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Natural Fiber Reinforced Green Composites with Epoxy Polymer Matrix and its Mechanical Properties Analysis

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Abstract—Present scenario, the most of the materials used for diverse applications are alternative materials as composite materials, in this maximum of the researchers are explored invention of natural fiber reinforced green composites because of easy accessibility of natural fibers and treating of natural fibers are simple and renewable, good mechanical properties, cheap and ecofriendly. In this investigation, the availability of different natural fibers and its mechanical properties and also manufacturing of NF (Sisal, Kneaf) reinforced epoxy polymer matrix green composites are discussed. The essential properties required for engineering applications are tested and evaluated. This paper concludes that the manufacturing of Natural Fiber Reinforced Polymer Composite Lamina by hand layup process and the properties are tested as per the ASTM standards. Finally, we concluded that Kneaf fibered reinforced polymer composite has good mechanical properties then the Sisal Fibered Reinforced Composite.

Keywords*-Natural Fibers, Epoxy Resin, Laminate Preparation, Tensile Test, Flexural Test, Impact Test, NFRPC.*

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I. INTRODUCTION

Now a day's, the emerging trends in usage of engineering materials in broad areas of applications are Automobiles, aircrafts and space the conventional materials are used, these are supplanted by an alternative materials are composite materials. Preceding few years the Metallic Fiber Reinforcement was used for Composites, but these composites has the specific property called strength to weight ratio is decreasing and the cost increases. i.e. overcoming above problem the metallic fibers are replaced by natural fibers because of low density, easy availability, low cost, easy processing, renewable, biodegradable and eco-friendly [1][2][14]. The composite specific property strength to weight ratio increases tremendously.

In present days the polymers are substituted by different conventional metals or materials in various applications. This is possible because of polymers offers more advantages then the conventional materials these are flexibility of manufacturing different shapes and parts, easy of processing, cost reduction, high productivity and easy handling, getting change of properties are possible. Because of these reasons the reinforced polymer composites are better advantages than the conventional materials [7].

A. Composite and its constituents

Composite is a material that contains at least two or more different components, clearly separated one from another and uniformly filling its volume, and produced, in order to create specific properties, which contains reinforcing phase and matrix phase [1][4]. Reinforcement segment is in the form of fiber layers, impregnated natural fiber sheets, meshed fibers or particles, and is combined with additional materials called matrix material deeds as binding proxy (polymers). Reinforcement materials have superior mechanical assets and acts as the primary load-carrying members and the matrix material acts as a binding proxy to hold the fibers in a anticipated location, configure ration and transfers load to the fibers through the fiber-matrix interface and also Safeguards the fibers from environmental damage.

II. NATURAL FIERS

Natural fibers or Bio fibers are renewable fibers that can be extracted from animals, plants and mineral resources. However the habit of natural fibers for composite materials are typically separated into two groups, primary natural fibers are agro based fibers from plant, leaf, stem, bast, shells, etc. for example: sisal, jute, Kenaf, hemp, bamboo are especially harvested for their fiber content and the secondary fibers are take out from agro waste; for example: coir, pineapple, rice, corn and wheat straws, oil palms, etc. The natural fibers are used abundantly in different applications because of significant properties low density, renewable, easy availability, cheap, biodegradable, eco-friendly friendly, moderately or completely recyclable, and also superior mechanical properties of strength to weight ratio [1][2].

A. Classification of natural fibers

Natural fibers are classified into three major categories are plant fibers, animal fibers and mineral fibers are as shown in Figure. 1.

Natural fibers are the substances which are extracted from plants, minerals and animals that can be spun and weave into filament, thread or rope. The firstborn fibers used by mankind are flax, cotton and silk, but even the other fibers like jute, sisal, Kenaf, banana, hemp and coir have been cultivated since ancient times. Present days the above natural fibers have been cultured for extracting fibers [2]. The main reasons of increasing production of Natural Fibers are because of broad usage for making bio-composites, green composites and Natural Fiber Rein Forced Composites (NFRCs). These Fibers are readily available, reliable quality and extensively available and environmental friendliness [2][7]. There are different types of natural fibers explained in the below.

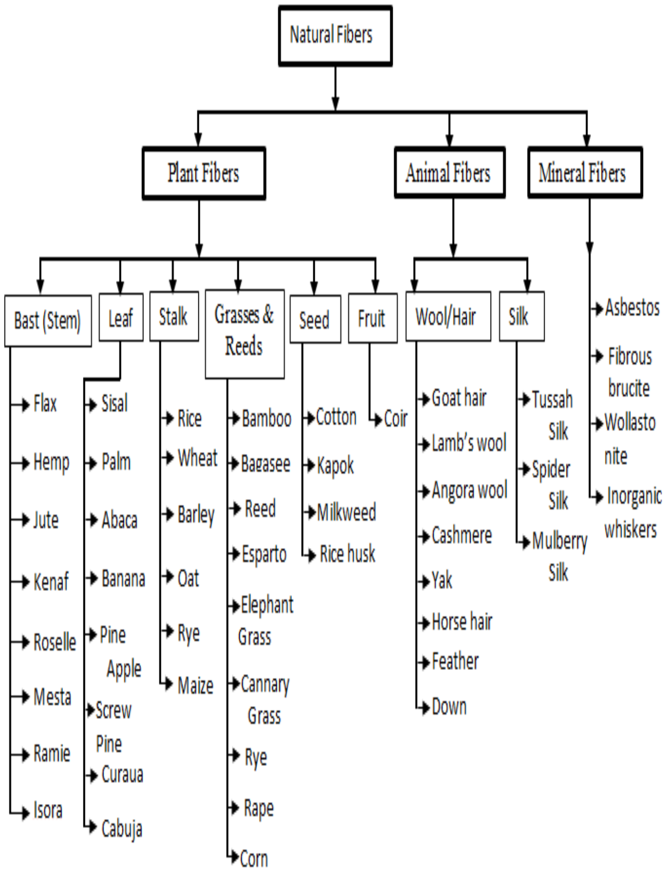


Figure 1. Classification of Natural Fibers

Figure 2. Different Plants and its Fibers

1. Kenaf fiber extracted from bast or stalk of the plant scientific name Hibiscus cannabinus L is a worm season fiber crop has a single, straight and branchless stalk [3][5]. The fiber removed from the outer fibrous bark is also known as bast fiber. Kenaf fibers are having superior tensile strength, flexural strength and also good impact strength, low density.

2. Banana plant not only provides the fruit but it also gives the banana fiber in the stem and fruit. Banana fibers are extracted after the fruit is harvested and in the group of bast fibers is as shown in Figure. 2. Banana fiber has a leading application and was primarily used for making items like ropes, mats in past usage, but present broadly utilized for production of composite materials [11]. By increasing environmental awareness and growing worth of green fabrics, banana fiber has good qualities and now its applications are wide in other fields such as clothing garments and home furnishings also.

3. Jute is a lengthy and glossy vegetable fiber fall under the bast fiber that can be rolled into coarse, strong threads [8]. It is produced from plants in the genus Corchorus belonging to the family Sparrmanniaceae. The industrial term for jute fiber is raw jute is as shown in Figure. 2. The fibers are 1–3 meters (3–10 feet) long. Jute is a golden fiber by its color and high cost.

4. Sisal fiber is under Agavaceae family, the fiber is extracted from leaf of a sisal plant is a recyclable and eco-friendly friendly. Sisal fiber is a robust, tough, stable and multipurpose material and it has been accepted as an important source of fiber for composites is as shown in Figure. 2. It is usually recognized that the mechanical properties of fiber reinforced polymer composites are controlled by features such as nature of matrix, fiber-matrix interface, fiber volume or weight fraction, fiber orientation etc
5. Coir is a fruit natural fiber extracted from the outer shell of coconut, the fruit of Cocosnucifera, a hot plant of the Arecaceae (Palmae) family. The coarse, rigid, ruddy brown fiber is made up of smaller filaments and composed of lignin, a arboreal plant substance, and cellulose [6]. The treated coir fiber is as shown in Figure. 2. They are used in the products such as flooring mats, carpets, brushes, beds, etc. White coir used for coconuts, is used for making bigger brushes, cord, rope and fishing nets.

B. Processing of natural fibers

Fibers are removed by spun through hand extraction machine composed of either toothed or non-toothed knives [9].

(a) **(b)**
Figure 3. Fiber treatment and Meshed fiber

Then the fibers are cleaned in running water to remove Skins in the rolled fibers such as coating of cellulose, broken fibers, pigments, etc., are removed manually by the use of comb, and then the fibers were treated with NaOH solution for one day as shown in Figure. 3(a), after that soaked and washed in distill water, cleaned and sun dried [1][4]. Once the fibers are dried, weaving is done in the hand looms. The treated and untreated fibers are meshed with the size, 300 mm × 300 mm manually is as shown in Figure. 3(b).

C. Mechanical properties of natural fibers

The mechanical properties of various natural fibers are as shown in Table I. The properties of natural fibers are analogous so that the Kenaf fiber has good strength low density same as sisal fiber [1][8].

TABLE I. PROPERTIES OF NATURAL FIBERS

S.No	Fiber	Density (gm/cm^3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)
1	Jute	1.3	393 - 773	26.5	1.5 – 1.8
2	Sisal	1.45	511 - 635	9.4	2.0 – 2.5
3	Flax	1.5	345 – 1035	27.6	2.7 – 3.2
4	Kenaf	1.45	930	53	1.6
5	Hemp	1.47	690	70	1.6
6	Cotton	1.5 – 1.6	287 - 597	5.5 – 12.6	7 – 8
7	Coir	1.2	175	4 – 6	30
8	Banana	1.35	711 - 789	15 – 32	5.9
9	Bamboo	1.1	500 - 575	27 – 40	1.9 – 3.2
10	Pineapple	1.56	170	62	2.4
11	Oil palm	1.56	248	3.2	25
12	Ramie	1.5	560	24.5	2.5

III. COMPOSITE PREPARATION

In this paper Epoxy LY556 and it mixed with Hardener HY951 to prepare a laminate material with the Ratio of mixing epoxy and hardener is 10:1 [4] after that the Composite laminate preparation of materials used for the present investigation is fabricated by hand layup process [4][10]. Meshed Kneaf fibers of 300 mm length were used to prepare the specimen. The composite specimen consists of total five layers in which meshed Kneaf fiber layers are fixed in top to bottom of the specimen such a way that layer by layer and these processes are shown in schematic diagram as shown in Figure. 4. The meshed Kneaf fiber is placed on the Mylar sheet for 1.2 mm thick and then the resin is coated on the Kenaf fiber using roller brush. Further the layer of Kenaf fiber is placed on the layer of resin coated and then again coated the resin. Then this technique was continual up to entire five layers and Resin coated further evenly scattered in the fiber using roller.

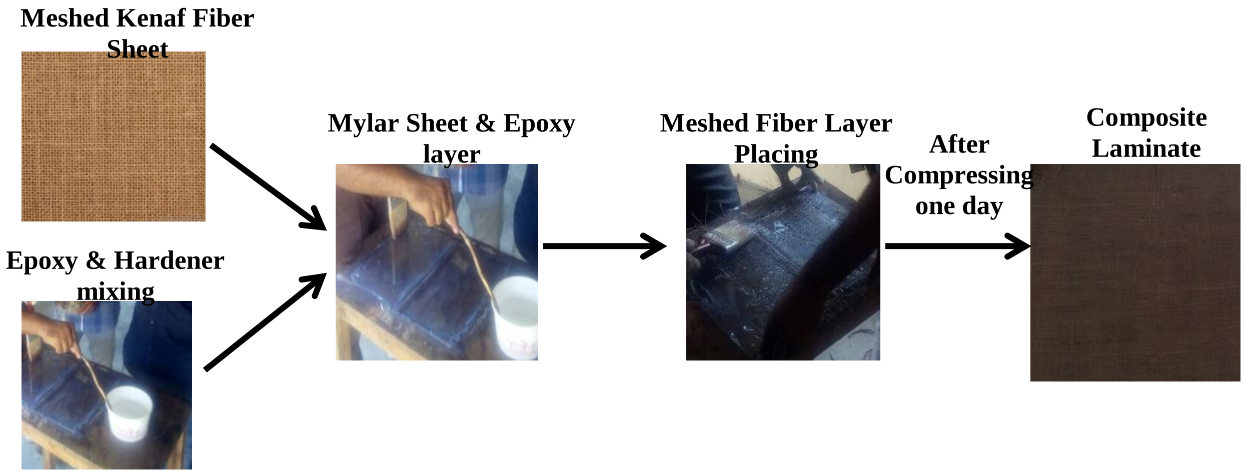


Figure 4. Composite Laminate Preparation

After final coating laminated sheet is placed in the compression molding machine and kept one day at room temperature.

IV. XPERIMENTAL PROCEDURE

A. *Tensile Test*

The composite specimen is prepared for tensile test according to the ASTM D638 standard and the machine specifications are also chosen according to the ASTM D638 [4][5][12].According to the ASTM D638 standard the dimensions of specimen used are 250 ×25× 5mm.

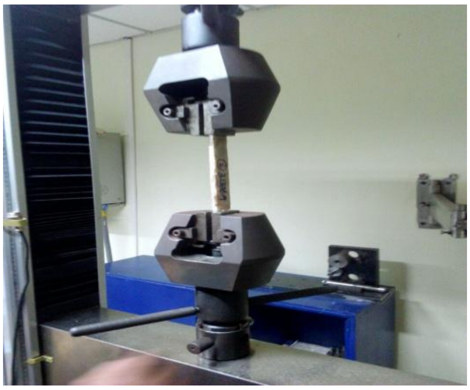


Figure 5. Tensile Test

This test involves placing the specimen in a Universal Testing Machine (UTM) jaws as shown in Figure.5. The specimen subjected it to the tension according to specific load until it fractures.

B. *Flexural Test (3-Point Bending)*

The flexural specimens from the composite laminate are prepared as per the ASTM D790 standard [4][10][13]. The 3-point flexure test is the most common flexural test as shown in Figure. 6, for composite materials. The specimen deflection is measured by the crosshead position. Test results include flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine (UTM) and applying force on it until it gets fracture. The specimen used for conducting the flexural test. According to the ASTMD790 standard the dimensions of specimen used are 250 ×25× 5mm

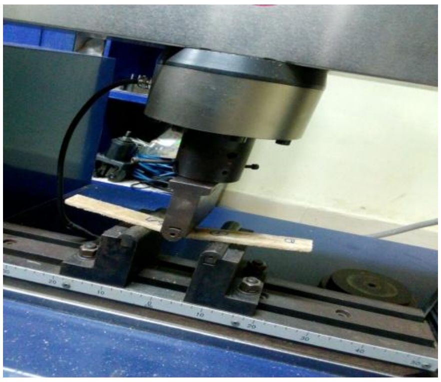


Figure 6. Flexural (3-Point Bending) Test

C. *Impact Test*

The impact test specimens from the composite laminate are prepared according to the required dimension followed by the ASTM-A370 standard [10][12].

Figure 7. Impact Test

During the testing process, the specimen must be loaded in the testing machine and allows the pendulum until it fractures by using the (charpy) impact test setup as shown in Figure. 7. The energy required to break the material can be measured easily and can be used to measure the toughness of the material and the yield stress. The impact strength (Toughness) values were calculated by dividing the energy by cross sectional area (80 × 10 mm) of the specimen.

V. MATHEMATICAL MODELING

A. *Tensile Test:*

Figure. 8 (a) & (b) shows the tensile test specimens before and after conducting test of Kenaf fibered reinforced polymer composite and sisal fibered reinforced polymer composite with different samples of same cross sectional area and the values are tabulated in given Table II.

TABLE II. TENSILE TEST OBSERVATIONS

Sample	Composite	Ultimate tensile load in KN	Ultimate tensile strength in Mpa
S1	Pure Sisal fiber	1.43	11.44
S2	Pure Sisal fiber	1.40	11.2
Average		1.415	11.32
S3	Pure Kneaf fiber	2.291	18.33
S4	Pure Kneaf fiber	2.25	18.00
Average		2.271	18.165

(a) **(b)**

Figure 8. Tensile Test Specimens

Formula Used

Tensile Strength = F/A

Where,

F = Ultimate Tensile load in N

A = Cross sectional area in mm^2

A = Thickness × Width = 125 mm^2

B. *Flexural Test: (3 point bending)*

Figure. 9 (a) & (b) shows the Flexural Test specimens before and after conducting test of Kenaf fibered reinforced polymer composite and sisal fibered reinforced polymer composite with different samples of same cross section and the values are tabulated in given Table III.

TABLE III. FLEXURAL TEST OBSERVATIONS

Sample	Composite	Compression load in KN	Ultimate Flexural strength in Mpa
S1	Pure Sisal fiber	0.5	33.45
S2	Pure Sisal fiber	0.5	34.13
Average		0.5	33.79
S3	Pure Kneaf fiber	1	48.56
S4	Pure Kneaf fiber	1	43.84
Average		1	46.2

(a) **(b)**

Figure 9. Flexural Test Specimens

Formula Used

$$\sigma = {}^{3PL}/_{2bh^2}$$

Where,

σ = Flexural strength in MPa

P = Load in KN

L = Length of span in mm

b = Width in mm

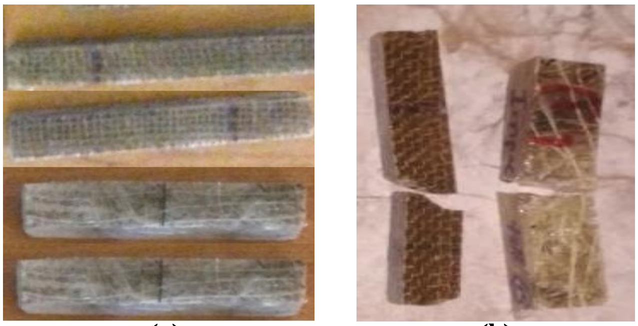
h = Thickness in mm

C. *Impact Test (Charpy)*

Figure.10 (a) & (b) shows the Impact test specimens before and after conducting test of Kenaf fibered reinforced polymer composite and sisal fibered reinforced polymer composite with different samples of same cross section and the values are tabulated in given Table IV.

TABLE IV. IMPACT TEST OBSERVATIONS

Sample	Specimen	Energy in Joules	Impact Strength in MPa
S1	Pure Sisal fiber	6.0	1.5
S2	Pure Sisal fiber	6.0	1.5
Average		6.0	1.5
S1	Pure Kneaf fiber	10	2.5
S2	Pure Kneaf fiber	12	3.0
Average		11.0	2.75



(a) **(b)**

Figure 10. Impact Test Specimens

Formula Used

Impact strength = E/A

Where

E = Energy absorbed by a specimen

A = Cross sectional area of specimen

= Cross section area of specimen= **80×10mm**

VI. RESULT AND DISCUSSION

In the present days, the NFRPC are used for different applications and their effects on mechanical properties are evaluated and their properties are compared. The tested properties of Kenaf fibered reinforced polymer composite and sisal fibered reinforced polymer composites as shown in Table V. below

TABLE V. IMPACT TEST OBSERVATIONS

Sample	Ultimate Tensile Strength in MPa		Ultimate Flexural Strength in MPa		Impact Strength in MPa	
	Sisal Fiber reinforced	Kenaf Fiber reinforced	Sisal Fiber reinforced	Kenaf Fiber reinforced	Sisal Fiber reinforce	Kenaf Fiber reinforced
S1	11.44	18.33	33.45	48.56	1.5	2.5
S2	11.2	18.00	34.13	43.84	1.5	3.0
Avg	11.32	18.16	33.79	46.2	1.5	2.75

A. *Comparison of Tensile Strength*

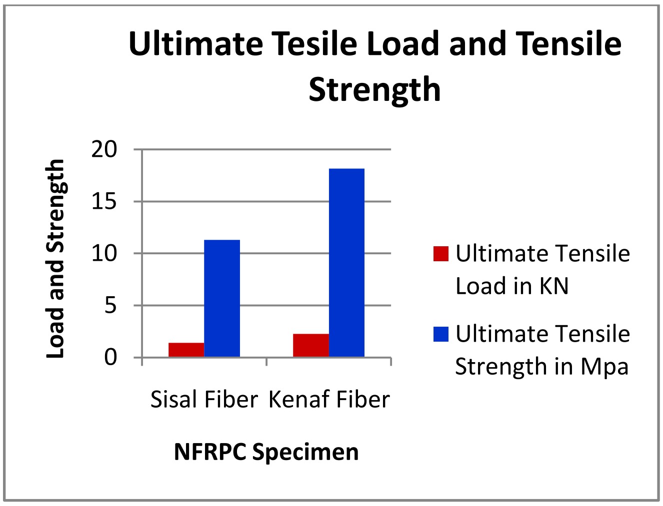


Figure 11. Comparison of ultimate tesile load and Tensile strength

The variant of Tensile Strength for Kenaf fiber and Sisal fiber reinforced polymer composite is as shown in the above graph Figure.11. The specimen of Kenaf fibered reinforced composite has highest tensile strength of 18.16 MPa and Sisal fibered reinforced composite has low tensile strength of 11.32 MPa. The tensile strength of Kenaf fibered reinforced composite is 6.84 MPa greater than that of Sisal fibered reinforced composite.

B. *Comparison of Flexural Strength*

The variant of Flexural Strength for Kenaf fiber and Sisal fiber reinforced polymer composite is as shown in the above graph Figure.12. The specimen of Kenaf fibered reinforced composite has highest flexural strength of 46.2 MPa and Sisal fibered reinforced composite has low flexural strength of 33.79 MPa. The flexural strength of Kenaf fibered reinforced composite is 12.41 MPa greater than that of Sisal fibered reinforced composite.

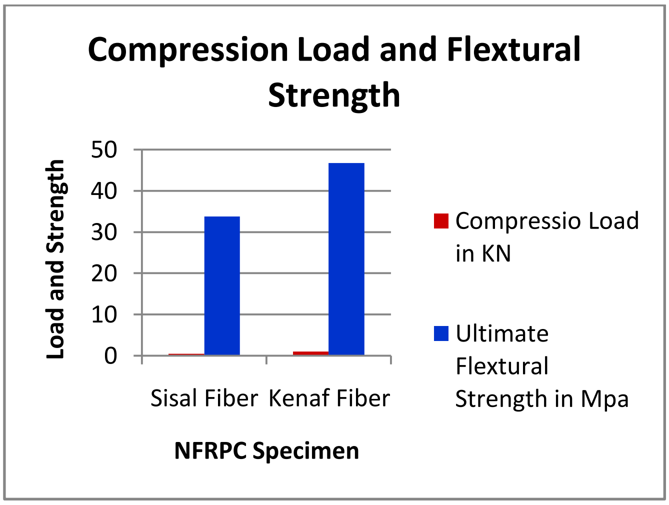


Figure 12. Comparison of Flexural Strength

C. *Comparison of Impact Strength*

The variant of impact strength for Kenaf fiber and Sisal fiber reinforced polymer composite is as shown in the above graph Figure.13. The specimen of Kenaf fibered reinforced composite has highest impact strength of 2.75 MPa and Sisal fibered reinforced composite has low Impact Strength of 1.5 MPa. The impact strength of Kenaf fibered reinforced composite is 1.25 MPa greater than that of Sisal fibered reinforced composite.

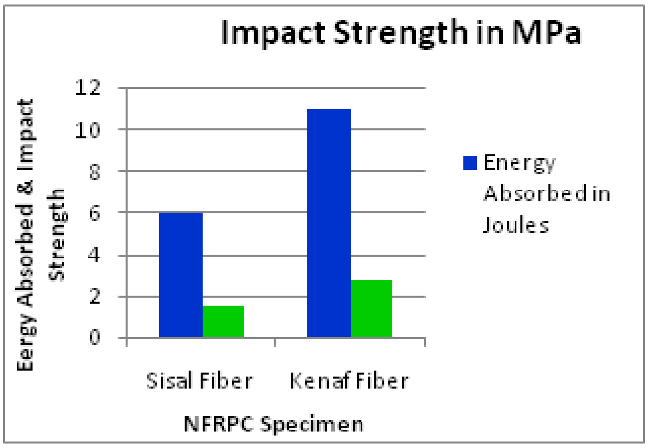


Figure 13. Comparison of Impact Strength

VII. Conclusion

From the experimental results are obtained, the following conclusion are sown in Figure. 14.

- The Tensile strength of Kenaf fiber Reinforced is 6.84 MPa greater than that of Sisal fiber Reinforced composite.
- The Flexural Strength of Kenaf Fiber Reinforced is 12.41 MPa greater than that of Sisal Fiber Reinforced Composite.
- The Impact Strength of Kenaf Fiber Reinforced composite is 1.25 MPa greater than that of Sisal Fiber Reinforced Composite.

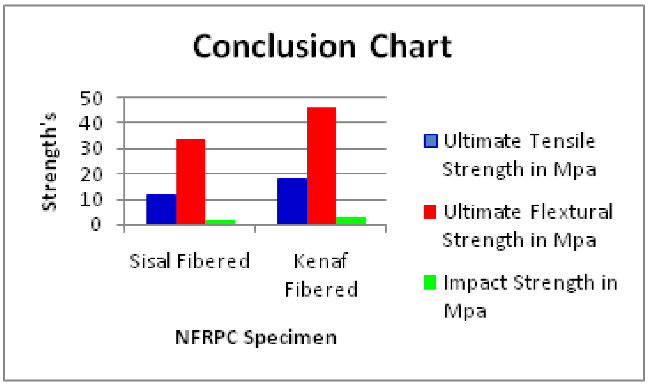


Figure 14. Comparison of Tensile, Flextural and Impact Strength

From the obtained experimental results with data analyzing system it was found that when Kenaf Fiber is reinforced with epoxy resin polymer matrix, then the tensile load was higher. Also found that, the tensile and comprehensive load was higher than the sisal fiber reinforced composite. This was happened due to reinforcing of higher tensile force material such as Kenaf fiber layer. If the natural fibers are in meshed form then the force will be resolved equally, so that the strength may higher.

Whenever, the reinforcing material having higher strength the composite laminate will get higher strength. Therefore from the obtained testing results, it was calculated that when meshed Kenaf fiber reinforced polymer composite gives good ultimate tensile strength, Flexural or bending strength and also Impact strength than the short sisal fiber reinforced polymer composite. Therefore this will be suitable for automotive and aerospace and structural applications.

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