"Effect of Fiber Volume on Mechanical Properties of Alkaline Treated Unidirectional Long Kenaf Fiber with Egg Shell Powder Reinforced Polymer Matrix Composite"

Abhishek S.A [1] Deemanth Gowda TM[2]
Koushik Raj A R[3] Hemanth R[4]
[1,2,3,4] U. G. Students,
Department.of Mechanical Engineering,
Sapthagiri College of Engineering, Bangalore,
Visvesvaraya Technological University,
Belgavi, Karnataka.

T. Venkate Gowda[5] Anil Kumar P R[6]
[5,6]Assistant Professors,
Department of Mechanical Engineering,
Sapthagiri College oF Engineering, Bangalore,
Visvesvaraya Technological University, Belgavi, Karnataka.

***Abstract* - Recently due to increasing interest in eco-friendly materials, studies on ecofriendly fiber obtained from nature have been actively conducted to the area of composite. Natural plant fibers like Jute, Sisal, Coir, Kenaf, Flax, Hemp, Sugarcane Bagasse, Bamboo pineapple leaf and Banana are typically used in composites as a reinforcing material either as continuous (very long) or discontinuous (chopped) fibers due to their low cost, high tensile strength, low thermal expansion, high strength to weight ratio, renewability, biodegradability and exponential growth. Although, the natural fiber has less strength than the synthetic fiber such as carbon fiber, it has similar strength to glass fiber. Accordingly, it can apply as very advantageous composite when an appropriate resin has been selected. Environmental concerns are now driving demand for recycled polymer (Thermoplastics) such as Polypropylene (PP), Poly Ethylene (PE), Polystyrene (PS), Polyethylene Sulphide (PPS), and Polyolefin etc. For various applications, especially in automotive and aircraft industries. The specimens are prepared according to ASTM standards and the different values are observed. Here filler material used is Egg powder which enhances the tensile property of the material.**

1.0 INTRODUCTION

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight.

1.1Definition of Composite

A composite material is defined as the combination of two or more macro constituent materials, which are essentially insoluble into each other such that the properties of the combination are better than the sum of the properties of each constituent taken separately. The objective of this combination is to derive the best qualities of the constituent materials. These composites exhibit desirable qualities, which the constituents themselves may not possess.

1.2types of Composites

In a broad way composite materials can be classified into three groups in the basis of matrix materials. They are:

1. Metal matrix composites (MMC)
2. Ceramic matrix composites (CMC)
3. Polymer matrix composites (PMC)

1.2.1metal Matrix Composites:

These composites have many advantages over monolithic metals like higher specific strength, higher specific modulus, better properties at elevated temperatures, and lower coefficient of thermal expansion. Due to these attributes metal matrix composites are under consideration for wide range of applications.

1.2.2ceramic Matrix Composites:

One of the main objectives in preparing ceramic matrix composites is to increase the toughness. Naturally it is hoped and also it is found that there is a contomitant improvement in strength and stiffness of ceramic matrix composites.

1.2.3polymer Matrix Composites:

Most commonly used matrix materials are polymeric. In general the mechanical properties of polymers are inadequate for many structural purposes. Generally their strength and stiffness are low compared to metals and ceramics. To overcome these difficulties other materials are reinforced with polymers.

Two types of polymer composites are:

- Fiber reinforced polymer (FRP)
- Particle reinforced polymer (PRP)

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1.2.4fibre Reinforced Polymer

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers. The fibers carry the loads along their longitudinal directions. Sometimes filler might be added to smooth the manufacturing process, impact special properties to the composites, and to reduce the product cost. Common fiber reinforcing agents include asbestos, carbon/graphite fibers, beryllium, beryllium carbide, beryllium oxide, molybdenum, aluminum oxide, glass fibers, polyamide, natural fibers etc. Similarly common matrix materials include epoxy, phenolic, polyester, polyurethane, polyetheretherketone (PEEK), vinyl ester etc.

1.3particle Reinforced Polymer

Particles used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminum and amorphous materials, including polymers and carbon black. Particles are used to increase the modules of the matrix and to decrease the ductility of the matrix. Particles are also used to reduce the cost of the composites. Reinforcements and matrices can be common, inexpensive materials and are easily processed. Some of the useful properties of ceramics and glasses include high melting temperature, low density, high strength, stiffness; wear resistance, and corrosion resistance.

1.4natural Fibres

Natural fibers are made from plant, animals and mineral sources. Fibers are a class of hair like materials that are continuous filament similar to pieces of thread. They can be used as a reinforcement of composite materials. Thermosetting plastics have been used as a matrix in polymer composite because of its uniqueness and attractive properties. Polyester resin is most important matrix which possess strength to weight ratio that far exceeds any of the present materials.

Natural fibers can be defined as bio-based fibers of vegetable and animal origin. This definition includes all natural cellulosic fibers (kenaf, banana, cotton, jute, sisal, coir, flax, hemp, abaca, ramie, etc.) and protein based fibers such as wool and silk. Practically in all countries natural fibers are produced and used to manufacture a wide range of traditional and novel products from textiles, ropes, nets, brushes, carpets, mats, mattresses to paper and board materials. The growing environmental concern on global warming have inspired the automobile, structural, construction, packing industries etc., to search for sustainable materials that can replace conventional synthetic polymeric fiber. Natural fibers seem to be a good alternative since they are readily available in fibrous form and can be extracted from plants at very low costs.

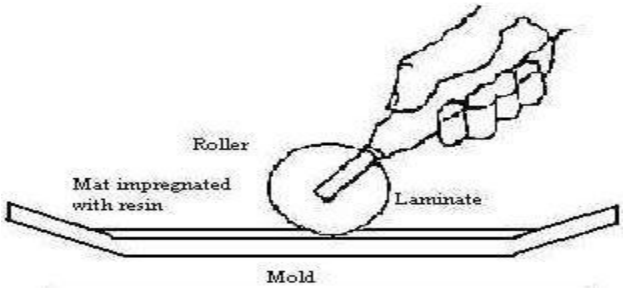
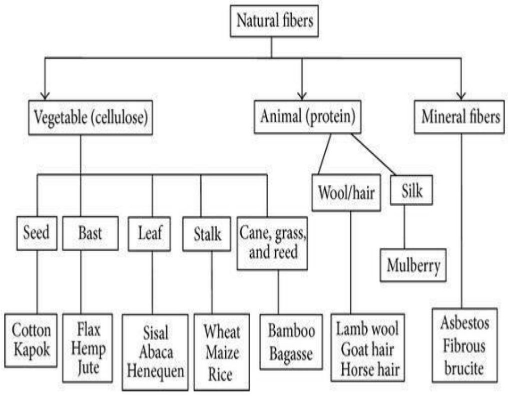


Figure 1.0: Hand lay-up

1.5classification of Natural Fibre Composites:



1.6 Fabrication Method & Preparation of Kenaf Fibre Reinforced Polyester Composite Specimen

Each layer of fabric was pre-impregnated with matrix material which is prepared by mixing general purpose polyester resin, accelerator and catalyst in the weight ratio of 1:0.02:0.026 respectively and these layers were placed one over the other in the mould with care to maintain practically achieved tolerance on fiber alignment. Casting was cured under light pressure for 2 hours before removal from the mould.

Hand lay-up technique is used to prepare specimen as shown in Figure. 1.0. The working surface was cleaned with thinner to remove dirt and a thin coat of wax is applied on the surface to get smooth finish. Then a thin coat of polyvinyl alcohol (PVA) is applied for easy removal of mould. Kenaf fiber is cut to the required dimensions for test specimen pre-impregnated with matrix material and placed one over the other in the mould. Casting was cured under light pressure for 2 hours before removal of mould. All test specimens were molded and prepared according to ASTM-D standard to avoid edge and cutting effect, thereby minimizing stress concentration effect.

Specimen length, width, gauge length, depth and configuration for each test and required cross head speed are clearly specified in the Table 1.0.

Sl. No.	Specimens Tested	ASTM-A370 Standard	Length a (mm)	Width b (mm)	Depth d (mm)	Gauge length e (mm)
1	Tensile	638	165	20	3	54
2	Bending	790	80	12.7	3	---

Table 1.0

1.7 Course Work

EGG Shell Powder is selected as the filler material to the matrix . From the various reference and study it was found that there will be a desirable increase in the property of the tensile specimen and also hardness up to certain extent .

The composition of egg shell powder shows that there is a huge amount of calcium content present in the egg shell powder .The composition of egg powder is as shown in the table below:-

Amount Per Selected Serving	Weight in mg	%DV
Calcium	900	90
Iron	-	-
Magnesium	24.0	6
Phosphorous	8.4	1
Potassium	8.0	0
Sodium	9.0	0
Zinc	-	-
Copper	-	-
Manganese	-	-
Selenium	-	-
Fluoride	-	-

Table 1.1 Composition of Egg Shell Powder

1.8 Preparation of Egg Shell Powder :-

Poultry chicken egg is taken and the outer shell is first separated .This outer shell is first dried for about 15 days and is powdered finely .Since there will be course particles , using a sieve plate the fine powder is extracted and then added as the filler material.

Fig1.1 :- Preparation of Egg Shell Powder

1.9 Percentage Variation Of Egg Powder In Composite Material

COMPONENT	MATRIX	FIBERS	EGG POWDER
1.	76%	20%	4%
2.	72%	20%	8%
3.	68%	20%	12%

Table 1.2 Percentage Variation

2.0 CALCULATIONS

2.0.1Density of Egg shell Powder

Data :-

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Mass = 0.1923 gm

$$\text{Volume} = \frac{3.142}{4} * D^2 * l = 2.1205\ cm^3$$

$$\text{Density} = \frac{0.1923*10}{2.1205} = 0.90686\ gm/mm^3.$$

- *Calculations for 76% polymer, 20% Kenaf Fibers and 4% Egg Shell Powder*

1. Volume of Die = Volume Of Composite
   $V_c = 200 * 150 * 3.5$
   $V_c = 105000\ mm^3$
2. Density of Composite (ρ_c)

   $$\frac{1}{\rho_c} = \frac{W_f}{\rho_c} + \frac{W_m}{\rho_m} + \frac{W_e}{\rho_e}$$

   $$= \frac{0.2}{1.13*10^{-3}} + \frac{0.76}{1.17*10^{-3}} + \frac{0.04}{0.9243*10^{-3}}$$

   $\rho_c = 1.2132 * 10^{-3}\ gm/mm^3$
3. Weight of Composite
   $W_c = \rho_c * V_c$
   $= 1.2132 *10^{-3} *105000$
   $W_c = 127.39$ gm
4. Volume of Fiber
   $v_f = V_f * v_c$
   $= 0.2*105000$
   $v_f = 21000\ mm^3$
5. Volume of Matrix
   $v_m = V_m * v_c$
   $= 0.76 * 105000$
   $v_m = 79800\ mm^3$
6. Volume of Egg shell powder
   $v_e = V_e * v_c$
   $= 0.04 * 105000$
   $v_e = 4200\ mm^3$
7. Weight of Fiber
   $w_f = \rho_f * v_f$
   $= 1.13 * 10^{-3} *21000$
   $w_f = 23.73$ gm
8. Weight of Matrix
   $w_m = \rho_m * v_m$
   $= 1.17*10^{-3} *79800$
   $w_m = 93.76$ gm
9. Weight of Egg powder
   $w_e = \rho_e * v_e$
   $= 9.243*10^{-4} *4200$
   $w_m = 3.80$ gm
10. Weight of Composite
    $W_c = w_f + w_m + w_e$
    $= 23.73 + 93.76 + 3.80$
    $W_c = 121.29$ gm.
    Therefore the weight of composite for 76% Polymer , 20% Kenaf and 4% egg powder is 121.29gm .
    6.4.2 Calculation of Tensile Stress

- Composition 76% Polymer ,20% Fiber ,4% Egg shell powder

$$\text{Stress} = \frac{\text{Load}}{\text{Area}}$$

$$= \frac{2608.558}{42}$$

Stress = 62.108 MPa

2.0.2 Calculation of Tensile strain

- Composition 76% Polymer ,20% Fiber ,4% Egg shell powder

$$\text{Strain} = \frac{\text{Initial Area-Final area}}{\text{Initial Area}}$$

$$= \frac{39.25\text{-}34.823}{39.25}$$

Strain = 0.11

2.0.3 Calculation for Bending Specimen

- Composition 76% Polymer ,20% Fiber ,4% Egg shell powder

$$\text{Bending Stress} = \sigma = \frac{3}{2} * \frac{PL}{bh^2}$$

$$= \frac{3}{2} * \frac{267.721*60}{14.840*3.990^2}$$

$$= 103.57 \text{ MPa}$$

2.0.4 Calculation of Young's Modulus

- Composition 76% Polymer ,20% Fibre ,4% Egg shell powder

$$\text{Young's Modulus} = E = \frac{\text{STRESS}}{\text{STRAIN}}$$

$$= \frac{62.108}{.11}$$

$$= 564.618 \text{ MP}$$

3.0 RESULTS AND DISCUSSIONS

Sl .No	Combination (Matrix-Fibers)%	Ultimate Tensile Strength (MPa)	Bending Break Load (N)	Hardness
1.	90 – 10	37.18	173.6	78
2.	80-20	45.48	139.3	78
3.	70-30	37.35	196.1	79
4.	60-40	55.89	30.402	80
5.	50-50	90.23	65.707	81

Table 1.3 Comparison of properties with different composition for Treated Specimens without Egg Shell Powder

Sl.No	Combination (Matrix-Fibers-Filler material)%	Ultimate Tensile Strength (MPa)	Bending Break Load (N)	Hardness
1)	76-20-4	62.108	267.721	79
2)	72-20-8	51.83	210.84	80
3)	68-20-12	37.35	222.67	79

Table 1.4: Comparison of properties with different composition for Treated Specimens with Egg Shell Powder

2.1 Conclusion

The following points are the conclusions drawn from the experimentation of Kenaf reinforced Epoxy Matrix Composites.

1. The Kenaf-epoxy composite specimens prepared as per ASTM standards subjected to mechanical characterization results were analyzed and compared.
2. The present investigation revealed that different composition of fibre influences the improved or enhanced properties of composites.
3. The maximum Tensile stress is obtained for composites reinforced with 20 wt. % fibre (NaOH Treated) i.e. .55.89 N/mm^2
4. The maximum bending stress is obtained for composites reinforced with 20% wt. % fibre (NaOH Treated) i.e. 139.25 N
5. The maximum Shore D hardness number obtained for composites reinforced with 20% wt fibre (NaOH Treated) i.e 78
6. The maximum Tensile stress is obtained for composites reinforced with 20 wt. % fibre (NaOH Treated) and 4 wt % Filler material i.e. 62.108 N/mm^2
7. The maximum bending stress is obtained for composites reinforced with 20% wt. % fibre (NaOH Treated) and 4 wt % Filler material i.e. 267.721 N
8. The maximum Shore D hardness number obtained for composites reinforced with 20% wt fibre (NaOH Treated) and 4 wt % Filler material i.e 79.
9. By considering all the combinations the preferable combination of the composite material is (76% Matrix,20% Fibre,4% Egg shell Powder) by wt.

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