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Experimental Investigation on Mechanical and Water Absorption Properties of Kenaf/Glass fiber Hybrid Composites

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Abstract
The awareness towards reducing the cost of production and harmful destruction in the environment are the major concern in many industries. In recent days, the natural fibers become attractive in major industries. The natural fiber reinforced composites has procured the attention of industrialists and scientists for the application in automotive, aerospace, consumer goods, building and construction and for many other structural applications. It offers many benefits mainly low cost, light weight, renewable and biodegradable. The materials made using synthetic FRP composites which is used in many applications are getting declined due to their adverse environmental impact, higher initial costs and their use in non efficient structural forms. Kenaf fiber which is obtained from the stem of kenaf plant is used. Kenaf fiber consists of robust mechanical property which is considered as an extremely valuable natural fiber. The work investigates the Mechanical properties and water absorption behaviour of dedicated kenaf laminate and kenaf/glass fiber hybrid composites. The major drawbacks in natural fiber are its resin incompatibility and water absorption. Surface treatment of fiber is made to improve the interfacial bonding between the fiber and resin and to reduce the moisture absorption. Laminates are fabricated using Hand lay-up technique. Mechanical properties such as tensile, impact and flexural test for Natural kenaf and kenaf/glass hybrid laminates were obtained. Samples preparation and Mechanical property testing were carried out as per ASTM standards.

Keywords: *Kenaf, Hybrid, Hand layup, Mechanical properties, surface treatment,Water absorption*

I. INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics are the dominant rising materials. The volume and number of applications of composite materials have grown rigidly, penetrating and achieving new markets. Engineers and manufacturing units are involved in a constant search for a new, improved materials and processing techniques to lower the cost of production and to increase profit. Composites are becoming an essential part of today's materials, since they offer many advantages. Composites provide broad range of applications offering very high potential payoff. In general the composite materials consist of a matrix reinforced with fibers. Fibers are the principal constituents in a fiber reinforced composites. They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. Proper selection of the type, volume fraction, length and orientation of fiber is very important, due to the establishment of disposal methods for glass fiber reinforced plastics and their recycling laws are important contemporary subjects because many environment problems have appeared and worsened throughout the world. The search for an alternative and environmental friendly material is considered highly important because of global warming and other environmental effect.[1].

The uses of natural fiber reinforced composites represent attractive and suitable methods for replacing the synthetic fibers. Woven fabrics offer many advantages in terms of manipulative requirements including dimensional stability, good conformability and deep draw shape ability.

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Compared with unwoven unidirectional composites, woven fabric composites provide more balanced properties, higher impact resistance, easier handling, and lower fabrication cost in specific for parts with complex shapes.

Natural fibers offers higher benefits such as low cost, light weight, non abrasive, free from health hazard, higher resistance to fracture, biodegradable, recyclable, easier processing techniques, higher strength and stiffness and it contains acceptable specific strength properties. But over many advantages they posses some disadvantages such as resin incompatibility i.e. improper adhesion between the fiber and resin. The second major issue with natural fiber is water absorption. It absorbs water through direct contact or the moisture in the environment. This cause swelling and voids formation which leads to increase in weight of the composites results in nullifying the advantage of light weight [6]. To overcome these drawbacks the treatment of fiber is receiving greater attention.

II. RELATED WORKS

As a result of increasing demand for environmental friendly materials and the desire to reduce the cost of traditional fibers (i.e., carbon, glass and aramid) new bio-based composites have been developed. Researchers have begun to focus attention on natural fiber composites (i.e., bio composites), which are composed of natural or synthetic resins, reinforced with natural fibers. Natural fiber provides significant cost advantages and ease of processing along with being a highly renewable resource, in turn reducing the dependency on synthetic fibers. Recent advances in the use of natural fibers (e.g., Kenaf, flax, sisal, jute, hemp, straw, switch grass, coir and bamboo) in composites have been reviewed by several authors.

The recent development of natural fiber reinforced polymer composites including an experiment on composites reinforced with Hemp fibers. The use of natural fibers is seen increased in the range of industrial applications of natural fibers in many automotive manufacturer is deserved.[3] Water absorption behavior of natural fibers leads to a major concern. Water absorption test was conducted by immersing samples into three different environmental conditions including sea water, distilled water and rain water for 24 hours in room temperature. The effect of mechanical strength of natural and hybrid composites is investigated. It is observed that the effect of humidity aging deteriorates the mechanical properties of NFRP composites. The water uptake molecules fill the cavities and cracks within the composites and render the structure more flexible. This research initiates more to work on the problems of water absorption of natural composites.[4]

Investigation on the nature of fibers reinforced with epoxy is performed. These fibers are subjected to surface treatment and they are characterized by mechanical tests. The results obtained are, increase in tensile strength by increasing the fiber percentage and maximum increase in fiber lowers the tensile strength. This work makes to understand that it is possible to enhance the properties of fiber reinforced composites through fiber surface modification.[5]

An overview of the developments made in the area of kenaf fiber reinforced composites, in terms of their market, manufacturing methods, and overall properties is reviewed. Several critical issues and suggestions for future work are discussed. This work encompassed the potential of kenaf fiber as an alternative to replace conventional synthetic fibers as reinforcement in composites. It is observed that kenaf fiber availability and readiness to be used with various manufacturing processes that have never been associated with other natural fibers before for the methods of pultrusion and filament winding etc.[2]

The database of material properties of natural fiber composites was organized systematically. 29 types of natural fiber composites in the application of AHP (Analytical Hierarchy Process) are utilized for the study. The most suitable natural fiber composite is determined by considering main criteria and sub-criteria in the hierarchy model. Several sensitivity analysis scenarios were conducted to verify the final decision. The most suitable material is kenaf 60% + pp is observed in this study and the selection of kenaf fiber is motivated.[6]

The use of natural fiber fabric as a reinforcement of composite materials in the special concern towards automotive applications is focused. This work concludes that proper fiber surface treatment should be developed and implemented at industrial scale, the investigation of mats is compiled by analyzing the effects of different layup and manufacturing techniques.[7]

The major issues of fiber reinforced composites such as resin compatibility and water absorption is addressed, the study concludes that natural composites consist of lesser specific properties

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when compared with the synthetic fiber made composites. It also states that fiber treatment is needed to reduce the water absorption and increase the wettability of fibers.[8]

Reaction of natural fiber composite before and after NaOH treatment was analyzed. Coir fibers were treated with NaOH solution with concentrations from 2% to 10% separately, and their tensile strength is measured. It is observed that no significant difference was revealed in the composite tensile strength among the case of 2% and 4% and it proves that usage of 5% NaOH is optimized for natural fiber composite and also the decreased trend of fiber tensile strength with increased NaOH density is found.[9]

The developments of coir composite and mechanical properties were evaluated. Scanning electron micrographs obtained from fracture surfaces were used for a qualitative evaluation of the interfacial properties of coir epoxy and compared with glass fibers. Study reveals the significance of surface treatment that must be processed in Natural fiber.[10]

A lot of research has been attempted on natural fiber reinforced polymer composites but research on kenaf based polymer composites is very rare. Against this background, the present research work has been undertaken, with an objective to explore the potential of kenaf polymer composites by comparing the dedicated kenaf with that of glass kenaf hybrid composites.

III. PROPOSED WORK

A. *Scope*

Composites are becoming an essential part of today's materials. It becomes the fastest developing research and development areas of material science. Rapid advancements in the science of fibers, matrix materials, processing, interface structure, bonding and their characteristics on final property have taken place in recent years. Natural fiber has received much attention from the research community over the past decade. Natural fibers are now considered as a serious alternative to composite materials as a reinforcing agents. In present day natural fibers are attractive in many industries, such as automotive, aerospace due to their superior properties mainly light weight, high stiffness, strength to weight ratio, renewability and wide availability.

The widespread use of synthetic fiber-reinforced polymer composite has a tendency to decline because of their higher initial costs, their use in non-efficient structural forms and most importantly their adverse environmental impact. The availability of natural fiber is higher and it is proven that it causes lesser impact on the environment since it is recycled thermally. It is free from health hazards. Therefore according to good mechanical properties, the usage of natural fibers was retained in many applications. Technological development in composite materials provides improved performance capabilities due to the growing industrial demand.

A. *Selection of Fiber*

The dedicated natural kenaf laminate and kenaf/synthetic glass (hybrid) composite laminate are fabricated and utilized for this study. Kenaf fiber is the strongest among other natural fibers which provides good mechanical and thermal properties when blended with PP [2]. Kenaf is a fast growing plant which is extracted from the stems of plants genus hibiscus, from the species named Hibiscus Cannabinus, it requires less water to grow, rising to heights of 12- 14 feet in just 4 - 5 months with the yield of 1600 kg/ha. The availability of kenaf fiber is enriched due to its increased usage in automotives and other applications. Figure 1 and 2 shows the fibers used.

Fig. 1. Kenaf Fiber
Fig. 2. Glass Fiber

Epoxy is used as a matrix, which provides stronger adhesive property. The curing reaction for epoxy resin will start immediately upon addition of a suitable catalyst and accelerator. The epoxy resin used in this work is normally pre-accelerated. Once die catalyst is added, the curing reaction starts immediately at the room temperature.

B. *Surface Treatment of Fiber*

The Natural fibers are derived from lignocelluloses, they are hydrophilic in nature and hence they become weak at the interface between

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fiber and the matrix. The main disadvantage encountered in including a fiber into a polymer matrix is the lack of good interfacial adhesion between the two components, which results in poor properties in the final product. Due to poor adhesion, mechanical properties of the natural fiber composite are low and hence it becomes important to improve the adhesion either by physical or chemical methods. Previous studies have shown that by appropriate surface treatment, mechanical properties of the fiber can be improved. Fiber matrix interfacial adhesion can be improved with many chemical modifications of the fiber. One of the familiar and effective chemical modifications applied to kenaf fiber is an alkaline treatment based on sodium hydroxide (NaOH), is shown in equation 1.

$$\text{Fiber-cell-OH} + NaOH \rightarrow \text{Fiber cell-O-}Na^{+} + H_2O + \text{impurities} \quad (1)$$

Alkali treatments have proven effective in removing impurities from the fiber, decreasing moisture absorption, enabling mechanical bonding and thereby improving matrix-reinforcement interaction. Study shows that, In the case of NaOH density with 10%, lower tensile strength of the composite was noticed compared to the cases of 2%, 4%, 6% and 8%. This demonstrated that the fiber deterioration in the 10% case was serious. The study resulted that 6% NaOH is the optimized one for the surface treatment of natural fiber [11].

Kenaf fibers are immersed in the 6% NaOH solution for two hours and after immersion the treated fibers are rinsed with distilled water to remove the excess of sodium in them. The washed fibers are dried in sunlight for one day and it is dried in shade for three days.post curing is done to remove surface moisture in the fiber by placing the fiber in the circulating hot air oven for 30minutes at 50^{o} C. [9]

C. *Rule of Mixture*

Calculation for Laminate Fabrication

The amount of fiber and matrix which influence the mechanical property must satisfy the condition of rule of mixture. This amount of fiber and matrix required for the composite laminate fabrication is determined by the following rule of mixture equation

$$V_f + V_m = 1$$

Where,

V_f = Volume fraction of fiber

V_m = Volume fraction of matrix

By following the standards of Rule of Mixture,

(i) Kenaf laminate is procured with the usage of 30% fiber & 70% Matrix

(ii) Kenaf Glass Hybrid laminate is procured with the usage of 25% fiber & 75% Matrix

IV. FABRICATION

Kenaf and glass fabric laminates were cut into pieces of 300×300 mm^2. Hand layup technique is followed for the fabrication of composite material. The composite laminate was prepared by the impregnation of the fabric with the epoxy resin. The casting is cured for 24 hours in compression moulding machine with nominal pressure of 320 psi at room temperature. After the curing process, samples of relevant dimensions for mechanical property testing are cut using a diamond wheel cutter according to the dimensions specified by ASTM standards. Edge finishing is made to obtain the uniform surface finish.

V. EXPERIMENTAL EVALUATION OF MECHANICAL PROPERTIES

RESULTS OF MECHANICAL PROPERTY TESTING OF DEDICATED KENAF AND HYBRID COMPOSITE LAMINATE

The mechanical properties, namely the tensile, flexural and impact properties of dedicated kenaf and hybrid glass/kenaf composite laminate were evaluated. Hybridization of synthetic glass fabrics is expected to improve the mechanical properties of natural kenaf fabric. The reported values are average values of test results conducted for three trials.

Tensile Test

Samples are subjected to a controlled tension until failure. Standard test method for is ASTM D3039. Two different samples are prepared according to the fiber used. Kenaf laminate and kenaf-glass hybrid laminate. The experiments are repeated to three trials and the average values are utilized for the results.

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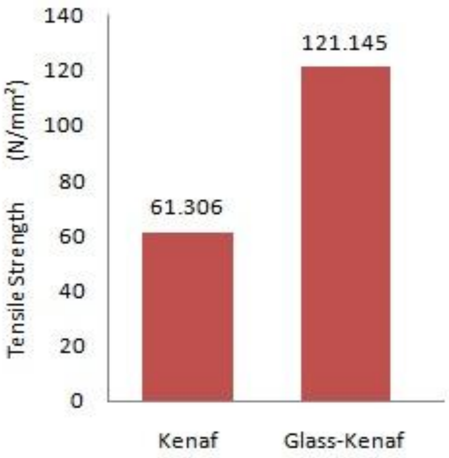

Fig. 3. Comparison of Tensile Strength

The maximum Tensile strength is found for hybrid arrangement, as 121.14 MPa, almost double the value obtained for dedicated kenaf laminates. This is due to high resistance offered by high modulus glass fiber against tensile loading.

Flexural Test

The flexural test measures the force required to bend under three point loading constraints. Standard test method for flexural testing is ASTM D790.The three point flexural test is the most common flexural test for composite materials.

Flexural strength of dedicated Kenaf laminate is found increased than that of hybrid Glass/Kenaf laminate which has a flexural strength of 55.28MPa but the dedicated kenaf laminates consists of flexural strength of 81.72 MPa.

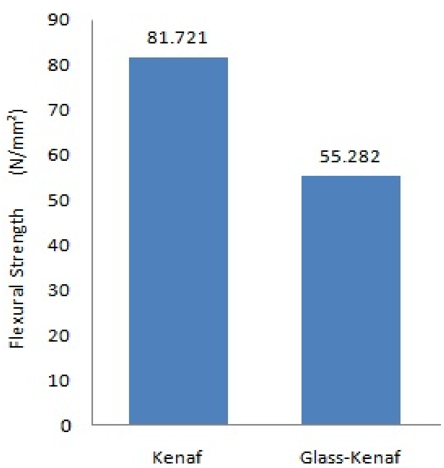

Fig. 4. Comparison of Flexural Strength

This is because the dedicated kenaf laminate offers more resistance in flexural loading than the hybrid laminate. Generally, hybrid arrangements of natural fiber composite laminates shows higher strength than that of dedicated natural fiber composite laminates, but this study shows that natural composite laminates are effective than the hybrid in flexural strength.

Impact Test

Impact Testing provides the information on how a samples of a known material will respond to an impact stress. The standard test method for impact testing is ASTM D256.

Using the impact test the energy needed to break the material can be measured easily and can be used to measure the toughness of the material and the yield strength.

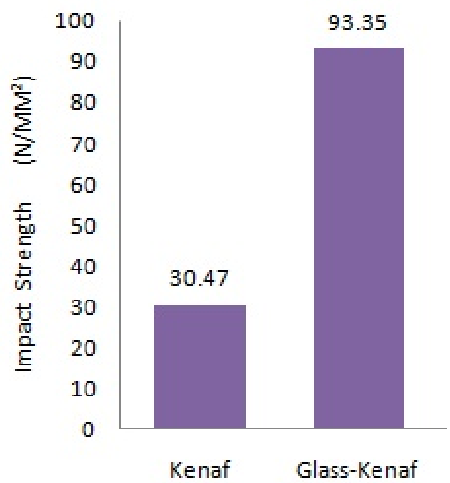

Fig. 5. Comparison of Impact Strength

The Impact strength offered by the dedicated kenaf laminate and the hybrid laminate is shown in fig 5. There is a wider variation in impact strength between the glass-kenaf and the dedicated kenaf laminates. This variation in impact strength is caused due to the effect of alternate layers made up of different fabrics affect the crack propagation during impact loading. Dedicated Kenaf laminates

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can be used in the application subjected to a lower impact stress.

VI. WATER ABSORPTION INVESTIGATION

Most Asian countries are surrounded by areas with high humidity. Based on this fact, the effect of humidity on composite materials should be investigated by the researchers to ensure the composite materials can be used in humid environment safely. Historically, all types of polymer composites absorb moisture when immersed in water or in humid environment. The natural fiber composite tends to absorb moisture higher than other composites. It is because of the hydrophilic nature of the fiber that is very sensitive towards water absorption, causing instability in the properties.

The moisture penetrates into the micro gaps between polymer chains of composite material. The other common mechanisms are capillary transport into the gaps and flaws at the interfaces between fibers and polymer, because of incomplete wet ability and impregnation, and transport by micro cracks in the matrix.

Water absorption of natural fiber composite is a serious concern particularly for outdoor application. The effect of water absorption on the natural and hybrid composites is investigated at room temperature. The moisture absorption amount is obtained by calculating the different percentage weight before and after the immersion process.

A. *Experimental Investigation*

The hydrophilic nature of natural fibers is a major drawback for their application as reinforcement for composites. The moisture uptake in fiber composites has a deleterious effect on their mechanical properties. The NFRP Composites working in the application under moisture tends to result in lower tensile and flexural properties. The water absorption study was performed in accordance with ASTM D 5529. The samples were immersed in first day to fourth week at room temperature. The weight change was then recorded and monitored periodically. The percentage of water absorption in the composites was calculated by determining the weight difference between samples immersed in water and dry samples using equation 2.

$$W\,(\%) = \frac{[W_i - W_f]}{W_i} \times 100\% \qquad (2)$$

Where

$W\,(\%)$ is the moisture content in percentage;
W_f is the weight of the wet sample at certain time:
W_i is the initial weight of the sample.

All the samples are dried in a circulating hot air oven at 50^0C to remove the moisture content from it and then they are allowed to cool at room temperature. The samples are made from both treated and untreated kenaf fiber. The fiber which is subjected to alkaline treatment and the untreated fiber are fabricated in the form of laminates and these samples are immersed in distilled water.

The effect of water absorption on kenaf fiber and kenaf/glass hybrid fiber reinforced epoxy composites was investigated by subjecting the composite laminates in distilled water for the period of 4 weeks at room temperature. The weight increase is calculated daily, samples is taken out of water and all the surface water was removed with a clean dry tissue. The immersed samples are subjected to tensile and flexural test after the first 2 weeks and the fourth week. Loss in weight is seen at the fourth week due to the particle precipitate from the samples.

Table I. Shows the weight percentage measured daily for both the treated and untreated samples, from the first day to the completion of fourth week.

TABLE I. WEIGHT PERCENTAGE OF TREATED AND UNTREATED SAMPLES

Duration	Days count	Treated Specimen weight (%)		Untreated Specimen weight (%)		
		Kenaf	Kenaf/glass	Kenaf		Kenaf/glass
0th day	0	--	--		--	--
1st day	1	1.368	0.52		3.58	4.09
1st week	7	3.091	1.68		5.51	5.28
2nd week	14	4.358	2.12		7.73	7.76
3rd week	21	4.91	2.48		10.71	9.38
	24	**5.625**	2.68	25	**12.84**	**11.77**
	27	5.321	**3.00**	27	10.97	11.35
4th week	28	5.220	2.92	28	10.56	11.15

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The weight percentage of treated samples is lower than the untreated samples, this shows the water absorption of NFRP composite laminates is reduced after the alkaline treatment. Percentage of absorption for dedicated kenaf laminate is higher than the hybrid laminate.

Figure 6 shows the plots of untreated samples. Weight percentage of dedicated kenaf laminate is higher than the hybrid. The water absorption in untreated Samples arehigher than the treated samples in both the dedicated natural and hybrid composites.

Fig. 6. Plots of Untreated Samples

Figure 7 shows the plots of treated samples, it shows the marginable reduction in water absorption when compared with the untreated composite samples. Thus the surface treatment of fiber is proven effective to overcome the problem of water absorption in natural fiber reinforced polymer composites.

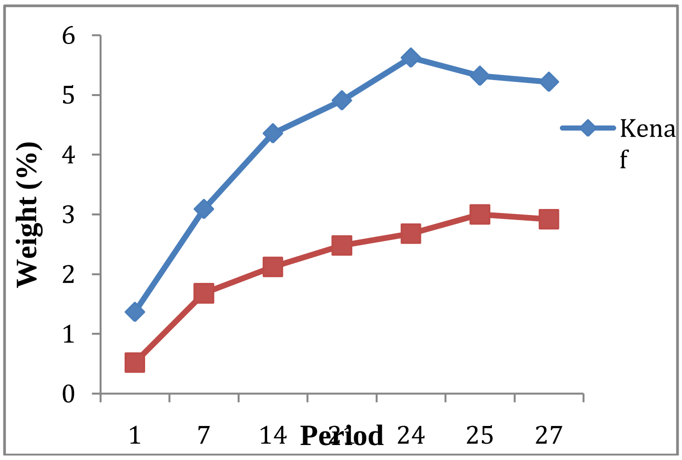

Fig. 7. Plots of Treated Samples

B. *Mechanical property testing*

The samples immersed in distilled water are periodically monitored and its weight is measured. The mechanical property such as tensile and flexural strength is tested after the completion of first two weeks and the completion of fourth week.

Table II shows the tensile and flexural testing results of treated and untreated samples. Samples immersed in distilled water are subjected to tensile and flexural testing on completion of first two weeks and on the completion of four weeks.

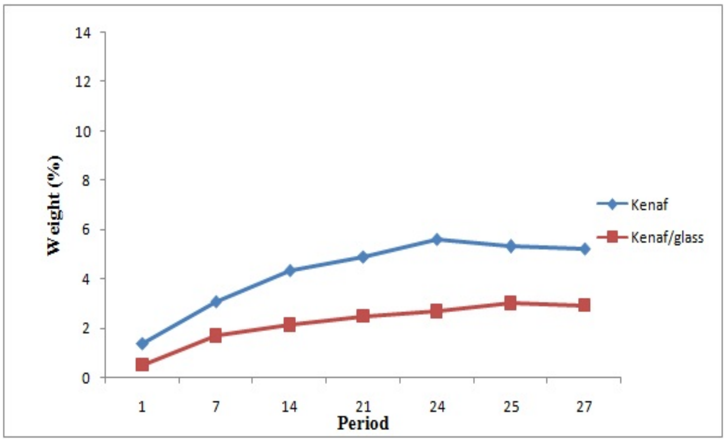

TABLE II. MECHANICAL PROPERTIES OF TREATED AND UNTREATED SAMPLES

Period	Mechanical testing / Sample Type	Treated Specimen		Untreated Specimen	
		Glass/Kenaf	Kenaf	Glass/Kenaf	Kenaf
End of 1 & 2 week	Tensile	58.78	42.51	54.59	39.6
	Flexural	77.73	69.65	64.78	55.17
End of 4th week	Tensile	54.49	39.6	45.87	29.93
	Flexural	75.68	67.43	59.34	47.61

* Results obtained are average of three trials   * All values are in N/mm2

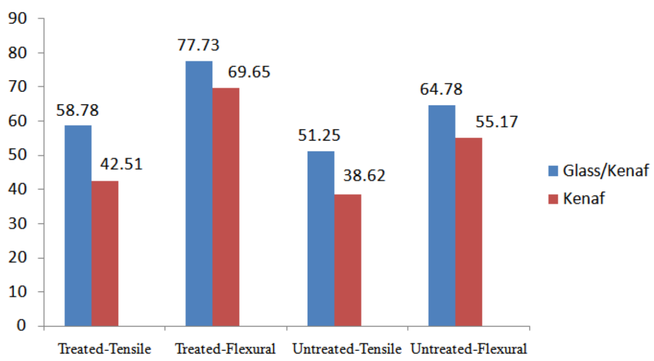

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Fig. 8. Testing results after first two weeks of immersion

Figure 8 shows the results of tensile and flexural test of kenaf and hybrid laminates after the completion of first two weeks of immersion in water.

The samples immersed in distilled water are periodically monitored for its increase in weight percentage. At the end of first two weeks, absorption of water in the treated samples is lower than the absorption of water in the untreated samples.

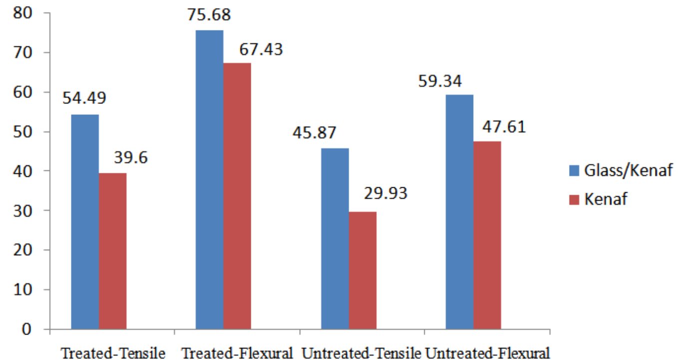

Fig. 9. Testing results after four weeks of immersion

Figure 9 shows the results of tensile and flexural test of kenaf and hybrid laminates after the completion of four weeks of immersion in water.

Compared with the untreated laminates, treated samples consist of higher tensile and flexural strength. Since the water absorption of untreated composite laminates is higher than the treated laminates. Water absorption is lower in glass/kenaf hybrid laminates and the difference between the mechanical properties of both the samples is marginable and there is a higher difference at the end of four weeks due to the effects of humidity aging and the hydrophilic nature of kenaf fibers. The testing result at the end of four weeks shows that pre-treated kenaf glass hybrid laminates possess higher strength than the untreated laminates, since the untreated Natural fiber composite laminates consists of free hydroxyl groups which readily absorbs the water.

VII. CONCLUSION

Composites have become an integral part of our day-to-day life and can be found everywhere. This work considers the major drawbacks of natural fiber composites such as poor interfacial bonding and water absorption. An attempt is made to improve the fiber properties through surface treatment techniques and the result shows considerable difference between the untreated composites and pre-treated composite laminates.

The main drawbacks in utilizing natural fiber reinforced composites are resin incompatibility and moisture absorption. Fiber matrix interfacial adhesion is improved by the chemical modifications applied to the fiber. Mechanical characterization layered woven kenaf fiber laminate and the hybrid laminate was carried out through experimental investigation and the results are discussed.

Water absorption behavior of the composite laminates is investigated by periodically monitoring the increase in weight percentage of composite samples and the its properties are evaluated.

The Result shows that surface treatment procures optimistic results and blending the glass fiber with natural kenaf fiber helps to gain the increased strength.

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