



## Research Article

# Investigation on Mechanical Properties of Bamboo and Coconut Fiber with Epoxy Hybrid Polymer Composite

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The present study focused to improve material characteristics and quality in terms of the NaOH concentration for treating the coconut and bamboo fiber to enhance the mechanical properties of natural fiber polymer-based hybrid composites. The NaOH-treated fibers were washed thoroughly using distilled water and allowed to dry for 24 hours. Composition of each specimen, bamboo (B) and coconut (C) fiber with epoxy composite, was prepared by hand layup process as per the American Society for Testing and Materials (ASTM) standard. The proportionality of the material was carefully fulfilled according to the previous literature reports. The weight fraction of the composite material content was set to be 30% and 70% of epoxy (E) resin and isolated fibers. Three distinct criteria were used to calculate mechanical parameters such as tensile strength, flexural strength, and material hardness. It was found that the combination of 70% E with 30% BC of hybridized composite had a maximum tensile strength of 62.42 MPa, whereas the flexural strength and hardness of the other combinations, such as 70% E with 30% C and 70% E with 30% B, were observed to be 58 MPa and 185 HRC (Hardness Rockwell C), respectively.

## 1. Introduction

The past few decade materials accrued from the surrounding nature such as wood, sticks, bricks, stones, animal skins, and bones. However, the people are fascinated to weave natural fibres to make cloths with composed materials which are silk and cotton. Highly, the synthetic materials from plastics can

be organic and inorganic category or natural fiber or synthetic material. The researches encountered the need of the customer represented as synthetic organic plastics and essentially termed as polymers. Some other elements contained nitrogen, oxygen, silicon, chlorine, etc. In general, polymers are regulated by the process of polymerization, and monomers are bonded in line chain mode. Composite

material is defined as a mixture of matrix and reinforcement to make superior properties of the components. Based on the material dimension, alignment and angle position which will affect the properties of material [1]. The past decade composite materials were dominated as emerging materials such as plastics, mica, and ceramics. However, in order to establish applications of composite materials, the market focused on cost, availability, and safety. As a result, the market has steadily grown and penetrating acquired materials. Recently, several innovative techniques were done in composite industries and overcome certain cost hurdles. Accordingly, different essential things should be followed up with respect to designing, tooling, quality control/assurance, material process, etc. [2]. Fiber-reinforced polymer offered cost-effectiveness to overcome the market dream, and certain applications may cover both cost and weight such as cascades for engines, replacements for welded metallic parts, cylinder, and ducts. Usage of composite is increased day by day, and adoption increased throughout the industry, and composites are lightweight, more stiffness, more strength, etc., and additionally, their corrosion and chemical resistant in nature functions with increasing the service life during the cycle and all-natural composite structure using many applications and materials used based on resin soybean oil and natural fibers such as flax, recycled paper, and cellulose. Then, the researcher team focused on the next gen of bio-composites with the example of fiber-reinforced composite with the combination of matrix and reinforcement from natural and renewable resolution termed as hybrid composite. Recently, the bamboo can be significantly used because of its easy availability. It has appreciable mechanical characteristics. It can be recyclable. In addition, wastes from bamboo can be effectively utilized in the form of fibers, ash, and particulates. Different studies have reported that the bamboo fibers can be accompanied effectively for the corresponding increase of the mechanical properties of the composites. As reported elsewhere, biodegradability and thermal stability the of matrix can be significantly improved with the addition of bamboo fiber. Similarly, the coconut fiber is known as a nonedible, which is widely considered as waste material and usually dumped in landfills. Also, this possesses good strength and modulus. Previous researches have shown that coconut fiber has the ability to improve the compressive strength when incorporated into epoxy matrix. The tremendous factors were considered to invent new manufacturing lightweight composites [3]. Figure 1 displays the methods and stages of fabrication. In the present study, the NaOH concentration for treating the coconut and bamboo fiber to enhance the mechanical properties of natural fiber polymer-based hybrid composites was investigated.

## 2. Literature Review

Based on the previous experimental results, the highest mechanical properties, with tensile strength of 39.16 MPa and flexural strength of 61.10 MPa measurement (date palm hybrid composites), can be achieved by nonhybridization. The properties of bamboo/palm hybrid polymer composites varied depending on hybridization or nonhybridization.

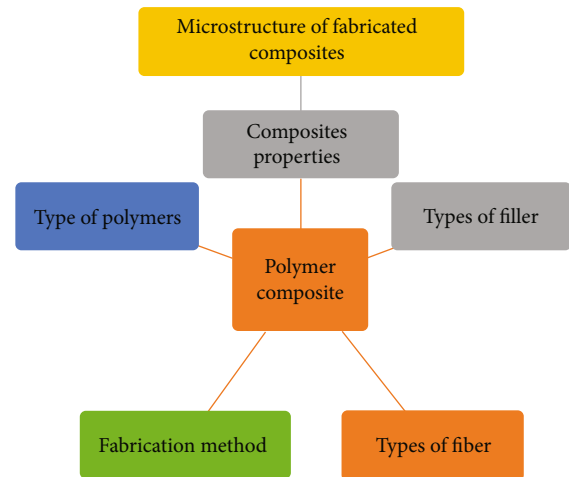


FIGURE 1: Methods and stages of fabrication.

Water absorption treatment has shown a significant result of the reduction of hydrophilic characteristics followed by the material treatment to agglomerate the particle and achieve excellent adhesion between the materials [4]. The effect of fiber loading on the performance of sisal and bamboo epoxy resins. They used NaOH to remove the hydrophilic characteristics of the hybrid composite hydroxyl groups in hemicellulose, cellulose, and lignin. As a result, the material had achieved high adhesion between fiber and matrix [5]. Alkaline treatment reduces the mechanical strength of bamboo. The contact between untreated bamboo and epoxy resin is poor. If the tensile strength and Young's modulus of the bamboo fiber fall, the adhesion between bamboo fiber and epoxy resin could be enhanced by alkali treatment [6]. Unidirectional fiber pattern, different overlapping length of adjacent fiber bundle, and randomized of individual fiber end. Tensile stiffness is unaffected by discontinuity pattern, but inserted randomized fiber and discontinuity resulted in a loss of 85% longitudinal tensile strength in comparison to unidirectional bamboo fiber composite [7]. Six distinct random oriented fiber-reinforced polyester composite samples were created. Tensile strength and Young's modulus both reduced coir fiber inclusion, however, increasing the stiffness and ductility of coir fiber composites [8]. Effect of bamboo fiber-reinforced epoxy and rice husk filler loading on modulus of elasticity, flexural strength, and impact strength was evaluated. 15% filler loading resulted in higher modulus of elasticity, flexural strength, and impact strength. The modulus of elasticity increases linearly with filler loading [9]. When coconut coir fiber was combined with epoxy, it resulted in a plastic material with corresponding tensile strength, input strength, and hardness strength. The hardness of the material increases as the weight percentage of the coir fiber increases. The maximum tensile strength of bamboo fiber was 84.61 MPa [10, 11].

## 3. Experimental Work

3.1. *Specimen Preparation.* The experimental work was designed and constructed in accordance with the American



FIGURE 2: Bamboo and coconut shell powder.

TABLE 1: Properties of coconut fiber and bamboo fiber.

Properties	Coconut fiber	Bamboo fiber
Density	1.288 g/cm <sup>3</sup>	0.9 g/cm <sup>3</sup>
pH	11.6	6
Moisture content	10% max.	14.01%
Sp. gravity	1.33	0.68
Water absorption	23%	26.2%

TABLE 2: Properties of epoxy resin.

Properties	Values
Grade	LY556
Color	Pale yellow
Sp. gravity	1.10-1.20
Epoxy content	5.0-5.9 Eq/kg
Volatile content	0.75%

TABLE 3: Material composition.

Samples	Bamboo fiber	Coconut fiber	Epoxy	Treatment
Bamboo (B)/epoxy (E)	30	—	70	
Coconut (C)/epoxy	—	30	70	NaOH
Bamboo/coconut/epoxy	15	15	70	

Society for Testing and Materials (ASTM) standard plate dimensions of 300 \* 250 \* 10 mm. First stage of work is mixing resin and hardener with tabulated/calculated proportion and assured by weight measuring equipment. All the components are completely reacted on the specific container. Figure 2 shows the bamboo and coconut shell powder, and Table 1 shows the properties of coconut fiber and bamboo fiber which were determined as per the standard procedure. Epoxy resins (polyepoxides) are a class of reactive polymers which usually contain epoxide groups. In the present study, the epoxy resin (LY-556) was used as matrix

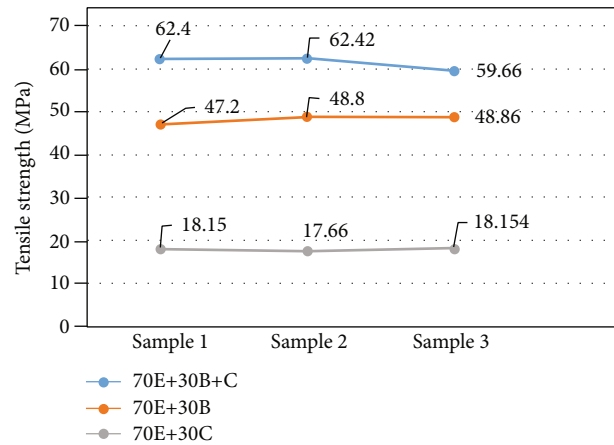


FIGURE 3: Samples testing for tensile strength.

binder which was supplied by StarChem, India Ltd. Epoxy resin and hardener mixing thoroughly with the proportions of 10:1. Table 2 shows the properties of epoxy resin that were obtained from the experimental procedure. Primary polymer content is distributed uniformly over the plate and rolled up. Secondary layer fiber content was placed over the surface and matted up uniformly by process of rolling. Excess air was evacuated and contained by the rolling tool while under brief pressure. The final stage of the process ensures the ASTM dimensions with agreement to close the mould by wooden plate or steel plate with uniformly applied specific load. It has been considered for curing the epoxy after loading. All of the specimens were constructed to provide ASTM standard dimensions and are sliced to perform various tests to evaluate the composite. Table 3 displays the material composition in which the samples were made.

#### 4. Result and Discussions

Mechanical testing is performed on three separate samples (70E + 30B, 70E + 30C, and 70E + 30BC) (tensile, hardness, and flexural testing). The testing ranges may vary depending on the amount of samples. Figures 3–5 show the average values for each testing result. Figure 3 shows that 70E + 30 BC had a maximum tensile strength of 62.42 MPa, which remained constant for samples 1 and 2. Similarly, Figures 4 and 5 show the maximum hardness and flexural strength for which the sample was suitable. For samples 2 and 3, 70 E + 30B obtained the ideal range and sustained 185 HRC, while 70E + 30C obtained the consistent range. For samples 1 and 3, the best range and sustained average value for flexural strength was 70E + 30C.

Figure 6 depicts a graphical representation of varying fiber contents versus tensile strength variation for three different combinations of changed surfaced material. The true measured tensile strength was increased by increasing the ranges up to 62.42 MPa. Tensile strength significantly decreases in the order of 48.8 MPa and 18.15 MPa for bamboo epoxy and coconut epoxy alone. The descent of the tensile strength gradually slant in the order of 48.8 MPa and 18.15 MPa for bamboo epoxy and coconut epoxy alone.

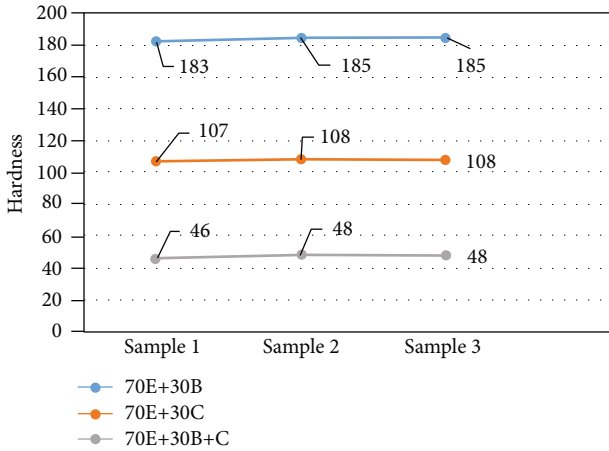


FIGURE 4: Samples testing for hardness (HRC).

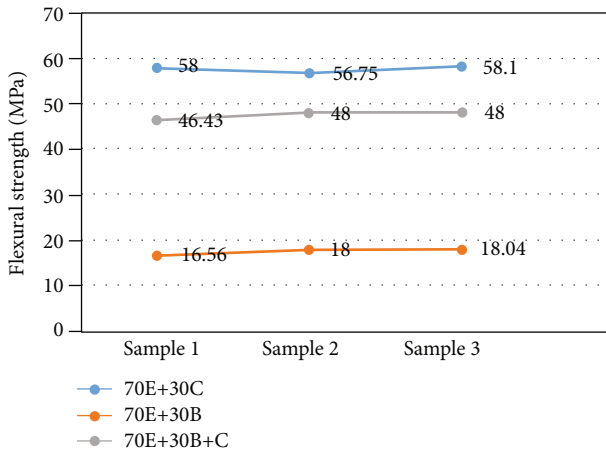


FIGURE 5: Samples testing for flexural testing.

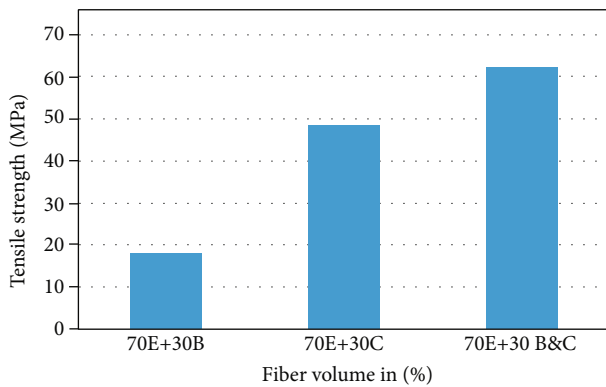


FIGURE 6: Tensile strength with different fiber contents.

The addition of NaOH treatment for both bamboo and coconut fiber isolated and combined material marginally were increased correspondingly. After alkali treatment, the fiber was derived from the sun light reaction for 24 hours, and a finer fiber with excellent solid crystal was generated. During the material composition and epoxy combination

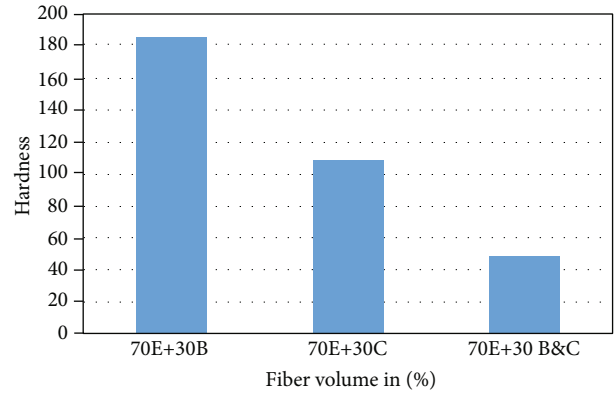


FIGURE 7: Hardness vs. fiber volume in %.

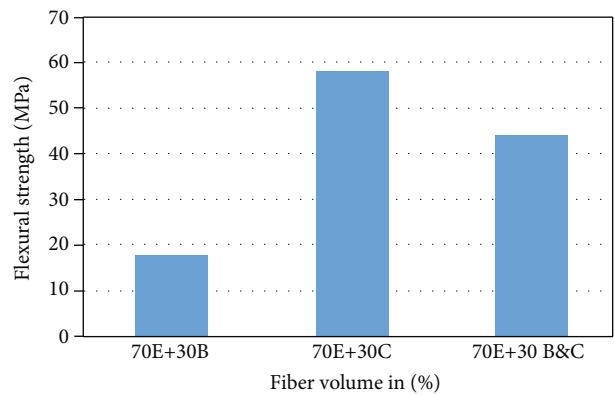


FIGURE 8: Flexural strength for various fiber contents.

were perfectly adhered with the material inspected by the testing result, the rate of tensile strength had reached 62.42 MPa for the recognized designation of the material 70E + 30BC.

Figure 7 indicates the hardness range 185 HRC at 70E + 30B. This reversal character was improved as a result of material dispersion, and surface modification treatment is a significant factor. A single-dried material is arranged uniformly, and fiber contents were distributed along the plate dimension. Once epoxy was coated over surface and after loading the material, perfect interaction between the materials has been formed. Interlocking the material and bonding structure to a greater level resulted in hardness tests at a maximum of 185 HRC and corresponding 70E + 30C and 70E + 30BC observed at 108 and 48 HRC, respectively.

Figure 8 represents 70E + 30C composite with a maximum flexural strength of 58 MPa. The important factor is considered to reach the maximum value for loading fiber content of materials of 30% for all the fibers bamboo and coconut; additionally, surface treatment had been done to improve the material properties for the superiority level. Certain parameters were reached by the isolated combination of the ingredients (hardness and flexural strength). However, the hybrid combination 70E + 30BC achieved the majority of the expected features.

## 5. Conclusion

The present study is aimed at improvising the mechanical properties of coconut and bamboo fiber. Accordingly, in order to attain the best mechanical qualities, three alternative fiber loadings were examined. It was found that the material configuration comprised flawless orientation of the fiber was retained after the surface treatment followed by sun light exposure that was made ideal crystal structure forms. From the studies, the experimental results of the bamboo and coconut epoxy hybrid composites demonstrated the highest mechanical performance compared to bamboo and coconut composites without hybridization. Significantly, the maximum tensile strength of the 70E + 30BC hybrid composite was observed to be 62.42 MPa. Likewise, the 70E + 30B and 70E + 30C combinations achieved maximum hardness and flexural strength of 185 HRC and 58 MPa, respectively.

## Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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