

# Fabrication and Property Evaluation of Hemp–flax Fiber Reinforced Hybrid Composite

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**Abstract** In terms of innovative and high-performance reinforcement, hemp and flax solutions have not only met the technical requirements of composite manufacturers but also reduced environmental impacts. This paper aims to fabricate the hemp–flax fiber reinforced hybrid composite and to determine the mechanical properties such as flexural strength, flexural modulus along with moisture absorption performance. Hand lay-up method was used to fabricate the composites. The specimens were tested with the universal testing machine (UTM). Hybridization effect is clearly visible with the results. The results revealed that, the highest flexural strength (53.45Mpa) as well as flexural modulus (3.43Gpa) was exhibited by the sample composed of 30% hemp-10% flax reinforced hybrid composite. Water absorption behavior has shown that hybridization has increased the water uptake.

**Keywords** Hemp Fiber, Flax Fiber, Flexural Properties, Water Absorption, Composite

## 1. Introduction

Nowadays due to some inherent properties natural fiber reinforced composites are superior to synthetic composite because of its light weight, biodegradability, renewability and environment friendly nature [1,2]. Cost optimization and ability to withstand in the erosive environment accelerate the potential applications of these composites in many rapidly growing engineering fields [3, 4]. Specific properties of natural fiber reinforced composites compared to the conventional ones encourage its versatile use. At the same time, potentiality of the natural fibers is hindered by the discrepancy of fiber and poor water absorption characteristics [5]. In spite of these circumstances comprehensive researches are being carried out to use natural composites as a proficient material in the electrical and electronic equipment, civil constructions, chemical

equipment and machinery constructions, automobile and marine industries, aircraft manufacturing, furniture and so on [6-8].

Among all of the natural fibers, hemp fiber contains some unique physical and mechanical properties [9, 10]. The impact of mechanical properties of hemp fiber increases with a growing weight fraction of the fibers when it is immersed into water [11]. A research was conducted on hemp fiber reinforced polythene composite to study the tensile and flexural strength with a variable fiber content ranging from 10% to 30% which revealed that tensile strength increases and flexural strength decreases gradually compared with 50% fresh and recycled HDPE [12].

Flax is another natural fiber renowned for its rigidity. It is the perfect replacement for the synthetic fiber and big revolution for the construction and roofing sector. Flax fibers and its composites possess great advantages and they have a wide range of applications because of their unique properties [13]. Lot of research has been performed on the mechanical, chemical and also physical properties of flax fibers and their composites [14, 15]. It was found that mechanical properties of flax fiber increases with an increasing weight fraction of the fibers because of its cellulose content when it is immersed into water [16].

Mechanical as well as ecological properties of Flax and hemp fibers position them to be increasingly used in various, innovative sectors of the industry taking into account sustainable development, performance and competitiveness [17-23]. Addition of epoxy resin to the composite manufacturing shows the remarkable effect on their properties [24-27]. Certain rules should be followed to prepare the epoxy resin according to the properties of both epoxy and hardener [28].

## 2. Materials and Method

### 2.1. Materials

Reinforcements such as hemp and flax fibers were

collected from Jute Research Institute, Dhaka, Bangladesh. Figures 1 and 2 show the photograph of hemp and flax fibers respectively. Table 1 indicates the typical mechanical properties and table 2 specify the chemical composition of hemp and flax fibers. Epoxy resin (LAPOX L-12) with hardener (LAPOX K-6) was used as matrix and was procured from Nasim Plastic Industries Limited, Dhaka, Bangladesh.



**Figure 1.** Hemp fibers



**Figure 2.** Flax fibers

**Table 1.** Typical Mechanical Properties of Hemp and Flax Fiber [29, 30]

Properties	Materials	
	Hemp fiber	Flax fiber
Density (g/cc)	1.4	1.4
Tensile strength (MPa)	550–900	800–1500
Elastic modulus (GPa)	70	60–80
Specific strength (s/g)	393–643	571–1071
Specific modulus ("/g)	50	43–57
Elongation at failure (%)	1.6	2.7–3.2
Moisture absorption (%)	6–12	8–12

**Table 2.** Chemical Composition of Hemp and Flax Fiber [31, 32]

Components	Materials		
	Hemp fiber	Flax fiber (Raw flax)	Flax fiber (Ratted flax)
Cellulose (%)	77.5	56.5	64.1
Hemi-cellulose (%)	10.0	15.4	16.7
Lignin (%)	6.8	2.5	2.0
Pectin (%)	2.9	3.8	1.8
Fat & wax (%)	0.9	1.3	1.5
Water soluble materials (%)	1.8	10.5	3.9

## 2.2. Method

### 2.2.1. Sampling

The samples are identified as mentioned in the following table 3.

**Table 3.** Sample Identification

Sample types	Identification
40% hemp + 0% flax+ 60% (epoxy resin + hardener)	A
30% hemp + 10% flax+ 60% (epoxy resin + hardener)	B
25% hemp + 15% flax+ 60% (epoxy resin + hardener)	C
15% hemp + 25% flax+ 60% (epoxy resin + hardener)	D
10% hemp + 30% flax+ 60% (epoxy resin + hardener)	E
0% hemp + 40% flax+ 60% (epoxy resin + hardener)	F

### 2.2.2. Fabrication of Composites

Hand layup technique was followed to fabricate the hemp-flax reinforced hybrid composites. Hemp and flax fiber were cut with 30cm long. The Epoxy resin and hardener was mixed in the proportion of 10:2. The epoxy and hardener were mixed thoroughly in a clean beaker by using a glass rod to avoid formation of air bubbles. A glass plate of the dimension 40cm ×40 cm was positioned on a suitable place. A mylot paper with similar dimension to the glass plate was cut and placed on the glass plate. Then fibers were placed homogeneously on that paper before applying the epoxy resin. Extra attention was paid so that the fibers were precisely and uniformly distributed. To ensure the proper organization of the filaments, they were preserved in that form under loaded condition with a weight press for 5 to 10 minutes. Then epoxy resin with hardener was applied thoroughly on the layers of fibers and rolled with a hand roller machine. After it was covered with another mylot paper and rolled with the hand rolling machine to remove unwanted air bubbles and uniform distribution. A dead weight of 15 kg was loaded on the arrangement for 18 to 20 hours at room temperature. Same process was followed to produce the other specimens.

### 2.2.3. Testing of Samples

The flexural properties such as Flexural strength (FS) and Flexural modulus (FM) of the prepared composites were assessed by using universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD, series S, UK) at Institute of Radiation and Polymer Technology Laboratory, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. Flexural testing was carried out as per ASTM: D790-10 [33]. Crosshead speed of 10 mm/min and a gauge length 50 mm were maintained.

For the measurement of water absorption percentage, each composite was weighted before test. Cut samples

were kept in an oven at 80°C for 24 hr. It was taken out from the oven and immediately weighed. Then, composite samples were immersed in a static water bath at 25 °C for time interval of 12 hours (up to 144 hours). After certain periods of time, samples were taken out from the bath and wiped by tissue paper, then weighed. Water uptake percentage was determined by using the following equation [34, 35].

$$(\%) \text{ weight gain} = \left[ \frac{W_f - W_i}{W_f} \right] \times 100$$



Figure 3. Universal Testing Machine (UTM)

## 3. Results and Discussion

The maximum stress experienced by any material or object at the instant of its failure is depicted by the flexural properties. The quality of structures being used for construction is well judged by flexural strength [36, 37]. Flexural properties of hemp and flax fiber reinforced hybrid composite were evaluated to use it as a frame of wooden house [38].

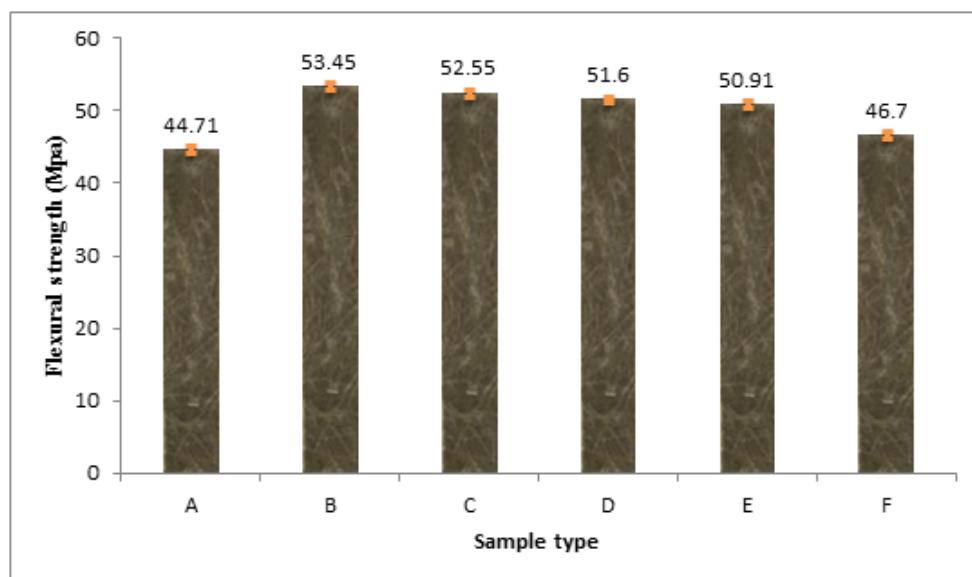


Figure 4. Effect of flexural strength on hemp and flax fiber reinforced hybrid composite

### 3.1. Flexural Properties

#### 3.1.1. Flexural Strength

The above figure (figure 4) depicts the relation between flexural strength and weight fraction of composite. It is clearly marked from the figure that pure hemp has the lowest flexural strength and the second lowest is the pure flax composite. Flexural strengths for the remaining composites are close to each other. Maximum flexural strength 53.45 Mpa has been observed for sample B (30H/10F) and gradually decreases for the remaining composites as the amount of hemp fiber content decreases for the respective composites. Hemp fiber imparts more strength and stiffness because of its constituents (cellulose, hemi-cellulose, lignin and pectin) and for the containment of fibers within the tissue [10]. It can be assumed that, in this hybridization hemp fiber has comparatively more influence on flexural strength than the flax fiber and the samples order are found as B>C>D>E>F>A.

#### 3.1.2. Flexural Modulus

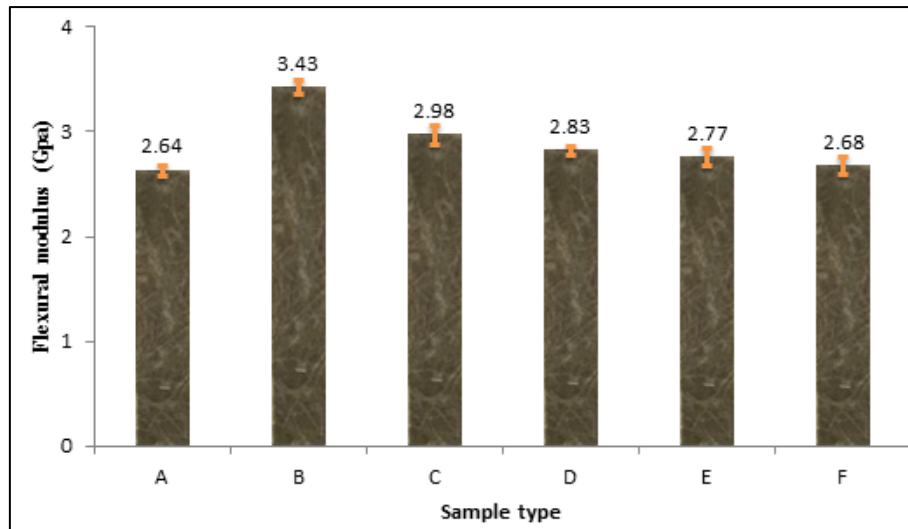


Figure 5. Effect of Flexural Modulus on Hemp and Flax Fiber Reinforced Hybrid Composite

The above trend (figure 5) demonstrates the flexural modulus (Gpa) for various composites with varying weight fraction. It is clear from the figure that, there is no such major variation in flexural modulus. Both pure hem and flax composite have lower flexural modulus compared to the others. It can be well specified from figure 5 that hybridization has definitely improved the flexural property. Sample B shows the highest flexural modulus 3.13Gpa and this is very robust compared to other composites. Depending on flexural modulus, the samples order for the hem-flax reinforced hybrid composite are found as B>C>D>E>F>A.

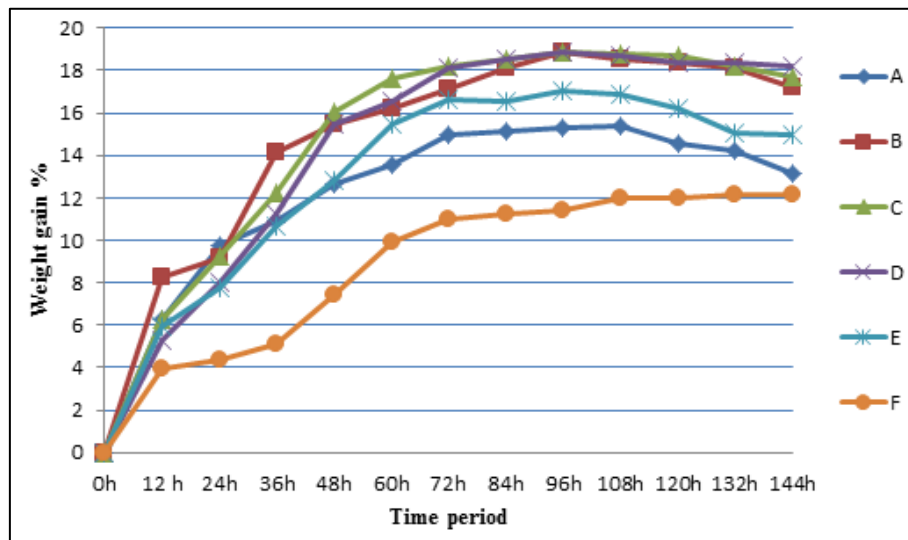


Figure 6. Time Period vs. (%) of Weight Gain of Composites

### 3.2. Water Absorption

One of the major concerns is the moisture absorption test for using composite material in outdoor application as well as to check its degradability [38-40]. The water absorption percentages of hemp and flax fiber reinforced hybrid composite specimens are shown in the above illustration for different soaking time. All composites showed maximum value after 96 hours, and the least absorption in the beginning. All composites exhibited a similar trend excluding sample D (15hemp-25flax). Pure hemp exhibited highest absorption behavior on the contrary pure flax (F) absorbed the least moisture and the moderate behavior was observed for hybrid composites. The highest water uptake percent was observed for sample B. The samples A, B, C shows gradual increase in absorption up to 96 hours and then starts to decrease. In case of sample D gradual weight gain continues till 96 hours and reaches at maximum. Then it gradually decreases and again starts to increase after 144 hours. The trend for sample E shows that, weight gain characteristics is same as the other composites till 96 hours but remains almost constant after that. This phenomenon can be explained by diffusion mechanism, capillary action, or the manner of transport of water molecule [41]. Whereas pure flax (F) gains weight progressively till 144h hours.

The effect of fiber content on the flax –hemp fiber hybrid composite is noticeable. 30hemp-10flax exhibited highest flexural properties in terms of flexural strength and flexural modulus. Fiber content by weight has the favorable impact on flexural properties of hemp fiber than flax fiber [42]. At the same time hemp fiber is more susceptible to moisture absorption than the flax fiber. In this sense 30hemp-10flax shows relatively optimum property while considering strength and water uptake than the other samples.

### 4. Conclusions

The motivation of this research was to investigate the flexural and water absorption behavior of hemp-flax fiber reinforced hybrid composites. Both the fiber contents were varied between 10 to 30%. The flexural strength (53.45Mpa) as well as flexural modulus (3.13Gpa) of 30hemp-10flax hybrid composite exhibited better results than any other composite. Different scenario has been observed for water absorption behavior. The tendency of water absorption was also perceived higher in 30hemp-10flax hybrid composite than any composite. So it would be wise to use this combination where strength and durability is of major concern and not for outdoor application where susceptibility to water is more. Hemp and flax straw with cement, lime, clay binders etc. are used to prepare composite for various applications especially replacing wooden structures [38]. But no specific proportion of these two fibers is not maintained. This

30hemp-10flax can be a useful combination for using it in the frames of wooden house.

It can be said that though hybridization has definitely improved the mechanical properties, trade-offs should be considered between strength and moisture absorption for application.

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