 International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 2, No. 4, October 2013

Research Paper

MECHANICAL BEHAVIOR OF STACKING SEQUENCE IN KENAF AND BANANA FIBER REINFORCED-POLYESTER LAMINATE

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Recently the use of natural fiber reinforcedPolyestercomposite in the various sectors has increased tremendously. The interest in Fiber-Reinforced Polyester Composites (FRPC) is growing rapidly due to its high performance in terms of mechanical properties, significant processing advantages, excellent chemical resistance, low cost, and low density. The development of composite materials based on the reinforcement of two or more fiber types in a matrix leads to the production of laminate composites. In the present investigation, the effect of hybridization on mechanical properties on Kenaf and Banana Reinforced Polyester composite (KBRP) were evaluated experimentally. The main aim of this paper is to review the work carried out by using kenaf and banana fiber composite. This is due to the environmental problems and health hazard possessed by the synthetic fiber during disposal and manufacturing. The reinforcement made by using the kenaf and banana fiber shows its potential to replace the glass fiber composite. Composites were fabricated using Hand lay-up technique. The results demonstrate that hybridization play an important role for improving the mechanical properties of composites. The tensile and flexural properties of hybrid composites are markedly improved as compare to un hybrid composites. Water absorption behavior indicated that hybrid composites offer better resistance to water absorption.In addition to the mechanical properties, processing methods and application of kenaf and banana fiber composite is also discussed. This work demonstrates the potential of the hybrid natural fiber composite materials for use in a number of consumable goods.

Keywords: Kenaf fiber, Banana fiber, KBRPC, Polyester

INTRODUCTION

Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and

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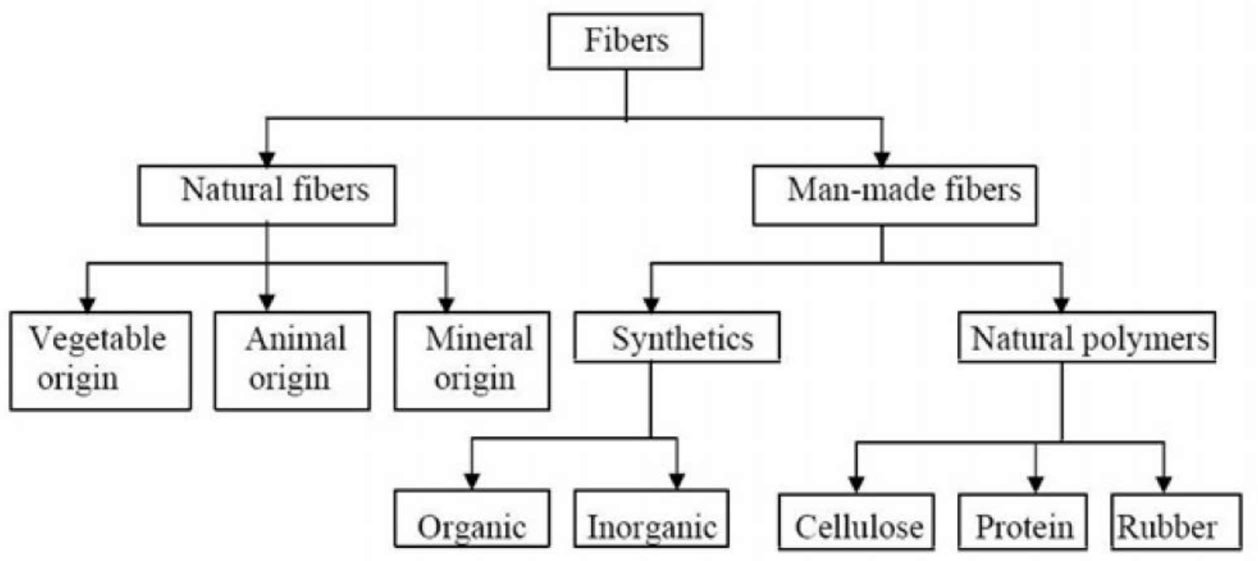
Figure 1: Classifications of Fibers



strength of metals can be increased, while large co-efficient of thermalexpansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide (Figure 1).

Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumino silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density.

The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

Polymer Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low densityof the constituents the polymer composites often show excellent specificproperties.Advanced compositesuse boron, carbon, Kevlar as the reinforcing fibers with epoxy as the common matrix polymer.

Natural Fiber Composites

Fiber-reinforced polymer composites have played a dominant role for a longtime in a variety of applications for their high specific strength and modulus.The manufacture, use and removal of traditional fiber-reinforced plastic,usually made of glass, carbon or aramid fibers-reinforced thermoplastic andthermo set resins are considered critically because of environmental problems. By natural fiber composites we mean a composite material that is reinforcedwith fibers, particles or platelets from natural or renewable resources, incontrast to for example carbon or aramide fibers that have to be synthesized.Natural fibers include those made from plant, animal and mineral sources. In Figure 2 Natural fibers can be classified according to their origin.

Figure 2: Classification of Natural Fibers

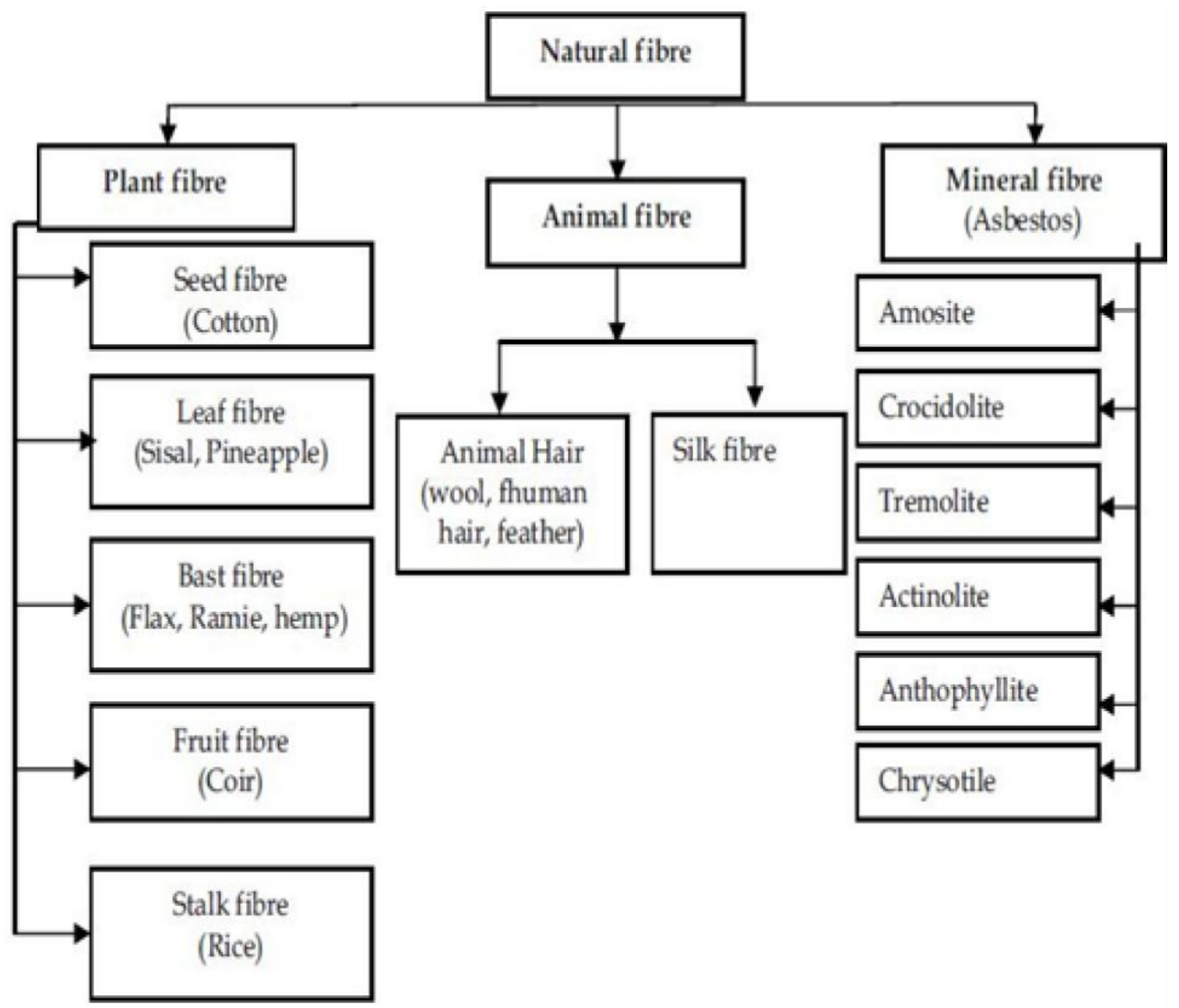
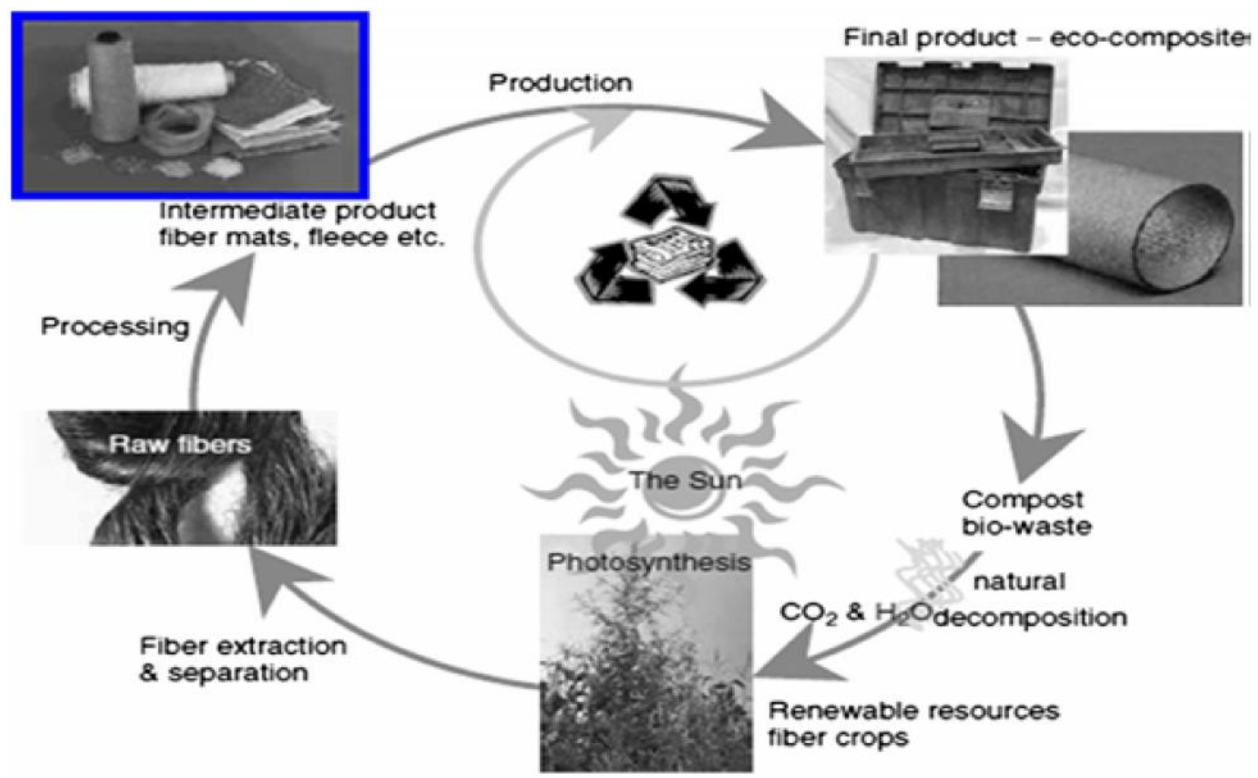


Figure 3: Natural Fibers Recycling



LITERATURE SURVEY

This chapter outlines some of the recent reports published in journal on Mechanical behavior of natural fiber based polymer composites with special Emphasis on laminate of kenaf and bananafiber reinforced polyester composites.

On Natural Fiber Reinforced Composites

Information on the usage of banana fibers in reinforcing polymers is limited in the literature. In dynamic mechanical analysis, Demir (2006) have investigated banana fiber reinforced polyester composites and found that the optimum content of banana fiber is 40%. Mechanical properties of banana-fiber-cement composites were investigated physically and mechanically by De Rodriguez (2006). It was reported that kraft pulped banana fiber composite has good flexural strength.

In addition, short banana fiber reinforced polyester composite was studied by Fung (2003); the study concentrated on the effect of fiber length and fiber content. The maximum tensile strength was observed at 30 mm fiber length while maximum impact strength was observed at 40 mm fiber length. Incorporation of 40% untreated fibers provides a 20% increase in the tensile strength and a 34% increase in impact strength. GansterJand Fink (2006) tested banana fiber and glass fiber with varying fiber length and fiber content as well. Huda (2005) studied the tensile and flexural properties of the green composites with different pineapple fibre content and compared with the virgin resin.

Figure 4: Kenaf and Banana Fiber

Kenaf Fiber

Banana Fibers

Kenaf is an herbaceous annual plant that is grown commercially in the United States in a variety of weather conditions, and it has been previously used for rope and canvas. Kenaf has been deemed extremely environmentally friendly for two main reasons; (a) kenaf accumulates carbon dioxide at a significantly high rate, and (b) kenaf absorbs nitrogen and phosphorous from the soil (Michell, 1986).

Iwatake (2008) carried out research work on filament wound cotton fibre reinforced for reinforcing High-Density Polyethylene (HDPE) resin. Joseph (2002) also studied the use of cotton fibre reinforced epoxy composites along with glass fibre reinforced polymers. Joseph (1997) investigated the new type woodbased filler derived from Oil Palm Wood Flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric analysis and the results are very promising. Kalaprasad (1997) developed composites using jute and kenaf fibre and polypropylene resins and they reported that jute fibre provides better mechanical properties than kenaf fibre.

Luyt (2005) performed one of the pioneering studies on the mechanical performance of treated oil palm fiber-reinforced composites. They studied the tensile stressstain behavior of composites having 40% by weight fiber loading. Isocyananate-, silane-acrylated, latex coated and peroxide-treated composite withstood tensile stress to higher strain level.Isocyanate treated, silane treated, acrylated, acetylated and latex coated composites showed yielding and high extensibility. Tensile modulus of the composites at 2% elongation showed slight enhancement upon mercerization and permanganate treatment. The elongation at break of the composites with chemically modified fiber was attributed to the changes in the chemical structure and bondability of the fiber.

Objectives of the Research Work

The objectives of the project are outlined below.

- To develop a new class of natural fiber based polyester composites to explore the potential of laminates of kenaf and banana fiber.
- To study the effect of stacking sequences of laminates on mechanical behaviour of kenaf and banana fiber reinforced polyester based composites.
- Evaluation of mechanical properties such as: tensile strength, flexural strength, tensile modulus, impact strength.

Problem Statement

Natural fibers can be produced in many types of reinforcement composites, such as continuous and discontinuous unidirectional fibers, random orientation of fibers, etc. By taking the advantages from those types of reinforced composites such as produced good properties and reduced the fabrication cost, they had been used in the development of automotive, packaging and building materials. A growing interest in woven composites has been observed in recent years.

A woven fabric contains fibers oriented on at least two axes, in order to provide great strength and stiffness. Woven composites are known to be complex systems, which have additional features such as, interlace spacing or gap, interlace point and unit cell. There are very few reports on woven fabric composites reported so far. The popularity of woven composites is increasing due to simple processing and acceptable mechanical properties. Woven fabric composites provide more balanced properties in the fabric plane than unidirectional laminas. The usage of woven composites has increased over the recent years due to their lower production costs, light weight, higher fracture toughness and better control over the thermo-mechanical properties.

The weaving of the fiber provides an interlocking that increases strength better than can be achieved by fiber matrix adhesion. Failure of the composite will require fiber breakage, since fiber pullout is not possible with tightly woven fibers. Based on our knowledge, there are less works having been done on the woven natural fiber composites. Realizing the advantageous of natural fibers and woven pattern, these two factors have been considered in the present work.

In this research project, three types of natural fibers; sisal,jute were utilized as reinforcement. These two types of natural fibers were used because of their ability to be produced in a continuous form, and hence able to be produced into a woven mat form of thin layer. Then these thin layers are converted in to different sequences of laminates such that KB, BK laminates. Finally to find the mechanical effects on these laminates such that impact strength, tensile strength, water absorption test, flexural strength.

METHODOLOGY

Manufacturing Methodsfor Fiber Composite

There are several methods for making of natural fiber composites. Most of the techniques commonly used for making glass fiber composites are applicable for making natural fiber composites. However, the well known method for composites making are as followings: Hand Lay-up/Spray up is one of the cheapest and most common processes for making fiber composite products. In this process, the mold is waxed and sprayed with gel coat and cured in a heated oven. In the spray up process, catalyzed resin is sprayed into the mold, with chopped fiber where secondary spray up layer imbeds the core between the laminates resulting a composite. In hand layup processing, both continuous fiber strand mat and fabrics are manually placed in the mold. Each ply is sprayed with catalyzed resin and with required pressure compact laminate is made.

Resin transfer Molding (RTM) provides high quality finished surface on both the sides of composites with a relatively low energy makes perfect shapes. The fabricator generally gel coats the mold halves, then lays continuous or chopped strand mat and closes the mold. Resin transfers into mold through injection pressure, vacuum pressure, or both. Cure temperature depends on the resin system. Compression molding is a molding technique for making composite materials with low unit cost with faster cycle times. Sheet Molding Compounds (SMC) is a sheet that sandwiches fiber between two layers of resin paste. Fiber/ Fabric drop onto the paste and a second film carrier faces with another layer of resin. When the SMC is ready for molding, the mold is closed, clamped, and between 500 and 1,200 psi pressure is applied. After curing, mold is opened and the sheets were removed manually or through an injector system and ready for use.

Automated injection molding of thermoset Bulk Molding Compound (BMC) has increasingly taken over markets previously held by thermoplastics for application in electrical and automotive components, housing appliances, and motor parts. BMC is a low-profile (nearly zero shrinkage) formulation of a thermoset resin mix with 15-20% chopped fiber. Injection molding is a fast, high volume, low pressure, and closed process. Injection speeds are typically 1-5 s and nearly 2,000 small parts can be produced per hour. A ram or screw type plunger forces a material shot through the machine’s heated barrel and injects it into a closed, heated mold. Heat build-up is carefully controlled to minimize curing time.

After cure and injection, parts need only minimal finishing. Filament winding is an automated, high volume process that is ideal for manufacturing pipe, tank, shafts and tubing, pressure vessels, and other cylindrical shapes.

The winding machine pulls dry fibers from supply racks through a resin bath and winds the wet fibre around a mandrel. Pultrusion is the continuous, automated closed-molding process that is cost effective for high volume production of constant cross sectional parts. Pultruded custom profiles include standard shapes such as channels, angles, beams, rods, bars, tubing and sheets.

Preparation of Composites

The matrix of unsaturated polyester and monomer of styrene are mixed in the ratio of 100:25 parts by weight respectively. Then the accelerator of methyl ethyl ketene peroxide 1% by weight and catalyst of Cobalt Naphthenate of 1% by weight were added to the mixture and mixed thoroughly. In present work the composites were prepared by hand lay-up technique, the releasing agent of silicon is sprayed to glass mould and the matrix mixture is poured in to the mould. The fiber is added to matrix mixture, which was poured in the glass mould. The excess resin was removed from the mould and glass plate was placed on top. The castings were allowed to cure for 24 hrs at room temperature and then casting is placed at a temperature of 80 °C for 4 hrs. The composite is released from mould and are cut to prepare test specimens.

Specimen Preparation and Test Machine

The test specimens for tensile and Impact test,Flexural Test,Water Absorption Testwere cut as per American standard testing method (ASTM) specifications in Table 1. The Instron Universal Testing Machine (UTM) (supplied by Instron Corporation, Series 9, automated testing machine) used for tensiletest and Impact testing machine is used for Impact Testing. Sample 3 were tested in each case and compared with samples 1 and 2 in Table 7 and graph plotted shown in Figure 7.

Table 1: ASTM Standards for Specimen Preparations

S. No.	Type of Test	ASTM Standard	Specimen Size (mm)
1.	Impact Testing	D 4812	64 x 10 x 10
2.	Tension Test	D 3039	250 x 20 x 17
3.	Flexural Test	D 790	154 x 13 x 4
4.	Water Absorption Test	D 570	25 x 25

In these methods, a mixture of sisal and jute was used. The total fiber volumetric fraction of the composites used in chemical compositions of kenaf fiberthis work was 25%, within this percentage, the volumetric relation between kenaf and banana fiber was modified according to the compositions: 50% kenaf and 50% banana fiber;

RESULTS AND DISCUSION

Impact Strength of Kenaf/Banana Laminate Hybrid Composite

The impact strength of sisal/jute laminate hybrid composites is presented in Table 2. It is observed that the laminate composite is exhibiting higher impact strength than the kenaf and banana.fiber reinforced composite. The kenaf/bananalaminate hybrid composite impact strength is higher than kenaf reinforced composite but lower than glass fiber reinforced composite. The increase in impact strength of hybrid composite is because of laminated of kenaf and banana.

Tension Testing

Specimens for tension test were carefully cut from the laminate and shaped to the accurate size using emery paper. Tests were conducted

Table 2: Impact Strength of Kenaf/Banana Laminate Hybrid Composite

S. No.	Material	Energy Absorbed Force in (J)	Energy Spend to Break the Specimen in (J)	Energy Absorbed by the Specimen in (J)	Impact Strength in N/mm
1.	Specimen 1 (Kenaf)	60	52	8	80
2.	Specimen 2 (Banana)	60	48	12	120
3.	Specimen 3 (Kenaf and Banana)	60	44	16	160

Table 3: Tensile Properties of Laminated Kenaf with Banana Composites

S. No.	Material	Maximum Stress in (N/mm^2)	Maximum Strain	Maximum Load in (N)
1.	Specimen 1 (Kenaf)	10.58	0.440	3.6×10^3
2.	Specimen 2 (Banana)	13.46	0.032	1.75×10^3
3.	Specimen 3 (Kenaf and Banana)	15.00	0.024	4.5×10^3

using Shimadzu make testing machine (model: AG-IS 50 KN, capacity: 5T, and accuracy: 0·2%) at a cross head speed of 5 mm/min as per ASTM D3039. Identical specimens numbered Specimen3were tested and result derived. The tested mechanical property values for kenaf and banana composites and laminated kenaf and banana composites aregiven in Table 3, graph plotted shown in Figure 5.

The kenaf and banana laminated hybrid composites exhibited averagetensile strength values of 15 MPa. The average tensilestrength of kenaf and banana composites wasfound to be 10.58 and 13.46 MPa. The increase of tensile strength andmodulus values in kenaf hybrid composite is due to theaddition of kenaf with banana fiber composites.

Flexural Testing

Flexural test was conducted as per ASTM D 790 usingInstron machine (Model no: 3382) with Series IX softwareand load cell of 10 KN at 2·8 mm/min rate of loading. Themodulus values for kenaf and banana composites and laminated kenaf and banana composites are givenin Table 4. The point of deviation from linearity is the indication of failureinitiation due to development of crack on the tensionside. The kenaf and bananahybrid composite exhibited the averagevalue of flexural strength to be 82.63, 98.25 MPa, whereas the laminated sisal and jute hybrid composite exhibited 113.61 MPa. Buttheir mechanical properties were slightly different because oftesting direction.

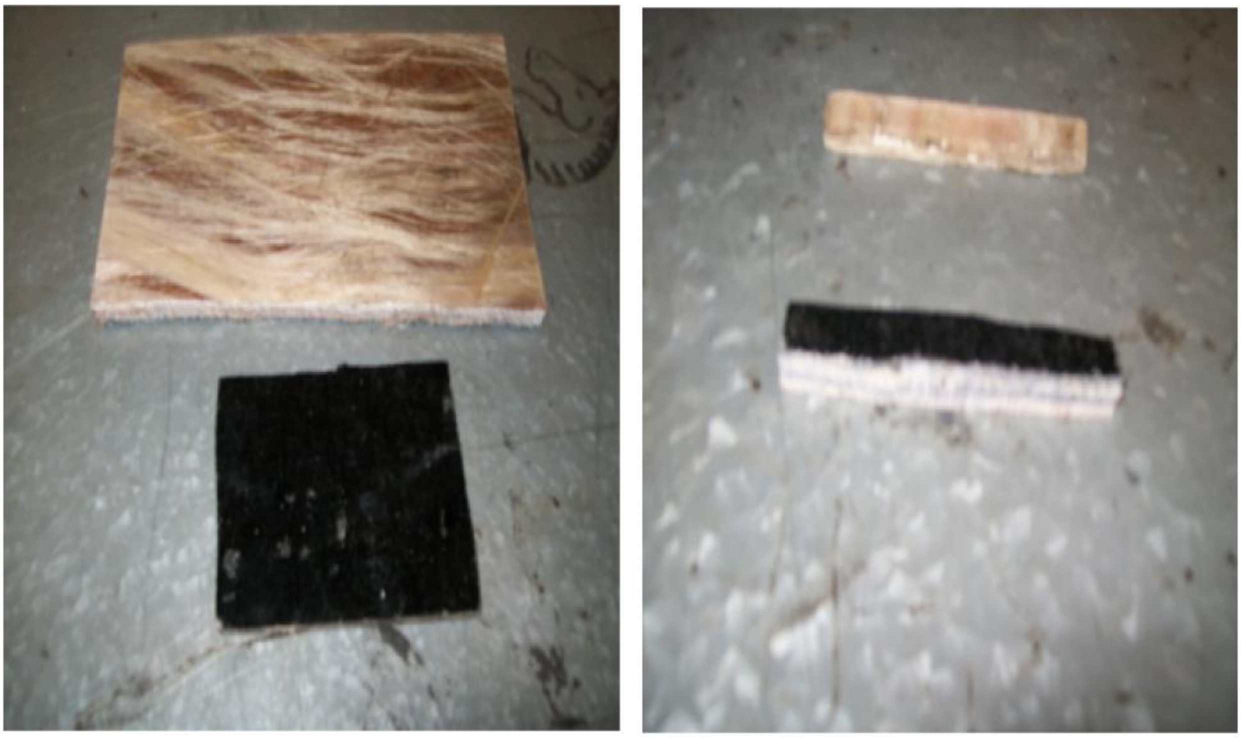
Water Absorption Behavior of Composite

The water absorption characteristics of kenaf/ banana hybrid fiber reinforced polyester composite werestudied by immersion in distilled water at room temperature for 3, 6, 9 and 12 hours. The test specimens (25 mm x 25 mm) were cutfrom composite and tested for water absorption as per ASTM D-570. Edges of the sample were sealed with polyester resin. Samples were dried for 24 hours at 50 °C. After 24 hours samples were

Table 4: Flexural Observations for Specimen 3

S. No.	Load		Dial Gauge Reading		Flexural Modulus in Gpa	Flexural Strength in (N/mm^2)
	Kg	N	in Divisions	In mm		
1.	0	0	0	0	0	113.61
2.	1	9.81	112	1.12	13.39	
3.	2	19.62	221	2.21	14.41	
4.	3	29.43	300	3.00	15.14	
5.	4	39.24	390	3.90	15.99	
6.	5	49.05	470	4.70	16.73	
7.	6	58.86	560	5.60	17.58	
8.	7	68.67	640	6.40	18.32	
9.	8	78.48	1050	10.50	22.16	
10.	9	88.29	1140	11.40	23.00	
11.	10	98.1	1220	12.20	23.75	
12.	11	107.91	1320	13.20	24.68	

Figure 5: Sample Specimen



weighed accurately. Conditioned samples were thenimmersed in distilled water at room temperature for 3, 6, 9 and 12 hours. Samples were taken out of water after appropriate timeperiod and wiped with a tissue paper to remove surface water. They were then

Table 5: Observations for Water Absorption Test

S. No.	Time in (Hours)	Weight of the Specimen 1 in (g)	Weight of the Specimen 2 in (g)	Weight of the Specimen 3 in (g)
1.	0	50	60	75
2.	3	50.2	60.3	75.35
3.	6	50.35	60.42	75.45
4.	9	50.52	60.51	75.61
5.	12	50.61	60.62	75.73

Table 6: Tabulated Result for Water Absorption Test

S. No.	Material	Amount of Water Absorbed in (g)	Percentage of Water Absorbed in (%)
1.	Specimen 1 (Kenaf)	0.61	1.20%
2.	Specimen 2 (Banana)	0.62	1.03%
3.	Specimen 3 (Kenaf and Banana)	0.73	0.97%

Table 7: Comparisons of Kenaf, Banana and Kenaf/Banana

S. No.	Type of Fiber	Impact Strengthin (N/ mm)	Percentage Amount of Water Observed in (%)	Tensile Strength in (N/mm^2)	Flexural Strength in (N/mm^2)
1.	Specimen 1	80	1.20%	10.58	82.63
2.	Specimen 2	120	1.03%	13.46	98.25
3.	Specimen 3	160	0.97%	15.00	113.61

Figure 6: Impact Strength of Kenaf/Banana Laminate Hybrid Composite

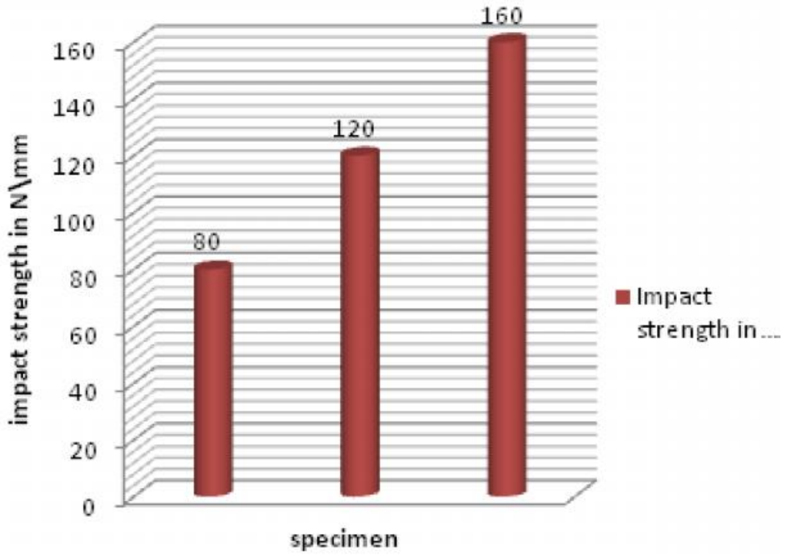


Figure 7: Tensile Properties of Laminated Kenaf / Banana Composites

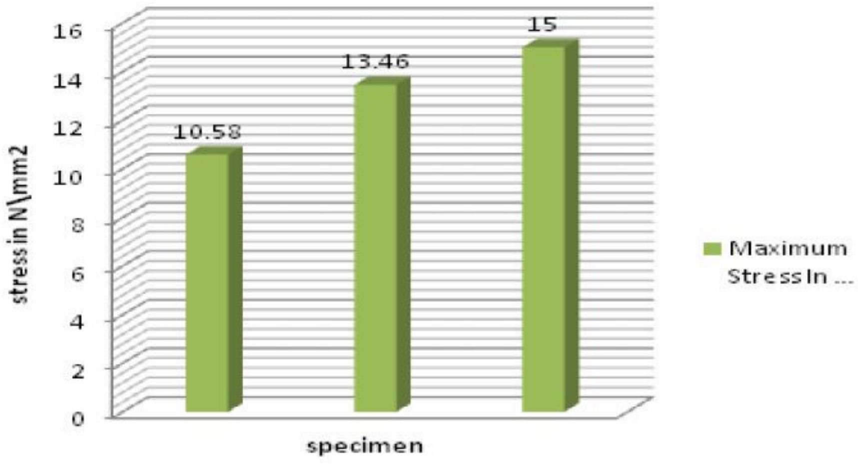


Figure 8: Tabulated Results for Water Absorption Test

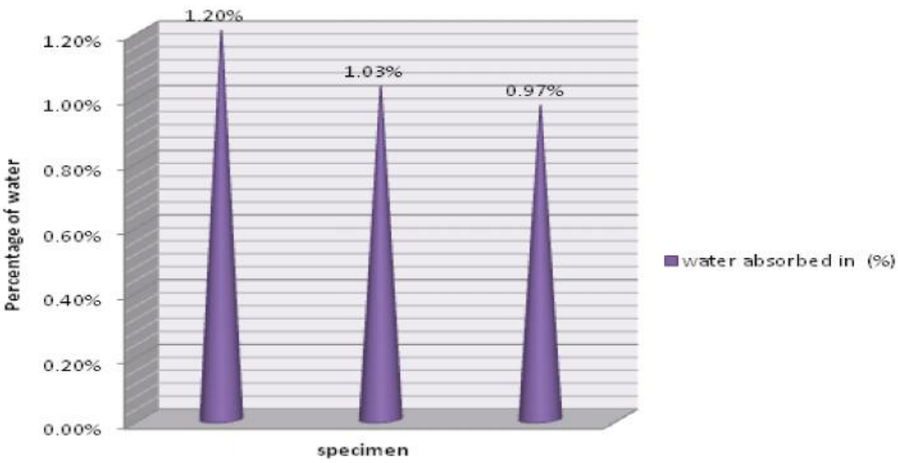
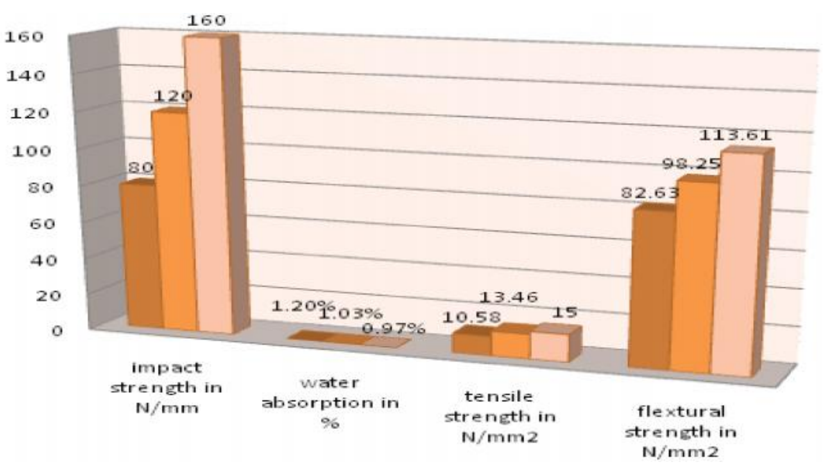


Figure 9: Comparisons of Kenaf, Banana and Kenaf / Banana



weighed. Water absorption can be calculated and tabulated in Tables 5 and 6 graphs plotted shown in Figure 6.

Formula

Moisture absorption % = W2 – W1/W1*100,

where

W1 = Initial weight of composite,

W2 = Final weight of composite.

CONCLUSION

This experimental investigation of mechanical behavior of Kenaf and Bananalaminate-polyester composites leads to the following conclusions:

The characterization of the composites reveals thatthe hybridization is having significant effect on the mechanical properties of composites. The properties of the composites withdifferent hybridization under this investigation are presented in Tables 1, 2 and 3. Result shows the effect of hybridization on the tensileproperties of natural fiber composites. Among the allcomposites, the composite having outer layer of kenaf and core ofbanana had the highest modulus, tensile and flexural strength andcomposite having skin of banana and core of kenaf shows lowest mechanical properties.

Water absorption is one of the major concerns inusing natural fiber composites in many applications. In thisstudy, 3, 6, 9 and 12 hour water absorption was measured by the weight change method for the kenaf,/ Banana hybrid fiberreinforced polyester composites in sandwich constructions. The results are shown in Tables 4 and 5. The water absorption in hybrid composites was negligible. In 24 hours, maximum and minimum water uptake was shown by KBRPC. Water absorption after 24 hrs increases at the rateof 0.97-1.2%.

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