ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

FABRICATION & STUDY OF MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED POLYMER COMPOSITES

Hemant Mohan Kawade*[1], Dr. Narve N.G.[2], Prof. Mundhe V.L.[3]
* M.E Student, Manufacturing Engineering, JSPM's Bhagwant Institute of Technology Barshi, Maharashtra, India.
Principal, Yashoda Technical Campus Satara, Maharashtra, India.
H.O.D Mechanical Engg. Dept., JSPM's Bhagwant Institute of Technology Barshi, Maharashtra, India.

DOI: 10.5281/zenodo.1147598

ABSTRACT
Use of natural fibers as reinforcement have gained the importance in the recent years due to the eco-friendly nature. These natural fibers offer a number of advantages over traditional synthetic fibers. This paper deals with the evaluation of mechanical properties namely, Tensile strength (TS), Flexural strength (FS), Vickers Hardness (Hv), Impact Strength (J). Specimens were prepared by hand lay-up technique and are cut as per ASTM standards to perform test. In the present work experimental investigation has been carried out on different weight percentage of bamboo fiber (0, 15, 30 and 45) is used to modify epoxy resin properties. The experimental result reveals that the mechanical properties of the composite material were highly influenced by the fiber volume fraction (fiber loading). Addition of alumina (Al_2O_3) particulate at various proportions as filler material the mechanical properties viz. Tensile strength, Flexural strength, Hardness, Impact strength are improved.

KEYWORDS: Bamboo fiber, Polymer matrix, Tensile strength, flexural strength, Hardness, Impact strength and alumina particulate.

I. INTRODUCTION
As a result of the growing environmental awareness (e.g., increased pollution, increasing demand for biodegradable materials, new environmental laws and regulations), manufacturers and scientists are keen to study novel environmental friendly materials. Over the last decade intensive research and development has been carried out in order to develop powerful composites using natural fibers, offering good bio-degradability and sustainability. A biodegradable material will slowly undergo biodegradation by surrounding microorganisms, bacteria, and exposure to the elements and hence could provide solutions to end-of-life issues after service life. Nowadays, the fibers resulting from wood, animals, leaves, grasses and other natural sources are commonly used as reinforcement in composites used for various applications, like automotive (interior and exterior), building, ship, packaging *etc.*, due to their unusual properties compared to other synthetic fibers. Advances in manufacturing techniques in natural fiber-reinforced composites have allowed the car industry to utilize these composites in interior trimmings. Besides the environmental benefits, compared to glass fiber composites, the natural fiber reinforced composites with the equivalent performances have higher fiber content, resulting in less pollution from synthetic polymer matrix, and much lighter weight, reducing the amount of driving fuel in automotive applications.

Table 1. Comparison between natural fibers and synthetic Fibers

Fiber	Advantages	Disadvantages
Natural fiber	Biodegradable	Inhomogeneous quality
	Low density/price	Dimensional instability
Synthetic fiber	Moisture resistance	Difficult in recycle
	Good mechanical properties	Relative high price

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The mechanical properties of a composite depend on the nature of the resin, fiber, resin-fiber adhesion, cross-linking agents and not the least on the method of the processing. Therefore, any improvement in the property is evaluated as compared to that of the polymer matrix undergone the same processing. Usually with an increase in the fiber content in the composition, the tensile and flexural property gradually improves. Beyond certain limit of the fiber content, however, depending on the method of processing, the adhesion between the resin and the fiber decreases resulting in the decrease in the strength of final products. Epoxy resin has excellent adhesion to a large number of materials and could be further strengthened with the addition of fiber.

Materials used for composite material

i) ***Matrix*** - Polymer matrices can be either thermoplastic or thermoset. The most commonly used thermoset resins are epoxy, vinyl ester, polyester and phenolics. Among them, the epoxy resins are being widely used for many advanced composites due to their many advantages such as excellent adhesion to wide variety of fibers, good performance at elevated temperatures and superior mechanical and electrical properties. In addition to that they have low shrinkage upon curing and good chemical resistance. Due to several advantages over other thermoset polymers as mentioned above, epoxy (LY 556) is chosen as the matrix material for the present research work. It chemically belongs to the 'epoxide' family and its common name of epoxy is Bisphenol-A-Diglycidyl-Ether

ii) ***Reinforcement*** - Fiber is the reinforcing phase of a composite material. The present research work, bamboo fiber is taken as the reinforcement in the epoxy matrix to fabricate composites. In general, bamboo is available everywhere around the world and is an abundant natural resource. The scientific name of the type of bamboo used for this work is Dendrocalamus strictus [73].

Table 2. Properties of bamboo Fiber

Properties	**Values**
Tensile Strength	140 - 230 MPa
Flexural Strength	107 MPa
Young's Modulus	15600 MPa
Density	0.6 – 1.1 g/cm^3
Elongation at brake (%)	0 %

iii) ***Filler Material*** - Particulate fillers are plays an important role for the improvement of performance of polymers and their composites. Due to the many advantages, different weight percentages of alumina (Al_2O_3) particulate is used as filler material for fabrication of bamboo fiber reinforced epoxy composites in the present work.

Machines to be used

i) ***Universal Testing Machine***
Computerized UTM standard TUE-C-1000 is used to perform tensile & flexural test on different percentages of specimen is used.

ii) ***Impact tester***
To check impact strength of different specimen's standard AIT- 300N is used.

iii) ***Hardness Testing Machine***
Micro-hardness tester MV-100 is used for micro-hardness measurement on composite samples.

II. LITERATURE REVIEW

In fiber reinforced polymer composites, the fibers can be either synthetic fibers or natural fibers. Advantages of natural fibers over synthetic fibers include low density, availability, low cost, recyclability and biodegradability [1-3]. Mechanical properties of natural fiber based polymer composites are influenced by many factors such as fibers volume fraction, fiber length, fiber aspect ratio, fiber-matrix adhesion, fiber orientation, etc. [4]. A great deal of work has already been done on the effect of various factors on mechanical behavior of natural fiber reinforced polymer composites. The post-impact behaviour of jute fiber reinforced polyester composites subjected to low velocity impact has studied by Santulli [5]. Effect of fiber content on tensile and flexural properties of pineapple fiber reinforced poly (hydroxybutyrate-co-valerate) resin composites has studied by Luo and Netravali [6]. A systematic study on the properties of henequen fiber has made by Cazaurang et al. [7] and reported that fibers have mechanical properties suitable for reinforcement in thermoplastic resins. Bamboo fiber reinforced composites with different polymers have been reported, including epoxy resin [8, 9], polypropylene (PP) [10, 11], poly (butylenes succinate) (PBS) [12], and polylactic acid (PLA) [13]. The mechanical properties and fracture mechanisms of bamboo fiber reinforced polymer composites under different loading conditions is studied by Shin et al. [14-16]. Thwe and Liao [17] studied the effects of fiber content, fiber length, bamboo to glass fiber ratio, and MAPP content on mechanical properties of bamboo fiber reinforced plastics and bamboo-glass fiber reinforced plastics. Jiang et al [18] studied the mechanical behaviour of poly (3-hydroxybutyrate-co-3-hydroxyvalerate)/bamboo pulp fiber composites. Okubo et al. [19] studied the tensile strength and modulus of bamboo fiber reinforced polypropylene based composites. The mechanical properties of bamboo fiber reinforced polypropylene composites was studied and compared with those of commercial wood pulp by Chen et al. [20]. The effect of bonding agent on mechanical properties of bamboo fiber reinforced natural rubber composites was studied by Ismail et al. [21]. The effect of fiber length on tensile properties of short bamboo fiber reinforced epoxy composites was studied by Rajulu et al. [22]. In polymers, fillers are used for a variety of reasons such as cost reduction, density control, improved processing, control of thermal expansion, optical effects, magnetic properties, thermal conductivity, electrical properties, and improved hardness and wear resistance, flame retardancy etc. A great deal of work has been made on the effect of fillers on polymer composites. When silica particles are incorporated into polymer matrix, they play an important role in improving various properties of the composites [23, 24]. Polymers and polymer matrix composites reinforced with metal particles have a wide range of industrial applications [25, 26]. The effect of various filler parameters on mechanical properties of composites is studied by many investigators. The structure and shape of silica particle have significant influence on the mechanical properties of composites [27]. The effect of filler size and shape on the mechanical properties of composites was studied by Nakamura et al. [28, 29].

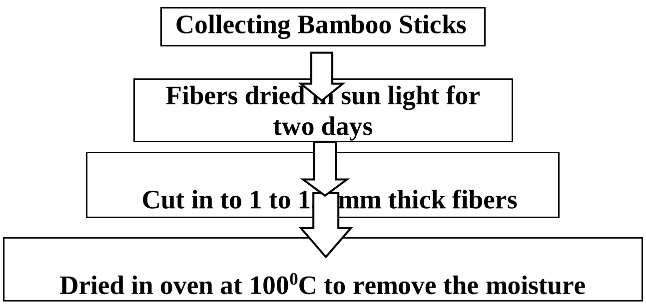
III. MATERIAL PREPRATION

A. Matrix material –

The epoxy resin LY-556 is supplied by Electrocoating & Insulation Technologies Private Ltd. Hinjewadi, Pune. Epoxy resin has wide range of industrial applications because of its high strength and good adhesiveness properties. Curing take place at atmospheric pressure and room temperature after addition of hardener.

B. Bamboo fiber –

Bamboo fiber is used as reinforcing material which is collected from local source. Dendrocalamus strictus is used which is lignocellulosic composite, in which cellulose fibers are embedded in lignin matrix. The 1 to 1.5 mm thick fiber is used in this study. It is natural material abundantly present in most of Asian countries having good strength and low weight. It is widely used in household products like containers, chopstick, mats, handcrafts, chairs etc. It is also used in building applications such as floor, walls, ceiling, windows, doors etc. Growing rate of bamboo is very high.



C. Filler material –

An Al_2O_3 powders is used in a range of 80-100µm collected from Electrocoating & Insulation Technologies Private Ltd. Hinjewadi, Pune. It is used to increase mechanical properties of composite material.

D. Moulds –

A stainless steel mould having dimensions of 160 × 100 × 20 mm^3 is used for composite fabrication.

E. Preparation of composite –

The short bamboo fiber and Al2O3 particulates are mixed with epoxy resin by the simple mechanical stirring and the mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The composite samples of four different compositions (EB-1 to EB-4), in which no particulate filler is used. The other composite samples EBA-1 to EBA-4 are prepared in four different percentages of alumina particulates (0wt%, 5wt%, 10wt% and 15wt% of alumina) is used keeping bamboo fiber at a fixed percentages (i.e. 45wt%). A releasing agent vinyl polish is used to facilitate easy removal of the composite from the mould after curing. The entrapped air bubbles (if any) are removed carefully with a sliding roller and the mould is closed for curing at a temperature of 30°C for 24 h and constant weight is put on it . After curing, the specimens of suitable dimension are cut for mechanical and erosion tests.

Table 3. Designation of Composites

Composites	Compositions
EB-1	Epoxy + Bamboo Fiber (0 wt. %)
EB-2	Epoxy + Bamboo Fiber (15 wt. %)
EB-3	Epoxy+ Bamboo Fiber (30 wt. %)
EB-4	Epoxy + Bamboo Fiber (45 wt. %)
EBA-1	Epoxy + Bamboo Fiber (45 wt. %) + Alumina (0 wt. %)
EBA-2	Epoxy + Bamboo Fiber (45 wt. %) + Alumina (5 wt. %)
EBA-3	Epoxy + Bamboo Fiber (45 wt. %) + Alumina (10 wt. %)
EBA-4	Epoxy + Bamboo Fiber (45 wt. %) + Alumina (15 wt. %)

***F.* Standard specimen sizes –**

Specimen size is as per the ASTM Standards and containing different percent of epoxy, bamboo fiber and filler material.

IV. TEST PERFORMED

A. Mechanical Properties –

1. Tensile Test –

The tension test was performed on all the seven samples as per ASTM D3039-76 test standards. The tension test is generally performed on flat specimens. A uni-axial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 150 mm specimens with fibers parallel to the loading direction should be 25 mm wide and by using UTM with test standards perform tensile test on different bamboo and filler percentage specimens showing below.

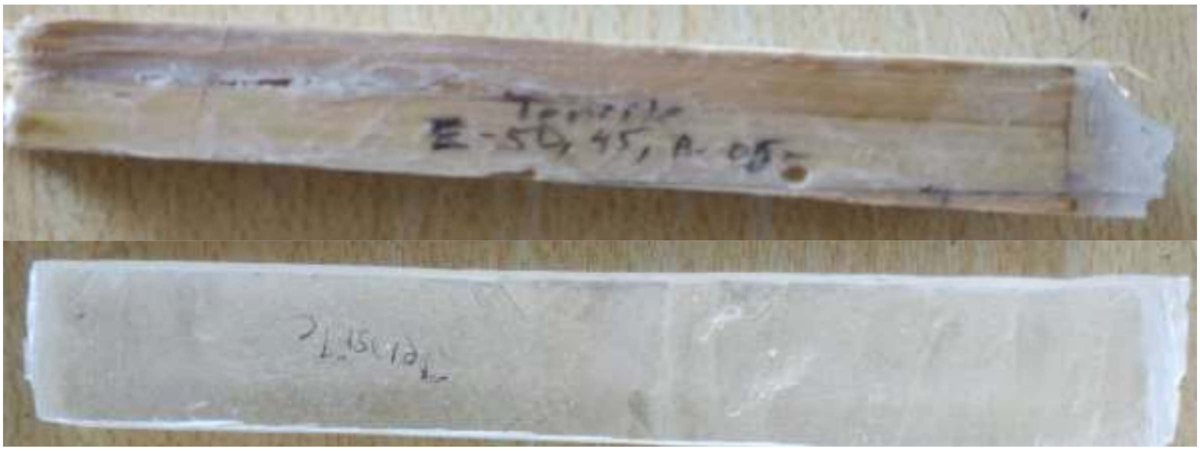


Figure 4.1 Specimen before tensile test

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Figure 4.2 Grip components for tensile test

Figure 4.3 Specimen after tensile test

2. *Flexural Test –*

To find out the flexural strength of the composites, a three point bend test is performed using UTM. The cross head speed was taken as 10 mm/min and a span of 50 mm was maintained. The strength of a material in bending is expressed as the stress on the outermost fibers of a bent test specimen, at the instant of failure. In a conventional test, flexural strength expressed in terms of MPa is equal to,

Flexural Strength = 3PL / 2bd2

Where, P= applied central load (N)
L= test span of the sample (m)
b= width of the specimen (m)
d= thickness of specimen under test (m)

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Figure 4.4 Specimen before flexural test

Figure 4.5 Grip components for flexural test

Figure 4.6 Specimen after flexural test

3. Hardness Test –

Micro-hardness tester is used for micro-hardness measurement on composite samples. A diamond indenter in the form of a right pyramid of a square base of an angle 136° between opposite faces is forced under a load F into the sample. After removal of the load, the two diagonals of the indentation (X and Y) left on the surface of the sample are measured and their arithmetic mean L is calculated. The load considered in the present study is 24.54N and Vickers hardness is calculated using the following equation:

$$Hv = 0.1889\ (F/L2) \qquad \text{and} \qquad L = (XY)/2$$

Where F is the applied load (N), L is the diagonal of square impression (mm), X is the horizontal length (mm) and Y is the vertical length (mm).

4. Impact Test –

Finally, impact tests are carried out on composite specimens as per ASTM D 256 using an impact tester. The pendulum impact testing machine ascertains the notch impact strength of the material by shattering the V-notched specimen with a pendulum hammer, measuring the spent energy, and relating it to the cross section of the specimen. The standard specimen for ASTM D 256 is 64 × 12.7 × 3.2 mm and the depth of the notch is 10.2 mm.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Figure 4.7 Specimen Before impact test

Figure 4.8 Specimen after impact test

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

V. RESULTS AND DISCUSSION

A. Bamboo Fiber Reinforced Polymer Composite without Filler –

Mechanical characteristics of composites without filler –

Table 4. Mechanical properties of the composites without filler

Composites	Hardness (Hv)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J)
EB-1	128.2	70	531	0.2451
EB-2	117.33	77	585.185	0.3044
EB-3	205.6	75.80	300.60	1.0258
EB-4	199	69.60	582	1.3764

It is evident from the Table 4. that at 30wt% of fiber loading the composites show better mechanical properties as compared to others.

B. Alumina filled bamboo fiber reinforced epoxy composites

Mechanical characteristics of composites with filler –

Table 5. Mechanical properties of the composites with filler

Composites	Hardness (Hv)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength(J)
EBA-1	199	69.60	582	1.3764
EBA-2	195.8	72	504	0.2895
EBA-3	194.7	66.80	468	0.4860
EBA-4	218.4	64.60	469.5	0.4370

It is evident from the Table 5. that at 45wt% of fiber loading the composites show better mechanical properties as compared to others.

V I. CONCLUSION

The experimental investigation on the effect of fiber loading and filler content on mechanical and erosion behavior of short bamboo fiber reinforced epoxy composites leads to the following conclusions obtained from this study are as follows:

1. The successful fabrications of a new class of epoxy based composites reinforced with short bamboo fibers have been done.
2. The present investigation revealed that 45wt% fiber loading shows superior hardness, tensile strength and impact strength. Whereas, for flexural strength show better in 30wt% of fiber loading. As far as inclusion of filler content in the bamboo-epoxy composites, the mechanical properties are inferior as compared to unfilled composites.
3. Possible use of these composites such as pipes carrying coal dust, industrial fans, helicopter fan blades, desert structures, low cost housing, automobile interior and exterior etc. is recommended. However, this study can be further extended in future to new types of composites using other potential natural fibers/fillers and the resulting experimental findings can be similarly analyzed.

REFERENCES

[1] Saheb D.N., Jog J.P., (1999). Natural fiber polymer composites: a review. Adv Polym Technol; 18(4):351-63.
[2] Maldas D., Kokta B.V., Raj R.G. and Daneault C., (1988). Improvement of the mechanical properties of sawdust wood fibre-polystyrene composites by chemical treatment. Polymer 1988; 29(7):1255–65.
[3] Sgriccia N., Hawley M.C. and Misra M., (2008). Characterization of natural fiber surfaces and natural fiber composites, Composites: Part A 39 1632–1637.

[4] Kahraman R., Abbasi S. and Abu-Sharkh B., (2005). Influence of Epolene G-3003 as a Coupling Agent on the Mechanical Behavior of Palm Fiber-Polypropylene Composites, International Journal of Polymeric Materials, 54(6), pp. 483-503.
[5] Santulli C., (2001). Post-impact damage characterisation on natural fibre reinforced composites using acoustic emission NDT & E International, 34(8), pp. 531-536.
[6] Luo S. and Netravali A.N., (1999). Mechanical and thermal properties of environmentally friendly green composites made from pineapple leaf fibres and poly (hydroxybutyrate-co-valerate) resin, Polymer Composites, 20(3), pp. 367-378.
[7] Cazaurang-Martinez M.N., Herrera-Franco P.J., Gonzalez-Chi P.I. and Aguilar-Vega M., (1991). Physical and mechanical properties of henequen fibers, Journal of Applied Polymer Science, 43(4), pp. 749-756.
[8] Saxena M., Gowri S., (2003). Studies on Bamboo polymer composites with polyester amide polyol as interfacial agent, Polym. Comp. 24:428–436.
[9] Das M., Pal A. and Chakraborty D., (2006). Effects of mercerization of bamboo strips on mechanical properties of unidirectional bamboo–novolac composites, Journal of Applied Polymer Science100: 238–244.
[10] Mi Y., Chen X. and Guo Q., (1997). Bamboo fiber-reinforced polypropylene composites: Crystallization and interfacial morphology, J. Appl. Polym. Sci. 64:1267–1273.
[11] Chen X., Guo Q. and Mi Y., (1998). Bamboo fiber-reinforced polypropylene composites: A study of the mechanical properties. J. Appl. Polym. Sci. 69:1891–1899.
[12] Kori Y., Kitagawa K. and Hamada H., (2005). Crystallization behavior and viscoelasticity of bamboo-fiber composites. J. Appl. Polym. Sci. 98:603–612.
[13] Lee S-H., Wang S., (2006). Biodegradable polymers/bamboo fiber biocomposite with bio-based coupling agent. Composites Part A: Applied Science and Manufacturing, 37, 80–91.
[14] Shin F.G., Xian X.J. and Yipp M.W., (1989). Development and Evaluation of Bamboo/Plastic Composites, Proceedings of VII International Conference on Composite Materials (ICCM-VII), 4, pp. 467-474.
[15] Shin F.G., Xian X.J. and Yipp M.W., (1991). Reinforcements Mechanism in Bamboo/Epoxy Composites, Composite Design, Manufacture and Application, SAMPLE, 1-M-1-10.
[16] Xian X.J. and Shin F.G., (1989). Evaluation of Mechanical Behaviour and Application of Bamboo Reinforced Plastic Composites, Advances in Mechanics, 19(4), pp. 515-519.
[17] Thwe M. M. and Liao K., (2000). Characterization Of Bamboo-Glass Fiber Reinforced Polymer Matrix Hybrid Composite, Journal Of Materials Science Letters 19, 1873 – 1876.
[18] Jiang L., Huang J., Qian J., Chen F., Zhang J., Wolcott Michael P. and Zhu Y., Study of Poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV)/Bamboo Pulp Fiber Composites: Effects of Nucleation Agent and Compatibilizer, J Polym Environ, DOI 10.1007/s10924-008-0086-7.
[19] Okubo K., Fujii T. and Yamamoto Y., (2004). Development of bamboo-based polymer composites and their mechanical properties, Composites Part A: Applied Science and Manufacturing, 35(3), pp. 377-383.
[20] Chen X., Guo Q. and Mi Y., (1998). Bamboo fiber-reinforced polypropylene composites: A study of the mechanical properties, Journal of Applied Polymer Science, 69(10), pp. 1891-1899.
[21] Ismail H., Edyham M.R. and Wirjosentono B., (2002). Bamboo fibre filled natural rubber composites: the effects of filler loading and bonding agent, Polymer Testing, 21(2), pp.139-144.
[22] Rajulu A.V., Baksh S.A., Reddy G.R. and Chary K.N., (1998). Chemical resistance and tensile properties of short bamboo fiber reinforced epoxy composites, Journal of Reinforced Plastics and Composites, 17(17), pp. 1507-1511.
[23] Nielsen L.E. and Landel R.F., (1994). Mechanical properties of polymers and composites, 2nd ed. New York: Marcel Dekker, pp.557.
[24] Peters S.T., (1998). Handbook of composites. 2nd ed. London: Chapman and Hall, pp. 242-243.
[25] Kim J., Kang P.H. and Nho Y.C., (2004). Positive temperature coefficient behavior of polymer composites having a high melting temperature, Journal of Applied Polymer Science, 92(1), pp. 394-401.
[26] Nikkeshi S., Kudo M. and Masuko T., (1998). Dynamic viscoelastic properties and thermal properties of powder-epoxy resin composites, Journal of Applied Polymer Science, 69(13), pp. 2593-2598.
[27] Yamamoto I., Higashihara T. and Kobayashi T., (2003). Effect of silica-particle characteristics on impact/usual fatigue properties and evaluation of mechanical characteristics of silica-particle epoxy resins, JSME International Journal-Series A: Solid Mechanics and Material Engineering, 46 (2), pp. 145-153.
[28] Nakamura Y., Yamaguchi M., Kitayama A., Okubo M. and Matsumoto T., (1991). Effect of particle size on fracture toughness of epoxy resin filled with angular-shaped silica, Polymer, 32(12), pp. 2221-2229.
[29] Nakamura Y., Yamaguchi M., Okubo M. and Matsumoto T., (1991). Effect of particle size on impact properties of epoxy resin filled with angular shaped silica particles, Polymer, 32(16), pp. 2976-2979.