Fabrication and evaluation of flexural properties of natural fiber reinforced polymer composite: Bamboo/ Hemp

Sanjay Tiwari
Research Scholar,
Dr.A.P.J. Abdul Kalam Technical University, Lucknow
Uttar Pradesh, India

Dr. Vinay Pratap Singh
Assistant Professor,
Department of Mechanical Engineering,
Harcourt Buttler Technological Institute, Kanpur Uttar Pradesh, India

Abstract: Natural fibers are getting attention from researchers and academicians to utilize in polymer composites due to their eco-friendly nature and sustainability. The aim of this article is to find the flexural strength of natural fiber reinforced polymer composite. Short fiber having length 5-7 mm of hemp and bamboo are selected as reinforcing element with Epoxy Resin LY 554/6 and Hardener HY951. In the present work, flexural property is tested for bamboo; bamboo/hemp; hemp and epoxy resin composites according to ASTM standard. Four sample of constant fiber content of 20% is prepared. The results of flexural test on composite showed that the improvement in flexural strength, particularly hemp reinforced polymer composite. This improvement is about 26% more compared to flexural strength of epoxy resin. Traditional hand-lay-up method was used to prepare the samples.

Key Words: Composite material, Natural fiber, Hybrid Composite, flexural Strength.

I. INTRODUCTION:

Despite the fact that glass fiber reinforcement plastics have excellent thermal and mechanical properties. It is difficult to devise suitable disposal method for them. Due to many environmental problems the disposal for glass fiber reinforced plastics (GFRP) and their recycling has been seriously acknowledged [1]. Because of their biodegradable nature, natural fibers have been increasingly adopted to replace the synthetic polymer in the industrial application [2-3]. Due to the natural alignment of the carbon-carbon bond with in the structure of organic fiber it is expected that their linear chain polymer would possess significant strength and stiffness. Over the last two decades, there has been increased interest in the sourcing of cheaper new materials used in the automotive and aerospace industries [4] and natural fiber composite have maintained a position at the top of the list.

As for as the characteristics is concern, bamboos are tall, perennial, arborescent grasses, belonging to the Bambusae, a tribe under Gramineae. Earlier the fracture properties of bamboo culm and nodes have been studied [5]. Bamboo is a typical natural composite material and the fibers are distributed densely in the outer surface region and sparsely in the inner surface region. It is evident that the fracture toughness of bamboo culm depends on the volume fraction of fibers. The bamboo has multi nodes and functionally gradient structure [6-8].

Hemp is an annual plant native to central Asia and known to have been grown for more than 12,000 years. It probably reached central Europe in the Iron Age and there is evidence of its growth in the UK by the Anglo-Saxons (800-1000 AD). It is now grown mostly in the EU, Central Asia, Philippines, and China. According to Food and Agriculture Organisation (FAO), almost half of the world’s industrial hemp supply is grown in China, with most of the remainder being cultivated in Chile, France, the Democratic People’s Republic of Korea, and Spain [9]. India is leading producer of Hemp in world.

The main constituents of hemp fibers are cellulose, hemi-cellulose, lignin, and pectin. Cellulose, hemi-cellulose, and lignin are basic components that define physical properties of fibers. Cellulose is the stiffest and the strongest organic constituent in the fibers. Perhaps the biggest drawback of hemp fibers is the variability in their composition. This, invariably results in variability in their physical and mechanical properties. Diameters and properties of natural fibers vary significantly depending upon factors such as source, age, retting and separating techniques, geographic origin, and rainfall during growth [10].

II. MATERIALS AND METHODS

2.1 Matrix Material

2.1.1 Epoxy Resin LY 554/6

Epoxy resin LY 554/6 is widely used in industrial application because of their high strength and mechanical adhesiveness characteristic. It is also good solvent and have good chemical resistant over a wide range of temperature.

2.1.2 Hardener HY951

Hardener HY951 of density 0.97 to 0.99 g/cm3 used as curing agent. The weight percentage of hardener used in the present investigation is as per recommendation of [11].

2.2 Reinforcing Element

2.2.1 Bamboo Fiber

Bamboo plants are giant, fast-growing grasses that have woody stems. The characteristics of each vary in size, growth habit, sun tolerance, soil moisture needs and heat/ cold temperature tolerance. Several investigators have examined bamboo as a source of bast fiber and as a source of cellulose from pulping the bamboo [12]. One of benefits using bamboo fibers is that the bamboo is an abundant natural resource in Asia and Middle & South America. Bamboo fibers are often known as natural glass fiber due to its high strength with respect to its weight derives from fibers longitudinally aligned in its body [13]. The tensile strength of bamboo is relatively high and can reach 370 MPa [14]. This makes bamboo an attractive alternative to steel in tensile loading application. In the present work, short bamboo fiber of length 5-7 mm is taken as the reinforcement material. The bamboo used for this work is collected from the local source. This is one of the predominant species of bamboo in Andhra Pradesh, Orissa, Uttar Pradesh, Madhya Pradesh and Western Ghats in India.

Figure-1: Bamboo Fiber

2.2.2 Hemp Fiber

The hemp used in this study was produced in Uttar Pradesh, India. Table 1 and Figure 2 show the chemical composition [15-16] and bundle of the hemp fibers, respectively. This composition plays an important role in influencing the characteristic of the fibers. Hence, the composition may affect the properties of the composites.

The fibers were washed with water to remove dust and ash. Then, the hemp fibers were sterilized in boiling distilled water in an oven maintained at 100 ℃ for 1 h. After these processes, the fibers were rinsed in tap water and then dried in an oven at 70 ℃ for 12 h. In the present work, short hemp fiber of length 5-7 mm is taken as the reinforcement material.

	Cellulose	Pectin	Hemicelluloses	Lignin	Waxes and oils
wt.%	70.2-76.12	0.9-1.55	12.28-22.4	3.7-5.7	0.8-1.59

Table 1. The chemical composition of hemp fibers

Figure-2: Raw Hemp Fiber

2.3 Method and Sample Preparation

2.3.1 Method

The fabrication of the various composite materials is carried out through the hand lay-up technique. The mould used for preparing composites was made from two rectangular chromium plated mild steel sheets having dimensions of 300 mm×300 mm. Four beadings were used to maintain a 6.70 mm thickness all around the mould plates. The functions of these plates are to cover, compress the fiber after the epoxy is applied, and also to avoid the debris from entering into the composite parts during the curing time. A homogeneous mixture of epoxy and hardener in 10:1 ratio was prepared to laminate the short fibers in mould.

2.3.2 Sample Preparation

The mould was cleaned and dried and a thin layer of wax was applied for easy removal of composite from mould. The epoxy mixture was laid uniformly over the mould using a brush. Then a layer of the chopped strand mat was applied over the layer of epoxy. The same process was repeated until three such layers of epoxy and chopped strand mat are applied. Now the mould was closed and compressed for a curing time of 24 h.

Total four samples of same size were prepared for flexural testing.

Width: 12mm
Thickness: 6.70 mm
Length: 150mm
Fiber content in sample: 20%

Sample 01: 20% Bamboo Fiber + 80% Epoxy with hardener
Sample 02: **Hybrid Composite-**
20% Hemp & Bamboo Fiber in 2:1 ratio + 80% Epoxy with hardener
(Two layers of Hemp fiber and one layer of bamboo fiber is laminated.)
Sample 03: 20% Hemp Fiber + 80% Epoxy with hardener
Sample 04: 100% Epoxy with hardener

After the curing process, test samples were cut to the required sizes prescribed in the ASTM standards and tested.

III. FLEXURE TEST

The strength of material in bending, expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. After fabrication the test specimens were subjected to flexural tests as per ASTM standards. Four different specimens of bamboo; bamboo/hemp; hemp & epoxy resin were tested to evaluate the flexural strength at central Institute of Plastic Engineering & Technology, Lucknow, Uttar Pradesh, India. The tests were conducted at a speed of 2.86 mm/min at room temperature (303 K). Three-point bending (flexural) tests were carried out on the specimen at room temperature. The specimen is placed onto two supports having a 107.20 mm span length between the supports.

IV. RESULTS AND DISCUSSIONS

The flexural strength of different four samples is tabulated in table 2 and compared in figure 3(a). Test curve for all the four samples are listed in Figure 3(b), Figure 3(c), Figure 3(d) & Figure 3(e).
All measures of the strength reported here shows that the hemp fiber reinforced polymer specimens (sample 03) is significantly stronger than others.

Sample No	Max Flexural Load (N)	Flexural Strength@Max Load (Mpa)	Flexural Elongation @ maximum load (%)	Flexural Load@Break (N)	Flexural Strength @Break (Mpa)	Flexural Elongation@Break (%)	Modulus (MPa)
1	278.77	**83.22**	1.18	9.42	2.81	1.32	14287.10
2	292.26	**87.24**	1.08	3.89	1.16	1.19	12418.30
3	338.03	**100.90**	0.79	52.52	15.68	0.89	14612.90
4	265.27	**79.19**	1.47	-39.98	-11.93	3.38	9430.50

Table 2. Flexural test results

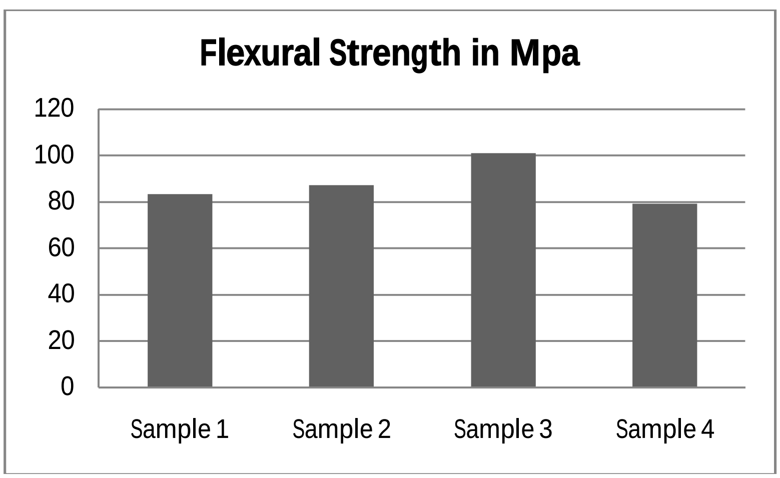

Figure 3(a) - Flexural Strength of samples

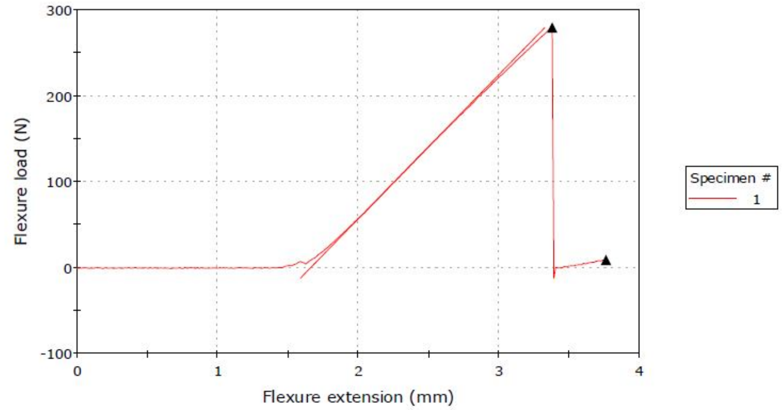

Figure 3(b) - Flexural Test Curve for sample 01

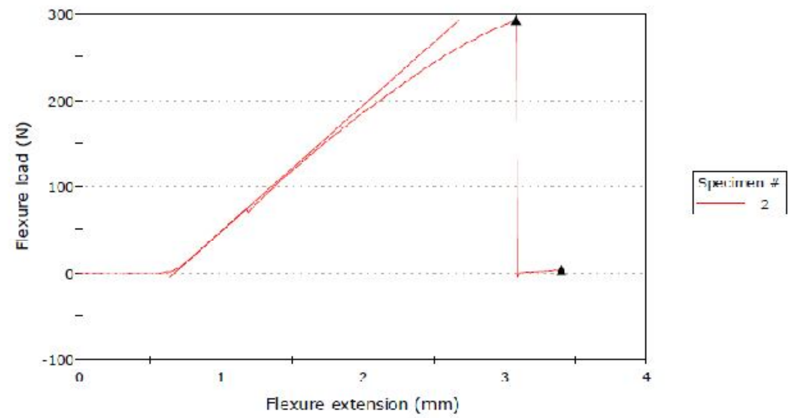

Figure 3(c) - Flexural Test Curve for sample 02

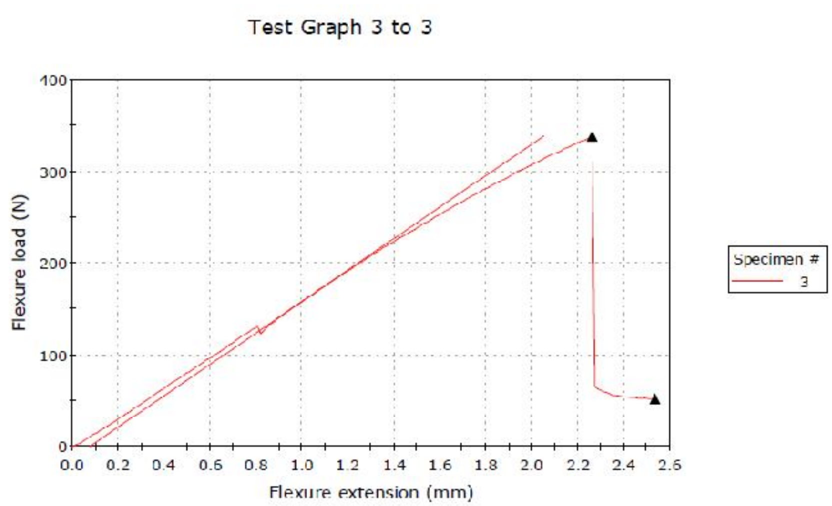

Figure 3(d)- Flexural Test Curve for sample 03

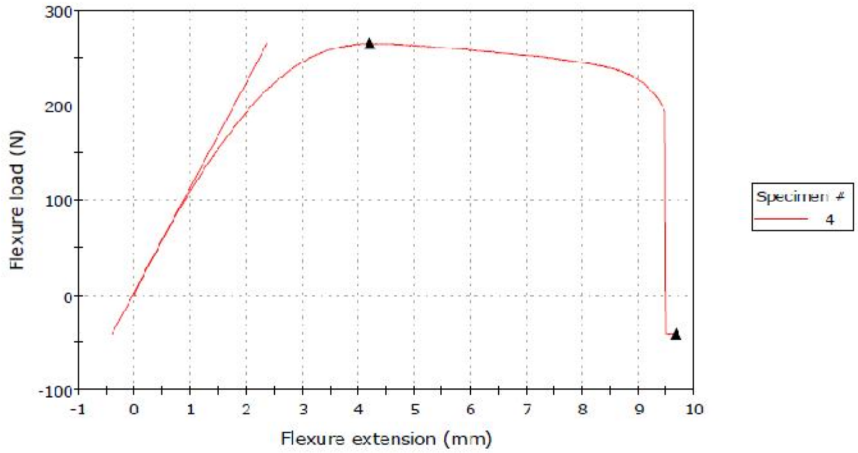

Figure 3(e) - Flexural Test Curve for sample 04

V. CONCLUSIONS

The present study has led to the following conclusions:

- Sample of epoxy resin without any reinforcing element has lowest flexural strength i.e.79.19 Mpa.
- Sample of bamboo fiber with epoxy resin shows improvement in flexural strength i.e. 83.22 Mpa. This improvement is about 5% more compared to flexural strength of epoxy resin sample.
- Sample of hybrid composite bamboo/hemp with epoxy resin further shows the improvement in flexural strength i.e 87.24 Mpa. This improvement is about 10% more compared to flexural strength of epoxy resin sample.
- Sample of hemp fiber with epoxy resin shows highest flexural strength i.e. 100.90 Mpa. This improvement is about 26% more compared to flexural strength of epoxy resin sample.
- Flexural strength can be further investigated by changing the weight ratio of hemp fiber/changing in orientation of fiber/using fiber surface treatments or changing in size of fiber etc.
- Their main disadvantage is the variability in their properties. Extensive research has been carried out on hemp fiber composites using thermoplastic, thermoset, and biodegradable polymer matrices.
- Another disadvantage of hemp fiber composites, their moisture absorption, can also be overcome by using suitable fiber surface treatment.
- It is suggested that these hemp fibers reinforced epoxy composites can be used as an alternate material for synthetic fiber reinforced composite materials.

REFERENCES

[1] Torres FG, Cubillas ML. Study of the interfacial properties of natural fiber reinforced polyethylene. Polym Test 2005; 24:694 – 8.

[2] Gram H, Person H, Skarendahi A. Natural fibre concrete. Falkoping: Gummessons Tryckeri AB; 1984.

[3] Josep PV, Kuruvilla JK, Sabu T. Effect of processing variables on the mechanical properties of sisal fibre reinforced polypropylene composites. Compos Sci Technol 1999;59:1625–40.

[4] Biswas S, Mittal A, Srikanth G. Development of natural fibre composites in India, News & Views, TIFAC. New Delhi: DST; 2005.

[5] Amada S, Untao S. Fracture properties of bamboo. Composites Part B 2001;32:451–9.

[6] Amada S, Munekata T, Nagase Y, Ichikawa Y, Kirigal A, Yang Z.The mechanical structures of bamboos in view of functionally gradient and composite materials. J Comput Mater 1996;30 (7): 800–19.

[7] Lakkard SC, Patel JM. Mechanical properties of bamboo, a natural composite. J Fibre Sci Tech 1981;14:319–22.

[8] Nogata F, Takahashi H. Intelligent functionally graded material: bamboo. Compos Eng 1995; 5(7):743–51.

[9] 'Natural Fibres', Online Referencing, www.naturalfibres2009.org 2009, (accessed xx xxxx).

[10] Netravali AN and Chabba S. Composites get greener. Mater Today 2003; 6: 22–29.

[11] Singh V. K. and Gope P.C.; Silica-Styrene-Butadiene Rubber Filled Hybrid Composites: Experimental Characterization and Modeling (2010), Journal of Reinforced Plastics and Composites, Vol. 29, No. 16/2010, pp. 2450-2468.

[12] Rajulu, A.V., S.A. Baksh, G.R. Reddy and K.N. Chary, 1998. Chemical resistance and tensile properties of short bamboo fiber reinforced epoxy composites. Journal of Reinforced Plastics and Composites, 17(17): 1507- 1511.

[13] Okubo, K., T. Fujii and Y. Yamamoto, 2004. Development of bamboo-based polymer composites and their mechanical properties. Composites: Part B, 35: 337-383.

[14] Thwe. M.M and Liao. K, 2003. Environmental effects on bamboo-glass/polypropylene hybrid composites, Journal of Materials Science, 38: 363-376.

[15] D. Sedan, C. Pagnoux, T. Chotard, A. Smith, D. Lejolly, V. Gloaguen, P. Krausz // J. Mater. Sci. 42 (2007) 9336.

[16] Biores. Technol. 99 (2008) 94. M. Kostic, B. Pejic, P. Skundric //