absorption test

Moisture absorption and thickness swelling tests were conducted in accordance with ASTM D570-98. Four specimens for different layers (Single, Double and Triple layers) were cut with dimensions of 140 x 15mm (length x width) and the experiment was performed using test samples. The specimens prior to testing were dried in an oven at 800 C and then were allowed to cool to room temperature and kept in a desiccator. The weight of the samples were taken before subjected to steam, saline water and distil water environments. After expose for 12 hr, the specimens were taken out from the moist environment and all surface moisture was removed with a clean dry cloth or tissue paper. The specimens were reweighed to the nearest 0.001 mg within 1 min. of removing them from the environment chamber. The specimens were weighed regularly from 12-156 hrs with a gap of 12hrs of exposure. The moisture absorption was calculated by the weight difference. The percentage weight gain of the samples was measured at different time intervals by using the following equation:

$$\%M_t = \frac{(W_t - W_0)\times 100}{W_0} \qquad (3.1)$$

Where 'W_0' and 'W_t' denote the oven-dry weight and weight after time 't', respectively. Equilibrium Moisture Content (EMC) of the sample is the moisture content when the periodic weight change of the sample was less than 0.1% and thus the equilibrium state was assumed to be reached.

The thickness swelling (TS) was determined by using the following equation:

$$TS(t) = \frac{H_t - H_0}{H_0}\times 100 \qquad (3.2)$$

Where, 'H_t' and 'H_0' are the composite thickness after and before the water immersion respectively.

2) Mechanical testing of sample

a) Tensile test

The tensile test is generally performed on flat specimens. The most commonly used specimen geometries are dog-bone

and the straight side type with end tabs. The specimen used in present case is shown in fig 3.3 (a). The tensile tests were conducted according to ASTM D 3039-76 standard on a computerized Universal Testing Machine INSTRON H10KS. The span length of the specimen was 42 mm. the tests were performed with constant strain rate of 2 mm/min.

Figure-3.4 (a) UTM machine sample unloaded for tensile testing

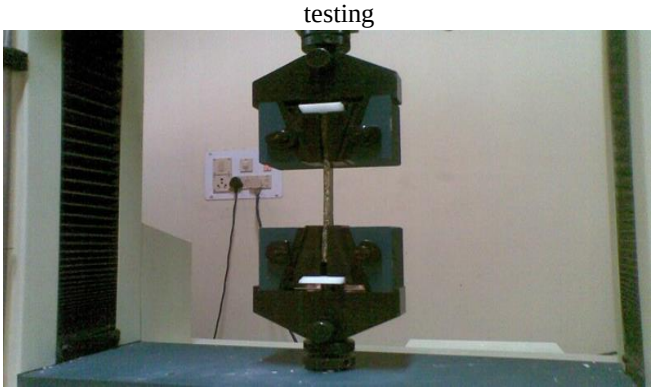

Figure 3.4 (b) UTM machine sample loaded for tensile testing

b) Flexural test

Three point bend test was carried out in an UTM machine in accordance with ASTM D790-03 to measure the flexural strength of the composites. The loading arrangement for the specimen and the photograph of the machine used are shown in figure 3.5. All the specimens (composites) were of rectangular shape having length varied from 100-125 mm, breadth of 100-110 mm and thickness of 4-8 mm. A span of 70 mm was employed maintaining a cross head speed of 0.5mm/min.

The flexural strength of composites was found out using the following equation

$$\tau = \frac{3fl}{2bt^2}$$

Where τ is the flexural strength, f is the load, l is the gauge length, b is the width and t is the thickness of the specimen under test.

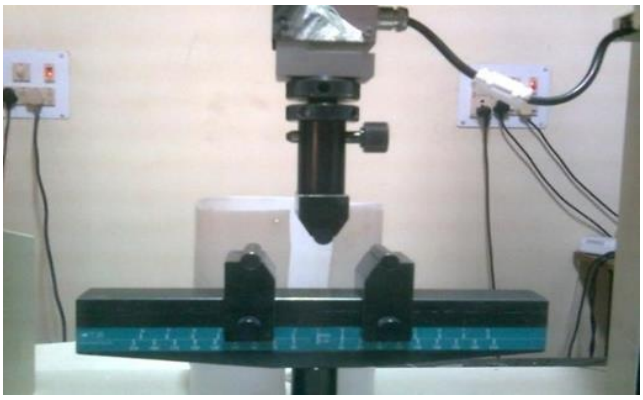

Figure 3.5 UTM machine sample unloaded for flexural testing

IV. RESULTS AND DISCUSSION

Measurement of Diffusivity

The water sorption kinetics in LCF reinforced epoxy composite has been studied through the diffusion constants k and n. The behaviour of moisture sorption in the composite was studied by the shape of the curve represented by the equation (3.3) [37, 38]:

$$\frac{M_t}{M_m} = kt^n \qquad (3.3)$$

Where, Mt is the moisture content at specific time‘t’, Mm is the equilibrium moisture content (EMC), and k and n are constants.

The diffusion coefficient or diffusivity (Dx) of moisture absorption was calculated using the following equation:

$$D_x = \pi\left[\frac{h}{4M_m}\right]^2\left(\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}\right)^2 \qquad (3.4)$$

where ‘M_m’ is the maximum percentage of moisture content, ‘h’ is the sample thickness, ‘t_1’ and ‘t_2’ are the selected points in the initial linear portion of the plot of moisture absorption (M_t) versus $\sqrt{t}$ (Figure-3.21) and ‘M_1’ and ‘M_2’ are the respective moisture content.

V. CONCLUSIONS

Based on experimental results, this study has led to the following conclusions:

- The Luffa Cylindricafibre can successfully be used as reinforcing agent to fabricate composite by suitably bonding with epoxy resin. .
- On increasing the fibre content the strength, modulus and work of fracture increases and the best combination is found with Double Layered composite.
- The fibre surface modification by chemical treatments significantly improves the fibre matrix adhesion, which

in turn improves the mechanical properties of composite.

- The moisture uptake and thickness swelling values increases with increase in fiber loading. Both values are found to be higher in saline environment than in distil water environments. However these values are considerably reduced with chemical treatments of the fibre.
- Under all environment conditions, the moisture diffusion process of both treated and untreated Luffa Cylindricafibre composites are found to follow the Fick's law.
- Fibre breakages are found to be the predominant mode of failure as ascertained from the morphology of the treated fibre composites.

Table–3.1. Variation of weight gain and thickness swelling of untreated Luffa Cylindrica fibre epoxy composite (flexural) with immersion time expose at distil environment.

No. of layers	Immersion Time 't' (hrs)	Weight of the Sample	Percentage of weight gain (%M)	Thickness at time 't' H(t)	Thickness Swelling TS (t)
Single Layer	0	12.761	0	0.59	0
	12	12.986	1.763184703	0.591	0.169491525
	24	13.038	2.170676279	0.592	0.338983051
	36	13.063	2.366585691	0.593	0.508474576
	48	13.136	2.938641172	0.594	0.677966102
	60	13.213	3.54204216	0.595	0.847457627
	72	13.228	3.659587807	0.596	1.016949153
	84	13.253	3.855497218	0.597	1.186440678
	96	13.283	4.090588512	0.598	1.355932203
	108	13.486	5.681372933	0.599	1.525423729
	120	13.598	6.559047097	0.6	1.694915254
	132	13.598	6.559047097	0.6	1.694915254
	144	13.598	6.559047097	0.6	1.694915254
	156	13.599	6.566883473	0.6	1.694915254

Table–3.2 Variation of weight gain and thickness swelling of treated Luffa Cylindrica fibre epoxy composite (flexural) with immersion time expose at distil environment.

No. of layers	Immersion Time 't' (hrs)	Weight of the Sample	Percentage of weight gain (%M)	Thickness at time 't' H(t)	Thickness Swelling TS (t)
Double Layer	0	15.504	0	0.707	0
Sample 3	12	15.954	2.90247678	0.709	0.282885431
	24	16.123	3.99251806	0.71	0.424328147
	36	16.421	5.914602683	0.713	0.848656294
	48	16.652	7.404540764	0.715	1.131541726
	60	16.669	7.514189886	0.717	1.414427157
	72	16.701	7.720588235	0.719	1.697312588
	84	16.821	8.494582043	0.721	1.98019802
	96	17.015	9.745872033	0.723	2.263083451
	108	17.125	10.45536636	0.725	2.545968883
	120	17.131	10.49406605	0.726	2.687411598
	132	17.131	10.49406605	0.726	2.687411598
	144	17.132	10.500516	0.726	2.687411598
	156	17.132	10.500516	0.726	2.687411598

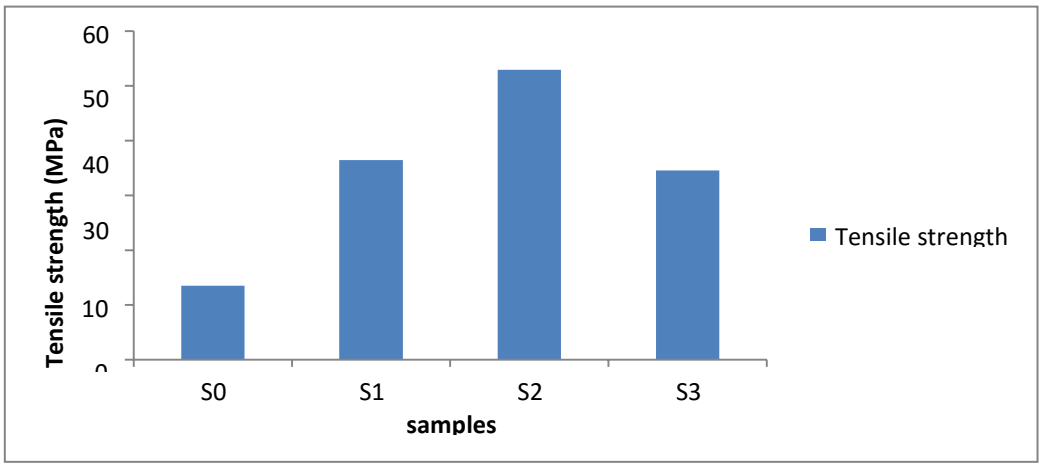

Figure-3.6 Variation of tensile strength with different layers of untreated Luffa Cylindrica fibre epoxy composites exposed to saline water environment.

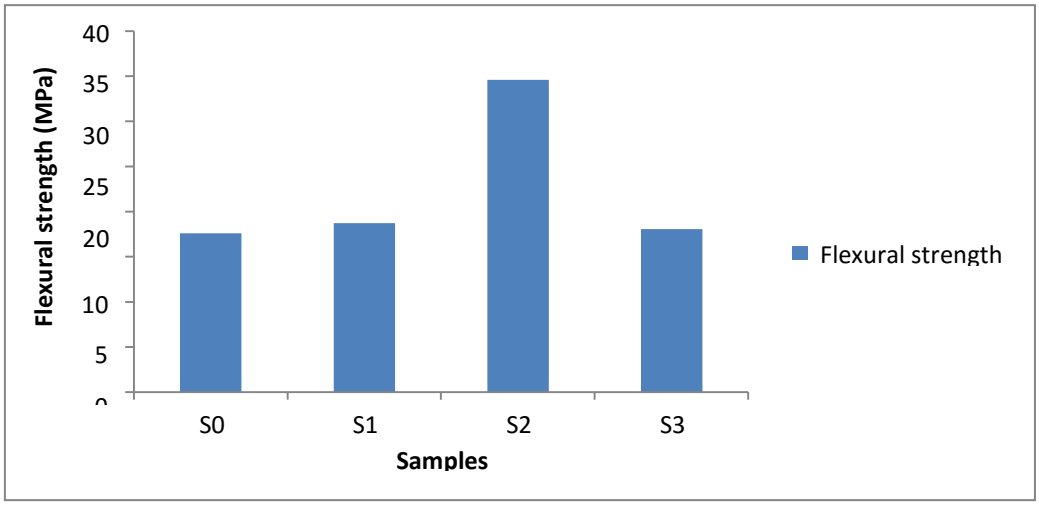

Figure-3.7 Variation of flexural strength with different layers of untreated Luffa Cylindrica fibre epoxy composites exposed to saline water environment.

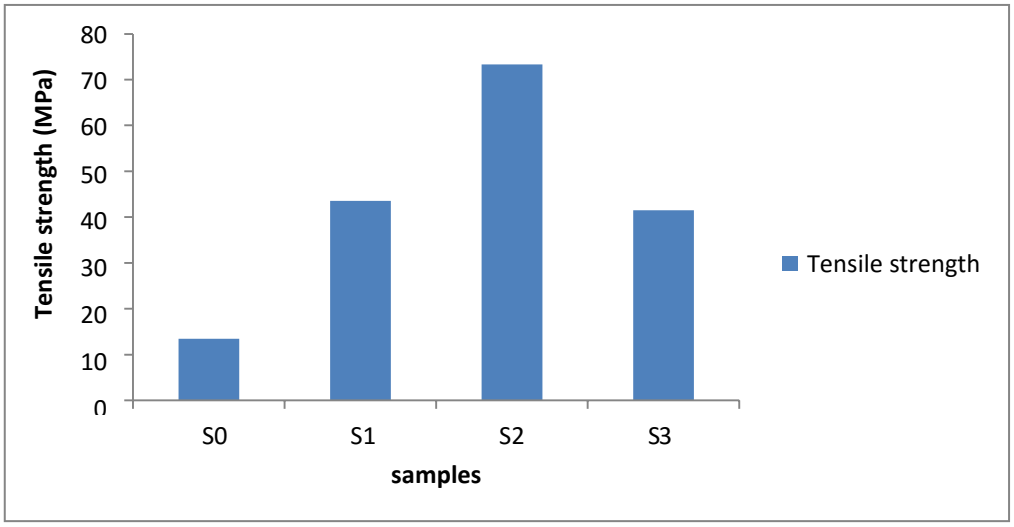

Figure-3.8 Variation of tensile strength with different layers of untreated Luffa Cylindrica fibre epoxy composites exposed to distil water environment.

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