

Effect of Bamboo Charcoal on Biodegradable Hybrid Green Composites of Sisal / Banana Fibres / Vinyl Ester Resins

P.Manimaran^{1,*}, S.Vinayagamoorthi², R.Baskaran², M. Udaya Karthick¹ and A. DineshPrasad¹

¹Department of Mechanical Engineering, Kamaraj College of Engineering and Technology, Virudhunagar.

²Department of Polymer Technology, Kamaraj College of Engineering and Technology, Virudhunagar .

ARTICLE INFO

Article history:

Received: 23 December 2016;

Accepted: 5 January 2017;

Published: 10 January 2017;

Keywords

Natural Fiber Hybrid Composites,
Vinyl ester,
Sisal and Banana fibers,
Bamboo charcoal.

ABSTRACT

Hybrid composites developed by combining natural fibers/natural fiber and natural fibers/synthetic fibers with epoxy, polyester, phenolic, poly vinyl ester, etc., resins are well established. In this present study, hybrid composites were prepared with banana fiber, sisal fiber and with bamboo charcoal by hand layup method according to ASTM standards. The various weight percentages of fibers in the resin and bamboo charcoal were used to gain insights into the effect of fiber content and charcoal filler on the mechanical properties (Impact, Tensile and Flexural). Scanning electron microscopy (SEM) was used to examine the morphology of these materials.

© 2017 Elixir All rights reserved.

1. Introduction

Technological innovation, which replaces all petroleum-based materials by biomaterials, would be the task of scientists and engineers, because fossil resources will disappear in the near future. Environmental compatibility of polymer composites has become an important characteristic as the need to reduce environmental hazards is increasing worldwide.[1,2] Recent studies have yielded promising results with hybridization of natural fibres for reinforcement. Hybrid composites developed by various researchers, by combining natural fibers/natural fiber and natural fibers/synthetic fibers with epoxy, polyester, phenolic, poly vinyl ester, poly urethane resins, etc., are well established [3]. The excellent properties of natural fiber based composite materials are renewable, carbon neutral, biodegradable, low density, high specific strength, stiffness, less weight, non-abrasiveness to process equipment, abundant availability and growing demand for eco friendly products by the consumers. Hence natural fibers are widely used in aerospace, automotive, construction and packaging industries. Fibre-reinforced composites are attracting more interest for light weight-sensitive applications as their excellent stiffness and strength are combined with a low density.

Kretsis reviewed the tensile, compressive, flexural and shear properties of hybrid fibre-reinforced plastics [4]. Kuruvilla et al reviewed sisal fibre reinforced polymer composites with special reference to the structure and properties of sisal fibre, processing techniques, and the physical and mechanical properties of the composites [5]. In the recent research of hybrid composite, many publications occurred in the field of natural fibre hybrids, mainly driven by environmental concerns [6-8]. As detailed in the recent papers natural fibre hybrid composites are often a combination of a natural fibre with another natural fibre [9-11] or with synthetic fibre [12-15].

Evaluation of the effect of hybridization on mechanical performance of short banana/sisal hybrid fibre reinforced polyester composites found that tensile properties of NFCs were improved with addition of banana fibres [16]. The mechanical performance of short randomly oriented banana and sisal hybrid fibre reinforced polyester composites [17] was investigated with reference to the relative volume fraction of the two fibres at a constant total fibre loading of 0.40 volume fraction (V_f), keeping banana as the skin material and sisal as the core material. A positive hybrid effect was observed in the flexural strength and flexural modulus of the hybrid composites. Dynamic studies on mechanical properties of randomly mixed sisal and banana fiber were carried out and it is observed that the flexural and tensile modulus shows improvement in results.

Bamboo charcoal is a renewable material that has a number of useful characteristics, such as high electric conductivity and self-lubricity, and can be used as an electromagnetic shield and a friction material. On the other hand, bamboo charcoal has a larger surface area (300 m²/gm) than wood charcoal (30 m²/gm) and thus has approximately four times more cavities and a four-fold higher absorption capacity. These properties of bamboo charcoal make it a promising adsorbent material for enrichment and analysis of environmental concern. The most notable characteristics of charcoal are its hexagonal molecular structure, solid quality and fine porosity. The enhancement of a granular filling system in composites depends on the interface bonding strength between fibers and resins. The nano sized bamboo charcoal, which fill holes, resulting in denser composite materials. Also the particle distribution between macromolecular chains can have the effect of crosslinking, which enhances the matrix resins. The present work focused with the main objective of introducing a new set of polymer

hybrid composites using bamboo charcoal as a filler to enhance the mechanical property.

2. Materials and Methods

2.1 Natural Fibers

Over the last decade, composites of polymers reinforced by natural fibers have received increased attention. Natural fibers such as sisal and banana possess good reinforcing capability when properly compounded with polymers.

2.2 Banana

Banana plant is a large perennial herb with leaf sheaths that form pseudo stem. Mature banana pseudo-stem (*Musa paradisiaca*) was obtained from farm and was cut into length of 500 mm shied longitudinally and each was totally submerged in water for 20 days. This source of fibers provides great strength. Banana fiber at present is a waste product of banana cultivation. Hence, without any including cost input, banana fibre can be obtained for industrial purposes. Banana fibre is found to be good reinforcement in polyvinyl ester resin.

Sisal fiber was made from the large spear shaped tropical leaves of the Agave Sisalana plant. It is a strong, stable and versatile material and it has been recognized as an important source of fiber for composites. Sisal leaf were obtained from farm and was cut into length of 800 mm sliced longitudinally and were chopped. The lustrous strands, usually creamy white, average from 80 to 100 cm in length and 0.25 to 0.45mm in diameter. Sisal fiber is fairly coarse and inflexible. It is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater.

2.3 Resin

Unsaturated Vinyl ester resin- grade ECMALON 4411, Density-1.05 g/cm³, Heat distortion temperature-125°C., Gel time: 13 mins at 25°C.

Promotor: Di methyl aniline

Catalyst : Methyl Ethyl Ketone Peroxide (MEKP)

Accelerator : Cobalt naphthenate

Resins and chemicals were purchased from M/S GVR Enterprises, Madurai, Tamilnadu, India.

2.4 Preparation of composite

Composites are prepared as per the ASTM E-1530 standards. The resin mixture is prepared by adding accelerator and catalyst to resin at room temperature for curing. The samples were prepared using Hand lay-up technique. Hand lay-up technique was adopted to fill up the prepared mould with an appropriate amount of Vinyl ester resin mixture and unidirectional fibers, starting and ending with layers of resin. Fiber deformation and movement should be minimized to yield good quality, unidirectional fiber composites. Therefore at the time of curing, a compressive pressure of 0.06 MPa was applied on the mould and the composite specimens were cured for 24 hours. The specimens were also post cured at 500°C for 2 hours after removing from the mould.

The nano composites were prepared by mixing vinyl ester resin with bamboo charcoal particles using a mechanical stirrer. The mixture was sonicated at 60°C for 2 hrs, followed by degassing for 30 min. The mixture was poured into a container made from transparency film, and cured in an oven at 60°C for 16 hrs, then at 120°C for 48 hrs. Table 1 shows different composition of specimens.

3 Mechanical Testing

3.1 Tensile tests

The tensile test was carried out in universal testing machine (UTM) at a speed of 2.5 mm/ min.

Table 1. Composition of specimens

Composites	Composition (Wt %)			
	Resin and Hardener	Banana	Sisal	Bamboo charcoal
C1	60	20	20	-
C2	60	20	15	5
C3	60	15	15	10

Three specimens were made from banana, sisal and bamboo charcoal hybrid composites are tested. The specimens were prepared in the dumb bell shape according to the standard ASTM D638. In each case, the specimens were tested to obtain the average value. Tensile test was carried out by the specimen was clamped in the required fixture of the machine and the load was applied until the specimen breaks. Standard deviation range is $\pm 5\%$ on strength and modulus.

3.2 Flexural tests

Flexural test used to determine the maximum stress induced in the outer most fiber. The flexural test (three-point bending) was carried out in the universal tensile testing machine according to ASTM: D790 standards at room temperature with a cross-head speed 25 mm/min and a span of 40 mm. In this test, the specimen was subjected to a compressive load at its halfway between the supports until the specimen fractures or breaks.

During the experiment compression occurred in the top surface layer of the specimen and the bottom surface layer was subjected to tension. The middle layer was subjected to shear. Thus flexural behaviour was analysed until the failure of the composite specimen takes place due to the combination of bending and shear [18].

$$\text{Stress } \sigma = \frac{3PL}{2bh^2} \quad \text{Strain} = \frac{6Db}{L^2}$$

where,

σ – Stress at the outer surface N/mm²

P – Applied force N

L –Length of the span in mm

b - Width of beam in mm

h - Thickness of beam in mm

D – Deflection of the beam in mm

Flexural modulus = Stress / Strain N/mm²

3.3 Impact Test

Impact test is used to measure the amount of energy spent for breaking the material in joules.

The impact specimens are prepared according to the required dimension as per ASTM-D 256 standard. . The standard specimen size as per ASTM D 256 is 70 mm× 10 mm × 3 mm and the depth under the notch is 10 mm. Izod testing machine is used to measure the impact strength of the material. The specimen is loaded in testing machine and allows the pendulum until it fractures the notch. Corresponding values of impact energy of different specimens are recorded directly from the dial indicator.

Using the impact test, the energy required to break the material can be measured easily and can be used to measure toughness of the material and the yield strength. The impact strength can be calculated by

$$I = K / A$$

Where, I – Impact strength in KJ/m²

K- Energy required to break the specimen in J

A –Area of cross section in m²

3.4 Hardness Test

The hardness test was done in Rockwell hardness testing apparatus and generally conducted in flat specimens.

The dimension of the specimen is 40mm × 40mm × 3mm and Half inch diameter of the intender ball is used. Load of 60 kg is applied as per the ASTM standard of testing and the L scale is chosen.

3.5. Morphology of nanocomposites

Scanning Electron Microscope (SEM) is used to examine the morphology of the composite samples. By the application of the tensile load fracture takes place in the specimen. SEM images are taken to observe the interfacial properties, internal cracks and internal structure of the fractured surfaces of the composite materials. All the specimens are coated with conducting material before observing the surfaces through SEM. The fractured surfaces of the composite specimens are examined by scanning electron microscope JEOL JSM-6480LV. The samples are washed, cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV.

4 Results and Discussions

In this present scenario, natural fibers are used as reinforcement in polymer composites in various applications in aerospace, automotive, construction and packaging industries. The objective of this work is used to determine the mechanical properties like tensile, flexural, impact strength and hardness for sisal, banana and bamboo charcoal and its hybrid epoxy composite. The morphological analysis of the surface of the specimens is carried out by using scanning electron microscope.

Tensile Tests

A universal testing machine is used to test different composites and the results were compared to select the best composite material. The ultimate tensile strength of sisal, banana and bamboo charcoal and its hybrid composite specimens are carried out using tensile test. The tensile load observed for the different composite specimens tested are presented in Table 2

Table 2. Tensile test results of the composites

Sl. no	Composites	Elongation %	Tensile strength (Kg/cm ²)
1	C1	2.52	45.98
2	C2	2.65	50.56
3	C3	3.63	55.59

The results represented that the average ultimate tensile strength and % elongation is maximum for the banana/sisal fiber/10%bamboo charcoal reinforced composite. The tensile strength of the specimen is increased due to the addition of bamboo charcoal. The specimen strength is increased by mixing the proper proportion of the matrix and the reinforcement. Further it is increased by making the fibers in as nano materials and subjected to various chemical treatments such as mercerization, silane treatment, benzoylation, etc., before made into composites. Hence chemical treatments have improved the surface properties of natural fibers and improve the adhesive bonding ability of the fibers with the matrix.

4.1 Flexural properties

It is noticed that the flexural load carrying capacity for the banana/sisal composite is 143.31N but the flexural load carrying capacity is increased to 170.55 N and 189.63 N by adding 5% and 10% bamboo charcoal to banana/sisal fibers. The comparative results of flexural load, stress, strain and Flexural modulus of the hybrid composite specimens are presented in Table 3. Flexural strength is a measure of stiffness. The result shows that the proper binding between the fiber, charcoal and matrix may increase the stiffness of the hybrid composites to some extent.

Flexural properties may also be increased by changing with other polymer matrix, due to the good adhesion between the fibers, fillers and matrix.

Table 3. Flexural test results of the composites

Sl.no	composite	Load N	Deflection mm	Stress N/mm ²	Strain X 10 ⁻³	Modulus X 10 ³ N/mm ²
1	C1	143.31	1.54	183.73	2.77	66.280
2	C2	170.55	1.61	218.65	2.89	75.448
3	C3	189.63	1.72	243.115	3.09	78.525

Impact properties

Izod impact test is used to conduct the Impact test to determine the loss in energy. From the results it can be observed that the impact strength is higher in the hybrid composites having 10% bamboo charcoal fillers. Pure banana/sisal fibers having impact strength as 0.0549 J but after adding the fillers it is increased to 0.0736 N. Impact strength of various composite specimens are presented in the Table 4.

Table 4. Impact strength results of the composites

Sl.no	Composites	Impact strength (J/mm)
1	C1	0.0549
2	C2	0.0651
3	C3	0.0736

Impact strength depends upon the fibre resistivity during fracture. It is observed that hybridization of fibers with increased % of fillers increases the impact strength.

4.2 Hardness Tests

Rockwell hardness machine is used to determine the hardness of the hybrid composites. Table 5. shows that the results of different hybrid composites.

Table 5. Hardness tests results of composites

Sl.no	Composites	Rockwell hardness
1	C1	96.5
2	C2	98.5
3	C3	99.0

It can be observed that the hardness is increased due to the addition of bamboo fillers in the composites. Hardness for banana/sisal fibers is 96.5 and it is further increased to 98.5 and 99 by adding the fillers as 5 % and 10% respectively.

4.3 Morphological Analysis

Scanning Electron Microscope (SEM) has been used to carry out the morphological study. The composite specimens was cut into small pieces of dimension 5x5 mm and its cross sectional view is analysed through SEM. SEM images of prepared specimens of the banana/sisal fibers, 5% and 10% fillers and its hybrid composites undergone tensile test of magnification factor 100 × are shown in Fig. 1 and Fig 2.

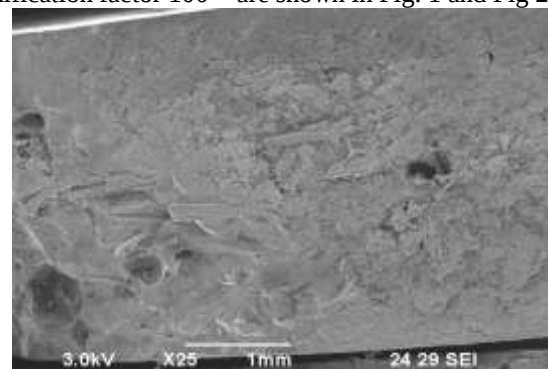


Fig 1. SEM image.

It is observed from the figures, the fracture takes place in the matrix and fiber materials. Further the figure demonstrated that the crack, matrix fracture, voids and fiber pull outs and voids in many spots owing to the tensile load applied in the hybrid composite specimens.

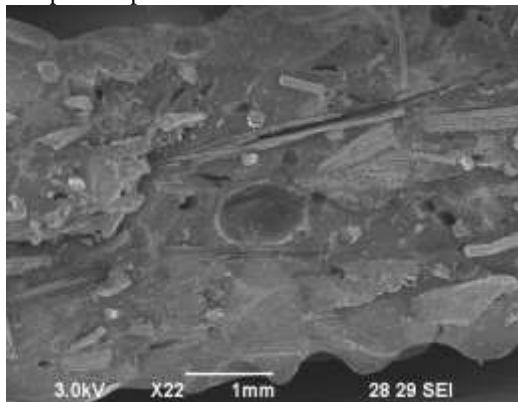


Fig 2. SEM image.

The SEM image of tensile fractured specimen indicates that there is a poor adhesion between the fiber, filler and resin in the fractured specimens. It is inferred that the specimens are failed well in advance due to this. Hence care should be taken by finding the suitable manufacturing method to prepare the hybrid composite specimens.

4. Conclusions

This experimental investigation of mechanical behavior of banana/sisal, and banana/sisal /bamboo charcoal fillers reinforced vinyl ester composites leads to the following conclusions:

- New natural fiber hybrid composites with bamboo charcoal as fillers is experimented.
- in this study. The mechanical properties will be change with change in composition of fibers.
- From the results hybridization of banana/sisal fibers/ bamboo charcoal fillers are having high tensile strength and flexural modulus.
- Impact strength of hybrid composite with fillers also high.
- From this study it can be observed that the natural fibers slowly replacing the synthetic fibers due to the advantage of having recyclable biodegradable and providing as green environment.
- In this work the length of fibers are kept constant, if length variation takes place, properties also changes.

Acknowledgment

The authors would like to thank the Management, Dean and Principal of Kamaraj College of Engineering and Technology, Virudhunagar.

References

1. T. W. Frederick, W. Norman, Natural fibers plastics and composites, Kluwer Academic Publishers, New York, 2004.
2. J.A. Foulk, D.E. Akin, R.B. Dodd, Proceedings of 2000 Society of Automotive Engineers World Congress and Exposition, Detroit, Michigan, March 6–9, 2000.
3. Jawaid, M.; Abdul Khalil, H.P.S. Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. *Carbohydrate Polymers*. 2011, 86, pp. 1–18.

4. Kretsis G. A review of the tensile, compressive, flexural and shear properties of hybrid fibre-reinforced plastics. *Composites*. 1987; 18(1), pp.13-23.
5. Kuruvilla Joseph, Romildo Dias Tolêdo Filho, Beena James, Sabu Thomas & Laura Hecker de Carvalho, A Review on sisal fiber reinforced polymer Composites, *Revista Brasileira de Engenharia Agrícola e Ambiental*, 1999, 3(3), pp. 367-379.
6. Yentl Swolf, Larissa Gorbatikh, Ignaas Verpoest, Fibre hybridisation in polymer composites: a review, *Composites Part A: Applied Science and Manufacturing*, 2014, 67, pp. 181-200.
7. Nunna S, Chandra PR, Shrivastava S, Jalan AK. A review on mechanical behavior of natural fiber based hybrid composites. *Journal of Reinforced Plastics and Composites*, 2012, 31(11), pp.759-769.
8. Venkateshwaran N, Elayaperumal A, Sathiya GK. Prediction of tensile properties of hybrid-natural fiber composites. *Composites Part B: Engineering*, 2012, 43(2), pp.793-796.
9. Jawaid M, Khalil H. Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. *Carbohydrate Polymers*, 2011, 86(1), pp.1-18.
10. Boopalan M, Niranjana M, Umapathy MJ. Study on the mechanical properties and thermal properties of jute and banana fiber reinforced epoxy hybrid composites. *Composites Part B: Engineering*, 2013, 51, pp. 54-57.
11. Idicula M, Joseph K, Thomas S. Mechanical Performance of Short Banana/Sisal Hybrid Fiber Reinforced Polyester Composites. *Journal of Reinforced Plastics and Composites*, 2010, 29(1), pp.12-29.
12. John K, Naidu SV. Tensile properties of unsaturated polyester-based sisal fiber-glass fiber hybrid composites. *Journal of Reinforced Plastics and Composites*, 2004, 23(17), pp. 1815-1819.
13. Sabeel Ahmed K, Vijayarangan S. Tensile, flexural and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites. *Journal of Materials Processing Technology*, 2008, 207(1-3), pp.330-335.
14. Amico SC, Angrizani CC, Drummond ML. Influence of the Stacking Sequence on the Mechanical Properties of Glass/Sisal Hybrid Composites. *Journal of Reinforced Plastics and Composites*, 2010, 29 (2), pp. 179-189.
15. Pavithran C, Mukherjee PS, Brahmakumar M, Damodaran AD. Impact properties of sisal-glass hybrid laminates. *Journal of Materials Science*. 1991; 26(2):455-9.
16. Idicula M, Joseph K, Thomas S. Mechanical performance of short banana/sisal hybrid fiber reinforced polyester composites. *Journal of Reinforced Plastics and Composites*, 2010, 29(1), pp. 12–29.
17. M Idicula, N.R Neelakantan, Z Oommen, K Joseph, S Thomas. A study of the mechanical properties of randomly oriented short banana and sisal hybrid fiber reinforced polyester composites, *Journal of Applied Polymer Science*, 2005, 96(5), 1699-1709.
18. A. Shadrach Jeya Sekaran, K Palani Kumar, and K Pitchandi, *Bulletin of Materials Science*, 2015, 38(5), pp.1–11.