Tensile Properties of Long Untreated and Alkali Treated Napier Grass Fiber Strands/Epoxy Composites

Venkata Parasuram Kommula, Obi Reddy Kanchireddy, Mukul Shukla, and Tshilidzi Marwala

***Abstract*—**Napier grass fiber strands were extracted using the combined mechanical and water retting process. The extracted fiber strands were treated with various proportions (5, 10 and 15% w/v) of NaOH solution to improve their surface morphology and bonding with the resin. This study investigates the Tensile properties of composites made by reinforcing alkali treated, long Napier grass fiber strands in to epoxy resin with different orientations (0º). The composites were prepared with 0, 5, 10, and 15% of alkali treatment and with a fiber loading (weight %) of 10, 20, and 30%. The effect of alkali treatment, orientation and fiber loading on the tensile strength of the composites was analyzed using universal testing machine. Quantitative results from this study will be useful for more accurate design of Napier grass fiber strand reinforced composite materials for possible automotive applications.

***Keywords*—** Napier grass, Tensile strength, Alkali treatment.

I. Introduction

THE Epoxy resins are the most commonly used thermoset plastic in polymer matrix composites. Epoxy resins are a family of thermoset plastic materials which do not give off reaction products when they cure and so have low cure shrinkage [1]. They also have good adhesion to other materials, good chemical and environmental resistance, good chemical properties and good insulating properties.

Renewable materials from sustainable sources are increasingly used in a variety of applications. Epoxy matrix composites reinforced with natural plant fibers are one such example. There is need for fundamental and applied research into products and processes based upon biomaterials and to transfer these technologies to industry. By placing natural fibers in epoxy resin matrix, novel low cost biocomposites with desired properties can be made. Such biocomposites can provide many beneficial additions to the advanced global housing program.

Varada Rajulu et al. [2] studied the chemical resistance and tensile properties of epoxy/unsaturated polyester blend coated bamboo fibers. They reported that the tensile strength and chemical resistance of bamboo fibers increased by coating them with the blend and hence are favorable materials for making composites.

Harish et al. [3] investigated mechanical property evaluation of natural fiber coir composite. They reported that coir/epoxy composites exhibit excellent mechanical properties.

Mylsamy and Rajendran [4] studied the mechanical properties, deformation and thermomechanical properties of alkali treated and untreated Agave continuous fiber reinforced epoxy composites. Their study reveals that composites reinforced with NaOH treated Agave fibers were considerably good as the shrinkage of the fiber during alkali treatment had facilitated more points of fiber resin interface. They also found that the thermal stability is increased with alkali treatment.

Mylsamy and Rajendran [5] studied the mechanical behavior of short Agave fiber reinforced epoxy composites and reported that shortest fibers (3 mm) have good adhesion with the epoxy resin. Also reported that decreased fiber length and increased fiber-matrix interaction helped to improve fiber wetting, impregnation, and in turn resulted in better mechanical performance.

Verma et al. [6] reported studied the mechanical properties of layered laminate bamboo-epoxy composites and reported that the tensile and compressive strength of the laminates decreases with increase in lamina angle.

Obi Reddy et al. [7] studied the effect of alkali treatment (up to 5% concentration) on thermal degradation of Indian grown Napier grass fibers. In their study they reported that thermal stability, tensile properties and crystallinity of the fibers were improved on alkali- treatment.

Rao et al. [8] studied the suitability of Indian grown elephant grass extracted through chemical and retting process

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as a fiber reinforcement in polyester matrix. They reported that the composites were formulated up to a maximum of 31% of volume of fiber resulting in a tensile strength of 80.55MPa and tensile modulus of 1.52 GPa for elephant grass fibers extracted by retting process. They also found that the tensile strength and modulus of chemically extracted elephant grass fiber composites have increased by approximately 1.45 times to those of elephant grass fiber composites extracted by retting.

Obi Reddy et al. [9] analyzed and characterized the India grown Napier grass fibers (untreated, 2 and 5% alkali treated) using chemical, FTIR and solid state CNMR methods. They reported that Alkali treatment eliminated the amorphous hemicellulose component of the fibers to a larger extent.

Albuquerque et al. [10] studied effect of wettability and ageing conditions on the physical and mechanical properties of uniaxially oriented jute-roving-reinforced polyester composites. They observed that thermal ageing tended to decrease the composite mechanical properties, which was attributed to oxidative degradation of both fiber and matrix. They used SEM technique to probe the fiber surface wettability and interaction between fiber and matrix.

Rout et al. [11] studied the influence of fiber treatment on the performance of coir-polyester composites. They investigated that the surface modifications improved the fiber/matrix adhesion using scanning electron microscopy (SEM).

Varada Rajulu et al. [12] studied the tensile properties of glass rovings/ hydroxyl terminated polyester toughened epoxy composites. The morphology (SEM) of the cryogenically cooled and fractured surfaces indicated good bonding between the matrix and the reinforcement when a coupling agent was used.

The author’s main aim is to prepare Green composites using a new fiber and study their mechanical and other properties. As the suitability of the Napier grass fibers as reinforcement, the author prepared the laminates of Napier grass/epoxy composites and studied their properties in the present work. The effect of alkali treatment of the Napier grass fibers on the properties of the composites was also studied.

II. MATERIALS AND METHODS

A. Materials

In the present work, the Epoxy resin (Araldite® LY 556 and Hardener HY 951) was used as the matrix. The long Napier grass fibers were used as the reinforcement without and with 5, 10, and 15% alkali treatment at 0˚ orientation.

B. Treatment with NaOH

A portion of Napier grass fiber was treated with 5, 10, and 15% aqueous sodium hydroxide (NaOH) solution at room temperature, maintaining a liquor ratio of 30:1 and fibers were immersed in the alkali solution for 2 hours to remove the hemicellulose and other greasy materials. Then the fibers were washed with water repeatedly and to neutralize them, treated with dilute acetic acid. Finally the fibers were washed with distilled water before drying in hot air oven for a period of 24 hours.

C. Preparation of composite

From the previous studies, it is evident that the epoxy laminates are dimensionally stable and free from internal stresses due to their low cure shrinkage [7, 8]. Epoxy (LY 556) of density 1.15 g/cm3 matrix and hardener (HY951) of density 0.98 g/cm3 were used to fabricate the composite. The weight ratio of 100:15 was used to mix epoxy and hardener respectively. In the present work, the composite laminates were prepared with weights of 10, 20, and 30% of untreated and alkali treated Napier grass fiber strands. Prepared epoxy resin poured in to fill up the glass mould after arranging the long Napier grass fibers in 0˚ orientation . These laminates were allowed to cure for 24 hours at room temperature. Finally, the laminates are subjected to post curing for 3 hours at 100ºC in an oven. Two important factors such as alkali treatment and fiber loading (weight %) were considered as important factors in present work. Test specimens were prepared from these laminates after the curing process, as per the ASTM standards.

D. Testing

The tensile and flexural tests were conducted using INSTRON UTM of Model 3369 instrument. M/s PSI Instruments make impact testing machine was used to conduct Izod impact test. The specimens for each test were prepared as per ASTM specifications. The test specimens dimensions discussed in chapter 2. The temperature and humidity for this test were maintained at 22˚ C and 50% respectively. In each case, ten specimens were tested and the average values tabulated.

III. RESULTS AND DISCUSSION

The mechanical properties (tensile, flexural, and impact) of long Napier grass fiber reinforced Epoxy resin matrix composites were investigated by varying the fiber loading (weight ratio) and alkali treatment in two different orientations. The mechanical properties of composites with untreated, and alkali treated were studied.

A. Tensile properties

The tensile properties (modulus, strength and % elongation) values of untreated and alkali treated Napier grass fiber reinforced Epoxy resin matrix composites are presented in Table 1. These values are also representing as bar diagrams in Fig. 1 and 2. From Table 1 and Fig. 1 and 2, it can be observed that both tensile (modulus and strength) properties increased with increasing fiber loading. The increased tensile properties followed a linear increasing trend upto 10% alkali treatment and 20% fiber loading. From Table 1, it can also be observed that the tensile properties of the composites are higher than these of the matrix.

The tensile (strength and modulus) properties of neat epoxy, untreated and alkali treated Napier grass fiber strands reinforced epoxy composites, as a function of fiber loading are presented in Table 1, the corresponding graph shown in Figure 1 and 2. The tensile strength and modulus of the Napier grass fiber strands/epoxy composites increased with increasing fiber loading up to 20 wt.% and thereafter a decreases. However, in all the cases, the tensile strength and modulus of the composites were found to be higher than that for the matrix. At the composition of 20 wt.% Napier grass fiber strands by weight, the tensile strength and modulus of both untreated and various concentrations of alkali treated fiber strands composites were found to be as follows: untreated, 101.02 and 8940.17 MPa; 5% alkali treated, 120.87 and 9986.94 MPa; 10% alkali treated, 142.14 and 10908.4 MPa; and 15% alkali treated, 128.33 and 9508.8 MPa. The percent increase in tensile strength and modulus of different types of composites, respectively (presented in parentheses), over the matrix was: untreated (381.1 and 347.1%), 5% alkali treated (475.5 and 399.3%), 10% alkali treated (576.8 and 445.4%), 15% alkali treated (511.1 and 375.4%).

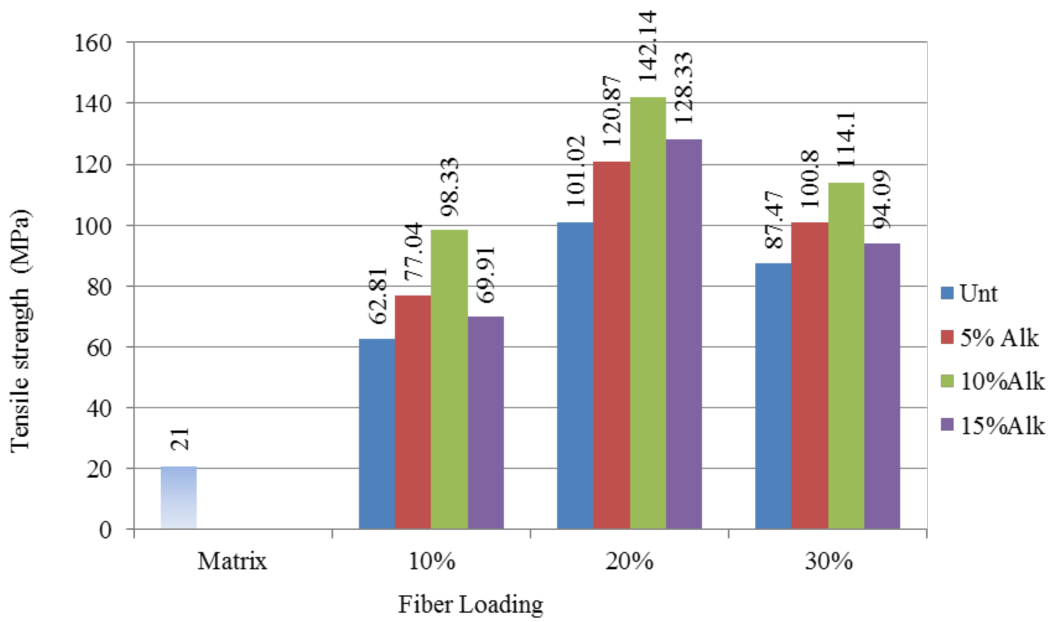

Fig. 1 Tensile Strength of long Napier grass fiber strands/Epoxy composites

The tensile strength and modulus of the composites increased with fiber loading upto 20% and thereafter decreased. Generally for higher fiber loadings, the preparation of the resin matrix between the fibers decreases leading to poor wetting and interfacial adhesion. However, in all cases, the tensile strength and modulus of the composites were found to be higher than for matrix. This observation indicates the reinforcing nature of the fibers. However, the % elongation of the composites varied only a little from the values of matrix.

B. Flexural properties

In order to assess the performance of the long Napier grass fiber/Epoxy composites for bending forces, their flexural properties were studied. The flexural modulus and yield strength of these composites employing native and alkali treated Napier grass fiber fiber strands are presented in Table 2 and also as bar diagram representation in Fig. 3 and 4. From the Table 2 and Fig. 3 and 4, it can be noticed that increasing trend of flexural properties with fiber loading upto 20% was observed, in all cases, these properties of the composites are found to be higher than for the neat matrix.

The flexural strength and modulus of these composites employing untreated, alkali-treated treated Napier grass fiber strands are presented in Table 2, the corresponding graphs shown in Figures 3 and 4. The flexural properties of composites showed a similar trend as that of their tensile properties. However, in all the cases, the tensile strength and modulus of the composites were found to be higher than that for the matrix. At the composition of 20 wt.% Napier grass fiber strands by weight, the flexural strength and modulus of both untreated and different concentrations of alkali treated fiber strands composites were found to be as follows: untreated, 103.25 and 6096.35 MPa; 5% alkali treated, 105.5 and 6114.34 MPa; 10% alkali treated, 111.33 and 6784.22 MPa; and 15% alkali treated, 92.52 and 5884.46 MPa. The percent increase in flexural strength and modulus of different types of composites, respectively (presented in parentheses), over the matrix was: untreated (129.4 and 143.8%), 5% alkali treated (134.4 and 144.5%), 10% alkali treated (147.3 and 171.3%), 15% alkali treated (105.6 and 135.3%).

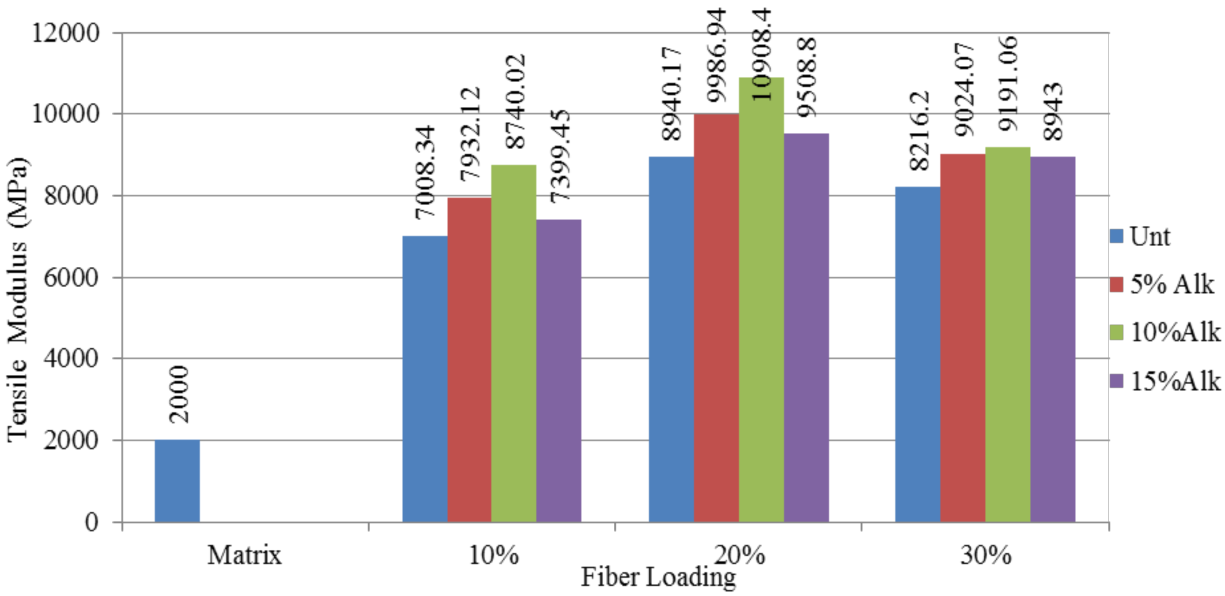

Fig. 2 Tensile Modulus of long Napier grass fiber strands/Epoxy composites

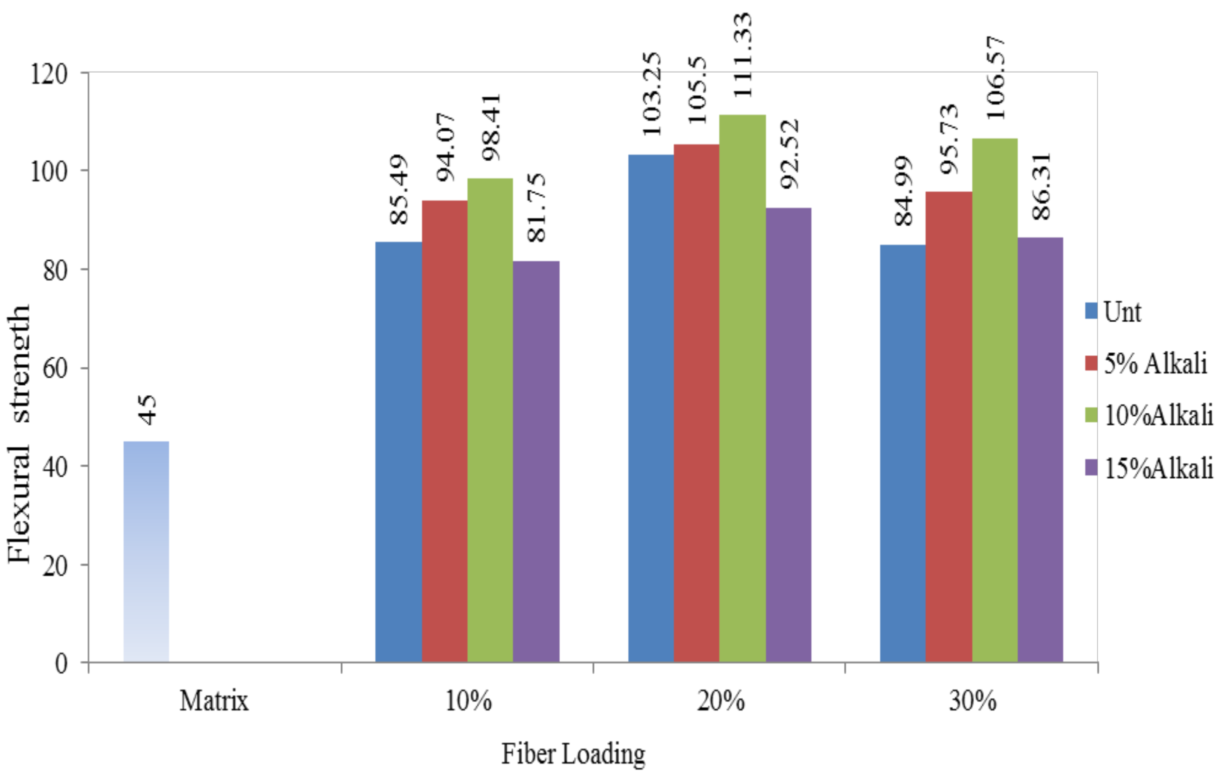

Fig 3 Flexural Strength of long Napier grass fiber strands/Epoxy composites

TABLE I
TENSILE PROPERTIES OF LONG NAPIER GRASSS FIBER STRANDS/EPOXY COMPOSITES

Fiber Loading (Wt%)	Strength (MPa)				Modulus (MPa)			
	Unt	Alkali treated			Unt	Alkali treated		
		5%	10%	15%		5%	10%	15%
Matrix		40			2000			
10	62.8	77.04	98.3	69.9	7008.3	7932.1	8740.0	7399.4
20	101.0	120.8	142.1	128.3	8940.2	9986.9	10908.4	9508.8
30	87.5	100.8	114.1	94.1	8216.2	9024.1	9191.1	8943

TABLE II
FEXURAL PROPERTIES OF LONG NAPIER GRASSS FIBER STRANDS/EPOXY COMPOSITES

Fiber Loading (Wt%)	Strength (MPa)				Modulus (MPa)			
	Unt	Alkali treated			Unt	Alkali treated		
		5%	10%	15%		5%	10%	15%
Matrix	45				2500			
10	85.5	94.07	98.41	81.75	3980.6	3606.24	4243.6	2994.3
20	103.2	105.5	111.3	92.52	6096.3	6114.34	6784.22	5884.4
30	84.99	95.73	106.5	86.31	5265.7	5450.53	5716.16	5406.9

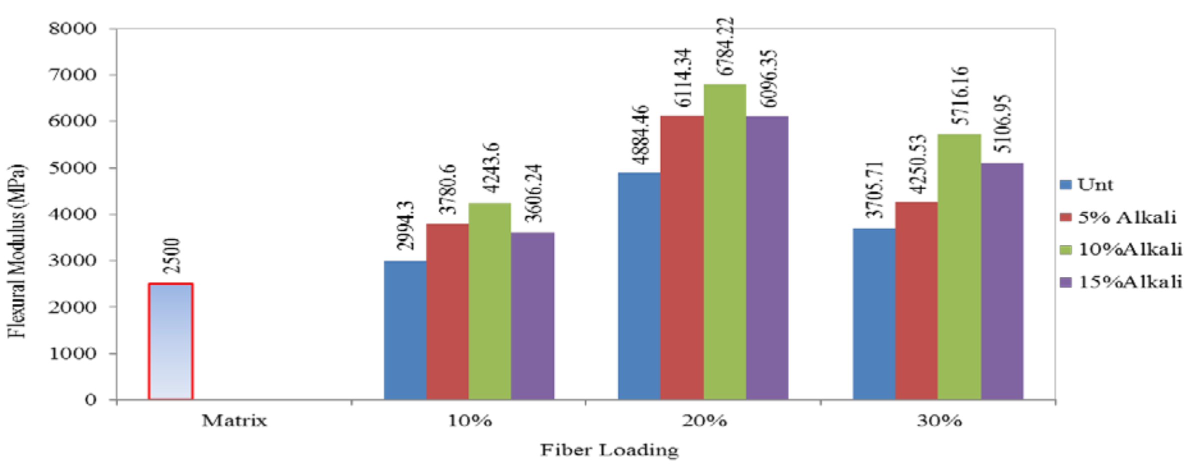

Fig. 4 Flexural Modulus of long Napier grass fiber strands/Epoxy composites

The long Native African grass fiber/Epoxy composites a regular trend was observed that the increase in their mechanical properties upto 10% alkali treatment and 20% fiber loading and with higher alkali concentration and fiber loading lead to lower the mechanical properties. This is due to the orientation and length of the fibers in the composites. However, the mechanical properties of the composites were found to be higher than those of the matrix. The chemical modification of the fibers by alkali treatment further improved the mechanical properties of the composites. When the Native African grass fiber fibers were treated with alkali, the fiber surface became rough. The roughening of the surface leads to increase in contact area which leads to lowering of contact angle of the resin on the fibers leading to improvement in interfacial bonding. Thus, this factor might be responsible for improvement of the mechanical properties of the composites under study when the fibers were chemically modified.

IV. Conclusions

The long Native African grass fiber/Epoxy composites were made for the first time and their mechanical properties are studied. The mechanical properties of the composites were found to be higher than the matrix. From the study it is clearly shows that there is a regular trend in the mechanical properties with fiber loading. The mechanical properties of the composites were further enhanced by the chemical modification of the fibers

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