European Online Journal of Natural and Social Sciences 2023;
Vol.12, No 1 pp. 1-7
ISSN 1805-3602

Experimental Analysis of Tensile and Flexural Strength of Water Lily Fiber Reinforced Polyester Resin Composite

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Received for publication: 10 September 2022.
Accepted for publication: 22 November 2022.

Abstract

Ethiopia has abundant invasive aquatic plants like water hyacinth and water lily. Large masses of these invasive plants have a negative impact on the water bodies specifically at Lake Tana, in Ethiopia by infesting and deteriorating water quality and reducing the quantity of water. In this research work, an attempt was made to fabricate a natural fiber reinforced composite in which water lily fiber was used as reinforcing material in the polyester resin matrix. Chopped water lily fiber reinforced polyester resin composites were prepared by varying the fiber weight percentage as 20%, 40% and 60%. The mechanical properties such as tensile strength and flexural strength were evaluated as per ASTM standards to evaluate the influence of fiber concentrations. The experimental result shows that an increase in fiber concentration enhanced the mechanical properties of water lily fiber reinforced polyester composite. It was found that the composite with 40 wt% of fiber exhibited a superior strength which could be suitably used for different applications.

Keywords: Water Lily, Natural fiber reinforced composite Chopped fiber, Flexural Strength, Tensile Strength.

Introduction

A composite material is a combination of two or more different materials that are mechanically bonded together. Depending upon reinforcing materials, composites are classified as particle reinforced and fiber reinforced composites. Fibers are the reinforcement and the main source of strength whereas matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers. Sometimes, filler might be added to smooth the manufacturing process, impart special properties to the composites, and / or decrease the product cost (Jauhari et al., 2015). Due to the increase in pollution and environmental threats, natural fibers are being exploited substantially as an alternative to synthetic fibers (Mohammed et al., 2015). Various types of natural fibers have been investigated for use in composites including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, etc. (Faruk et al., 2012).

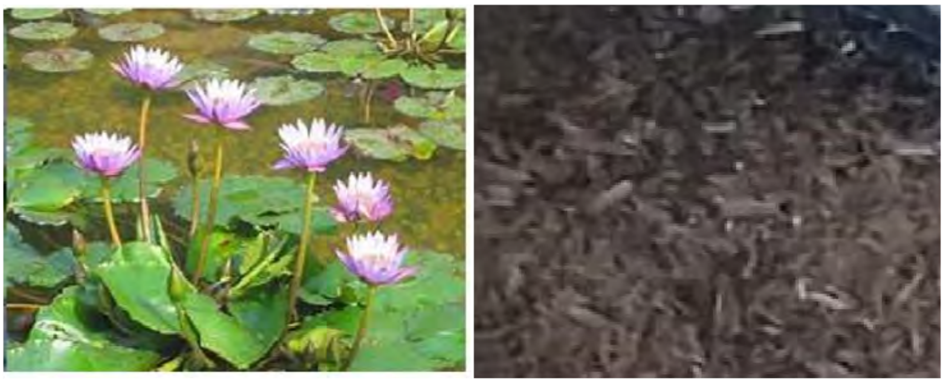
Based on matrix materials, composites are of three types such as metal matrix composites, ceramic matrix composites, and polymer matrix composites. When polymer resins are used as matrix material with any type of reinforcement such composite materials are called polymer matrix composites. There are two types of polymers namely thermosetting and thermoplastic are used in the fabrication of polymer matrix composites This type of composites is mostly used because of ease of fabrication, lower cost, and good electrical and thermal insulator and lower density (Kaushik et al., 2017). Nowadays polymer composite reinforced with natural fibers are mainly used for different engineering application, predominantly for the development of the interior panel of automobiles (Clyne and Hull, 2019).

More extensive studies have been made on the preparation and characterization of polymer composites reinforced with natural and synthetic fibers (Rokbi et al., 2011; Abdul Hamead et al., 2014; Surata et al., 2014; Haghdan, and Smith, 2015). The mechanical properties of jowar reinforced polyester resin matrix composites were studied (Prasad and Rao, 2011). It was found that the mechanical properties of composites made of jowar fiber were equal to that of bamboo composite and more than that of sisal composite. The effect of different weight ratio of matrix and fiber on the mechanical and morphological properties of palm fiber reinforced unsaturated polyester was studied by Chow et al., 2020 with 25w% fiber loading yielded the highest tensile modulus.

However, studies related to the use of water lily fiber in the fabrication of composites were not much explored in the literature (Vijayan and Krishnamoorthy, 2019). Hence, in this research work, a natural fiber obtained from water lily was selected as reinforcing material in polymer matrix composite. Water lily fiber reinforced polyester resin composites were prepared by varying the fiber weight percentage from 20% to 60% and its influence on mechanical properties of the polymer matrix composite was investigated.

Materials and Methods

In this work natural fibers are extracted from stems of water lily plant (Nymphaea spontanea) which was collected from the northern part of Lake Tana – Gorgora, in the Amhara region, Ethiopia. Lily fiber was selected in this research as a new natural fiber reinforcement into the polyester resin matrix. After extraction and drying of the fiber, it was chopped into small pieces. Figure 1 shows the water lily plant and the fiber chopped from stems.



(a) (b)

Figure 1. (a) Water lily plant, (b) Chopped fibers

The polyester resin was selected as matrix material in this study for preparing polymer matrix composite. Fly ash was selected in this study as filler material. Fly ash is found to be suitable for the preparation of lightweight composites with high strength (Kutchko and Kim, 2006). It was also found to improve the even distribution of and adhesion of fiber particles in the polymer matrix (Raja et al., 2014).

HY-95 hardener was used as a curing agent and as a catalyst to facilitate the curing time while preparing the composite. It is a highly suitable hardener for the polyester resin that determines the final characteristics Wax was another material which was used as a mold releaser due to its collapsibility after use.

To improve the adhesion between the fibers and matrix, fibers were subjected to surface treatments. Sodium hydroxide (NaOH) is the most commonly used chemical for cleaning/bleaching the surface of cellulosic fibers. The water lilies fibers (chopped) were soaked in a 10wt% NaOH solution for 24 hours. The treated fibers were washed in distilled water to neutralize the excess NaOH. The treated water lily fibers were dried in sunlight for three days before using as reinforcement in the synthesis of the composite.

The experimental specimens of polyester composite reinforced with water lily fibers were prepared using the hand lay-up and open mold techniques. Sheet metal molds having dimensions of 200mm x 80mm x 4mm and 170mm x 25 mm x 4 mm were used for making composite specimens for tensile and flexural strength respectively. The internal surfaces of the mold were sprayed with a release agent (wax) to facilitate easy removal of the composite from the mold. The polyester resin was impregnated with fly ash by homogeneously mixing them by a mechanical stirrer. Hardener was added to the fly ash impregnated resin with the resin to hardener ratio of 9:1 for preparing the composite specimen. Then, this resin mixture was poured into the mold. The lily fibers were then put on top of the resin layer in random orientation (chopped-strand) and compacted. After that, another layer of resin was applied on top of the chopped fibers and pressed gently by roller to remove any air bubbles. The above steps were repeated until the required thickness of the composite was attained. Composites were prepared by varying the fiber weight percentage from 20% to 60%. Prepared water lily fiber reinforced polyester composite specimen was left to cure for 8 hours at room temperature and then taken out of the mold. The composite was cut into a specimen of dimensions as shown were then cut to pieces of dimensions as per the ASTM D-3039, 2017 and ASTM D-790, 2010 standard as shown in Table 1 for the tensile and flexural tests respectively. The photograph of the prepared composite and the specimen for the tensile and flexural tests are shown in Figure 2. For each weight percentage of fiber three specimens were cut for determining tensile and flexural properties.

Table 1. ASTM standard for tensile and flexural specimen

Type Of Test	ASTM Standard	Dimension
Tensile Test	ASTM D-3039	200 x 25x4 mm^3
Flexural Test	ASTM D-790	170 x 25 x 4 mm^3

(a) (b) (c)

Figure 2. Photograph of the prepared lily fiber reinforced polyester composite (a) Prepared composites (b) Specimen for tensile (c) Specimen for flexural test

Result and Discussions:

The tensile and flexural properties of the three lily fiber reinforced polyester composite specimens were evaluated using a standard Universal Testing Machine according to the ASTM standards. Photograph of the fracture specimen after tensile test and flexural testing are shown in Figure 3. The results obtained from the tensile and flexural testing are given in Tables 2 and 3. The variation of tensile strength and flexural strength with respect to the weight percentage of the lily fiber are shown in Figures 4 and 5.

(a) (b)

Figure 3. Fractured specimen after (a) tensile test and (b) flexural test

Table 3. Results from tensile test

Weight percentage of fiber		**Tensile Strength [MPa]**		
	Specimen 1	**Specimen 2**	**Specimen 3**	**Average**
20%	18.5	12.67	14.56	15.24
40%	23	21	21.5	21.83
60%	14	16.67	9.17	13.28

Table 4. Results from flexural test

Weight percentage of fiber		**Flexural Strength [MPa]**		
	Specimen 1	**Specimen 2**	**Specimen 3**	**Average**
20%	72	73.2	74.4	73.2
40 %	79.2	84	88.8	84
60 %	93.6	86.4	76.8	85.6

From Figure 4, it was observed that with the increase in the fiber content, the strength of the composite increased up to 40 wt% of the lily fiber. Further increase in the fiber content decreased the tensile strength of the composites. It was evident that the specimen with 40 wt% fiber and 60 wt% resin possessed the highest tensile strength value of 21.83 MPa. Improvement in tensile strength was due to better interfacial strength between fiber and polyester matrix when compared to other specimens. When the fiber content increased beyond 40%, there was a significant reduction in tensile strength. The poor bonding between polyester matrix and lily fiber as well as a lower volume of matrix attributed to the reduction in tensile strength at a higher weight percentage of lily fiber (Ku et al., 2011; El-Shekeil et al., 2012).

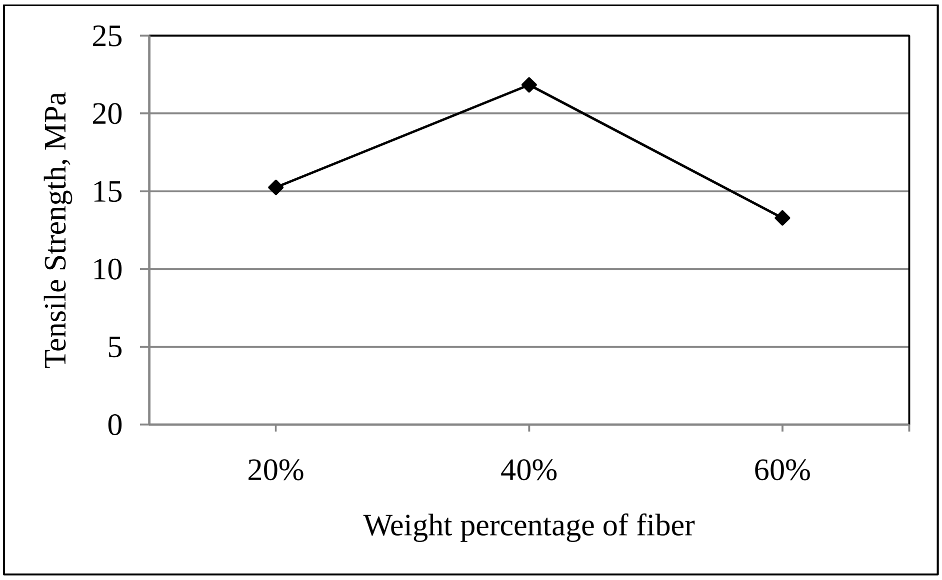


Figure 4. Variation of tensile strength with lily fiber weight percentage

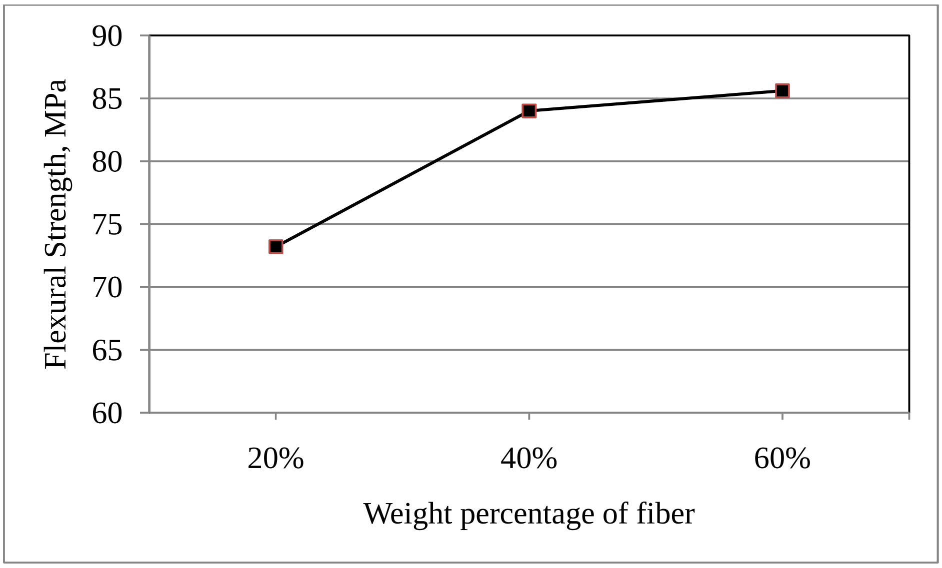


Figure 5. Variation of flexural strength with lily fiber weight percentage

Figure 5 revealed that the flexural strength of the lily fiber reinforced polyester composite increased with the increase in fiber content in the range selected in this study. The improvement in flexural strength can be explained based on the fiber-matrix interaction and load-bearing capacity which is common for polymers reinforced with fibers. The presence of more fiber in the matrix acted an obstacle for the crack to propagate through the matrix. This increased shear resistance (Haneefa et al., 2008) and thus increased the flexural strength of lily fiber reinforced polyester composite.

From the above analysis of the mechanical properties of the lily fiber reinforced polyester resin composites with different weight percentages of fiber, it was found that the composite with 40 wt% of fiber exhibited a superior strength in tensile and flexural compared to other composites.

Conclusion

The experimental investigation on the mechanical properties of water lilies fiber reinforced polyester composites led us to the following conclusions:

1. Water lily fiber reinforced polyester composites were successfully fabricated possible by varying the fiber loading using a simple hand lay-up technique.
2. Tensile strength was found to increase with the fiber up to 40% weight percentage. Beyond 40% fiber content, tensile strength decreased due to the poor bonding between fiber and matrix material.
3. Flexural strength of the fabricated composite increased with the increase in the fiber weight percentage.
4. Newly developed water lily fiber polyester composites are easy and economical to fabricate and possess good mechanical properties. Hence, these materials can be used for applications such as automobile interior parts, building components, and electronic packages.
5. Water lily fiber polyester composites can be used as an alternative to synthetic fiber composite materials.

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