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Influence of Chemical Treatment on Tensile, Bending and Water Absorption Behavior of Banyan/Banana Fibers Reinforced Hybrid Composites: An Experimental and FEA Investigation

Prabhakar C. G[1], Ranganath K J[2] and Dr. Sreenivas Reddy[3]

Department of Mechanical Engineering

Sha-Shib College of Engineering and Technology, Bengaluru, India[1,2]

R L Jallappa Institute of Technology, Bengaluru, India[3]

prabhu_cg8055@yahoo.in, rangamech@gmail.com, sreenivasam123@gmail.com

Abstract*: The Usage of Natural fibers based composites leading to high priority in the present industries is due to their property benefits over synthetic fibers. it is Because of completely biodegradable the banyan and banana fibers were used in the present work. The paper deals with experimental and FEA testing of tensile and bending behavior of Banyan (B) and Banana (Ba) reinforced composites with different volume fractions such as 25B/25Ba, 30B/20Ba and 35B/15Ba with 50% of epoxy resin. The hybrid composites with treated by 5% NaOH solution have better results compare to untreated fiber composites, with volume fraction of 30% Banyan fibers and 20% Banana fibers (30B/20Ba) gives higher Tensile and Flexural properties for both treated and untreated fibers composites compare to other volume fraction composites.The maximum tensile and bending strength was found in 30B/20Ba volume fraction, 63.37MPa and 67.07 MPa respectively for treated fibers composites, water absorption increases with increase in duration of immersion in composites up to 144 hrs*

Keywords: natural fibers, Banyan and Banana fibers, water absorption

I. INTRODUCTION

The fibres extracted from nature plants or tress and animals are called Natural fibres. These kinds of fibres are used in human's daily life commodities such as threads, wicks and ropes etc because of greater flexibility in nature. The natural fibres have several benefits such as easily available, less production cost, low specific weight; because of biodegradable property these are friendly towards environment and admirable at insulating and thermal properties. Use of natural fibres in the fields of aerospace, automobile, construction and many other industries are drastically increasing [1]. By implication of hybrid reinforced (synthetic/natural fibre) and appropriate fibre volume fraction, orientation and fabrication method improves the thermal, mechanical and physical properties that are not only by synthetic fibers but in addition of natural fibers [2]. The natural fibers composites have some limitations such as swelling, moisture absorption, poor resistance towards fire and chemical reaction between fibres and matrices materials which leads crack formation in both matrix and fibres, to overcome from such effects some techniques used such as alkaline, maleic anhydride grafted, permanganate and chemical treatment. These techniques also enhance the mechanical, thermal and physical properties [3].Bran as filler, an hybrid natural fibres composites (bidirectional Woven banyan fibers and neem fibers) were fabricated by hand layup process to analyze thermal properties like heat deflection temperature,

thermal conductivity, flame retardant and the coefficient of thermal expansion. With the use of dual natural fibers,thermal properties have greater improvements [4]. The field hockey equipments are made of synthetic fibers, over 90% of world produced of such equipments are from Pakistan and Sialkot, for durability, safety and efficiency point of view, and the researchers were replacing synthetic fibers with natural fibers like banana and additions of other natural fibers. With the hybrid composites the load baring capacity of hockey products as showed positive result [5]. Different processes involved while extraction of banyan fibers such as selecting proper aerial roots, soaking, bleaching and softening fibers were carried out. The fibers were treated with different chemical agents like sodium carbonate, sodium hydroxide, urea and enzyme to observe physical properties and were compared with other natural fibers. sodium carbonate treated fibers have high yield during extraction and sodium hydroxide gives best results towards properties as compared to others chemicals, mean while banyan fibers have moisture regain and retention compared to other fibers [6]. Cotton with Alkali treated and Areca fibers without treated have higher water absorption capacity compared to banana and pineapple leaves [7].With combined banyan woven and neem fibers hybrid composites, the tensile, compressive and flexural strength. With equal weight fraction of neem and banyan fibers have best at hardness and water absorption [8]. The effect of stacking series of hemp and sisal with green epoxy on physical, water absorption and mechanical properties were experimentally carried out, hybrid gives better mechanical properties than non hybrid, meanwhile water absorption as slightest resistance was observed [9]. Aerial roots of banyan are undergone with different mechanical test by treating them with Akali chemical and observed grater improvement in results [10].

II. MATERIALS AND METHODS

2.1 Materials

To carry out, the current research work, RawBanyan and Banana fibers were procured from M/s. Vruksha Composites, Tenali, Andhra Pradesh. The Hardener(HY951) and epoxy resin (LY556) were procured from Herenba Instruments and Engineers, Ambattur, Chennai. Normal glass was used for the preparation as mold material.

(a) (b)

Figure 1: a) raw banyan and banana fibers. b) The Hardener (HY951) and epoxy resin (LY556)

2.2 Preparation of Reinforcement and Matrix Material

The fibers are available in bundle form, hand sitting process used to choose fibres carefullyby rejecting or removing unnecessary materials, like small pellets, stems and foreign materials. Once unwanted materials are removed from fibres followed by cutting as shown in figure 2a and water treatment was carried out, fibres were dipped in the water and dried until the water substance completely eliminated from the fibers. Since after water treatment, fibers possess smooth surface and reeducation in adhesive property. So to overcome from these effects, the fibers were undergone with chemical treatment by using 5% NaOH solution later by using distilled water, fibers were cleaned and followed by drying in an oven [23, 18-20]. The treated fibers shown in figure 2b.

(a) (b)

Figure 2: a) Cutting of banyan and banana fibers. b) The treated fibers of banyan and banana.

Suitable amount of resin and hardener mixed with ratio of 10:1was put in a plastic container and stirred for 5mins for proper mixing, the mixture is allowed to settle to get clear solution. Once solution had settled it was taken for specimen preparation.

2.3 Composite Sample Preparations

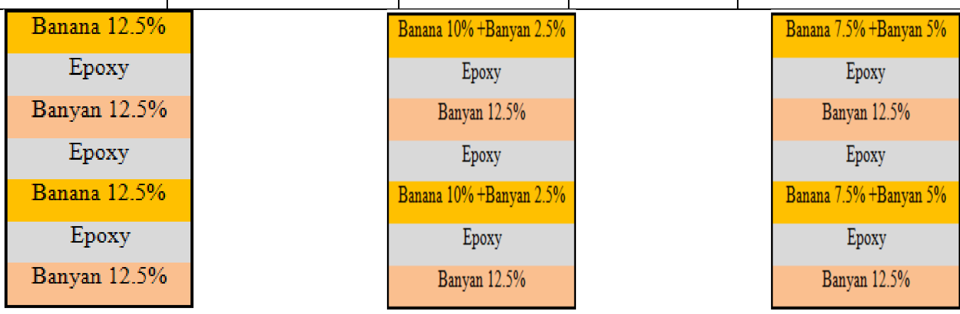
In the current work, Banyan (B) and Banana (Ba) fiber hybrid composites were fabricated in addition of epoxy resin. The hand layup process was chose to fabricate composites specimens, the fibers are stagnated properly without twisting and gap free in the mold with selected weight fraction of fibers and epoxy as shown in figure 3a. The fibers are placed in 00 orientation and vacuum bag process was used to uniform distribution of resin and remove excess resin from the mold as shown in figure 3b. Three different weight fractions of composites were fabricated by maintaining constant weight of epoxy as 50% and varying weight fraction of fibers as follows 25B/25Ba, 30B/20Ba and 35B/15Ba and the schematic representation of ply in composites shown in figure 4. In each cases three specimens, with and without chemical treatment were fabricated. After curing was complete,the composites were cut according to ASTM standard dimensions by use of CNC cutting machine. Table 1 gives weight fractions of samples

(a) (b)

Figure 3: a) the fibers are stagnating. b) Vacuum bag process.

Table 1. The weight fraction of composite samples

Composites with and without treatment	Total Matrix. (%)	Banyan (%)	Banana (%)	Total Reinforcement. (%)
25B/25Ba	50	25	25	50
30B/20Ba	50	30	20	50
35B/15Ba	50	35	15	50



(a) (b) (c)

Figure 4: Schematic layout of the ply sequence for banyan and banana fiber epoxy hybrid composites. (a) 25B/25Ba, (b) 30B/20Ba and (c) 35B/15Ba

2.4 Characterization Methods

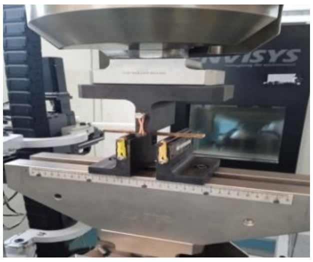
2.4.1 Tensile Test

A Nano Plug-n'-Play Series of servo-hydraulic type Universal testing machine by BISS shown in figure 5a, was used to measure the tensile modulus and strength of composites specimens. The test was carried at a crosshead speed of 2mm/min and 0.10mm/min strain rate for all the specimens. The specimens were tested according to ASTM D3039 [11-16]. In each variation in weight fraction, three specimens were tested and average values are taken.

2.4.2 Flexural Test

A Nano Plug-n'-Play Series of servo-hydraulic type Universal testing machine by BISS shown in figure 5a, was used to measure the flexural modulus and strength of composites specimens. We choose 3-point bending test and 3-point bend fixture as shown in figure 5b, because of applied load at the centre in 3-point bending is distributed uniformly over 4-point bending test. The test was carried at a crosshead speed of 2mm/min and 0.10mm/min strain rate for all the specimens. The specimens were tested according to ASTM D790 [17-22]. In each variation in weight fraction, three specimens were tested and average values are taken.

(a)



(b)

Figure 5: a) A Nano Plug-n'-Play Series of servo-hydraulic type Universal testing machine. b) 3-point bend fixture.

2.4.3 Water abortion Test

The effects of water absorption on hybrid composite specimens were analyzed according to ASTM D570 [25]. The dimensions for the specimens were 76.2x25.4x3mm was used [24-25].The experimentation of test begins with placing specimens in an oven at 600C for 24hrs so that moisture any water particles will be removed, immediately after removing from the oven the specimens were weighed (Wi). Later specimens were immersed into the distilled water for 24hrs, after 24hrs the specimens were taken out of the water bath and wiped using smooth cloth, after that the specimens were periodically weighed for mass gain (Wo) for every 24 hrs (24,48, 72, 96,120 and so on) until the water absorption of specimens attain saturation level [24]. The percentage of water absorbed by specimens at different time duration was calculated by using equation,

$$Wa\ (\%) = ((Wo - Wi)/\ Wi) \times 100$$

Where Wa is the water absorption, Wi is the weight of composite before immersion and Wo is the weight of composite after immersion.

2.4.4 Finite element analysis

In this work, the ANSYS 2020 R2 software is engaged to determine the tensile strength and bending strength of hybrid composite. The material properties of fibers and epoxy resin given in table 2. By the use of Rule of hybrid mixture, the longitudinal modulus E1 and poisson's ratio in longitudinal v12 and v13 is predicted, for transverse modulus E2 and shear modulus G12, G13 and G23 was predicted by modified Halpin-Tsai equation.

Table 2: Material properties

Materials	Young's modulus (GPa)	Poisson's ratio	Density (g/cm^3)
Banyan fibers	1.5	0.24	1.92
Banana fibers	3.5	0.28	1.35
Epoxy resin	2.8	0.35	1.19

III. RESULTS AND DISCUSSIONS

3.1 Effect of fibers on tensile properties.

The tensile strength and tensile modulus of Banyan and Banana hybrid composite is graphically represented in the figure 6, for both fibres treated and untreated conditions. It is noticed that with increase in banyan fibers in a composite from equal volume fraction (25B:25Ba) to volume fraction (30B:20Ba) increased with tensile strength, max load and tensile modulus. And also observed slight decrease in tensile properties from volume fraction (30B:20Ba) to volume fraction (35B:15Ba). For better results three specimens were tested and Avg value chosen as tensile property results, the results of different volume proportion of fibers for both untreated and treated fibers were listed in table 3 and table 4.

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Table 3: Tensile test without treatment.

Weight fraction	Tensile strength (MPa)	Avg	Tensile Modulus (GPa)	Avg	Max Load (kN)	Avg
25B/25Ba	18.234	18.326	1.594	1.599	1.161	1.161
	18.532		16.21		1.171	
	18.212		1.582		1.151	
30B/20Ba	48.821	49.166	5.812	5.864	4.192	4.193
	51.345		6.045		4.532	
	47.332		5.734		3.855	
35B/15Ba	42.567	43.867	4.102	4.186	3.789	3.88
	45.468		4.278		3.947	
	43.567		4.177		3.912	

Table 4: Tensile test with treatment.

Weight fraction	Tensile strength (MPa)	Avg	Tensile Modulus (GPa)	Avg	Max Load (kN)	Avg
25B/25Ba	23.412	23.612	2.047	2.056	1.491	1.496
	24.314		2.115		1.536	
	23.111		2.008		1.461	
30B/20Ba	62.686	63.372	7.463	7.557	5.383	5.407
	67.365		7.931		5.946	
	60.064		7.276		4.892	
35B/15Ba	54.656	56.532	5.267	5.393	4.865	5.003
	59.654		5.613		5.178	
	55.287		5.301		4.964	

With volume fraction for 30% Banyan fibers and 20% Banana fibers (30B:20Ba) given maximum tensile strength of 49.166MPa, maximum tensile modulus of 5.864GPa and maximum load of 4.193kN for untreated fibers composites. One of the major objectives of this work is focused on the change in properties between chemically treated and untreated fibers composites. From the experimental results it is observed that the chemically treated fiber composites have higher tensile properties compared to untreated fiber composites and also noticed that 28 to 31% increase in tensile properties from untreated to treated fiber composites. It because of better interaction and chemical bonding between fiber and matrix which is a result of removal of surface impurities and partial removal of amorphous hemicellulose and lignin and increase of crystallinity

3.2 Effect of fibers on Flexural properties.

The flexural strengths and Flexural modulus of Banyan and Banana hybrid composite is graphically represented in the figure 7, for both fibres treated and untreated conditions. It is noticed that with increase in banyan fibers in a composite from equal volume fraction (25B:25Ba) to volume fraction (30B:20Ba) increased with bending strength, max load and bending modulus. And also observed the decrease in flexural properties in decrease in banyan fibers from volume fraction (30B:20Ba) to volume fraction (35B:15Ba). For better results three specimens were tested and Avg value chosen as flexural property results, the results of different volume proportion of fibers for both untreated and treated fibers were listed in table 5 and table 6.

Table 5: Bending test without treatment.

Weight fraction	Flexural strength (MPa)	Avg	Flexural Modulus (GPa)	Avg	Peak Load (kN)	Avg
25B/25Ba	39.224	38.680	1.421	1.376	0.054	0.052
	38.837		1.387		0.052	
	37.978		1.321		0.051	
30B/20Ba	52.198	52.064	3.892	3.954	0.134	0.131
	51.896		3.967		0.127	
	52.098		4.002		0.132	
35B/15Ba	34.265	35.039	2.901	2.866	0.043	0.045
	35.423		2.811		0.045	
	35.429		2.887		0.047	

Table 6: Bending test with treatment.

Weight fraction	Flexural strength (MPa)	Avg	Flexural Modulus (GPa)	Avg	Peak Load (kN)	Avg
25B/25Ba	50.364	49.837	1.825	1.774	0.069	0.070
	50.954		1.820		0.068	
	48.194		1.676		0.065	
30B/20Ba	67.022	67.074	4.997	5.094	0.172	0.169
	68.088		5.205		0.167	
	66.112		5.079		0.168	
35B/15Ba	43.996	45.114	3.725	3.692	0.055	0.058
	46.475		3.688		0.059	
	44.959		3.664		0.060	

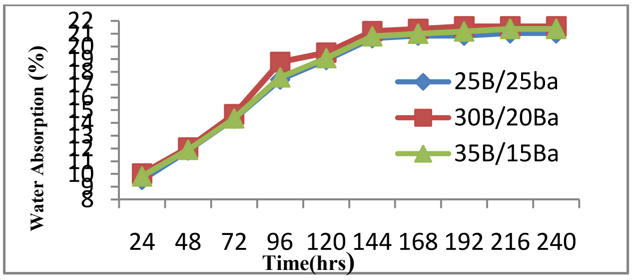
With volume fraction for 30% Banyan fibers and 20% Banana fibers (30B:20Ba) given maximum bending strength of 52.064MPa, maximum tensile modulus of 3.954GPa and maximum load of 0.131kN for untreated fibers composites. The work is focused on the change in properties between chemically treated and untreated fibers composites. From the experimental results it is observed that the chemically treated fiber composites have higher flexural properties compared to untreated fiber composites and also noticed that 27 to 31% increase in flexural properties from untreated to treated fiber composites.

The maximum tensile and bending load carrying capacity of Banyan and Banana hybrid composite is graphically represented in the figure 8, for both fibres treated and untreated conditions. It is observed that, volume fraction for 30% Banyan fibers and 20% Banana fibers (30B:20Ba) gives higher load carrying capacity for both treated and untreated fibers composites in tensile and bending condition.

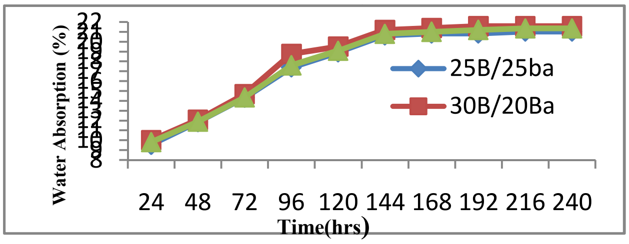
3.3 The effect of water absorption.

Water absorption is very important property to understand composite materials. Figure 9 tells about the water absorbed by treated and untreated composite specimens in terms of percentage for different volume fraction of fibers and duration of immersion. The water absorption takes place from 9-22% in both treated and untreated fibers composites with different duration; the water absorption remains saturation after 144 hours.

The composites with treated fibers have comparatively less water absorption about 2% compared to untreated fibers with same volume fraction and duration of immersion, this because the chemical bonding and interaction between fibers and matrix which makes removal of impurities on fibers surfaces and increase of crystallinity.



(a)Untreated



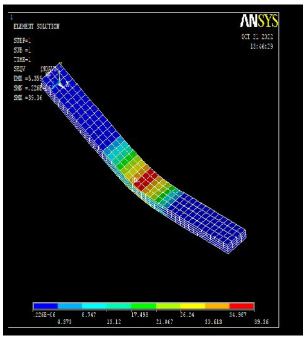
(b) Treated

Figure 9: Water absorption curve for the untreated and treated Banyan and Banana fibers reinforced epoxy composites.

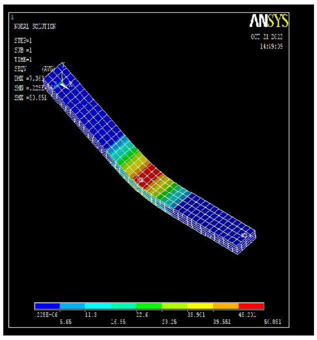
3.4 Simulation results.

The simulated stress distribution for tensile and bending strength of Banyan and Banana hybrid treated and untreated at different volume fractions was performed. Table 7 summarizes the comparison of experimental and simulated results; it is observed that the maximum percentage in difference between experimental and simulated results was found up to 3%.

The plots of the elemental solutions showing simulated stress distributions for Banyan and Banana hybrid treated and untreated composites are shown in figure 8. As the results indicate, tensile strengthsand flexural strengths increased in treated fibers composites



(a)Untreated



(b) Treated

Figure 10: Flexural stress distribution

Table 7: Comparison of Experimental and FEA results.

cal Properti	Untreated			FEA Untreated			Treated			FEA Treated		
	25B/ 25Ba	30B/ 20Ba	35B/ 15Ba	25B/ 25Ba	30B/ 20Ba	35B/ 15Ba	25B/ 25Ba	30B/ 20Ba	35B/ 15Ba	25B/ 25Ba	30B/ 20Ba	35B/ 15Ba
Tensile strength (MPa)	18.32	49.16	43.86	19.16	50.92	45.19	23.61	63.37	56.53	24.97	65.38	58.13
Bending strength (MPa)	38.68	52.06	35.03	39.36	54.12	36.08	49.83	67.07	45.11	50.85	68.89	46.75

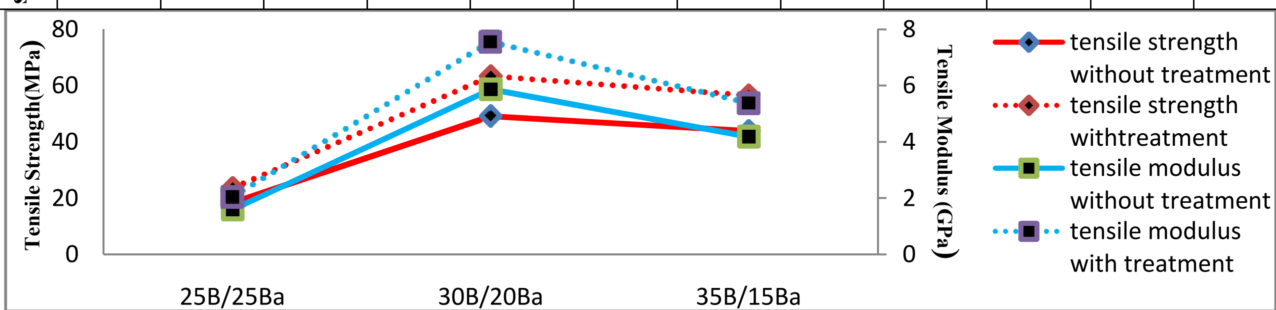


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Figure 6: Tensile strength and tensile modulus variation of natural fiber reinforced with and without treatment Composite for different volume fraction.

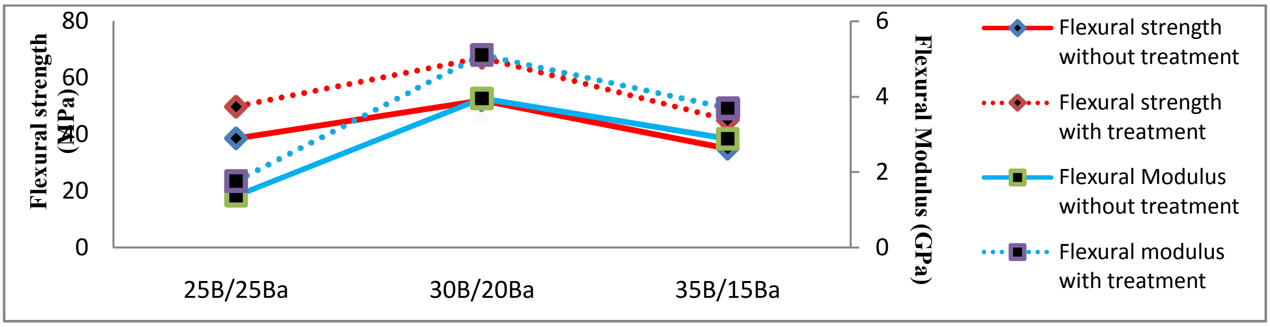

Figure 7: Flexural strength and Flexural modulus variation of natural fiber reinforced with and without treatment Composite for different volume fraction

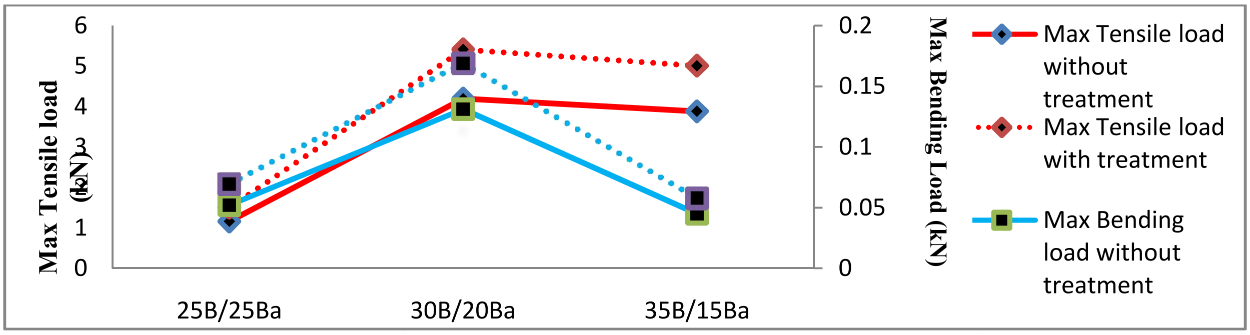

Figure 8: Max Tensile Load and Max Bending load variation of natural fiber reinforced with and without treatment Composite for different volume fraction.

IV. CONCLUSION

This work exposed the relative study of tensile, bending and water absorption behavior of chemically treated and untreated Banyan and Banana hybrid composites with different volume fractions. The following key observation was carried out in the study.

(i) The major study is focused on comparison on treated and untreated natural fiber composites properties, from the results its clearly shows that the chemically treated fiber composites were enhanced in tensile and bending strengths with avg of 29%.

(ii) Chemical treatment of fibers will improve the tensile and flexural strength in Banyan and Banana hybrid composites and can give 63.37MPa and 67.07MPa respectively.

(iii) Volume fraction of 30% Banyan fibers and 20% Banana fibers (30B:20Ba) gives higher Tensile and Flexural properties for both treated and untreated fibers composites compare to other volume fraction composites.

(iv) With increase in duration of immersion of composites in water will increase in water absorption up to 144 hours in both treated and untreated composites. But the treated fibers composites have less water absorption compare to untreated fiber composites.

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