Mechanical Strength and Water Absorption Analysis of Silane Treated Kenaf Natural Composites With Silicon Nanoparticles

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Research Article

Keywords: Kenaf fiber, Silicon particle, silane solution, water absorption, polymer epoxy composites

Posted Date: March 18th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-297917/v1>

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Abstract

This research is mainly focused on the analysis of tensile and flexural strength, water absorption angle measurement of untreated and silane treatment of natural kenaf fiber composites reinforced with silicon nanoparticles. The percentages of nano silicon were 0.5 wt%, 1.5 wt% and 2.5 wt%. Before reinforcement, the kenaf fiber was treated with silane solution (90 vol% of water and 10 vol% of pure silane) to enhance the bonding strength. The composites samples were prepared using Epoxy, Kenaf and Silicon nanoparticle (EKS) by the compression moulding process. The tensile and flexural strength were measured about automobile interior application. Moreover, the samples were immersed in water for 24 hours with different environmental conditions. The results indicated that the tensile strength of epoxy improved from 8-9% when increasing the nanoparticles. Also, it was found that 3-5% of strength enhancement in silane treated samples than untreated composites. Similarly, the flexural strength of silane treated samples were found higher about 4% than untreated samples. And, lower water absorption was noted with silane treated than untreated kenaf hybrid composites, which tends to improve the bonding. It causes improvements in mechanical strength with silane treated kenaf hybrid composites.

1. Introduction

The kenaf treated silicon-based hybrid composite materials are green composite materials, which are used in the protection of the environment [1]. Natural fibers are formed from renewable resources, and eco-friendly and relatively low-cost compared to other synthetic fiber materials [2]. The Pineapple leaf fibers and citrus fibers agriculture waste compared with tropical fruits, gives higher strength of mechanical properties [3]. The maximum number of the automotive interior component was designed and manufactured for successful reinforcement of natural composites like thermoplastics and thermoset composite materials [4]. But, natural composite fiber materials have prepared in a limited amount of reinforcement and the final output is the unpredictability in mechanical properties and water absorption behavior of composite matrix [5]. In flax fibers, composite materials have good potential compared with carbon fibers, the more materials required to form flax fibers [6]. The woven-based hybrid composite materials have good Mechanical, Morphological, and Water absorption Properties [7]. better results are experientially proved the highest value of tensile strength in non-woven and woven-based kenaf hybrid composite material [8]. The surface-modified Luffa Cylindrica fibre fiber gives good mechanical and water absorption behavior because of percentages added reinforcement materials [9]. Jute fiber reinforcement of composite materials comprises in fiber the maximum strength and highest bond into a matrix with the distinction between them [10]. The long-term water absorption test performance reinforced composite materials with creative and solution modified for hemp fibers in 3 re-agent inveterate that surface modifications of filler influence of water absorption process [11]. The water absorption in fibers and biocomposite has a major effect on their assets in properties and structures. With the increased uptake of moisture in reinforced hemp fiber, the tensile and flexural properties of unsaturated polyester composite have decreased [12]. To explain the wetness, water absorption of composite fiber materials, different models have been created [13]. Chemical or physical fiber surface treatment is used to decrease the

maximum moisture or water inclusion fillers in composite in various findings have been reposted concerning the water absorbability of the composite [14]. The chemical treatment has been reduced the overall water absorption of fibers and may have a positive impact on the quality parameters of composite materials depending on plant and matrix form, fibrous filler treatment conditions [15]. Amorphous elements such as in water storage, hemicelluloses also play a significant role. Higher hemicellulose fibers more moisture-absorbing material. In hemp fiber substantially minimum water droplets have been identified then, partial fiber removal ability fibers to absorb water is decreased [16–17]. The natural fiber extraction process can be carried out using various techniques, including mechanical, chemical, and biological methods. According to the amount of fiber generated or the nature and properties of fiber bundles obtained, each method poses various advantages or disadvantages. The sugar palm fiber reinforced vinyl ester composite materials soil expanded water retention, heated in sugar palm fiber composites, and simultaneously lowest mechanical properties of composite materials. Because of 200 hours soil buried also water absorption high range is 0.92 percentages. Vinyl ester in the percentage of 0.42 % [18]. The impact values of *Arenga pinnata* fiber treated added the epoxy resin composite developed because the fibers are getting age limit, composite materials are shown to improve the plasticity however cut back in strength. many research has been conducted to search out the impact of chemical reaction of mechanical parameters sugar palm composite material [19]. The fiber will go about as transporters of reinforced fiber when the fiber strengthened composites are applied with the load. At that point, the pressure will move to the lattice and fiber, hence lead to uniform pressure dissemination [20]. *Pinnata* fiber material has been effectively created in reinforcing operator of epoxy resin as a useful composite, is quality and inflexibility [21]. The composite exclusively begins to break up slowly over seven days recently the kenaf strands started to drop out from the composite. This water assimilation capability of the compound composite may have potential applications that require tall water absorption properties [22]. The water observation behaviors and high impact property in micro oven kanaf fiber test material casing layer and kenaf are called center fabrics. All test comes about uncovered reinforced composite in maximum natural fibers substance appears lowest density of kenaf fiber density is increased and encloses the maximum substance is (26.68%) [23]. The variable factors impacting the ultimate properties of hybrid composite incorporate lattice nature in general fiber substance, relative fiber volume, fiber length, shaping prepare, and fiber-matrix interface [24]. the impact substance of oil palm purges natural product or jute composite material. water assimilation influences of mechanical strength fiber composite materials [25]. The maximum water absorption is increasing because of the hydro polyvinyl group and natural fibers. It is comparatively designated in cellulose composite removals [26]. In this paper influence of nano silicon (IV) oxide particles have been added to the resin concentration to decrease the water absorption action of hybrid kenaf composite materials. A short-term water absorption performance of hemp fiber composite depends on mean particle length to bind in nature. The water absorption properties in composite toughened and pure and chemical reaction customized the hemp in three reagents confirmed because of surface modification of stuffing influence absorption [27]. Then the distribution of composite which represents and capability of poignant within is a specimen to the coefficient of diffusion process [28]. The chemical process of sisal fibers is going to analyze various immersion methods that are going to be used [29]. Moisture sorption behavior and inflammation of jute epoxy

biocomposite fiber moistures are observed are increased because of increasing is filled maximum fibers [30]. The swap resin is more discerning for fluoride absorption. Because accessibility of polymeric resins for discerning absorption is very scanty [31]. The main role of nano silicon particles with epoxy hybrid composite in reinforced kenaf fiber materials is increasing the physical, thermal strength also reduce the impact damage of the properties [32]. The purpose of creating fabric is to combine in good mechanical strength of workpieces while eliminating every destitute composite. Injoining of hardened strands and delicate networks is unused good mechanical strength enveloping points of interest of both the fiber and matrix materials, this work find out the highest mechanical strength and low water sorption conduct of epoxy resin silicon added hybrid composite materials.

2. Experimental Details

2.1 Materials used

Kenaf materials are ordered and adjacent Agri land of Andrapradesh (India). kenaf fibers are prepared annually and the maximum length is 3mm – 5mm. The surface-modification handle was done by utilizing corrosive hydrolysis prepare in this the molecule and common fiber was quickly submerged in arranged fluid amino

silane arrangement for treatment. The ethanol of weight 95 % and water of weight 5% were taken in measuring and mixed liberally. The specified weight rate of amino-silane generally 2 wt % was blended with fluid arrangement drop by drop to create a more uniform blend taken after blending. The reinforcements were at that point submerged within the arranged ethanol/Water arrangement (fluid) for a little period and taken out independently. The taken-out fortifications are cleaned flawlessly and added ethanol decay overabundance silanization substance of the temperature of 110°C in a hot oven to remove the moisture. The epoxy resin utilized in fluid DGEBA (LY556, Huntsman India Ltd) with a normal molar mass of 185 g/ m, the mass thickness is 1.18 g / cm³. The color of this fluid is yellowish having two epoxy rings at its closes. The joined epoxy rings open and shapes a linkage when curing prepared takes place. It could be a kind of thermoset gum having an exceptionally brittle structure in its nature. When blended with fiber the tensile strength, flexural strength, and toughness are getting increased. Ordinarily, epoxy resin is cured by utilizing an aliphatic or fragrant hardener with sensibility. The pot life of an aliphatic hardener with epoxy resin is around 35–45 min. The nano-silica solution used in this study consider was obtained from Sigma-Aldrich, the USA with a uniform molecule size of 25 nm. For the most part, the molecule density between 0.35 to 0.45 g/cm³ and having a spherical shape. The nano-silica has high thermal stability, high hardness, and higher chemical and electrical resistance. Additionally, the silica particles have tall antimicrobial substances.

2.2. Experimental Methods

2.2.1 Composite Material Fabrication

The surface-modified kenaf fiber of quantity 50 vol. % at the combined in changing volume rate of epoxy resin the nano-silicon particle is (0.5, 1.0, and 2.0 vol. %) have mixed. The mixed substances are stirred completely until degassing process. The aliphatic curing hardener of TETA is another advance included with the resin to hardener proportion 10:1 and blended until the hardener is total. The result of viscosity about the colloidal suspension has point poured into an elastic shape is 3 mm thin sheet also wax coated box. A (3 ply box) and 50 vol.% of kenaf mat fiber is laid in epoxy resins framework and captured discuss in air bubbles are removed using in a cotton roller. The excess of abundance resins is dropped in physically to arranged the uniform thickness.

2.2.2 Specimen Process

The preparation of silane-treated silicon added kenaf material is dispersed hybrid materials to slash from the molded sheet in (Abrasive jet machines 1515, Kent, USA). This waterjet machine is set up with a working weight of 250-350MPa, rough stream rate is 0.35 Kg/min, garnet dimensions are 80 meshed, and jet nozzle size is 1.1-2 mm are followed for process parameters. Figure 1 as shown in scanning electron microscope structure.

3. Composition Of Hybrid Composite Materials

The composition of kenaf fiber hybrid composite materials is Epoxy resin filled with high immersion level, and Kenaf fiber is the maximum size of 3mm and added the 50 vol %, and nano silicon particle is mixed with epoxy in 0–2.0 level of stirred composition. based upon the designation the material strength has been changed the composition of the material as shown in Table 1.

Table 1
Kenaf fiber material composition

S.No	Description	Epoxy resin wt. %	Kenaf fiber wt. %	Nano-silicon wt. %
1	E	100	0	0
2	E, K	50	50	0
3	E,K,S ₁	49.5	50	0.5
4	E,K,S ₂	48.5	50	1.5
5	E,K,S ₃	47.5	50	2.5
E- Epoxy; K- Kenaf fiber; S – Nano Silicon particle				

3.1 Material Testing

3.1.1 Tensile Test

The tensile strength, modulus, and elongation of cured kenaf- epoxy and nano-silica half breed epoxy composite are tested with (ASTM) standards D-638 and (ASTM D -3039). The testing machine utilized was a Universal testing machine (UTM) (FIE, India, F150 arrangement) with a 5-ton capacity and cross speed of 2.5 mm/sec. The plain epoxy workpiece was completed based on (ASTM D- 638) and reinforced kenaf composite material tested on (ASTM D 3039). Maximum material thickness of 3 mm in all composite workpieces. Figure 2 (b-c) shows the ASTM standard universal testing workpiece.

3.1.2 Flexural Test

The flexural test of kenaf fiber nano silicon hybrid matrix composites is assessed universal testing machine the maximum load of 40T is connected with (ASTM - D 790). A flexural test specimen was conducted on 3 point testing where the bending was placed at the center. Uniform thickness of 3 mm was kept up for all testing workpiece tested and 5 equal specimens were tried to discover the normal values. The equations 3.1 and flexural quality. Figure 3. (a,b) appears the ASTM flexural quality with measurements.

3.1.3 Water absorption test

The water absorption testing materials were conducted by a submersion test strategy in agreement with ASTM D – 570. The work piece was prepared square shape with measurements of 60 X 60 mm. The test proceeded for 72 hours with open atmospheric air. The formula 3.1 shows the immersion percentage of the water absorption test. Figure 4 (b) shows the water absorption test workpiece as per ASTM standards.

$$\text{Water absorption percentage (\%)} = [(W1 - W2) / W2] \times 100\% \dots\dots\dots(3.1)$$

Where,

W1 - Before weight immersion.

W2 - After weight immersion.

4. Result And Discussion

4.1 Mechanical Properties

Tensile test and flexural test values were conducted to silane treatment of silicon nanoparticles added the natural kenaf fiber reinforced epoxy hybrid composite plate are explained in Tables 2 and 3. The comparison of mechanical properties has been increased because of surface treatment silicon epoxy hybrid composite materials. The Fig. 5 shows that revolutionize of 53%, 55%, 58% & 62% and 55%, 56%, 58% & 59% were focusing of tensile strength of epoxy, kenaf and silicon (1%,2%,3%) untreated hybrid composite materials respectively. But the improvement of mechanical properties surface treatment reinforced hybrid kenaf fiber composite material is 50%, 53%, 56% & 59% and 57%, 58%, 59% & 60% were identified for Epoxy, Kenaf and silicon (1%, 2%, 3%). This change capacity of kenaf fiber also changes in silicon nanoparticles. A molecule for the most part retains procured moistures and made a high-strength

matrix. The silane treated reinforcement surface actuated NH₂ particles, The flexural test specimen properties are 55%, 56%, 57%, 61% & 63% were focused in composite preparation as shown in Fig. 6 is EK, EKS₁, EKS₂, and EKS₃ respectively. The increasing the flexural strength because of silicon –IV oxide mixed materials.

Table 2
Tensile property of un-modified and surface-modified hybrid composite:

S.No	Description	Tensile strength (MPa)		Tensile modulus (MPa)	
		Un-modified	Surface-modified	Un-modified	Surface-modified
1	E	66		2829	
2	EK	136	142	6188	6383
3	EKS ₁	142	154	6249	6512
4	EKS ₂	155	164	6456	6543
5	EKS ₃	169	175	6679	6779

Table 3
Flexural properties of un-modified and surface-modified hybrid composite

S.No	Description	Flexural strength (MPa)		Flexural modulus (MPa)	
		Un-modified	Surface-modified	Un-modified	Surface-modified
1	E	103		2043	
2	EK	207	223	5746	5845
3	EKS ₁	218	231	5880	5984
4	EKS ₂	231	248	5930	6232
5	EKS ₃	243	255	6075	6250

4.2 Morphological Analysis

4.2.1 Tensile strength

Figure 7.a,b shows the Scanning electron microscopic views of un-treated and surface modified kenaf fiber reinforcing silicon added epoxy composite materials.

The un-modified epoxy composites shown fiber pull out in matrix materials, whereas the surface-modified composite viewed in Fig. 4.4 there's refusal fiber pullout and besides the fiber parcels appears fine smashed pieces. This process because in un-treated kenaf fiber reinforced epoxy composite there's no adhesive between fiber and matrix hence it is isolated from the reinforcement stage while in surface-treated epoxy composite the attachment between fiber and matrix is exceptionally maximum form as fine broken shape.

4.2.2 Flexural strength

Figure 8.a,b shows that the Scanning electron microscopic views of the flexural test specimen in both untreated and surface-treated order of (EKS3). It is watched that the fractured place appears the wavier layer on the broken line. It shows the arrangement of a more miniaturized scale break. But in surface-treated EKS3 more shear glasses and stream marks are displayed, which demonstrates progressed ductility within the lattice due to the nearness of grip progressed kenaf fiber and nano silicon particles.

4.3. Water absorption test

Water absorption testing properties of epoxy material were confirmed in contact angle test methods. The drop load water is constrained on the test example and the images were captured using an optoelectronic system (HOLMERC- HO- IAD- CAM- 01). The images have been analyzed for measuring angles with the grounded point reference. The sensor used in this equipment is a CMOS sensor and the video resolution is 2592 X 1944. The lighting procedure utilized here was an LED-based framework Based on the contact point the surface pressure of each example was recognized.. The higher the contact angle lesser the water absorption and vice-versa.

4.3.1 Pure epoxy resin and hybrid composites

Table 4 shows that water sorption values unmodified and surface-modified hybrid composite materials. It is focused on plain resins shows a water immersion percentage of 0.085. It seems like a very minimum value. This very lower water absorption percentage is higher hydrophobic nature of epoxy molecules. In epoxy resin, there are more free OH molecules. These OH molecules are retains very higher hydrophobicity and repel the water uptake. Thus very lower water absorption phenomenon takes place. And silicon added to epoxy, kenaf hybrid composites are predicted the values of 0.81 for EKS3 and surface-treated water absorption values of 0.42 % as shown in Fig. 9. but we need to get the lowest values in treated as processed in 0.39% in EKS2 composition. Table 5 shows that contact angle of untreated and surface-treated hybrid composites, the contact angle values of pure epoxy resin in 86° and surface-modified in EKS2 values are shown that 60° from contact angle sessile drop tester image as shown in Fig. 10. This higher angle explicates the lower surface energy of the solid surface.

Table 4
Water absorption behavior of un-modified and surface-modified hybrid composites

S.No	Designation	Water absorption (%)	
		Un-modified	Surface-modified
1	E	0.085	
2	EK	0.66	0.44
3	EKS ₁	0.69	0.41
4	EKS ₂	0.75	0.39
5	EKS ₃	0.81	0.42

Table 5
Contact angle of un-modified and surface-modified hybrid composites

S.No	Designation	Contact angle (θ)	
		Un-modified	Surface-modified
1	E	86	
2	EK	56	64
3	EKS1	48	58
4	EKS2	45	60
5	EKS3	41	63

The experimental results show that comparison of un-treated nano silicon particles in fiber epoxy composite the surface treated nano silicon particles in fiber epoxy composite predicted the lower water absorption with a high contact angle percentage as shown in Fig. 11 (a-i). It is distinguished that the un-treated composites designation in EKS₃ gives a high level of water sorption percentage of 0.81 with a very lower contact angle of 41°. And treated hybrid composite kenaf material gives a sessile angle of 60° in EKS₂ composition. This is often since of exceptionally high surface energy of high moistures delicate the nano silicon particles. But in surface-treated nano silicon particles in fiber epoxy composites the water sorption is limited by lower surface energy limits.

5 Conclusion

Kenaf fiber material properties, the quantity of water immersion increases the composite to development from both un-modified and surface-modified process, but modified kenaf fiber composite materials have

minimum water absorptions as compared to un-modified fibers. Its actuality has explicit the chemical reaction of hybrid composites.. The silanization modification was done using acid hydrolysis process used in Ethanol and water of 95/5%. the particulate of hybrid materials temporarily wrapped up in preparation of modulated solutions. The nano silicon IV particles predicted the higher grip with matrix on comparison of untreated and surface-treated kenaf fiber materials. The morphological Scanning electron microscope (SEM) images confirmed the improvement and adhesion of fiber matrix, with the help of mechanical experimental results in fibers. Water absorption test of untreated and surface-treated silicon particle kenaf composite gives 41° in EKS_3 composite and 60° is fewer contact angles in EKS_2 shows that minimum water absorption behaviors.

Declarations

1. Funding: Not Applicable
2. Conflicts of interest/Competing interests: Not Applicable
3. Availability of data and material: Not Applicable
4. Code availability: Not Applicable
5. Authors' contributions

Parthipan N - Mechanical Strength testing and data collections

Ramesh C - Manuscript preparation

Mohanraj C - Water absorption Testing and data collections

Padmavathy S - Manuscript preparation

Chun Kit Ang- Morphological Testing and Proof Check.

6. Availability of data and material : Not Applicable
7. Compliance with ethical standards : Manuscript follows the journal ethical standards
8. Consent to participate : Manuscript received the consent from authors to submit the article
9. Consent for Publication: Manuscript received the consent from Insititute and authors to submit the article
10. Acknowledgments : Not Applicable

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Figures

Figure 1

Scanning Electron Microscope Image of Kenaf fibre

Figure 2

a Tensile specimen as per ASTM standards b Tensile samples before test c Tensile samples after the test

Figure 3

(a) Flexural test workpiece before test (b) Flexural specimens after test

Figure 4

(a) Water absorption specimens as per ASTM standards (b)) Water absorption test workpiece

Figure 5

Tensile strength graphs for untreated and treated kenaf fiber epoxy composite

Figure 6

Flexural strength graphs for untreated and treated kenaf fiber epoxy composite

Figure 7

a. SEM fractography of un-treated kenaf fiber composites b. SEM fractography of surface-treated kenaf fiber composite

Figure 8

a. an SEM Image of un-treated EKS3 flexural specimen b. SEM image of surface-treated EKS3 specimen

Figure 9

Water absorption graphs for untreated and treated kenaf fiber hybrid composite

Figure 10

Water absorption contact angle graphs for untreated treated kenaf fiber hybrid composite

Figure 11

Sessile drop Image of untreated and treated kenaf hybrid composite