

## AN EFFECT OF FIBER ORIENTATION OF TENSILE AND COMPRESSIVE PROPERTIES OF NATURAL HYBRID COMPOSITES

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### ABSTRACT

*The present and future needs have set a stage for innovation and technological development in the field of natural composite fibers because of their economical value and its eco friendly environment. Due to high stiffness and low density, composites can be implemented in various engineering applications. In this paper, the natural fibers namely Kenaf and Neem has been used as reinforcement to determine the mechanical characteristics of the hybrid composite. This composite fiber is formed by the arranging neem fiber and kenaf fiber enclosed by a glass fiber reinforced polymer in both parallel and perpendicular arrangements. This is to improve the mechanical properties of the hybrid composite that are fabricated by hand lay Process in which an epoxy resins LY556 and a hardener HY951 are used as a matrix. Tensile and Compressive test were performed and it has been compared with both the orientations. The result shows that the hybrid composites have been significantly better when it is layered in perpendicular orientation.*

**KEYWORDS:** Kenaf Fiber, Neem fiber, Hand Layup Method & Mechanical Testing

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### INTRODUCTION

Composite materials are materials formed by combining two or more individual constituents of different physical and chemical properties to give desirable application requirements. Lee et al (1) investigated the role of adhesion matrix by Carding process which provides a uniform blend of the two fibers followed by needle punching, pre-pressing and finally hot-pressing to form the composite material. Various industries, mostly consumes large amount of non renewable resources. Seyed et al (2) investigated biocomposite or renewable resources consist of biopolymers and natural fibers. Usage of these materials reduces the risks and hazards to the people comparatively to the non renewable resources. The mechanical properties of these materials are far better than the conventional plastics used by us in day to day life. In synthetic fibers if some parts are replaced with bio-fibers the weight of the polymer will be reduced also the abrasiveness of the material is reduced by means of which the machine damage is reduced. Crashworthiness plays a major role in transportation. Alkateb et al (3) found that by replacing the synthetic fibers and conventional fibers with bio fibers, the impact strength has improved thereby reducing the impact that can increase the crashworthiness of the vehicle. Kenaf fiber was taken and tested in replacing glass fibers and it shows excellent improvement in flexural strength and modulus. Also Kenaf mat is aligned in such a way that it can absorb more energy during impact. Majida et al (4) investigated the use of natural fiber as a reinforcing material in thermoplastic material represents an attractive and a suitable method of replacing the other synthetic fiber material. Natural fibers have high specific tensile strength, cheaper source, ecological advantages, low density, renewable resource, non-abrasive nature of processing

equipment and biodegradable. Misri et al (5) studied the filament winding process which can enhance the volume, size, shape, production speed of products and can also provide with thick cross section and flexibility in design. If this method is applied to produce the natural fibers the mechanical properties would be drastically high. Mahzabin et al (6) stated the reason for treating natural fibers is that they contain high hydroxyl groups which make them less adhesive in nature in matrix form. So they are treated with treatments like alkali treatment, saline treatment, etc. Kenaf grows up to 4.5m within 5 months. It has a high fiber yield. For growing it requires a short plantation cycle, low pesticides and it can grow under various weather conditions. Vijaya Ramnath et al (7) investigated Natural fibers such as jute and flax are far better than synthetic fibers. These natural fibers are combined to enhance the properties. Asumani et al (8) investigated the fibers which are treated with alkali will improve Fiber matrix interface. This is done because natural fibers have a lot of moisture content in them which is a major disadvantage of these natural fibers. As natural fibers absorb more moisture the effective interface bonding decreases which reduces the effective load transfer. Various treatments are done to fix this limitation. Alkali-silane treatment is more effective than treating individually. Based on the treatment, the interface between the fibers is determined. The tensile and compressive properties depend upon this interface. Vijaya Ramnath et al(9, 10, 11,12) used natural fibers are preferred because they are low in cost and also give good mechanical properties. Reinforced polymers provide furthermore required properties. They also increase the volume of the fiber. Volume of fiber is directly proportional to the volume. The interface bonding of the material depends upon the amount and type of resins used. Dry fibres have good elastic properties and wet fibres having good adhesive properties. Alkalised Kenaf fibres tend to show tensile strength, impact strength, and flexural strength properties. Pang et al (13) investigated the Kenaf fiber extracted from kenaf (*Hibiscus cannabinus*) plant has increased the interest of cultivation in farmers in accordance to the farming advantages including the ease of cultivation and its short growth cycle leading to minimal maintenance. Kenaf can be harvested with maximum yields every three to four months. It grows up steadily in tropical climates, with fewer requirements of fertilizers, water, and other essentials. Applications of kenaf fiber may include automotive interior lining, wallboards, ceilings and furniture. Chin et al (14) investigated the Kenaf fibre possess excellent sound absorption ability resulting in the production of BC- MPP by binding itself with a biodegradable polymer(polylactic acid) which increases its characteristic to withstand any kind of mechanical processes. Taufiq et al (15) studied that among all the natural fibres that are available, kenaf fibre shows its greatest potential that makes it suitable enough to replace the tobacco cultivation with kenaf. Tensile strength of kenaf fiber is higher than jute and sisal fibers; meanwhile it also has a higher modulus compared to sisal fibre. Huda et al (16) experimentally investigated that the natural fiber is one of the most significant composite in the field of technical utilization of natural fibers is the reinforced kenaf composites. The increasing popularity of laminated composites accounts mainly due to their low cost, high strength and stiffness to density ratio and highly resistive to corrosion when compared to the traditional construction materials such as wood. Mahjoub et al (17) studied the Kenaf plant can be expected to grow to a height of 3 meters and more within a 3 month span with a sufficient stem size around 50cm diameter providing a long fiber which remains the best characteristic of this plant. Kenaf Bast Fibre in comparison with other fibres has great potential of having the strength to weight and stress to weight ratio in the preferable manner. Kenaf absorbs CO<sub>2</sub> better than any other plants. 1 ton Kenaf absorbs 1.5 tons of CO<sub>2</sub>. It has high specific strength and stiffness and also helps in reducing global warming. Nordin et al (18) investigated the usage of Kenaf as the fibers have reduced the wear of the materials. Also, it has better mechanical strength. Earlier days, Kenaf has been used as ropes, canvas etc. Researchers say it is less abrasive and has high strength. So the interest in the usage of kenaf has increased. Xia et al (19) studied the Kenaf has good cellulose content. It has low density, low cost and high mechanical properties.

Alkali treatment of Kenaf improved its mechanical properties and epoxy composites. Introducing nano particles in these fibers furthermore increased their mechanical properties. After introducing nano particles to Kenaf the tensile strength of Kenaf was increased by 20%. Water absorption is a major drawback in natural fibers. But adding synthetic fibers in a bit, making them a hybrid composite material and based upon their environmental conditions this water absorption can be reduced. Abu Bakaret al (20) studied thermal and dynamic analysis plays a key role in the design and fabrication of the product. Kenaf with its properties has a greater advantage in this case. VijayaRamnath et al (21) investigated kenaf in twisted form for better efficiency. In vehicles where kenaf is used as fiber, fuel consumption is reduced due to its low weight. Vijaya Kumar et al (22) experimentally investigated the effect of tensile and impact property of neem with polyester composite and found that there is a significant improvement in the mechanical properties. Rajesh et al (23, 24 &25) experimentally investigated the properties of the combination of the natural and aramid fibers and the results found that it enhances the mechanical and wear properties of the hybrid composites.

## **MATERIALS**

### **Neem Fiber**

Neem fiber is usually extracted from the neem tree that can be commonly found in every area. The neem fiber is selected because of its high mechanical properties including tensile strength, acoustic and low abrasive nature. Also, it has good saline resistance properties which can be used in marine applications. The neem tree fiber is shown in Figure.1.



**Figure 1: Neem Fiber**

### **Kenaf Fiber**



**Figure 2: Kenaf Fiber**

Among all the natural fibres that are available, kenaf fibre shows its greatest potential that makes it suitably enough comparable mechanical properties than jute, flax, and sisal fibers. Tensile strength of kenaf fiber is higher than jute and sisal fibers. Figure.2 shows Kenaf fiber.

### Glass Fiber Reinforced Polymer (GFRP)



**Figure 3: Glass Fibre Reinforced Polymer**

GFRP is a composite material made up of a polymer matrix reinforced with several fibers. Glass Fiber Reinforced Polymer has advantages over cast aluminium manifold up to a 60% reduction in weight, improved surface quality and aerodynamic properties. It helps in reduction in components by combining parts and forms into simpler moulded shapes. Figure. 3 represents Glass Fiber Reinforced Polymer.

### Matrix



**Figure 4: Resin and Hardener**

Epoxy resin LY556 and Hardener HY951 are used. They are used as a binding agent. When blended together these two forms a high-strength plastic. Along with natural fiber they provide better mechanical strength. The resin and hardener shown in Figure. 4 are used in the ratio 10:1.

### FABRICATION PROCEDURE

The handlayup method is carried out for fabrication of hybrid composites. Before fabricating the composite, the moisture content in the fibers are removed by drying the fibers in the sunlight. After dried, the fibers are straightened by combing process. This makes the fibers perfectly aligned with each other. Now the fibers are ready for the fabrication process. First, a table should be kept clean and dust particles are removed. Now, Glass fiber reinforced sheets are laid on the table and the first layer of kenaf fiber is horizontally laid on the sheet covering the full area of the GFRP sheet. Then the resin and hardener mixture in the ratio 10:1 is laid on the kenaf layer using the brush covering the full area of the fibers. This mixture acts as a matrix medium for the layers and it serves the purpose of transformation of load from the fibers.

Then, the second layer of neem fiber is placed horizontally above the kenaf fiber and the same process is repeated. Again the matrix is filled over the layers. Similarly, the procedure is followed for 5 layers such that the thickness of the composite laminate can be achieved minimum for testing the composite specimen. This Composite Laminate represents Category I which includes GFRP, Kenaf and Neem fiber in Horizontal orientation. Similar procedure should be followed in the same way with vertical orientation which represents Category II. After the fabrication of composite laminate for two categories, it should be kept dry in atmospheric environment for 24 hours with a weight of 5kg placed over the composite laminate. Then, the composite laminate should be cut into several specimens according to ASTM standards of composite testing. Mechanical tests such as tensile and compression has been done to determine the mechanical properties of the composite specimen. The arrangement of the fibers in horizontal and vertical orientation is shown in table 1 and 2 respectively. Figure. 5 and 6 shows the composite laminated prepared in horizontal and vertical orientation respectively.

**Table 1: Arrangement of Fibers in Perpendicular Alignment**

GFRP Laminate
NeemFiber(90 <sup>0</sup> )
KenafFiber(90 <sup>0</sup> )
NeemFiber(90 <sup>0</sup> )
GFRP Laminate

**Table 2: Arrangement of Fibers in Parallel Alignment**

GFRP Laminate
NeemFiber(0 <sup>0</sup> )
KenafFiber(0 <sup>0</sup> )
NeemFiber(0 <sup>0</sup> )
GFRP Laminate



**Figure 5: Composite Laminate (90<sup>0</sup>)**



**Figure 6: Composite Laminate (0<sup>0</sup>)**

**EXPERIMENTAL SETUP**

**Composite Testing**

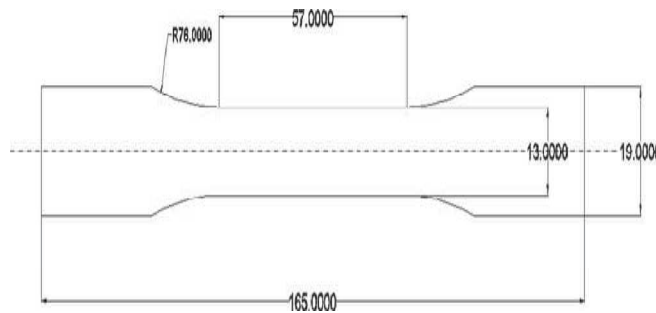
**Tensile Test**

For determining mechanical properties of the hybrid composite tensile test must be done to find the ultimate tensile strength of the material. Tensile test is done by Universal Testing Machine according to ASTM D-638 standard as shown in Figure.7. The dimensions and specifications of the composite specimen are shown in table 3. The specimen is held in the gripper between two jobs and it has been loaded in towards ran direction. Upon continuous loading, breakage of the specimen occurs which results in ultimate strength of the composite. The graph has been plotted against stress and strain which is shown below. The maximum value of Ultimate Strength in Mpa has been recorded. Due to the application of tensile load, the fibers get elongated and because of the presence of the kenaf fibers which has high tensile strength among

natural fibers it resists even if the other fibre breaks. The table shows the maximum ultimate strength of the composite for both the samples. Figure. 8(a) and 8(b) shows the tensile tested specimen for parallel and perpendicular orientation respectively.

**Table 3: Specifications of the Tensile Test Specimen**

	Sample 1	Sample 2
Sample type	Flat	Flat
Thickness	5.78mm	4.82mm
Width	12.76mm	12.82mm
Area	73.75mm <sup>2</sup>	61.79mm <sup>2</sup>
Gauge Length	50mm	50mm



**Figure 7: Tensile Test Specimen (ASTM: D638)**



**Figure 8 (a) Tensile Tested Specimen (Sample 1)**



**Figure 8 (b) Tensile Tested Specimen (Sample 2)**

**COMPRESSION TESTING**

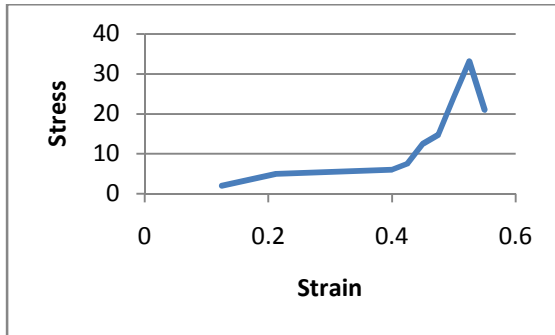
In tensile test the property of ductility acts where in compressive the property of malleability acts. For testing the compressive strength large cross-sectional area of the specimen is required. So, the specimen is cut into a square dimension. The compression test is done in the Universal Testing Machine and repeated for two times and the compressive strength is measured. The compressive test of natural fiber composites in this research was carried out as per ASTM D-690 standard. Due to continuous compression load, the fiber gets agglomerated with one end compressed. The Specifications of composite material sample 1 and 2 for the tensile test are shown in Table 4.

**Table 4: Specifications of the Compressive Test Specimen**

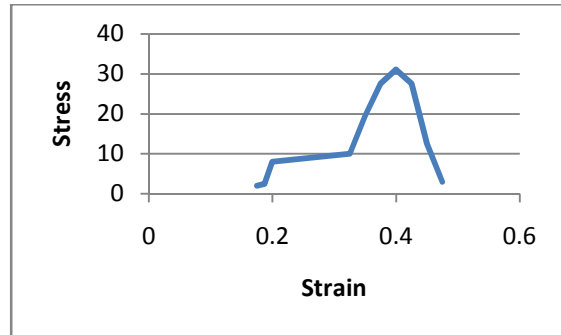
	Sample 1	Sample 2
Sample type	Flat	Flat
Thickness	5.51mm	4.84mm
Width	50.44mm	49.39mm
Area	277.92mm <sup>2</sup>	239.05mm <sup>2</sup>
Gauge Length	50.00mm	50.00mm

**RESULT AND DISCUSSIONS**

The tensile test conducted for both the samples are plotted in form of stress-strain relation. Stress is represented in  $N/mm^2$  as Y axis whereas strain in X axis.

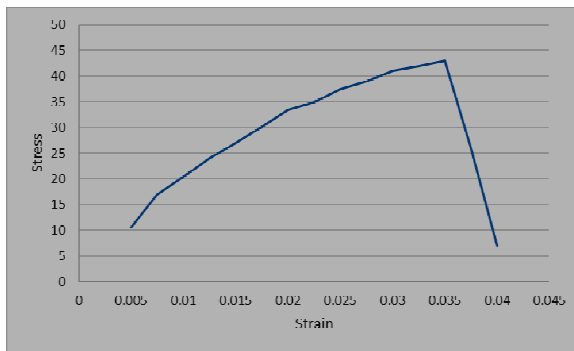


**Figure 9: Results of Tensile Test for Sample 1**

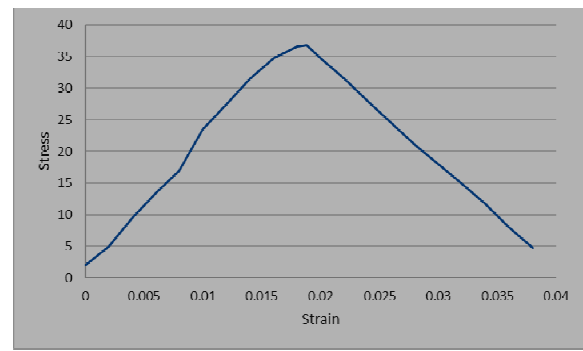


**Figure 10: Results of Tensile Test for Sample 2**

The graph shows the tensile properties with different orientations. The result of the tensile test shows that there is an enormous increase of stress with respect to strain upto an elastic limit. Due to this, kenaf resembles very high tensile strength along with neem fiber in the perpendicular orientation. Hence the tensile property is highly significant for the composite laminate in parallel orientation. In other hand, the sample with perpendicular orientation results shows that there is a gradual increase with increase in load and slightly get reduces the stress and then it breaks down to plastic zone. This is because of fiber orientation which the fibers are not active when it is loaded in the opposite direction. Hence, for the tensile test of both the samples, the content of the fiber increases as the load increases. The matrix medium exhibits high stiffness during the load, thereby it resembles more tensile properties. Stress Vs strain graph for tensile test for both the samples are shown in Figure. 5 and 6 respectively.



**Figure 11: Results of Compression Test (Sample 1)**



**Figure 12: Results of Compression Test (Sample 2)**

Based on experimental results of compression test, it is noted that the stiffness of the material is very high because of kenaf and neem fiber present in the hybrid composite. This fiber along with matrix medium resist the load to compress thereby it exhibits very high compressive properties. As there is a gradual increase in compression, the fiber in the specimen gets agglomerated in one side and finally due to further increase it breaks down with maximum compression strength. If the fiber orientation is good, then the strength of the fiber also gets strengthened. It is obvious that for orientation in perpendicular shows better results. Stress is represented in  $N/mm^2$ .

## CONCLUSIONS

In this work, various mechanical tests such as tensile and compression test has been done on different samples with different orientations. Based on experimental results, graphs between stress and strain are plotted. The following conclusion has been derived as follows. For tensile load, sample 1 of perpendicular orientation has break load of 2.44kN with ultimate strength of 33.15MPa. Similarly for Sample 2 it has break load of 19.2kN with ultimate strength of 31.05MPa in parallel orientation. For compression load, sample 1 has a maximum breaking load of 11.85kN and sample 2 has maximum breaking load of 8.76kN. In both the results of mechanical tests, it is obvious that both the kenaf and neemfibers as hybrid composite resembles high mechanical strength and it can be implemented in various engineering applications to reduce the overall weight of the composite and efficiency of the product can be improved.

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