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Mechanical Properties of Flax Fiber Reinforced Hybrid Composite

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ABSTRACT

Hybrid composites are fabricated by the combination of two or more fibers using a single matrix. Natural fiber reinforced composites are playing a vital role in recent years due to its biodegradable, recycling and eco-friendly nature. In this present work biodegradable hybrid composites are developed with Basalt fiber and commercially available Flax fiber as reinforcing fibers with epoxy resin as a matrix. The primary objective of my work is to increase the mechanical properties of natural flax-basalt fibers, this can be done using the filler material such as carbon nanotubes. In this study, the work has been done to demonstrate the fabrication of Flax-Basalt fiber reinforced Epoxy resin with special attention on the influence of stacking sequence (BFBFB) and weight percentage (0%,1%) of carbon nanotubes in epoxy resin. The composite laminate is fabricated by using compression moulding technique. The mechanical behaviour of prepared composites has been investigated using UTM.

1. INTRODUCTION

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly [1]. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective [2]. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle [3]. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals [4].

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of the transportation industry. Thus, the shift of composite applications from aircraft to other commercial uses has become prominent in recent years [5]. Increasingly enabled by the introduction of newer polymer resin matrix materials and high-performance reinforcement fibers of basalt, flax and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs [6].

High performance FRP can now be found in such diverse applications as composite armouring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers [7]. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and filets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc [8].

Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures [9]. Composites are now extensively being used for rehabilitation/ strengthening of preexisting structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity [10].

A composite material consists of two or more physically and/or chemically distinct, suitably arranged or distributed phases, with an interface separating them. It has characteristics that are not depicted by any of the components in isolation [11]. Most commonly, composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, noncontinuous, phase called the reinforcement, which is usually harder and stronger [12].

2. MATERIALS AND METHODS

2.1 MATERIALS USED FOR COMPOSITES

The raw materials used in this work are Flax fiber, Basalt fiber, Epoxy Resin and Carbon Nano Tubes. Flax fiber is extracted from the bast or skin of the stem of flax plant. Flax fibers are arranged in the form of thin filaments, grouped in longitudinal slender bundles distributed circularly around a central wooden cylinder. Flax fiber is soft, lustrous and flexible, stronger than cotton fiber but less elastic [13].

Basalt Fibers are made from extremely fine fibers of basalt which is composed of the mineral's plagioclase, pyroxene, and olivine. Basalt fibers are produced in a continuous process similar in many respects to that used to make glass fibers. The fibers typically have a filament diameter of between 9 and 13 µm which is far enough above the respiratory limit of 5 µm to make basalt fiber a suitable replacement for asbestos. They also have a high elastic modulus, resulting in excellent specific tenacity [14].

The epoxy group is characterized by its reactivity towards both nucleophilic and electrophilic species and it is thus receptive to a wide range of reagents or curing agents. Industrial interest and use of these resins resides in both the valuable properties of the cured resin, which include good adhesion to many substrates, relatively high toughness, good environmental resistance, high electrical resistivity, low shrinkage [15].

Carbon nanotubes (CNTs) are cylindrical molecules that consist of rolled-up sheets of single layer carbon atoms (graphene). This feature combined with carbon nanotubes' natural inclination to rope together via van der Waals forces, provide the opportunity to develop ultra-high strength, low-weight materials that possess highly conductive electrical and thermal properties. This makes them highly attractive for numerous applications.

2.2 METHOD OF PREPARATION OF COMPOSITE

Compression molding is the most common thermoset and thermoplastic polymer composite manufacturing process. It is normally used to produce composite components in high production volume such as automotive components. Compression molding is a process of molding in which a feeding material is placed into an open, heated mold cavity. The mold is then closed with a top plug and compressed with large hydraulic presses in order to have the material contact all areas of the mold.

The flax and basalt fiber were taken and cut to uniform size of (400*200) mm length. After cutting the fiber, it was measured using a digital weighing machine. The fibers were taken and evenly arranged in a die by applying modified resins in each layer. Then it is placed in the compression moulding machine where a fixed amount of heat and pressure is applied on it. Thus, the two different samples of composites were prepared by adding the 1% weight percentage of CNT powder. The weight percentage of CNT powder in composites is shown in Table 2.1. During the fabrication process a die of size (400*200) sq mm was used and the fabricate composite of thickness 3 mm was obtained.

Table 2.1. Varying Weight % of CNT powder in composite

SAMPLE	FIBER Wt%	RESIN Wt%	CNT Wt%
0% CNT	50	50	0
1% CNT	50	49	1

3. RESULTS AND DISCUSSION

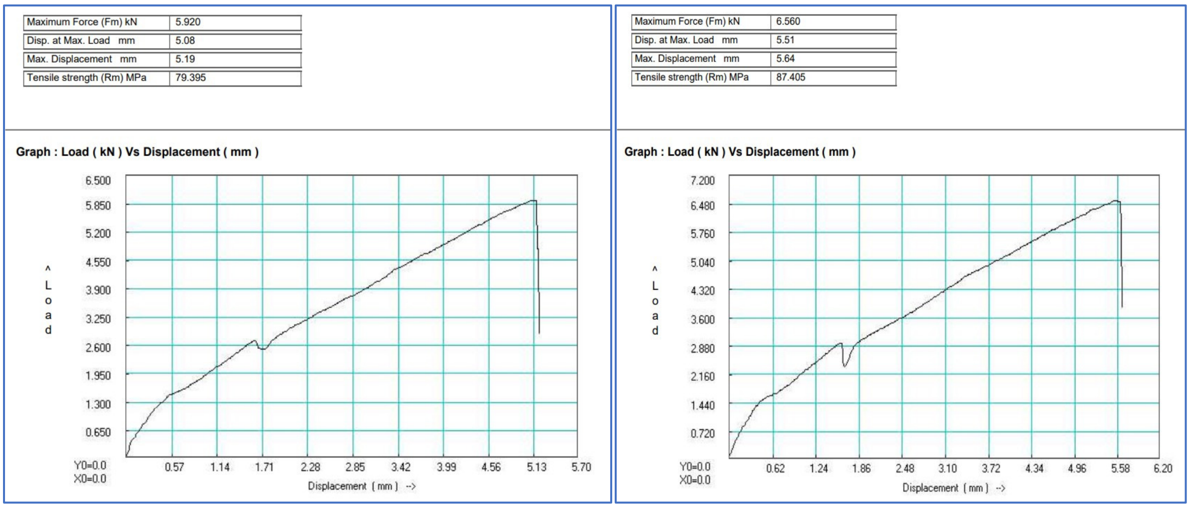
3.1 TENSILE STRENGTH

A universal testing machine is used to evaluate tensile strength for the developed samples. The tensile strength is Maximum load that a material can support without fracture when being stretched, divided by the original cross-sectional area of the material. Figure 3.1 & Table 3.1 shows the Tensile Strength for Developed Samples of Composites.

Tensile test on the sample with flax basalt fibre reinforced epoxy resin showed a tensile strength of 79.40 MPa and sample with flax basalt fibre reinforced epoxy resin with CNT showed tensile strength of 87.41 MPa. We can observe that the sample 2 with CNT has increased 10.10% more tensile strength that sample 1.

Table 3.1 Tensile Strength of Developed Samples of Composites

Sample Name	Test Parameter	UOM	Test Method	Result
Flax-Basalt Hybrid	Tensile Strength	MPa	ASTM D638	79.40
Flax-Basalt Hybrid CNT	Tensile Strength	MPa	ASTM D638	87.41



Maximum Force (Fm) kN	5.920
Disp. at Max. Load mm	5.08
Max. Displacement mm	5.19
Tensile strength (Rm) MPa	79.395

Maximum Force (Fm) kN	6.560
Disp. at Max. Load mm	5.51
Max. Displacement mm	5.64
Tensile strength (Rm) MPa	87.405

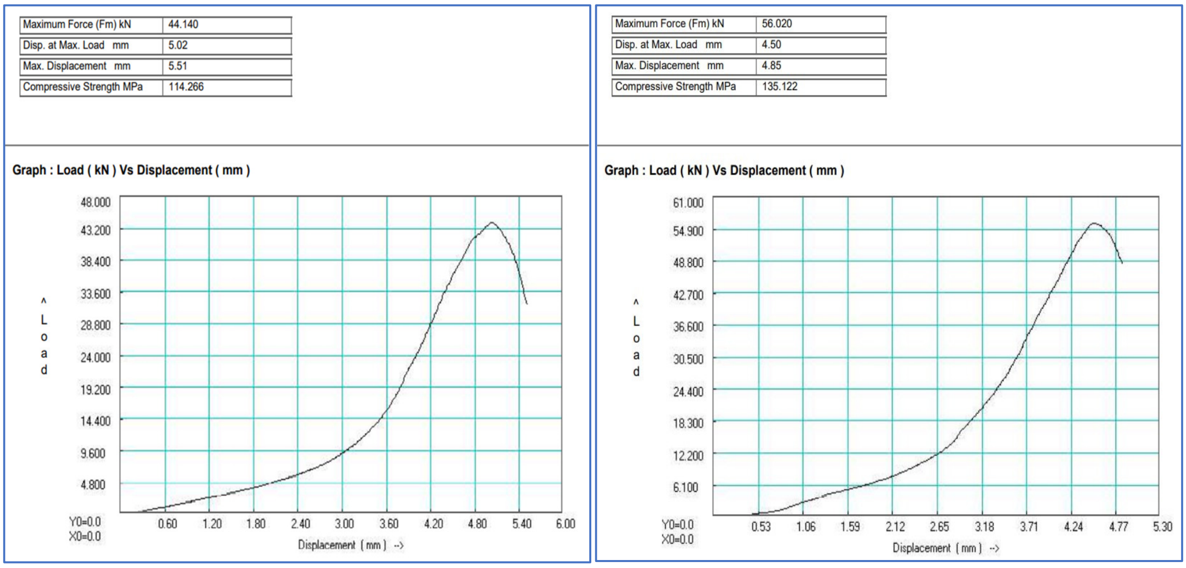
Figure 3.1 Tensile Strength of Developed Samples of Composites

3.2 COMPRESSIVE STRENGTH

A universal testing machine is used to evaluate compressive strength for the developed samples. A Compressive strength is the maximum compressive stress that, under a gradually applied load, a given solid material can sustain without fracture. Figure 3.2 & Table 3.2 shows the Compressive Strength for Developed Samples of Composites. Compressive test on the sample with flax basalt fibre reinforced epoxy resin showed a compressive strength strength of 114.27 MPa and sample with flax basalt fibre reinforced epoxy resin with CNT showed compressive strength of 135.42 MPa. We can observe that the sample 2 with CNT has increased 18.50% more compressive strength that sample 1.

Table 3.2 Compressive Strength of Developed Samples of Composites

Sample Name	Test Parameter	UOM	Test Method	Result
Flax-Basalt Hybrid	Compressive Strength	MPa	ASTM D695	114.27
Flax-Basalt Hybrid CNT	Compressive Strength	MPa	ASTMD695	135.42



Maximum Force (Fm) kN	44.140
Disp. at Max. Load mm	5.02
Max. Displacement mm	5.51
Compressive Strength MPa	114.266

Maximum Force (Fm) kN	56.020
Disp. at Max. Load mm	4.50
Max. Displacement mm	4.85
Compressive Strength MPa	135.122

Figure 3.2 Compressive Strength of Developed Samples of Composites

3.3. FLEXURAL STRENGTH

A universal testing machine is used to evaluate flexural strength for the developed samples. It is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Table 3.3 shows the Flexural Strength for Developed Samples of Composites. Flexural test on the sample with flax basalt fibre reinforced epoxy resin showed a flexural strength of 267.68 MPa and sample with flax basalt fibre reinforced epoxy resin with CNT showed flexural strength of 286.85 MPa. We can observe that the sample 2 with CNT has increased 7.16% more flexural strength that sample 1.

Table 3.3 Flexural Strength of Developed Samples of Composites

Sample Name	Test Parameter	UOM	Test Method	Result
Flax-Basalt Hybrid	Flexural Strength	MPa	ASTM D790	267.68
Flax-Basalt Hybrid CNT	Flexural Strength	MPa	ASTM D790	286.85

3.4. IMPACT ENERGY

An Izod testing machine is used to evaluate impact energy for the developed samples. Table 3.4 shows the Impact Strength for Developed Samples of Composites. Impact test on the sample with flax basalt fibre reinforced epoxy resin showed a impact energy of 84 KJ/m² and sample with flax basalt fibre reinforced epoxy resin with CNT showed impact energy of 92 KJ/m². We can observe that the sample 2 with CNT has increased 9.52% more flexural strength that sample 1.

Table 3.4 Impact Strength of Developed Samples of Composites

Sample Name	Test Parameter	UOM	Test Method	Result
Flax-Basalt Hybrid	Impact Energy	KJ/m²	ASTM D256	84
Flax-Basalt Hybrid CNT	Impact Energy	KJ/m²	ASTM D256	92

4. CONCLUSION

- The objective of this project work is to observe the mechanical properties of developed flax basalt hybrid composite and flax hybrid composite with CNT.
- The work has been done to demonstrate the fabrication of Flax-Basalt fiber reinforced Epoxy resin with special attention on the influence of stacking sequence (BFBFB) and weight percentage (1%) of CNT in epoxy resin. The composite laminate is fabricated by using compression moulding technique.
- Here we performed Tensile Strength, Compressive Strength and Flexural Strength by using Universal Testing Machine and Impact Energy using Izod Testing machine.
- By observing mechanical testing values of our developed hybrid sample 1 and hybrid sample 2 (with CNT), if we increase the wt % of Carbon Nanotubes (i.e, filler) in the fabricated composite it will increase the Mechanical Properties of developed composite.
- From the results obtained theoretically and experimentally, the combination of flax and basalt fiber with CNT developed composite shows better mechanical properties.

5. REFERENCES

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