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Effect of Fiber Length and NaOH Treatment on the Flexural Behavior of Coir Fiber Reinforced Epoxy Composite

Ayyavoo Karthikeyan[1*] Kalpana Anbarasu[2]
[1]Professor [2]Assistant Professor

[1]Departmentof Mechanical Engineering, Malla Reddy College of Engineering, Secunderabad, India – 500100.
[2]Department of Chemistry, Sri Saradha College for Women, Salem, India – 636 016

Abstract - *This paper presents the study on the effect of fiber length and fiber surface modification on flexural properties of coir fiber reinforced epoxy composites. The composite sample was fabricated with three different fiber lengths namely 10, 20, and 30 mm. The fiber treatment was carried out using sodium hydroxide (NaOH) solution at five different concentrations such as 2, 4, 6, 8 & 10%. The fabrication was made by hand lay-up techniques. Mechanical interlocking between fiber and matrix was observed from the SEM (scanning electron microscope) micrographs. The study reveals that increases NaOH concentration in the fiber treatment was found to increase the flexural strength up to 4% and further increase in NaOH concentration reduce the flexural strength and also the strength increase with increasing fiber length.*

Key words *- Coir fiber, epoxy matrix, fiber length, sodium hydroxide, flexural strength*

I. INTRODUCTION

Natural fiber composites have become a popular new materials because of their high strength and stiffness, natural availability and environmental ‘friendly’ [1-2]. Additionally they are also recyclable, renewable and have a very low raw material cost [3]. The advantage of natural lignocellulosic fibers over traditional reinforcing materials such as glass fibers, talc and mica are acceptable specific strength properties, low cost, low density, non-abrasive, good thermal properties, enhanced energy recovery and bio-degradability. The main bottle necks in the broad use of these natural fibers in various polymer matrixes are poor compatibility between fiber and the matrix and the inherent high moisture abortion, which brings about dimensional changes in the lignocellulosic based fibers [4]. The efficiency of a fiber reinforced composite depends on the fiber/matrix interface and the ability to transfer stress from the matrix to fiber. This stress transfer efficiency plays a dominant role in determining the mechanical properties of the composite. Coir is an important lignocellulosic fiber obtained from coconut tree which grow extensively in tropical countries. Because of its hard wearing quality, durability and other advantages. It is used for making a wide variety of floor furnishing materials, yarns, rope etc [5]. However these traditional coir products consume only a small percentage of the potential total world production of coconut husk. Hence research and development efforts have been underway to find new use areas for coir including utilization of coir as reinforcement in polymer composite [6-11]. The alkali treatment of coir fiber for coir polyester composites. The experimental results proved that flexural strength, modulus and impact strength of treated fiber composites were 40% higher than those containing the same volume fraction of untreated fibers [12]. Rout et al. [13] have studied the influence of fiber treatment on the performance of coir fiber polyester composites. The investigation proved that the 2% alkali treated coir fiber polyester composites showed better tensile strength (26.80Mpa) whereas 5% alkali treated composites showed better flexural (60.4Mpa) and impact strength (634.6 J/m). Karthikeyan et al. [14] have studied the coconut fiber reinforced epoxy composite with alkali treatment. The results proved that treated fiber composites have better impact strength (27kJ/m2) and also impact strength was greatly influenced by the fiber lengths. Therefore, in this research the coir fibre is chosen to be the sources of fiber for producing reinforced composites and investigate the effects of fiber length and surface modification by NaOH treatment on flexural properties of epoxy resin composites.

II. MATERIALS AND METHODS

In this work, the main studies were carried out to investigate how fiber length of coir fiber reinforced epoxy composite affects flexural strength with and without NaOH treatment. The coir fibers were collected from the rural area of Erode, Tamil Nadu. Coir fibers were carefully extracted from the coconut husk. A diameter of coir fiber was in the range of 0.2743mm. After that the coir fibers were immersed in the NaOH solution (2, 4, 6, 8, & 10% concentration) for 10days. Thereafter, fibers were rinsed with water to remove the excess of NaOH sticking in the fiber. The fibers were then dried at room temperature for 5 days. After that, composites containing 30% by weight of fiber were prepared using fiber of length in the range 10, 20, and 30 mm. A matrix was created by mixing epoxy resin with its hardener in the ratio 10:1 by weight percentage. The mixture was poured into the metal mould of size 300x300x3mm. The fabrication of the composite material was carried out through the hand lay- up technique. The top & bottom surface of the mold and the walls were coated with remover & allowed to dry. The chopped fibers with epoxy resin were mixed manually. Epoxy resin properly mixed with coir fiber was transfer to the mold and the mold close, and then it is pressed in the compression testing machine and left for 24hr for curing. After the curing process, the samples were cut into the required size prescribed in the ASTM D790 standards. The microstructure of composites sample was investigated by scanning electron microscope (SEM).

III. EXPERIMENTAL SETUP

Flexural strength is defined as a material's ability to resist deformation under load. The short beam shear tests are performed on the composite samples to evaluate the value of inter-laminar shear strength. It was a 3-point bend test, which generally promotes failure by inter-laminar shear. This test was conducted as per ASTM standard D790 using UTM. The loading arrangement is shown in Figure 1. The dimension of the specimen was (137x13x3) mm.

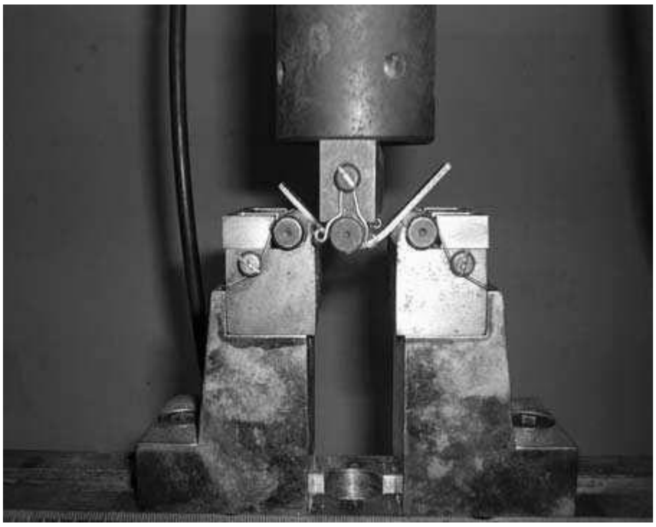
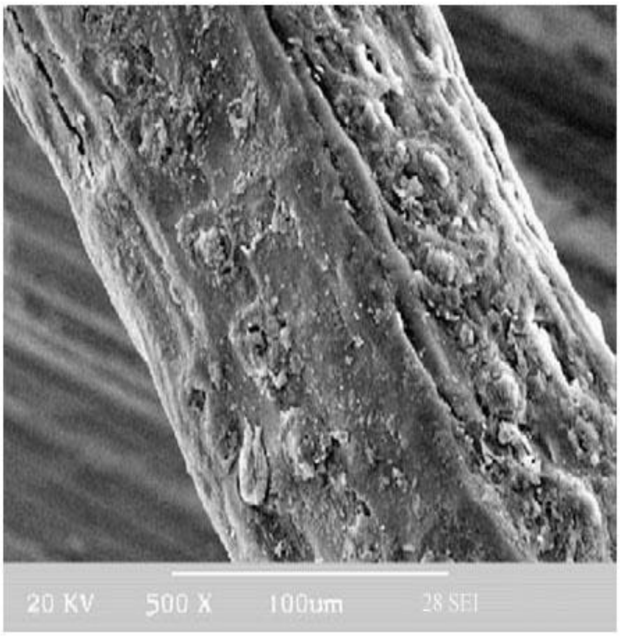


Figure 1 Loading arrangement for flexural test

IV. RESULTS AND DISCUSSION

The average diameter of untreated coir fiber rounded off to two decimals is observed to be 0.27mm. The average tensile strength of the coir fiber is found to be 617.6 mPa. SEM image of untreated coir fiber is shown in Figure 2.



Figures 2 SEM image of untreated coir fiber

The surface of the coir fiber is covered with a layer of substances, which may include pectin, lignin and other impurities. The surface is rough with nodes and irregular stripes. Figure 3 shows similar improvements in the flexural strength of coir fiber reinforced epoxy composite.

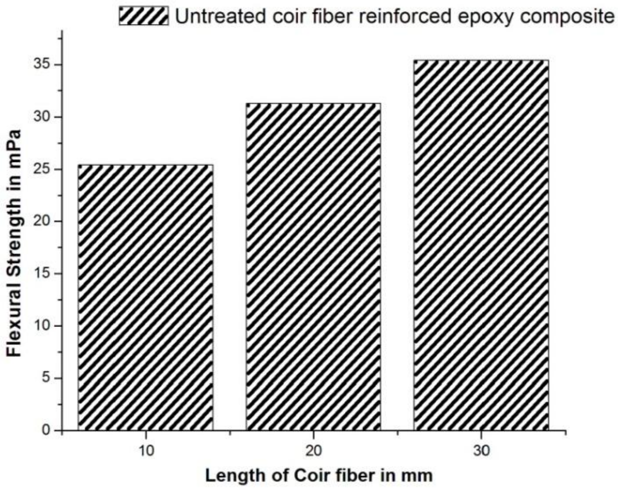


Figure 3 Flexural strength of untreated coir fiber composite

SEM picture (Figure 4) of failed coir epoxy composite under flexural loading also shows evidence for poor interfacial bonding. This gives a clue that the tensile and flexural strengths of coir fiber reinforced epoxy composite could be improved by increasing the length of the fiber and also by improving interfacial bonding.

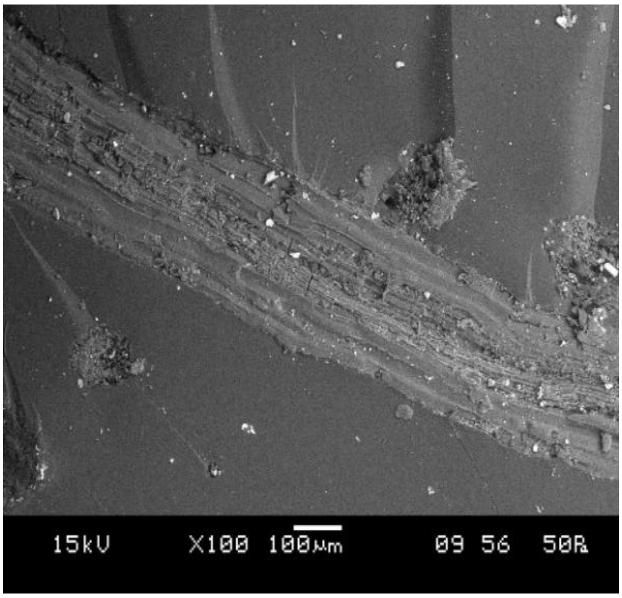


Figure 4 SEM image of failed 10mm long coir composite surface after flexural test

A. Alkaline treated coir fibre

In the composite load is shared between the matrix and fiber. The fiber offers resistance to load in two different ways. One is through its tensile strength and the other is through the interlocking of the fiber surface with the matrix. If the load carrying capacity of the fiber through their tensile strength is poorer than the resistance through the mechanical interlocking of the fiber, it will fail by tensile failure. If it is the other way, it will fail by slipping or pull out of fibers. The tensile resistance offered will be dependent on the net cross-section of the fiber. The mechanical interlocking of the fiber depends on three factors.

1. Co-efficient of sliding friction between the fiber and matrix.
2. Surface properties of the fiber (surface roughness) measured along the axis.
3. Total surface area of fiber.

The NaOH treatment results in changing all the above three parameters simultaneously. The nature of variation of the co-efficient of friction of the fiber is to be investigated. It may improve or deteriorate the frictional resistance offered. The tensile strength of NaOH treated coir fiber is presented in Figure 5.

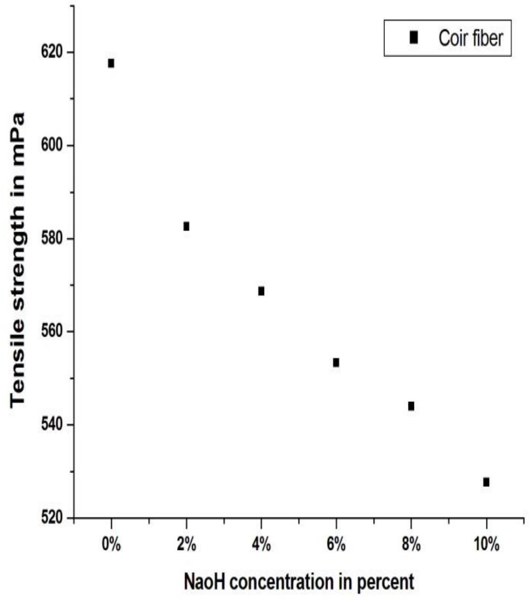


Figure 5 Tensile strength of NaOH treated coir fiber

A decreased trend in the tensile strength of the fiber is seen with increased NaOH concentration. Denser NaOH solution provides more Na+ and OH- ions to react with the substance on the fiber, causing greater amount of lignin, pectin to leach out. It seems that lignin, pectin are stronger than the core of the fiber and hence their removal results in loss of strength. The diameter of NaOH treated coir fiber is presented in Figure 6.

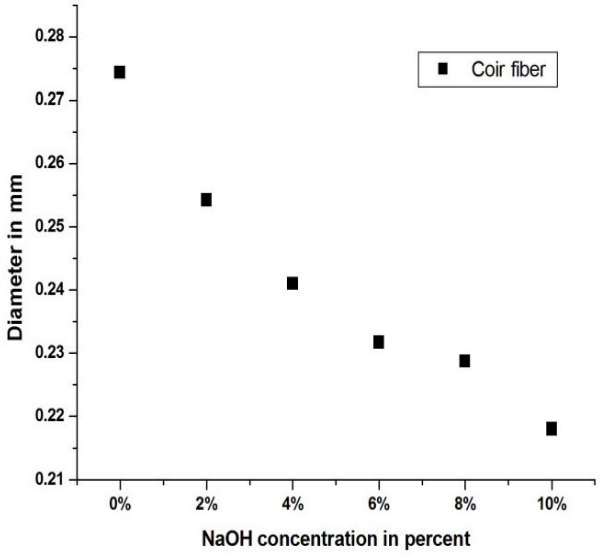


Figure 6 Influence of NaOH treatment on coir fiber diameter

Figure 6 shows how the variation in NaOH concentration affects the fiber diameter. Stronger NaOH solutions remove more and more lignin, pectin and other impurities from the surface of the coir fiber there by reducing the diameter.

B. SEM image of NAOH treated coir fiber

The effect of NaOH treatment on fiber surface morphology was analyzed by scanning electron microscope. The NaOH treatment seems to modify the surface of the coir fiber. Removal of pectin, lignin and other impurities has resulted in increase in the surface roughness. Figure 7 show the surface modification of coir fiber treated with 2% NaOH concentration. 2% NaOH solution has reacted with the nodes and strips on the fiber surface turning the fiber surface a bit smother than the untreated fiber surface.

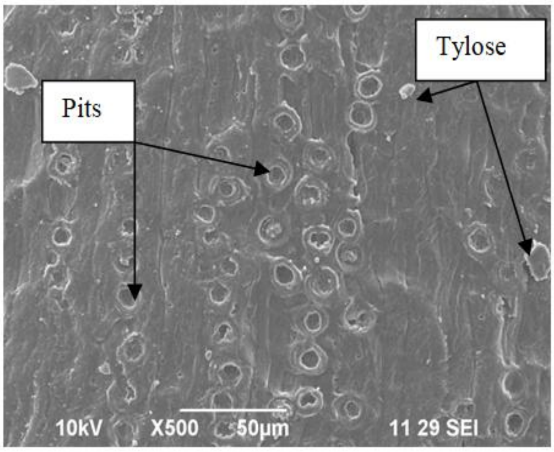


Figure 7 SEM image of 2% NaOH treated coir fiber

The SEM image also shows a number of pits which are evidence of such reactions. As a result of these reactions fatty deposits called tyloses are found to be dislodged and spread over the surface. As a result of increasing the NaOH concentration up to 4%, the surface roughness is increased as evidenced from more number of rows of pits on the surfaces. The globular protrusions called tyloses shown in Figure 7 are appearing on the fiber surface. Pits are seen to have spread along the entire cell wall outside of the parenchyma cells of NaOH treated fibers. The presences of pits after chemical treatment are important for increasing the effective surface area and the surface roughness, consequently improving the mechanical interlocking with the polymeric matrix. An increase in NaOH concentration up to 6% the surface roughness increases. Most of the fatty deposits have been removed from the fiber surface. Only shallow pits less in number are seen, on the fiber surface as compared to that of 4% concentration. Absence of ridges and valleys on the fiber surface may lead to less resistance to relative sliding between fiber and matrix. Increase in NaOH concentration up to 8%, has led to aggressive reaction leaving behind more number of ridges and valleys. There is also evidence for diameter having reduced. A further increase in NaOH concentration up to 10% leads to further increase in surface roughness. The fiber diameter is also seen to have further reduced. Increased surface roughness in the case NaOH treated coir fibers with 8% and 10% concentration may improve the interlocking between the fiber and matrix but at the same time the reduction in fiber diameter may weaken its load carrying capacity.

C. Flexural strength of NaOH treated coir epoxy composite

From Figure 8 it is seen that the flexural strength increases with increase in fiber length. The flexural strength of the composite increases with NaOH concentration up to 4% and reduces thereafter.

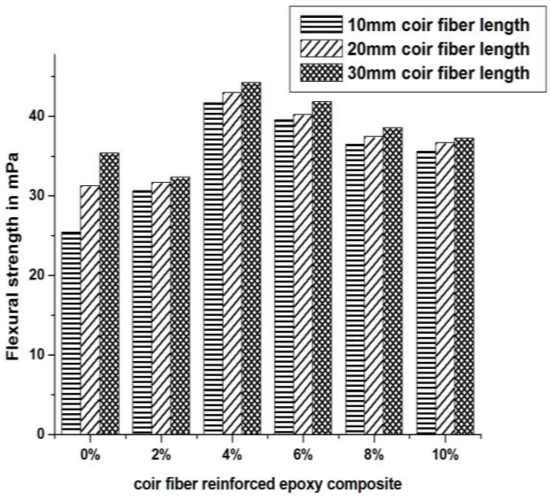


Figure 8 Flexural strength of untreated coir/epoxy composite and NaOH treated coir/epoxy composite

The flexural strength of the NaOH treated coir fiber reinforced epoxy composite has improved when compared to that of untreated coir fiber reinforced epoxy composite. SEM pictures of failed surfaces of NaOH treated 10mm fiber reinforced epoxy composite show evidence for fiber pullouts. Even though SEM pictures of NaOH treated 20mm fiber reinforced epoxy composites show similar pulled out fibers across the failed surface, they are less concentrated when compared to that of 10mm NaOH treated fiber reinforced epoxy composites (Figure 9). As for as the flexural strength is concerned reinforcing with 10mm NaOH treated fibers introduced a maximum of 63.99% increase when treated with 4% NaOH solution, whereas 20mm and 30mm NaOH treated fibers introduced only about 33.34% and 24.92% increase in the flexural strength.

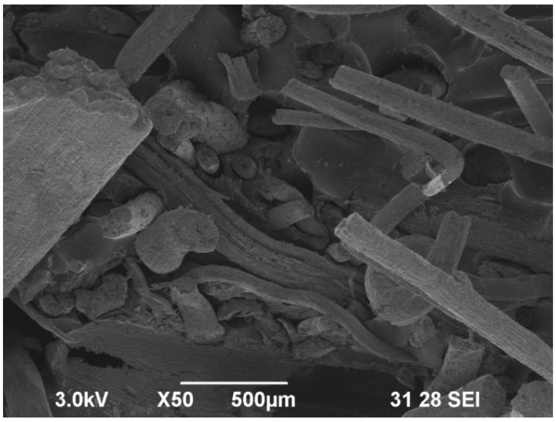


Figure 9 SEM image of 4% NaOH treated 10mm long coir/epoxy composite after flexural failure

Even though the fiber treated with higher concentrations of NaOH leads to improved surface properties as evidenced from reduced pull outs (Figures 10), the fiber diameter is also reduced as a result of which the flexural strength of the composite reduces. Hence 10mm fiber treated with 4% NaOH solution is found to be preferable to increase the flexural strength of the composites.

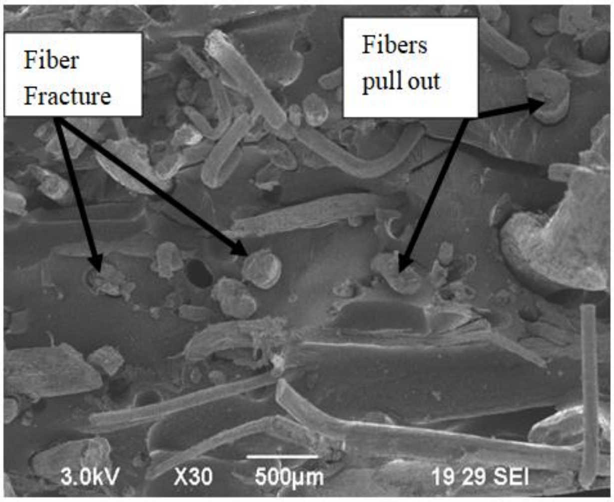


Figure 10 SEM image of 4% NaOH treated 20mm long coir/epoxy composite after flexural failure

V. CONCLUSION

1. This work shows that successful fabrication of a coir fiber reinforced epoxy composites with different fiber lengths is possible by simple hand layup techniques.
2. The surface of untreated coir fiber is covered with a layer of substance, which may include pectin, lignin and other impurities. The coir fiber surface is rough with nodes and irregular stripes.
3. For the untreated coir fiber of length 10mm, the mechanical interlocking between fiber and matrix is weak and the frictional resistance is small the fiber slips, thereby letting the fiber to take only limited tensile load.
4. Increasing the length of untreated fiber (20, 30mm) increases the surface area in the interface between fiber and matrix, increasing the frictional load carrying capacity.
5. When the fiber is treated with NaOH solution, a decreased trend in the tensile strength is seen with increased NaOH concentration. The NaOH solution reacts with the substance on the fiber, causing greater amount of lignin, pectin to leach out. Their removal results in loss of strength, due to reduced diameter and an increase in the surface roughness, thereby increasing the mechanical interlocking between fiber and matrix.
6. 10mm NaOH treated coir fiber reinforced epoxy composite introduced a maximum of 63.99% increase in flexural strength when treated with 4% NaOH solution, whereas 20mm and 30mm NaOH treated fibers introduced only about 37.34% and 24.92% increase as compared to that of untreated coir fiber reinforced epoxy composite.

VI. REFERENCE

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First. Author was born in Salem city, Tamil Nadu, India, in 1981. He received the B.E. Mechanical Engineering from Periyar University, salem in 2003 and M.E. Engineering Design degrees from Anna University, Chennai, in 2005 and the Ph.D. degree in mechanical engineering from Anna University, Chennai, in 2014. From 2006 to 2017, he was an Assistant professor and Associate Professor in the department of Mechanical Engineering, K.S.R. College of Engineering, Tiruchengode, Namakkal, Tamil Nadu. Now he is working as a Professor in the department of Mechanical Engineering, Malla Reddy College of Engineering, Secunderabad, India. He has published 07 research papers in international journals with good impact factor and 01 paper in international conference and 02 paper in national conference. He filed 05 patent among that 02 was completed registered. He was act as a reviewer of few journals and conferences. His research interest includes composites and anthropomorphic hand/Brain computer interface. He is guiding three Ph.D., research scholars.

Second. Author was born in Salem city, Tamil Nadu, India, in 1977. She received the B.Sc. Chemistry from Periyar University, Salem in 1997 and M.Sc. Chemistry degrees from Periyar University, Chennai, in 2005 and now submitted her Ph.D. thesis in 2017. From 2008 to 2017, she was an Assistant professor in the department of Chemistry, Sri Saradha College for Women, Salem, India – 636 016. She has published 08 research papers in reputed journals like Elsver international journals with good impact factor and 01 paper in international conference and 02 paper in national conference.