Journal of Applied Agricultural Science and Technology **ISSN: 2621-2528**
4 (1): 3-11 (2020)

EFFECT OF WATER ABSORPTION ON MECHANICAL PROPERTIES OF CALOTROPIS PROCERA FIBER REINFORCED POLYMER COMPOSITES

Raghu M J*, Govardhan Goud

Department of Mechanical Engineering, Bahubali College of Engineering, Shravanabelagola, Karnataka, India

*Corresponding author
Email: raghumjgowda@gmail.com

Abstract. *The present work investigates the effect of water absorption on mechanical properties of calotropis procera fiber reinforced epoxy polymer composites. The calotropis procera fiber chemical and mechanical testing was done to evaluate chemical composition and strength of the fiber. The composites are fabricated by reinforcing calotropis procera fiber in epoxy matrix by varying the fiber wt. % by traditional hand layup method. The water absorption of calotropis procera reinforced epoxy polymer composites at room temperature was found to increase with increasing fiber loading. The mechanical testing results of moisture exposed composites indicated decreased strength which may be due to degraded bonding between fiber and matrix.*
Keywords: *calotropis procera fiber, mechanical, polymer, composites*

1. Introduction

Fiber-reinforced polymer composites are used in manufacturing of several products right from household to high end aerospace applications. Synthetic fibers are widely used to reinforce polymer composites due to their low cost of manufacturing and good mechanical properties. The synthetic fiber reinforced polymer composites are non-renewable, non-biodegradable and impose problems in disposal after useful service causing environmental pollution (Sanjay & Siengchin, 2018; Vijay et al., 2019; Sanjay & Siengchin, 2019a). Natural fibres are renewable resources available in abundant, eco-friendly, and cost is relatively low compared to synthetic fibers. Natural fibers have high specific strengths, low density and biodegradable in nature, which is used as substitute for glass fiber and other synthetic fiber in wide applications. The popularly used natural fibers are jute, hemp, flax, sisal, coir, etc. The performance of natural fiber reinforced composites depends on factors like fiber chemical composition, microfibrillar angle, physical properties, mechanical properties, interaction of fiber with the polymer etc (Senthamaraikannan et al., 2019; Sanjay et al., 2018; Puttegowda et al., 2018). The hydrophilic nature of the natural fiber which leads to high moisture absorption is the main disadvantage in reinforcing polymer composites, and also poor compatibility between fiber and the matrix (Ngaowthong et al., 2019; Sanjay & Siengchin, 2019b; Sari et al., 2019; Abhishek et al., 2018). Natural fibers filled epoxy composites have great potential for engineering applications due to their environmental

https://doi.org/10.32530/jaast.v4i1.137

suitability, technical feasibility and economic viability. Various researchers used different treatments and coupling agents for the purpose of improving the performance of natural fiber-epoxy composites. However, alkaline treatment is the most widely used technique for enhancing the mechanical, thermal and water absorption properties of the natural fiber based epoxy composites due to economy and high efficiency. These methods have been widely employed to improve the incompatibility and poor interfacial adhesion between the filler and matrix (Ganapathy et al., 2019; Madhu et al., 2019; Rokbi et al., 2019; Kumaran et al., 2019).

The present research work is carried out to study the effect of water absorption on the mechanical properties of calotropis procera bast fiber reinforced epoxy composites. The composite specimens reinforced with various fiber weight proportions are fabricated and the mechanical properties of the composite before and after water absorption are investigated.

2. Methods

Calotropis procera Fiber Extraction

The stems of Calotropis procera plant are collected and dried under sunlight for 2-3 days. After drying, stems are dipped in water for 2-3 hours. Dipped stems were taken out and fiber was extracted by manual decorticating method. Extracted Calotropis procera fiber is as shown in Figure 1(a), Figure 1(b) shows the calotropis procera plant. The fibers have good length, strength, uniformity and fineness.

(a) Extracted Fiber (b) Calotropis procera Plant

Figure 1. Calotropis procera Plant and fiber

Chemical Composition and Tensile Strength of Calotropis procera Fiber

Chemical composition test for Calotropis procera fiber were carried out at SITRA Chemical laboratory, Coimbatore and the test results are tabulated as shown in Table 1. The Calotropis procera fiber were also tested for tensile strength at SITRA Chemical laboratory, Coimbatore and maximum tensile strength was found to be 294.30MPa.

Table 1 Chemical composition test results of fiber

Cellulose Content, %	81.01
Lignin Content, %	10.77
Wax Content, %	0.49
Ash Content (on dry basis), %	2.18
Moisture Content, %	6.14
Density, g/cc	1.34

Fabrication of Composites

The composite plates were fabricated by employing the traditional hand layup technique. The chopped Calotropis procera fibers of 5mm length were mixed with the epoxy resin and hardener to obtain various weight ratio of the reinforcement in the composite as per the experimental planning. The materials used for fabrication are L-12 Epoxy resin, K6 Hardener and Calotropis procera fiber. Figure 2(a) shows the Teflon cloth covered POP mold and Figure 2(b) shows the fabricated composite plate. The composite plates of 5%, 10%, 15% and 20% Calotropis procera fiber reinforcement were fabricated along with the neat epoxy plate. The test specimens are cut out from the fabricated composite plate as per the ASTM standards for mechanical testing.

Figure 2. (a) POP mold and (b) Composite plat

Mechanical Properties Testing of Composite Before and After Water Absorption

Water absorption testing was conducted by immersing the fabricated plates in water. The composite plates of different wt% of fiber reinforcement are dipped in water for 15 days. The composite plate’s initial weight and change in weight after every 24 hours of water absorption is noted down. The specimens were cut as per the standards out of the fabricated calotropis procera fiber reinforced epoxy composite plate’s and tested for mechanical properties before and after water absorption. The mechanical testing of composite specimens was carried out at NIE, Mysore.

3. Results and Discussions

Water Absorption Test

Water absorption test was carried out as per ASTM D570 standard. Composite plates were dipped in water for 15 days and change in its weight is noted down for every 24 hours. Since epoxy is hydrophobic in nature its weight is increased only by 0.57%. From the Figure 3 it is clear that as the quantity of fiber loading increases water absorption rate of the fiber reinforced composites also increases. This may be due to hydrophilic nature of fiber or due to more gaps between fiber and matrix material.

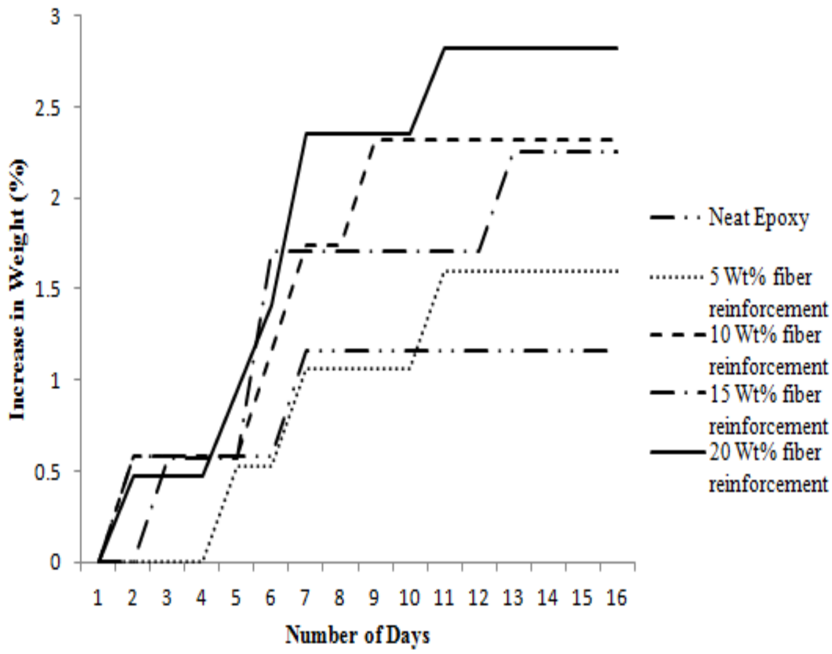

Figure 3. Water absorption behavior of composites

The water absorption occurs due to diffusion of water molecules inside the micro gaps between polymer chains, capillary transport of water molecules into the gaps and flaw at the interface between fibers and the polymer due to incomplete wettability, and by micro cracks in the matrix formed during process. Water absorption is found to be governed by Fick's law.

Tensile Test

Tensile test was carried out as per ASTM D638, before and after the water absorption of composite samples. Figure 4 indicates the decrease in tensile strength of water absorbed composite specimens compared to specimens without water absorption. The decrease in tensile strength and modulus is more for the specimens with high fiber loading due to more cellulose content. There is also corresponding decrease in fiber elongation due to loss of compatibility between fiber and the matrix.

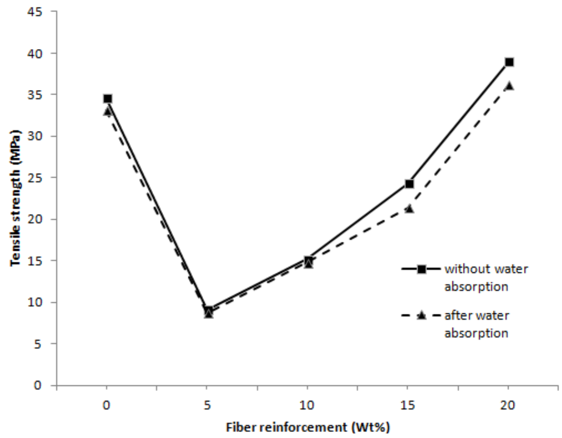

Figure 4. Tensile strength of composites

Table 2 and Table 3 show the tensile modulus and % elongation of the composite specimens before and after water absorption respectively. In general, the tensile strengths of these materials were decreased after the moisture uptake, due to the effect of the water molecules, which change the structure and properties of the fiber, matrix and the interface between them. Once the moisture penetrates inside the composite materials, the fibers tend to swell. The matrix structure can also be affected by the water uptake by processes such as chain reorientation and shrinkage.

Table 2 Modulus and % Elongation of dry composites

Sample [without water absorption]	Tensile modulus [Mpa]	% Elongation
Neat Epoxy	1380.70	1.14
5 Wt% Reinforcement	1617.19	2.83
10 Wt% Reinforcement	1701.15	2.96
15 Wt% Reinforcement	1831.90	3.63
20 Wt% Reinforcement	1907.13	4.06

Table 3 Modulus and % Elongation of water absorbed composite

Sample [after water absorption]	Tensile modulus [Mpa]	% Elongation
Neat Epoxy	1299.80	1.02
5gm Reinforcement	1519.32	1.80
10gm Reinforcement	1689.56	2.77
15gm Reinforcement	1763.51	3.51
20gm Reinforcement	1804.11	3.96

Flexural Test

Tensile test was carried out as per ASTM D790, before and after the water absorption of composite samples. Figure 5 indicates the decrease in flexural strength of water absorbed composite specimens compared to specimens without water absorption. Table 4 shows the Flexural modulus of the composite specimens before and after water absorption.

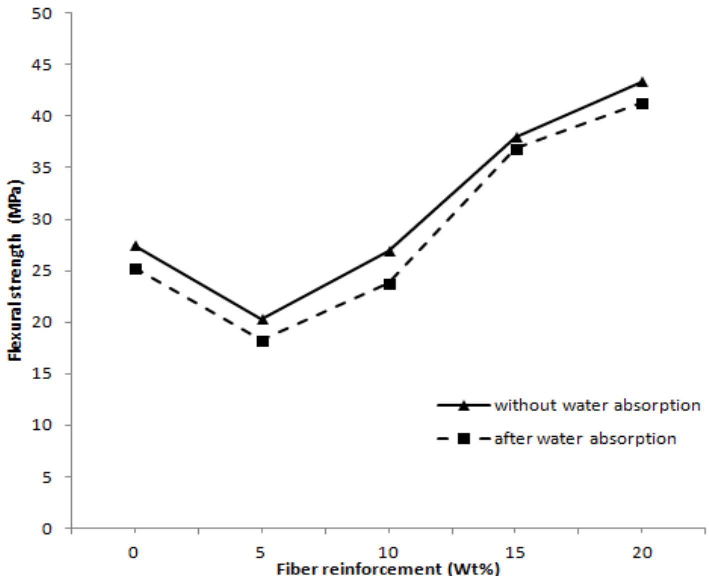

Figure 5. Flexural strength of composites

Table 4 Flexural properties of untreated specimen

	Flexural modulus [Mpa]	
Sample	Without water absorption	After water absorption
Neat Epoxy	2180.17	2080.17
5gm Reinforcement	3601.24	3500.24
10gm Reinforcement	3772.92	3700.38
15gm Reinforcement	4011.63	3987.61
20gm Reinforcement	4280.13	4188.17

In general, the flexural strengths of these materials are decreases after the moisture uptake, due to the effect of the water molecules, which change the structure and properties of the fiber, matrix and the interface between them. Once the moisture penetrates inside the composite materials, the fibers tend to swell. The matrix structure can also be affected by the water uptake by processes such as chain reorientation and shrinkage.

Impact Test

Impact test was carried out as per ASTM D256, before and after the water absorption of composite samples.

Figure 6 shows the impact strength of the composite specimens before and after water absorption. Impact strength is an important property that gives an indication of overall material toughness. Impact strength of fibre-reinforced polymer is governed by the matrix–fibre inter facial bonding, and the properties of both matrix and fibre. When the composites undergo a sudden force, the impact energy is dissipated by the combination of fibre pullouts, fibre fracture and matrix deformation. Normally in fibre-reinforced polymer composites, the impact strength increases as fibre content increases because of the increase in fibre pull out and fibre breakage.

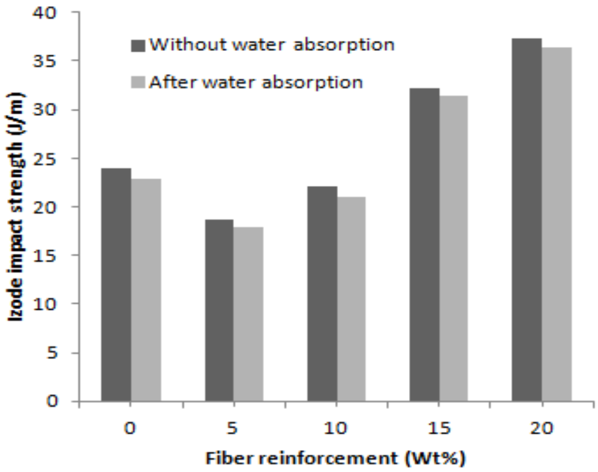

Figure 6. Impact strength of composites

Hardness Shore 'D'

Hardness test was carried out as per ASTM D-2240, before and after the water absorption of composite samples. Hardness test were performed on the samples with and without water absorption. From the Figur 7 it is clear that the hardness number increases as the amount of fiber content increases in the specimen in both with and without water absorbed specimens. It also indicates that the hardness number of water absorbed specimen is decreased compared to the specimens without water absorption.

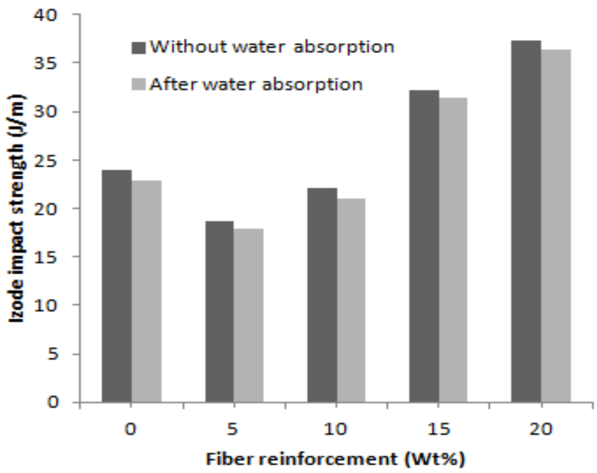

Figure 7. Hardness of composites

Density Test

Hardness test was carried out as per ASTM D792, before and after the water absorption of composite samples. The test results were plotted for density versus specimen composition as shown in Figure. 8.

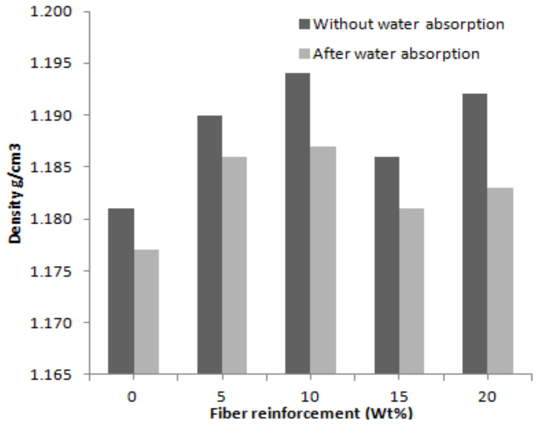

Figure 8. Density of composites

4. Conclusion

The mechanical properties of water immersed specimens were evaluated and compared with dry composite specimens. The percentage of moisture uptake increased as the fiber volume fraction increased due to the high cellulose content. The addition of fibers in the epoxy significantly increased the mechanical properties (tensile, flexural, impact, hardness, and density) of the specimen. However, calotropis procera fibers are hydrophilic in nature and hence have a poor resistance to water absorption. The water absorption of calotropis procera reinforced epoxy composite at room temperature was found to increase with increase in fiber content. Exposure to moisture caused a reduction in mechanical properties of the specimen. A possible explanation for this would be that bonding at the fiber-matrix interface is degraded as a result of water absorption.

Acknowledgements

The authors thankfully acknowledge the faculty and students of Bahubali College of Engineering, Shravanabelagola, SITRA chemical laboratory, Coimbatore and NIE, Mysore for the support rendered in carrying out this research work.

References

Abhishek, S., Sanjay, M.R., George, R., Siengchin, S., Parameswaranpillai, J. & Pruncu, C.I. (2018). Development of new hybrid Phoenix pusilla/carbon/fish bone filler reinforced polymer composites. *Journal of the Chinese Advanced Materials Society*, *6*(4), 553-560.

Ganapathy, T., Sathiskumar, R., Sanjay, M.R., Senthamaraikannan, P., Saravanakumar, S.S., Parameswaranpillai, J. & Siengchin, S. (2019). Effect of graphene powder on banyan aerial root fibers reinforced epoxy composites. *Journal of Natural Fibers*, 1-8.

Kumaran, P., Mohanamurugan, S., Madhu, S., Vijay, R., Lenin Singaravelu, D., Vinod, A., Sanjay, M.R. and Siengchin, S. (2019). Investigation on thermo-mechanical characteristics of treated/untreated Portunus sanguinolentus shell powder-based jute fabrics reinforced epoxy composites. *Journal of Industrial Textiles*, 0(0), 1-33.

Madhu, P., Sanjay, M.R., Pradeep, S., Bhat, K.S., Yogesha, B. & Siengchin, S. (2019). Characterization of cellulosic fibre from Phoenix pusilla leaves as potential reinforcement for polymeric composites. *Journal of Materials Research and Technology*, *8*(3), 2597-2604.

Ngaowthong, C., Borůvka, M., Běhálek, L., Lenfel, P., Švec, M., Dangtungee, R., Siengchin, S., Rangappa, S.M. & Parameswaranpillai, J. (2019). Recycling of sisal fiber reinforced polypropylene and polylactic acid composites: Thermo-mechanical properties, morphology, and water absorption behavior. *Waste Management*, *97*, 71-81.

Puttegowda, M., Rangappa, S.M., Jawaid, M., Shivanna, P., Basavegowda, Y. and Saba, N., 2018. Potential of natural/synthetic hybrid composites for aerospace applications. In *Sustainable Composites for Aerospace Applications,* 315-351). Woodhead Publishing.

Rokbi, M., Khaldoune, A., Sanjay, M.R., Senthamaraikannan, P., Ati, A. & Siengchin, S. (2019). Effect of processing parameters on tensile properties of recycled polypropylene based composites reinforced with Jute fabrics. *International Journal of Lightweight Materials and Manufacture*.

Sanjay, M. R., & Siengchin, S. (2018). Natural fibers as perspective materials. *King Mongkut's University of Technology North Bangkok International Journal of Applied Science and Technology*, *11*(4), 233.

Sanjay, M.R. and Siengchin, S., (2019a). Lightweight natural fiber composites. *Journal of Applied Agricultural Science and Technology*, *3*(2), 178-178.

Sanjay, M.R., and Siengchin, S., 2019b. Natural Fibers as Sustainable and Renewable Resource for Development of Eco-friendly Composites: A Comprehensive Review. *Frontiers in Materials*, *6*, p.226.

Sanjay, M.R., Madhu, P., Jawaid, M., Senthamaraikannan, P., Senthil, S. & Pradeep, S., (2018). Characterization and properties of natural fiber polymer composites: A comprehensive review. *Journal of Cleaner Production*, 172, 566-581.

Sari, N.H., Sanjay, M.R., Arpitha, G.R., Pruncu, C.I. and Siengchin, S., 2019. Synthesis and properties of pandanwangi fiber reinforced polyethylene composites: Evaluation of dicumyl peroxide (DCP) effect. *Composites Communications,* 15, 53-57.

Senthamaraikannan, P., Saravanakumar, S.S., Sanjay, M.R., Jawaid, M. and Siengchin, S., 2019. Physico-chemical and thermal properties of untreated and treated Acacia planifrons bark fibers for composite reinforcement. *Materials Letters*, *240*, pp.221-224.

Vijay, R., Singaravelu, D.L., Vinod, A., Sanjay, M.R., Siengchin, S., Jawaid, M., Khan, A. and Parameswaranpillai, J. (2019). Characterization of raw and alkali treated new natural cellulosic fibers from Tridax procumbens. *International Journal of Biological Macromolecules*, *125*, pp.99-108.