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Development and analysis of epoxy based hybrid composte

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Abstract
In recent years, there has been an increasing environmental consciousness and awareness of the need for sustainable development, which has raised interest in using natural fibers as reinforcement in polymer composite to replace synthetics fiber such as glass This work deals with the comparative study between the naturally available fibers that are used as reinforcement materials and epoxy resin as a matrix material in fiber reinforced composite laminates used for structural application. Present work utilizes the natural plant powder of bamboo, wheat, and oat. The composite prepared by taking two components at a time and mix it with epoxy and hardener of different percentage(10%, 20%) of various thickness(3mm, 5mm) and finally comparing result with individual composite testings prepare the specimen according to ASTM standards. various tests are performed include tensile test, three point bending test, impact test.
Keywords: *Bamboo Powder, epoxy resin, Tensile test, three point bending test, impact test.*

1. Introduction

For the four decades research in the field of material science is found to be enormous due to the scarcity of materials in its raw stage. Sidewise the present era of technology pull products, attracts customers with the goods that are available at much lesser cost, highly durable with ease of operation meeting one's ergonomic need. Composite are defined as "structural materials that consists of two or more combined constituents that are combined at macroscopic level and are not soluble in each other". One constituent is called reinforcement phase and the one in which it is embedded is called the matrix. The reinforcement phase material may be in form of fiber, particle, or flakes. The matrix phase material is generally continuous.

The advantages of natural fibers include low price, low density, unlimited and sustainable availability, and low abrasive wear of processing machinery. Further, natural fibers are recyclable, biodegradable and carbon di-oxide neutral and their energy can be recovered in an environmentally acceptable way.

2. Material study and Methodology

Natural fiber composites are by no means new to mankind. Already the ancient Egyptian used clay that was reinforced straw to build wall. In the beginning of 20th century wood or cotton fiber reinforced phenol or melamine formaldehyde were fabricated and used in electrical application for their non-conductive and heat-resistance properties. At present day natural fiber composites are mainly found in automotive and building industry and then mostly in application where load bearing capacity and dimensional stability under moist and high thermal condition are of second order importance. The present work deals with the preparation of composite laminate using natural fiber like bamboo, jute, and coir in an epoxy resin system owing to 60:40 fiber to matrix composition.

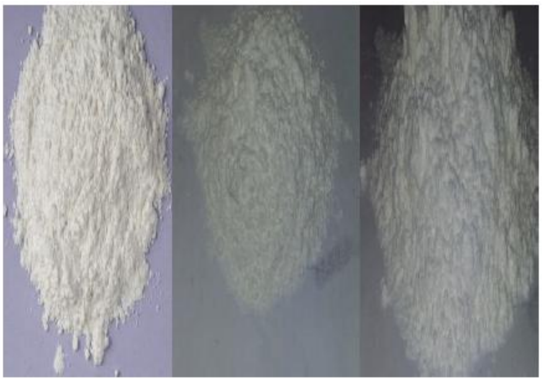

Figure 1 wheat, Bamboo and oat

Bamboo is a natural biological composite with superior mechanical strength and toughness. It belongs to a group of perennial evergreen in the true grass family poaceae, subfamily bambusoideae, and tribe bambuseae.

Bamboo fiber are an abundant natural material with mechanical properties comparable with those of glass fiber that are commonly used in fiber reinforced composites. Bamboo fibers stand out from the group of natural fiber due to the fast growing and high yield of this plant. The advantage of bamboo fiber is in their stiffness, high strength, low weight, low cost, biodegradable, non-abrasive nature and sound absorption. There is available considerable amount of studies and bamboo fiber reinforced composites especially fiber reinforced thermoplastic polymer (polypropylene, polylactic acid and polybutylene succinate) and fiber reinforced thermosetting resins (polyvinylchloride, polyester, novolac, epoxy resins). (Yao, Zongjin Li-2003)

Wheat flour is a powder made from the grinding of wheat used for human consumption. More wheat flour is produced than any other flour. Wheat varieties are called "soft" or "weak" if gluten content is low, and are called "hard" or "strong" if they have high gluten content. Hard flour, or bread flour, is high in gluten, with 12% to 14% gluten content, its dough has elastic toughness that holds its shape well once baked.

The oat (Avena sativa), sometimes called the common oat, is a species of cereal grain grown for its seed, which is known by the same name (usually in the plural, unlike other cereals and pseudocereals). While oats are suitable for human consumption as oatmeal and rolled oats, one of the most common uses is as livestock feed.

Table 1: wheat Nutritional value per 100 g

Energy	1.368KJ (327KCAL)
Carbohydrates	71.18g
Sugars	0.41g
Dietary fiber	12.2g
Fat	1.54g
Protein	12.61g
Vitamins	Thiamine (B1) (33%) 0.383. mg, Riboflavin (B2) (10%) 0.115 mg, Niacin (B3) (36%) 5.464 mg, Pantothenic acid (B5) (19%) 0.954 mg, Vitamin B6 (23%) 0.3 mg, Folate (B9) (10%) 38 µg,, Choline (6%)31.2 mg ,Vitamin E (7%)1.01 mg, Vitamin K (2%)1.9 µg,.

Table 2:oat Nutritional value per 100 g

Energy	1.628KJ(389Kcal)
Fat	6.9g
Protein	16.9g
Vitamins	Thiamine (B1) (66%)0.763 mg, Riboflavin (B2) (12%)0.139 mg, Niacin (B3) (6%) 0.961mg, Pantothenic acid (B5) (27%) 1.349 mg, Vitamin B6 (9%) 0.12 mg, Folate (B9) (14%) 56 µg.

3. Information of epoxy and hardener

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed, please do not alter them. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

3.1. Reasons for selecting the Epoxy and Hardener

- Adhesion to fibers and resin is very good.
- No by product formed during curing stage
- Low shrinkage during curing
- Very good solvent and chemical resistance
- Highly penetrative due to low viscosity.
- Superior adhesive property.
- High abrasion resistance.
- Resistance to creep and fatigue.
- Good electrical properties.
- Solid or liquid resins in uncured state
- Higher shelf life

3.2. Epoxy resin (ly556) and its hardner (hy951)

Product identification

- Trade name: Araldite Ly556
- Chemical family: epoxide
- Product type: Liquid resin

Ingestion: if swallowed give at least 3-4 glasses of water but do not induce vomiting, if vomiting occurrence give water again, do not give any thing by mouth to an unconscious or convulsing person. Get medical attention, have physician determine whether vomiting or stomach evacuation is necessary.

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Skin: For skin contact wash with large amount of running water and soap. If available for 15minuate, remove contaminated clothing and shoes get immediate medical attention. Discard or decontaminate clothing before re-use and destroy contaminated shoes.

Inhalation: if inhaled, removed from area to fresh air. Get medical attention if respiratory irritation develops or if breathing become difficult.

Eyes: For eye contact, immediately flash eyes for at least 15minute with running water, hold eyelids apart to ensure rinsing of the entire eye surface and lids with water. Get immediate medical attention.

Over exposure effects: irritation, sensitization and dramatis.:

Flash point >200(>392f)

Flash point method used closed cup

Stability and reactivity: Avoid strong acids or bases as bulk and elevated temperatures

Hazardous decomposition products:

Carbon monoxide, carbon di-oxide, aldehyde.

3.3 Physical and chemical properties

Aspect(visual) - clear

Colour (Gardner, ISO 4630)-pale yellow

Epoxy content (ISO 3000) 5.30-5.45 (eq/kg)

Viscosity at 25 centigrade (ISO 12058-1) 10000-12000 (m Pa s)

Density at 25centigrade (ISO 1675) 1.15- 1.20 (g/cm3)

Flash point (ISO 2719) >200 (centigrade)

3.4.About Hardener (HY951)

Product identification

Trade Name: Hardener HY 951

Chemical Family: Polyamine

Intended Use or Product Type: Epoxy Curing Agent

Hazards identification

Emergency Overview: Danger! Corrosive. Severe eye, skin and respiratory irritant. May cause allergic skin and respiratory reactions. Harmful if absorbed through the skin. Contact may cause chemical burns

First aid measures

Ingestion: If swallowed, immediately give at least 3-4 glasses of water, but do not induce vomiting. If vomiting occurs, give fluids again. Do not give anything by mouth to an unconscious or convulsing person. Get immediate medical attention. Have physician determine whether vomiting or stomach evacuation is necessary.

Skin: For skin contact, under a safety shower, immediately remove contaminated clothing and shoes. Wash affected areas thoroughly with large amounts of water, and soap if available, for at least 15 minutes. Get immediate medical attention. Discard or decontaminate clothing before re-use and destroy contaminated shoes.

Inhalation: If inhaled, remove from area to fresh air. If not breathing, give artificial respiration. Get immediate medical attention. If breathing is difficult, transport to medical care and, if available, give supplemental oxygen.

Eyes: For eye contact, immediately flush eyes for at least 15 minutes with running water. Hold eyelids apart to ensure rinsing of the entire eye surface and lids with water. If physician is not available, flush for an additional 15 minutes. Get immediate medical attention.

Overexposure Effects: Overexposure can cause moderate to severe skin, eye and respiratory irritation. Prolonged contact may result in chemical burns. May cause allergic skin and respiratory reactions such as irritation, itching and swelling. May be toxic by skin contact. Ingestion may cause nausea, vomiting, abdominal pain and diarrhoea. Inhalation of vapours may irritate nose, throat and lungs. Repeated or prolonged inhalation can cause lung damage.

Fire fighting measures

Flash Point: 230°F (110°C)

Flash Point Method Used: Closed Cup

Fire Fighting Extinguishing Media: Carbon dioxide, foam, dry chemical, water spray.

Fire Fighting Equipment: Use self-contained breathing apparatus.

Fire and Explosion Hazards: Decomposition and combustion products may be toxic.

(Faruk, Andrzej K.Bledzki,Hans-Peter,Fink, Sain-2000-2010)

4. Specimen Calculation

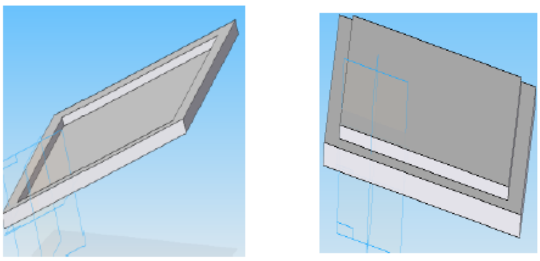

Figure 2 Mould box

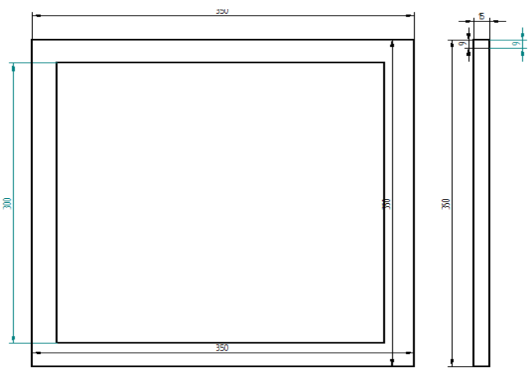

Figure 3 Mould box Dimensions

4.1 Composite material for 3mm thickness and 10% powders

Fiber percentage = 10%
Volume of the mould =30*30*0.3cm^3
Density of epoxy =1.645kg/cm^3
Mass = p*v= 1.645*270= 444.15g
Mass required + allowance =460g
Mass of fiber =460*0.1 =46g
Mass of epoxy + hardener = 460-46 = 414g
Epoxy: hardener = 10:1
Mass of epoxy = 414*10/11 = 376.36g
Mass of hardener = 414- 376.36 = 37.64g\

4.2 Composite material for 3mm thickness and 20% powders

Fiber percentage = 20%
Volume of the mould =30*30*0.3cm^3
Density of epoxy = 1.645kg/cm^3
Mass = p*v = 1.645*270= 444.15g
Mass required + allowance =460g
Mass of fiber =460*0.2 =92g
Mass of epoxy + hardener = 460-92 = 368g
Epoxy: hardener = 10:1
Mass of epoxy = 368*10/11= 334.54g
Mass of hardener = 368- 334.5= 33.45g

4.3 Composite material of 5mm thickness for 10% powders

Fiber percentage = 10%
Volume of the mould =30*30*0.5cm3
Density of epoxy = 1.645kg/cm3
Mass = p*v= 1.645*450= 740g
Mass required + allowance =750g
Mass of fiber =750*0.1
=75g
Mass of epoxy + hardener = 750-75
= 675g
Epoxy: hardener = 10:1
Mass of epoxy = 675*10/11 = 613.6g
Mass of hardener = 675- 613.5= 61.5g

4.4 Composite material of 5mm thickness for 20% powders

Fiber percentage = 20%
Volume of the mould =30*30*0.5cm3
Density of epoxy = 1.645kg/cm3
Mass = p*v= 1.645*450= 740g
Mass required + allowance =750g
Mass of fiber =750*0.2=150g
Mass of epoxy + hardener = 750-150= 600g
Epoxy: hardener = 10:1
Mass of epoxy = 600*10/11 = 545.45g
Mass of hardener = 600- 545.45 = 54.55g

5. Specimen Preparation

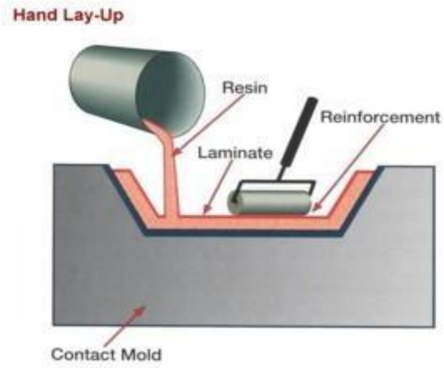

Figure 4 Specimen Preparation

Hand layup is the an open contact moulding process suited for making large, high strength part at low to medium level at lower cost. A combination of reinforcement in required form is cut and laid into an open mould and impregnated with resin. This is repeated for number of layers of reinforcements. Resin are impregnated by hand hence the name hand layup technique. This is usually accomplished by roller or brushes, with an increasing use of nip-roller type impregnator for forcing resin into reinforcements. Now the mould is pressed on the other half with hand so that the air bubble and excess resin are squeezed out. Laminates are left to cure under standard atmospheric condition say for about 24 hours. When the resin cures, the load on the mould is released and the surface of the mould is replicated on the side of composite facing mould.

Steps involved in fabrication
Step1: Personal preparation – wearing safety gloves, goggles, wearing protection covers, cleaning the work area and make it free of dust.
Step2: Mixing of epoxy with its hardener- mix the accurate percentage of resin with its hardener on the calculation made and stir it without letting it to cool down and get hardened.
Step3: Mix the powder with epoxy hardener mixture– after mixing the epoxy with its hardener then add the powder slowly to the mixture and then stir it properly so that to avoid formation air bubbles.
Step4: Squeezing by hand press –squeeze the material under hand press until the excess epoxy is drawn out and allow the specimen to dry by keeping the weight on it.
Step5: General inspection – once the layup is cured look for air bubble in the laminated carefully and then remove the Mylar sheet applied on either side.
Step6: Trimming - once the laminate is ready the outer edge are trimmed off and the specimen of required dimensions are cut contour cutting machine to perform necessary tests.

6. Mechanical characterization of natural plant powders reinforced composites

The mechanical testing has been done on the composite laminate specimen as per the guidelines in ASTM standards for the respective tests. The mechanical tests are usually performed to identify the strength parameter of any kind of material considered or prepared under the studies. The tests done are discussed below.

6.1 Flexural test (3 point bending)

This test method determines the flexural properties of fiber reinforced thermo set composites under defined condition. According to ASTM D 790,flexural testing has been carried out. A three point bending arrangement has been employed to carry out the flexural test. In this system, a center loading is utilized on a simply supported beam.

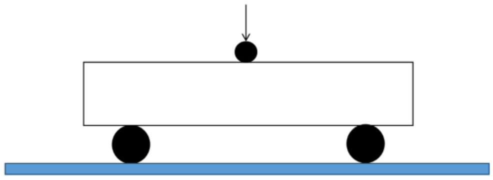

Figure 5 Schematic representation of 3-point bending fixture

The span length between center lines of support rollers has been marked.The specimen on the roller support at center has been placed. The dial gauge at the load point at top centrally is fixed. The load at the center of the span is applied at very slow rate until failure of the specimen. The simulation observations of load 'F' and deflection 'Y' has been observed.

6.2 Test specimen

According to ASTM D 790, the specimens were prepared for static bending. Each test specimen of 15mm width, length 120mm and span length of 90mm was used for the present investigation. The bending test specimen is shown in fig 6.

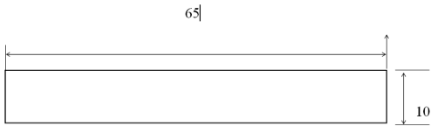

Figure 6 Flexural test specimen geometry(in mm)

Machinedata ZWICK/ROELL,Z020,LOADCELL-20 kN

Loading rate : 5mm/min
Specimen used : rectangular bar
Specimen dimension : 65mm×10mm

6.2 Tensile Test

According to ASTM D3039/D3039M-08 tensile testing has been carried out. The test method cover the determination of tensile properties of reinforced polymer in the form of shaped test specimen when tested under defined condition of pre-treatment, temperature, humidity and testing machine speed.

Machine data: ZWICK/ROELL, Z020,
LOADCELL- :20kn.
Loading rate :5mm/min
Specimen used : rectangular bar.
Specimen dimension: 200mm×15mm

According to ASTM D3039/D3039M-08, composite specimen were prepared for test. the specimen length of 200mm with a width of 15mm was prepared for this study, shown in fig 7.

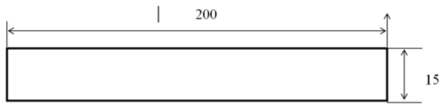

Figure 7 Tensile test specimen geometry(in mm)

The test specimen was placed between the two holders of the machine. The constant rate of loading of 5mm/min is applied on the specimen. The specimen of 200mm length (130mm gauge length), 15mm wide is used. The specimen is fixed in the tensile testing machine jaws and initial adjustment is made. The experiments are conducted on the specimen. The value of load and corresponding deflection are noted down. From these obtained values stress, strain and young's modulus are determined using following equations

Stress : P/A N/mm^2
Strain : e

The graph of stress and strain vs different composition are plotted and ultimate tensile, bending and impact strength are tabulated.
(Senthiil P V,Sirsshti-2014)

7. Results and Discussions

7.1 Bending test results

Table 3
10%oat-bamboo
Bending stress results

Sample	Flex modulus mpa	Flex strength mpa	Deformation %	Thickness mm	Width mm
1	3210	59	2.0	3	10
2	3120	34.7	1.1	3	10

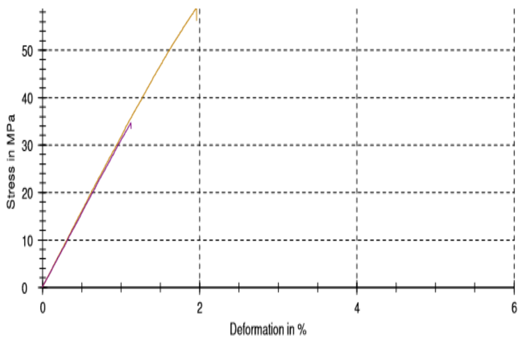

Figure 8: Graph (stress vs deformation) (10% oat-bamboo)

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Table 4
10%oat-bamboo
Bending stress results

Sample	Flex modulus MPa	Flex strength MPa	Deformation %	Thickness Mm	Width mm
1	3500	42.9	1.2	3	10
2	3620	41.8	1.2	3	10

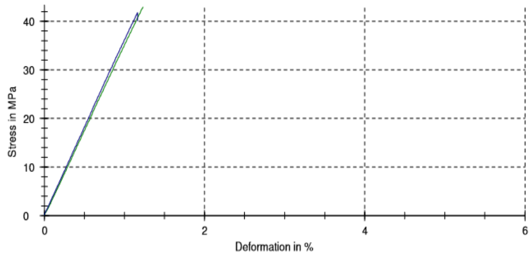

Figure 9: Graph stress vs deformation (10% wheat-bamboo)

Table 5
bending stress results (10% wheat-oat)

Sample	Flex modulus Mpa	Flex strength Mpa	Deformation %	Thickness(mm)	Width(mm)
1	3090	58.3	1.9	3	10
2	3480	49.5	1.4	3	10

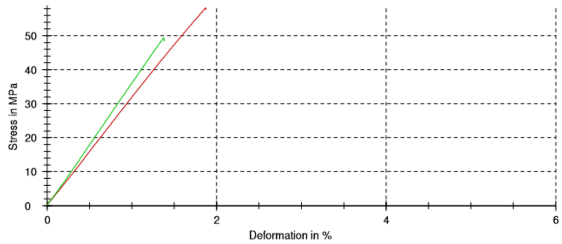

Figure 10: Graph stress vs deformation (10% wheat-oat)

Among the following observations, oat-bamboo has flex modulus of 3165Mpa, wheat-bamboo has 3560Mpa, oat-wheat has 3285Mpa hence wheat-bamboo has highest bending strength.

7.2 Tensile Test results

Table 6
Tensile stress results (10% bamboo-wheat)

Sample	Tensile Modulus Mpa	UTS Mpa	Tensile breaking strain %	Thickness mm	Width mm
1	534.5	30.5	2.9	3	15
2	387.1	25.9	2.7	3	15

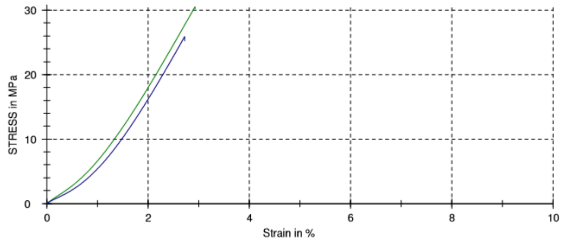

Figure 11: Graph stress vs strain (10% wheat-bamboo)

Table 7
Tensile stress results (10% oat-bamboo)

Sample	Tensile Modulus Mpa	Uts Mpa	Tensile breaking strain %	Thickness Mm	Width mm
1	341.3	22.4	2.2	3	15
2	512.1	22.1	2.2	3	15

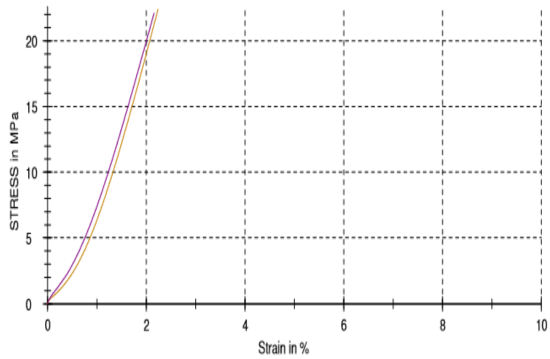

Figure 12: Graph stress vs strain (10% oat-bamboo)

Table 8
Tensile stress results (10% oat-wheat)

Sample	Tensile Modulus Mpa	Uts Mpa	Tensile breaking strain %	Thickness Mm	Width mm
1	178.3	35	4.1	3	15
2	257.7	32.3	3.8	3	15

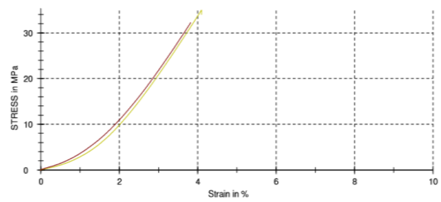
Figure 12: Graph stress vs strain (10% wheat-oat)

Among the following observations, Bamboo-wheat has tensile modulus of 460.8Mpa, oat-bamboo 426.7Mpa, and wheat-oat has 218Mpa hence bamboo-wheat has highest tensile strength.

7.3 Impact Test results

Table 9
Impact stress results (10% wheat-oat)

Sample	Impact strength J/m	Thickness Mm	Width Mm
1	69	3	12.5
2	71	3	12.5

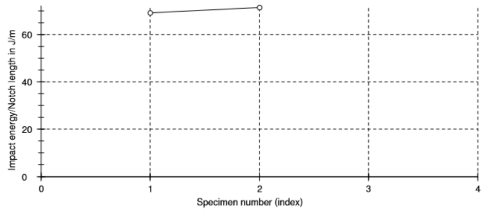

Figure 13: Graph impact energy/notch length vs specimen no. (10% wheat-oat)

Table 10
Impact stress results (10% oat-bamboo)

Sample	Impact strength J/m	Thickness Mm	Width Mm
1	29	3	12.5
2	38	3	12.5

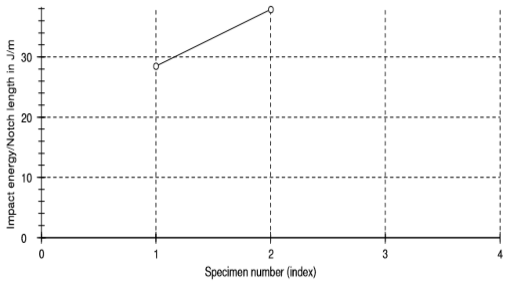

Figure 14: Graph impact energy/notch length vs specimen no. (10% bamboo-oat)

Table 11
Impact stress results (10 % bamboo-wheat)

Sample	Impact strength J/m	Thickness Mm	Width Mm
1	66	3	12.5
2	85	3	12.5

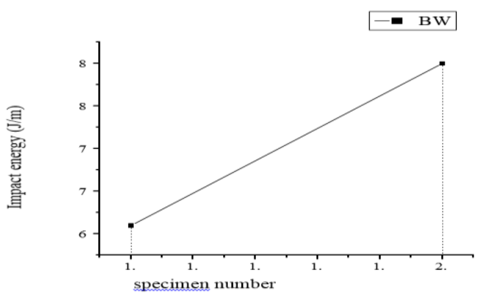

Figure 15: Graph (Impact energy vs specimen no.)(10 % bamboo-wheat)

Impact observation gives wheat-oat has impact strength of 70J/m,oat-bamboo has 33.5J/m and bamboo-wheat has 74.8J/m hence bamboo-wheat has highest impact strength.

8 Conclusion

In the present work the natural fiber reinforced epoxy polymer composite are considered. The natural fiber considered under this work are bamboo-wheat, bamboo-oat, oat-bamboo, combination of 10% composition there tensile modulus, bending modulus, impact strength are studied.

Table 12
Conclusion table

Composition	Tensile modulus (Mpa)	Bending modulus (Mpa)	Impact strength(j/m)
Wheat-oat	218	3285	70
Oat-bamboo	426.8	3165	33.5
Bamboo-wheat	460.8	3560	75.2

Acknowledgments

The satisfaction and the euphoria that accompany the successful completion of any task would be incomplete without the mention of people who made it possible, whose involvement and efforts made it possible. I express sincere thanks to my students involved in this.

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