Ilkogretim Online - Elementary Education Online, 2021; Vol 20 (Issue 3): pp. 5094-5102
http://ilkogretim-online.org
doi: 10.17051/ilkonline.2021.03.521

Mechanical Properties Of Banana And Coir Fiber As A Reinforcement In Green Composite: A Review

Vishal J. Pandya Assistant Professor Mechanical Engineering Department, Shantilal Shah Engineering College, Bhavnagar, Gujarat, India

Dr. Pravin P. Rathod Mechanical Engineering Department, Government Engineering College, Bhuj, Gujarat, India.

[3]Professor.

Corresponding Author: E-mail: visheepandya@gmail.com

Abstract
The use of natural fiber as reinforcement in polymeric composites for technical applications has been a research subject of scientists during last decade. Natural fibers have the advantages that they are renewable resources and have marketing appeal. Agriculture wastes can be used to prepare green composites. Consumption of plastics can also be reduced by using natural fiber reinforced composite. There is growing interest in the use of woven composites for structural applications. There is a great interest in the application of banana fiber as a substitute for synthetic fiber. This review gives pathway for designers on the specific application of green composites. A concise summary of the major attributes of biodegradable natural fibers are provided with their mechanical properties.

Keywords: Natural Fiber, Green Composite, Banana Fiber.

INTRODUCTION:

The natural material like wood is on the decline while the demand is increasing. Deforestation has created a serious environmental damage and it has become an urgent necessity to develop suitable substitute for wood. Among the various synthetic materials that have been explored and advocated, plastics claim a major share as a substitute. The natural plant-based fibers are abundant and have high specific mechanical properties. Biodegradable matrix material based green composites containing natural fibers have received considerable attention in the recent years due to possibility of replacing plastics [1, 2].

Green composites are defined in this review as biodegradable polymer with natural fibers. Green composites include nature fiber as a reinforcement material like coir, jute, cotton, bamboo, hemp, banana and biodegradable matrix materials. Natural fibers are eco-friendly, light weight, string, renewable and cheap. Natural fibers and binders provide sufficient mechanical properties in particular stiffness and strength at low price levels. Green composites are gaining importance due to their non-carcinogenic and biodegradable nature [3].

NATURAL FIBER REINFORCED MATERIALS:

Since many years development of synthetic fibers has dominated but nowadays the rising interest in environmental awareness is rapidly springing up in terms of industrial applications. In today's developing era the concern for the prevention of non-biodegradable resources has attracted researchers to develop biodegradable materials based on green principles. The use of natural fiber for the reinforcement of the composites has received increasing attention by the academic sector and the industry. Natural fibers are generally lignocelluloses in nature. The use of natural fibers composites matrices is highly beneficial because the mechanical properties of the resulting composites are greater than those of the un-reinforced matrix. Natural fibers are subdivided based on their origins, whether they are derived from plants, animals or minerals [4, 5].

Among plants, bast and leaf fibers have high potential as reinforcing agents in polymer composites. Banana is the largest herbaceous flowering plant and is often mistaken for trees. The leaves are spirally arranged and can grow up to 2.7m long. They are often used as ecologically friendly disposable food containers or as plates in Southeast Asia. The banana fiber has been used for textiles dating as far back as the 13th century.

The properties of natural fibers depend mainly on the nature of the plant, locality in which it is grown, age of the plant, and the extraction methods used. Banana fibers are abundantly found in coastal region of India, especially in Maharashtra, Tamilnadu and Gujarat. In India approximately 8.8×10^5 ha land is cultivated with banana plantations which yield about 3.5×10^5 hg/ha of fiber. The banana stalk is neither part of the fruit nor is it a permanent part of the tree. It was casually disposed of into landfills and rivers where it would oxidise and harm the local ecology. The use of agricultural by-products helps us to resolve the difficulty of what to do with agricultural waste and to lighten a disposal issue inherent to the paper industry. The banana stem contains fiber to of approximately 4 per cent of its weight. The cellulose content in the banana fiber and sisal fiber is almost the same, but the spiral angle of banana (11˚) is much lower than sisal (20˚). Hence the tensile properties of banana fiber are higher than sisal. Usage of banana fibers in the composite industry will boost the economy of banana cultivation, economy of the state and also open new job avenues for the rural people of the state.

Coir fibers are annual fiber plants, and they are found to be important sources of fibers for a number of applications. The natural coir fibers are copiously grown in tropic and subtropics regions of the world and India especially in the coastal regions of Kerala and Tamilnadu. In India approximately 20.9×10^5 ha land is cultivated with coir plantations which yield about 5.5×10^4 hg/ha of fiber. Coir is a fiber found between the hard inner shell and the outer coat of coconuts. The coir fiber is having poor reinforcing properties like low strength and modulus but it has found interest due to its low density, low thermal conductivity and high elongation. These fibrous materials are being used by the local people for making low cost articles but coir fiber can also be use by mixing with other fibers to take their advantage.

Shih and Huang [6] have prepared the banana fiber reinforced poly lactic acid using melt blend technique. Composite prepared using coupling agents and chemical modification exhibited improved composite properties because of improved compatibility between fiber and poly lactic acid. Pothan et al. [7] has compared the mechanical properties of banana fiber reinforced polyester with jute, sisal and coir reinforced composites. During experimentation water absorption showed an increase in water uptake with increase in fiber content. Maximum tensile strength was observed at 30mm fiber length while maximum impact strength was observed for 40mm fiber length. Comparative analysis with other natural fibers shows banana fiber composite has superior mechanical properties than other composites.

PROPERTIES OF NATURAL FIBER REINFORCED MATERIALS:

Table 1: Mechanical Properties of Natural Fiber

Sr. No.	**Name of Fiber**	**Density (g/cm3)**	**Diameter (μm)**	**Tensile Strength (MPa)**	**Tensile Modulus (GPa)**	**Elongation at Break (%)**
1	Abaca	1.5	28	756	31.1	2.9
2	Bagasse	1.25	---	290	17	---
3	Bamboo	0.6-1.1	88-125	140-441	11-36	1.3-8
4	Banana	1.35	50-280	529-914	7.7-32	1.8-3.7
5	Coir	1.15-1.45	40-450	106-175	1.27-6	15-59.9
6	Cotton	1.5-1.6	15.6-21	287-800	1.1-12.6	6-9.7
7	Curaua	1.38	9-10	913	30	3.9
8	Date Palm	0.92	100-1000	170-275	5-12	5-10
9	Flax	1.5	---	450-1500	27.6-38	1.5-3.2
10	Hemp	1.48	53.7	690-873	9.93	1.6-4.7
11	Henequen	1.2	180	500	13.2	4.8
12	Jute	1.3-1.45	25-200	393-773	2.5-26.5	1-2
13	Kenaf	0.749	43.3-140	223-624	11-14.5	2.7-5.7
14	Nettle	---	10-63	1594	87	1-6
15	Oil Palm	0.7-1.55	150-500	100-400	1-9	8-18
16	Piassava	---	---	109-147	1.1-4.6	6.4-21.9
17	Pineapple	1.44	20-80	413-1627	34.5-82.5	0.8-1.6
18	Ramie	1.45	34	400-938	24.5-128	1.2-3.8
19	Silk	---	---	252-528	7.32-11.22	20-25
20	Sisal	1.45	50-200	80-640	1.46-15.8	3-15
21	Wheat Straw	1.49	84-94	59-140	3.7-4.8	---

22	Wildcane	0.844	190-560	159	11.8	1.3
23	Wool	---	---	122-175	2.34-3.42	25-35
30	Aluminum Oxide	3.9	---	1900	370	---

Merlini et al. [8] has investigated the effect of alkali treatment on the banana fiber and its polyurethane reinforced composite. The study included the treatment of banana fibers with 10% weight of NaOH, prediction of critical fiber length, tensile strength of the fiber and composite. The experimental study shows that alkali treatment improves the interfacial bonding between fiber and matrix which in turn increases the tensile strength of the composite. Deepa et al. [9] has extruded the nano-fibers from banana fiber using steam explosion technique. Chemical analysis was carried out to investigate the presence of cellulose, lignin and hollow cellulose content of nano-fiber. The cellulose percentage of banana fiber increased from 63% to 95% which is very high when compared with conventional method of extraction of nanofibers. Also, the investigation revealed that the thermal stability of the treated nano-fibers is higher than that of untreated fiber. R. Badrinath et al. [10] has investigated the mechanical properties of banana and sisal reinforced polymer based composites. They observed that banana bi-directional fiber/epoxy composite has exhibit better tensile strength of 32.5MPa than banana uni-directional fiber which has only 20MPa. Impact and hardness test shows that banana fiber/epoxy uni-directional and bi-directional possess higher impact strength and load respectively than sisal fiber on both the orientations.

Table 2: Natural Fiber Constituent Contents

Sr. No.	**Name of Fiber**	**Cellulose (%)**	**Hemicellulose (%)**	**Lignin (%)**
1	Abaca	60.4	20.8	12.4
2	Bagasse	36.3-55.2	16.8-24.7	18.1-25.3
3	Bamboo	48.2-60.8	25.1	2.1-32.2
4	Banana	63-67.6	19	5
5	Coir	32-47	0.3-20	31-45
6	Cotton	82.7-92	5.7-6	0
7	Curaua	73.6	9.9	7.5
8	Date Palm	33.9	26.1	27.7
9	Flax	71-81	18.6-20.6	2.2-3
10	Hemp	70.2-74.4	17.9-22.4	3.7-5.7
11	Henequen	77.6	4-8	13.1
12	Jute	61-73.2	13.6-20.4	12-16

13	Kenaf	28-39	21.5-25	15-22.7
14	Nettle	79-83.6	6.5-12.5	3.5-4.4
15	Oil Palm	48-65	0-22	19-25
16	Piassava	31.6	---	48.4
17	Pineapple	70-82	0	5-12.7
18	Ramie	68.6-76.2	13.1-16.7	0.6-1
19	Sisal	56.5-78	5.6-16.5	8-14
20	Straw Wheat	28.8-48.8	35.4-39.1	17.1-18.6
21	Straw Rice	45	19.3	18.9
22	Wildcane	28.1-36.2	20.5-29.8	15.8-22

Chattopadhyay et al. [11] analyzed the biodegradability of banana, bamboo, and pineapple leaf fiber reinforced with polypropylene to form composites. The study showed that the biodegradability of the entire composite is between 5-15%.Hence, natural fibers from renewable resources which act as reinforcing agent in various synthetic polymers can address to the management of waste plastics, by reducing the amount of polymer content used which in turn, will reduce the generation of waste of the non-biodegradable polymers. Singh et al. [12] investigated the influence of silica powder on tensile properties of banana fiber/epoxy composite. It showed that the addition of silica increases the modulus of elasticity and impact strength of composite. Ramesh M. et al. [13] has evaluated the mechanical properties of banana fiber reinforced polymer composites. From the experimental study they have concluded that composite has maximum tensile and flexural strength of 112.58MPa and 76.53MPa respectively which is hold by the 50% banana fiber and 50% epoxy resin composites.

Natural Fiber Reinforced Materials vary among their mechanical properties such as tensile strength, tensile modulus, flexural strength, density and elongation etc. There are wide range of composites are used for different types of applications and density is one of the vital factors to consider the material for a specific application [9]. Table 1 shows the contents of various constituents of different plant fibers. The comparison of various mechanical properties like density and tensile properties of different natural fibers are shown in Table 2.

ADVANTAGES OF NATURAL FIBER REINFORCED MATERIAL:
Banana fibers, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable and cheap and have low density. The biodegradability of plant fibers can contribute to a healthy ecosystem while their low cost and high performance fulfils the economic interest of industry [32].

Table 3: Comparison of Natural Fiber and Synthetic Fiber

Factors	Natural Fiber	Synthetic Fiber
Density	Low	Twice that of Natural Fiber
Cost	Low	Comparatively High
Renewability	Yes	No
Recyclability	Yes	No
Energy Consumption	Low	High
CO2 Neutral	Yes	No
Health Hazard	No	Yes
Disposal	Biodegradable	Not Biodegradable

Mechanical properties of banana fibers are much lower than those of glass fibers but their specific properties, especially stiffness, are comparable to the glass fibers. Alkali treatments have been proven effective in removing impurities from the fiber, decreasing moisture absorption and enabling mechanical bonding and thereby improving matrix reinforcement interface. Banana reinforced fibers provides an important environmental advantage, as renewable resources are used instead of petroleum-based materials [33].

OPPORTUNITIES AND CHALLENGES:

In recent times, natural fiber reinforced composites have bring the opportunities in the field of automotive sector applications for the following reasons.

1. They are ecofriendly, biodegradable and unlike glass and other synthetic fibers the energy utilization to produce them is negligible.
2. The density of reinforcement plays vital role in fabrication of composite of plant based natural fibers which is very less as compared to glass and carbon fibers.
3. Some natural fibers are having competitive modulus to weight ratio than E-glass fiber which is beneficial in stiffness specific designs.
4. Natural fiber reinforced composites give superior acoustic damping than man-made fibers and therefore they are more suitable for noise attenuation which is prime requirement in interior automotive applications.
5. Natural fibers are very low cost material than glass and other fibers.

In last decade, efforts have been made to individualize fiber bundles but the problem of adhesion has remained a vital issue and has proved to be a challenge in the hunt for extended utilization of natural fibers as reinforcement. The hydrophilic nature of natural fibers unfavorably affects adhesion to a hydrophobic matrix and deteriorates the overall strength of composites.

CONCLUSIONS:

This review has provided a concise summary of the main natural fiber reinforce materials.

- Exploitation of non-renewable resources become a prime concerns which prioritizes the need of exploitation of renewable resources for the development of bio materials that could be used as an alternative to the conventionally used composite for automobile, biomedical, packaging and other commercial purposes.
- There is a wide range in the mechanical properties of green composites and therefore it is essential to carry out advanced research on the engineering of natural fibers for targeted applications.
- The main drawback of banana fibers used in composites is their moisture absorption property. Hence the recent research on the banana fiber composites has been directed towards fiber surface modification and matrix adjustments to enhance mechanical property of the finished composite material.

REFERENCES:

1. Asokan, P, M Firdoous, and W Sonal. "Properties and Potential of Bio Fibres, Bio Binders, and Bio Composites." Rev. Adv. Mater. Sci 30 (2012): 254–261.
2. Mwaikambo, Leonard Y, and Martin P Ansell. "Chemical Modification of Hemp, Sisal, Jute, and Kapok Fibers by Alkalization." Journal of Applied Polymer Science 84.12 (2002): 2222–2234.
3. Mitra, B C. "Environment Friendly Composite Materials: Biocomposites and Green Composites." Defence Science Journal 64.3 (2014): 244–261.
4. Alavudeen, A. "Studies on the Mechanical Properties and Wear Behavior of Banana/kenaf Fiber Reinforced Polyester Hybrid Composites." (2014)
5. Al-Bahadly, Ekhlas Aboud Osman, and others. "The Mechanical Properties of Natural Fiber Composites." (2013)
6. Shih, Yeng-Fong, and Chien-Chung Huang. "Polylactic Acid (PLA)/banana Fiber (BF) Biodegradable Green Composites." Journal of Polymer Research 18.6 (2011): 2335–2340.
7. Pothan, Laly A, Sabu Thomas, and N R Neelakantan. "Short Banana Fiber Reinforced Polyester Composites: Mechanical, Failure and Aging Characteristics." Journal of Reinforced Plastics and Composites 16.8 (1997): 744–765.
8. Merlini, Claudia, Valdir Soldi, and Guilherme M O Barra. "Influence of Fiber Surface Treatment and Length on Physico-Chemical Properties of Short Random Banana Fiber-Reinforced Castor Oil Polyurethane Composites." Polymer Testing 30.8 (2011): 833–840.
9. Deepa, B et al. "Structure, Morphology and Thermal Characteristics of Banana Nano Fibers Obtained by Steam Explosion." Bioresource Technology 102.2 (2011): 1988–1997.
10. Badrinath, R, and T Senthilvelan. "Comparative Investigation on Mechanical Properties of Banana and Sisal Reinforced Polymer Based Composites." Procedia Materials Science 5 (2014): 2263–2272.

11. Chattopadhyay, Sanjay K et al. “Biodegradability Studies on Natural Fibers Reinforced Polypropylene Composites.” Journal of Applied Polymer Science 121.4 (2011): 2226–2232.
12. Singh, V K et al. “Mechanical Behavior of Banana Fiber Based Hybrid Bio Composites.” J Mater Environ Sci 3.1 (2012): 185–194.
13. Ramesh, M et al. “Processing and Mechanical Property Evaluation of Banana Fiber Reinforced Polymer Composites.” Procedia Engineering 97 (2014): 563–572.
14. Bledzki, A K, S Reihmane, and J Gassan. “Properties and Modification Methods for Vegetable Fibers for Natural Fiber Composites.” Journal of Applied Polymer Science 59.8 (1996): 1329–1336.
15. Saha, Prosenjit et al. “Enhancement of Tensile Strength of Lignocellulosic Jute Fibers by Alkali-Steam Treatment.” Bioresource technology 101.9 (2010): 3182–3187.
16. Sreekumar, P A et al. “Effect of Fiber Surface Modification on the Mechanical and Water Absorption Characteristics of Sisal/polyester Composites Fabricated by Resin Transfer Molding.” Composites Part A: Applied Science and Manufacturing 40.11 (2009): 1777–1784.
17. Stamboulis, A, C A Baillie, and T Peijs. “Effects of Environmental Conditions on Mechanical and Physical Properties of Flax Fibers.” Composites Part A: Applied Science and Manufacturing 32.8 (2001): 1105–1115.
18. Hill, C A S, and H P S Abdul Khalil. “Effect of Fiber Treatments on Mechanical Properties of Coir or Oil Palm Fiber Reinforced Polyester Composites.” Journal of Applied Polymer Science 78.9 (2000): 1685–1697.
19. Ismail, Hanafi, M R Edyham, and B Wirjosentono. “Bamboo Fibre Filled Natural Rubber Composites: The Effects of Filler Loading and Bonding Agent.” Polymer testing 21.2 (2002): 139–144.
20. Jain, Seema, Rakesh Kumar, and U C Jindal. “Mechanical Behaviour of Bamboo and Bamboo Composite.” Journal of Materials Science 27.17 (1992): 4598–4604.
21. Kessler, R W et al. “Steam Explosion of Flax—a Superior Technique for Upgrading Fibre Value.” Biomass and Bioenergy 14.3 (1998): 237–249.
22. Malkapuram, Ramakrishna, Vivek Kumar, and Yuvraj Singh Negi. “Recent Development in Natural Fiber Reinforced Polypropylene Composites.” Journal of Reinforced Plastics and Composites (2008)
23. Swamy, R P et al. “Study of Areca-Reinforced Phenol Formaldehyde Composites.” Journal of reinforced plastics and composites 23.13 (2004): 1373–1382.
24. Graupner, Nina, Axel S Herrmann, and Jörg Müssig. “Natural and Man-Made Cellulose Fibre-Reinforced Poly (Lactic acid)(PLA) Composites: An Overview about Mechanical Characteristics and Application Areas.” Composites Part A: Applied Science and Manufacturing 40.6 (2009): 810–821.
25. Satyanarayana, K G et al. “Fabrication and Properties of Natural Fibre-Reinforced Polyester Composites.” Composites 17.4 (1986): 329–333.

26. Shibata, Shinichi, Yong Cao, and Isao Fukumoto. “Press Forming of Short Natural Fiber-Reinforced Biodegradable Resin: Effects of Fiber Volume and Length on Flexural Properties.” Polymer testing 24.8 (2005): 1005–1011.
27. Satyanarayana, K G et al. “Performance of Banana Fabric-Polyester Resin Composites.” Composite Structures 2. Springer, 1983. 535–548.
28. Satyanarayana, K G et al. “Materials Science of Some Lignocellulosic Fibers.” Metallography 19.4 (1986): 389–400.
29. Tomczak, Fábio, Thais Helena Demétrio Sydenstricker, and Kestur Gundappa Satyanarayana. “Studies on Lignocellulosic Fibers of Brazil. Part II: Morphology and Properties of Brazilian Coconut Fibers.” Composites Part A: Applied Science and Manufacturing 38.7 (2007): 1710–1721.
30. John, Maya Jacob, and Rajesh D Anandjiwala. “Recent Developments in Chemical Modification and Characterization of Natural Fiber-Reinforced Composites.” Polymer composites 29.2 (2008): 187.
31. Okubo, Kazuya, Toru Fujii, and Yuzo Yamamoto. “Development of Bamboo-Based Polymer Composites and Their Mechanical Properties.” Composites Part A: Applied science and manufacturing 35.3 (2004): 377–383.
32. Kispotta, U. G. “Synthesis and Characterization of Bio-Composite Material.”, 2011.
33. Dweib, M A et al. “All Natural Composite Sandwich Beams for Structural Applications.” Composite structures 63.2 (2004): 147–157.