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EFFECT OF FIBER CONTENT ON TENSILE AND FLEXURAL STRENGTH OF WATER LILY FIBER REINFORCED POLYESTER RESIN COMPOSITE

Ethiopia has abundant invasive aquatic plants like water hyacinth and water lily. Large masses of these invasive plants have a negative impact on the country's 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 the reinforcing material in a polyester resin matrix. Chopped water lily fiber reinforced polyester resin composites were prepared by varying the fiber content – 20, 40 and 60 wt.%. Mechanical properties such as tensile strength and flexural strength were tested as per ASTM standards to evaluate the influence of the fiber contents. The experimental results show that an increase in the fiber content enhanced the mechanical properties of the water lily fiber reinforced polyester composite. It was found that the composite with 40 wt.% fiber exhibited 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 the reinforcing materials, composites are classified as particle reinforced and fiber reinforced composites. Fibers are the reinforcement and the main source of strength, whereas the matrix glues all the fibers together in the given 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 cost of the product [1]. Due to the increase in pollution and environmental threats, natural fibers are being substantially exploited as an alternative to synthetic fibers [2]. Various types of natural fibers have been investigated for use in composites including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, etc. [3, 4].

Regarding the matrix materials, there are of three types of composites, such as metal matrix composites, ceramic matrix composites, and polymer matrix composites. When polymer resins are used as the 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, employed in the fabrication of polymer matrix composites. This type of composite is mostly used because of its ease of fabrication, lower cost, lower density, in addition to being a good electrical and thermal insulator [5]. Nowadays, polymer composites reinforced with natural fibers are mainly utilized for different engineering applications, predominantly for the production of the interior panels of automobiles [6].

More extensive studies have been carried out on the preparation and characterization of polymer composites reinforced with natural and synthetic fibers [7-12]. In this research work, the fiber obtained from a water lily plant was selected to fabricate a natural fiber reinforced composite because of the abundant availability of this plant at Lake Tana in the Amhara Region of Ethiopia. In addition, compared to other natural fibers, water lily fiber has superior mechanical characteristics which enable it to be used as reinforcement in composite fabrication. An early attempt was made by Comedis et al. [13] to make recycled eco-friendly containers using water lilies that do not decompose over time. Ignacio et al. [14] used water lily ash as cement replacement in the preparation of concrete. It was reported that the compressive strength of 1 wt.% ash added to the concrete mixture matched that of the regular concrete mixture.

However, studies related to the use of water lily fiber in the fabrication of polymer composites have not been explored much in the literature [15, 16]. Hence, in this research work, natural fiber obtained from water lily was selected as the reinforcing material for a polymer matrix composite. The water lily fiber reinforced polyester resin composites were prepared by varying the fiber weight percentage from 20 to 60% and its influence on the mechanical properties of the polymer matrix composite was investigated.

MATERIALS AND EXPERIMENTAL DETAILS

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

a)

b)

Fig. 1. Water lily plant (a) and chopped fibers (b)

Polyester resin was selected as the matrix material in this study to prepare the polymer matrix composite. Fly ash was also chosen as a filler material. Fly ash is found to be suitable for the preparation of lightweight composites with high strength [17]. It was also found to improve the even distribution and adhesion of the fibers in the polymer matrix [18].

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

To improve the adhesion between the fibers and matrix, the fibers were subjected to surface treatment. Sodium hydroxide (NaOH) is the most commonly employed chemical for cleaning/bleaching the surface of cellulosic fibers. The water lily fibers (chopped) were soaked in a 10 wt.% 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 use as reinforcement in the production of the composite.

Samples of the polyester composite reinforced with water lily fibers were prepared using the hand lay-up and open mold techniques. Sheet metal molds having dimensions 200 mm x 80 mm x 4 mm and 170 mm x 80 mm x 4 mm were used for making the composite samples for the tensile and flexural strength respectively. The internal surfaces of the molds 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 with a mechanical stirrer. Hardener was added to the fly ash impregnated resin at a resin to hardener ratio of 9:1 to prepare the composite samples. Then this resin mixture was poured into the mold. The water lily fibers were then put on top of the resin layer in random orientation (chopped strands) and compacted. After that, another layer of resin was applied on top of the chopped fibers and pressed gently with a roller to remove any air bubbles. The above steps were repeated until the required thickness of the composite was attained. The composites were prepared by varying the fiber content from 20 to 60 wt.%. The prepared water lily fiber reinforced polyester composite samples were left to cure for 8 hours at room temperature and then taken out of the mold. The composite samples were cut into specimens of dimensions as per the ASTM D-3039 [19] and ASTM D-790 [20] standards as shown in Table 1 for the tensile and flexural tests, respectively. The primary objective of the tensile test was to evaluate the in-plane tensile properties of the chopped water lily fiber reinforced polyester resin composite materials. The flexural strength test was conducted to evaluate the strength required for the composites to resist bending under three-point loading conditions. Photographs of the prepared composite samples and the specimens for the tensile and flexural tests are shown in Figure 2. For each weight percentage of fiber, three specimens were cut to determine the tensile and flexural strength.

TABLE 1. **ASTM standards for tensile and flexural specimens**

Type of test	ASTM	Dimensions
Tensile	ASTM D-3039	200 x 25 x 4 mm
Flexural	ASTM D-790	170 x 25 x 4 mm

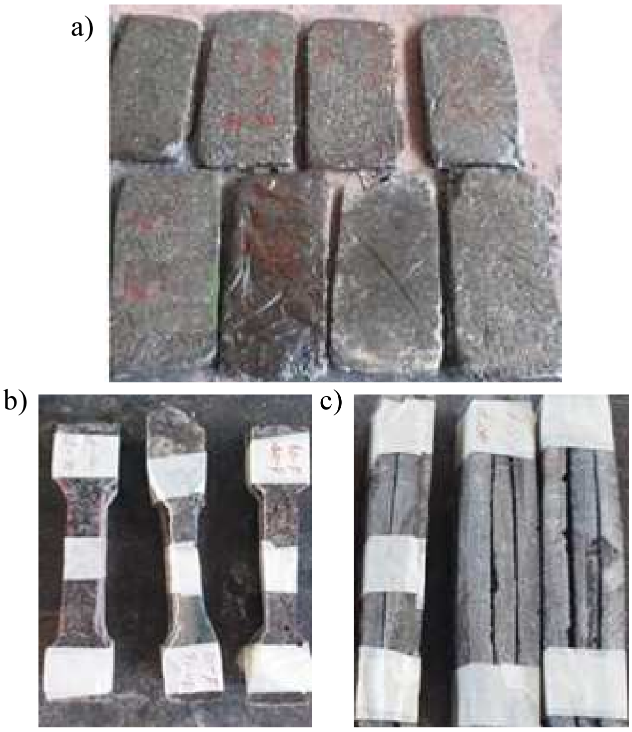

Fig. 2. Prepared water lily fiber reinforced polyester composite: a) prepared samples, b) specimens for tensile test, c) specimens for flexural test

RESULTS AND DISCUSSION

The tensile and flexural properties of the three water lily fiber reinforced polyester composites with varying fiber contents were evaluated using a standard Universal Testing Machine. Photographs of the fractured specimens after the tensile and flexural tests are shown in Figure 3.

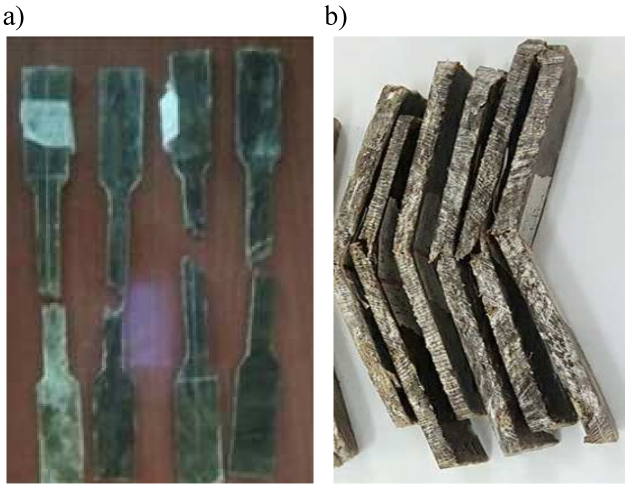

Fig. 3. Fractured specimens after: a) tensile test and b) flexural test

The results obtained from the tensile and flexural tests are given in Tables 2 and 3. The variations in the tensile strength and flexural strength with respect to the weight percentage of water lily fiber are shown in Figures 4 and 5.

TABLE 3. **Tensile test results**

Fiber [wt.%]	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. **Flexural test results**

Fiber [wt.%]	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

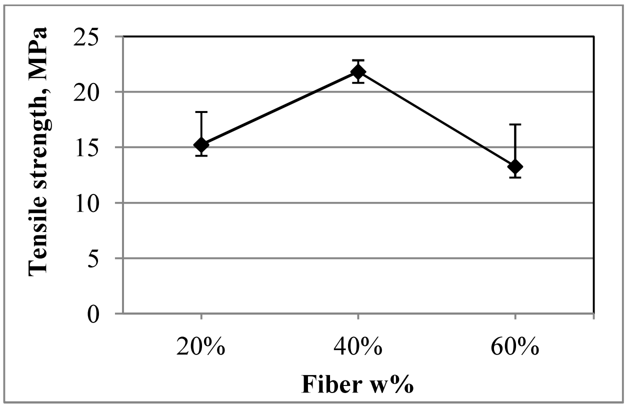

Fig. 4. Variation in tensile strength with water lily fiber content

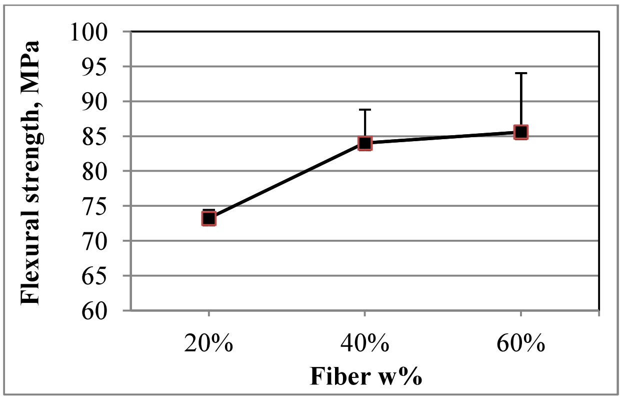

Fig. 5. Variation in flexural strength with water lily fiber content

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 water lily fiber. A further increase in the fiber content decreased the tensile strength of the composites. The specimen with 40 wt.% fiber possessed the highest tensile strength value of 21.83 MPa. Improvement in the tensile strength was due to better interfacial bonding between the fiber and the polyester matrix when compared to the other specimens. When the fiber content increased beyond 40%, there was a significant reduction in tensile strength. The poor bonding between polyester matrix and water lily fiber, as well as a lower volume of matrix attributed to the reduction in tensile strength at the highest content of water lily fiber [21, 22].

Figure 5 revealed that the flexural strength of the water lily fiber reinforced polyester composite rose 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 cracks to propagate through the matrix. This increased the shear resistance [23], and thus raised the flexural strength of the water lily fiber reinforced polyester composite.

From the above analysis of the mechanical properties of the water lily fiber reinforced polyester resin composites with different weight percentages of fiber, it was found that the composite with 40 wt.% fiber exhibited superior tensile and flexural strength compared to the other fiber contents. It can be inferred from the above findings that the water lily fiber reinforced polyester resin composite produced in this research study is inexpensive and has good mechanical properties. As a result, it might be utilized for applications like electronic packaging, building components, and automotive interior elements.

CONCLUSION

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

1. Water lily fiber reinforced polyester composites with different fiber contents were successfully fabricated using a simple hand lay-up technique.
2. The tensile strength was found to increase with a fiber content up to 40 wt.%. Beyond that content, the tensile strength decreased owing to the poor bonding between the fiber and the matrix material.
3. The flexural strength of the fabricated composite grew with the increase in the fiber weight percentage.
4. The newly developed water lily fiber reinforced 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 packaging.
5. Water lily fiber reinforced polyester composites can be utilized as an alternative to synthetic fiber reinforced composite materials.

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