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Experimental Testing On Carbon/Basalt Interwoven Fabric to Determine Its Mechanical Properties

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Abstract: In this research an attempt is made to analyse the mechanical properties for the plain weave hybrid composite of carbon and basalt fibers reinforced with polymer matrix. The interwoven fabric was made by hand-weaving method and various mechanical tests such as tensile, flexural, impact and hardness was carried out on the polymer matrix composite according to ASTM standards. Scanning Electron Microscope (SEM) is used to examine the morphology of fractured surface of hybrid composite during testing.
Keywords: Carbon, Basalt, Interwoven, Hand weaving, LY 556, Mechanical properties

I. INTRODUCTION

In the automotive, aerospace, and other industrial sectors, composite materials reinforced with woven, braided, and knitted fabrics are becoming more and more common for diverse structural applications. Variations of lay-up manufacturing, contact lamination, resin transfer moulding, vacuum/pressure bag moulding, autoclaving of fabric-based thermosetting prepregs, and compression/preform moulding of thermoplastic and thermosetting composites are a few examples of typical processing methods. Glass, aramid, carbon, and hybrid textiles, which are frequently employed as reinforcing materials, are made possible by textile preforming, which plays a significant role in composite technology. The key benefits of woven composites are their great process-ability and cost effectiveness, especially in lay-up manufacture of big structures. Woven fabrics are the most traditional fabrics constructed by weaving yarns together typically at 90° angles. They are of particular interest due to their mechanical performance compared to unidirectional laminate. Thus, that makes woven fabrics to balance properties throughout both the directions. This one layer could provide strength of multi layered composite with unidirectional fabric. In addition, making it light-weight and of less thickness. Another advantage of use of woven fabric in composite is that when composite is punctured fibers around the impact area gives strength independent of damage happened to other fibers [15]. In particular, the textile composite offer better dimensional stability over a large temperature, better impact resistance and tolerances, easier mold ability (due to flexibility).Hybrid composite has been developed to recondition the drawbacks of the single composite. The purpose of hybridization is to construct a new material which will retain the advantages of its constituents but not their disadvantages.

Carbon fiber composites are most widely used nowadays where light weight and high strength components are needed. It should also be noted that the cost of this material is very high compared to other fibers. Basalt fibers on the other hand, are ideally suited for the applications on required resistances against high temperatures, insulation properties. In addition, it has excellent durability and good water resistance and also it is inexpensive [6]. Due to their improved mechanical qualities, basalt fibres have attracted significantly more attention than other conventional fillers (glass fibres) as a source of fibrous reinforcement [16].

The research on creating hybrid composite materials out of carbon fibre mats and basalt fibre mats that are 40% reinforced with a 60% epoxy polymer matrix was presented by Razan A. Alshgari et al [1]. The outcomes demonstrated that the mechanical characteristics of the composite significantly changed when more carbon fibre layers were added.

Naveen et al [3]. looked at how the order of stacking affected the mechanical characteristics of a composite made of basalt and carbon fibre. The composites are created using a compression moulding technique with various ply laminate stacking sequences, with 30% fibre and 70% resin making up each specimen. The outcomes were significantly better for laminates made using carbon fibre as the top layer than with basalt fibre. The process for creating a unidirectional composite material out of basalt and carbon was introduced by Settipalli and Prasad [4]. The mechanical tests were conducted on specimens with various orientations, and the carbon basalt composite at 0 orientation angle produced the best results across the board.

Uzay et, al [5] explained the importance of hybrid composites to obtain desired mechanical and physical properties that cannot be provided from a single type of fiber reinforcement. The findings indicated that intraply hybrid composite laminate had a greater overall energy absorption capacity.

The majority of FRP composites are laminated uniformly, consisting of two or more unidirectional plies stacked on top of one another with the same or different fibre orientations. But if the ply itself is hybrid made by interweaving two different yarns, then the properties of FRP composite thus formed would provide better material properties in some aspects. In this research the different types of composites structures are compared and it takes testing on the standout structure. For this material is chosen with their advantages and disadvantages in their structural, thermal, electrical properties. Composite fabrication method is also needs to be chosen for particular composite based on requirement and resources available. Fabrication of new type of composite material is the focal objective of this particular study.

II. METHODOLOGY

A. Composite Preparation

The interwoven hybrid composite is constructed between carbon fiber and basalt fiber by hand-weaving the plain pattern. Poojan Fiber, Ahmedbad, provided the basalt fibre yarn, while Composites Tomorrow, Vadodara, provided the carbon fibre yarn. Comparison of properties between different materials is given in the Table I which shows the reason for selection of Carbon and Basalt.

TABLE I
Specifications of Various High-Modulus and High-Strength Fibers[19]

Material	Tensile Strength at Break (MPa)	Elongation at Break	Tensile Modulus (GPa)	Density (g/cc)	Melting temperature (°C)
Carbon	4200	1.8%	240	1.78	1200
Basalt	3300	3.15%	94	2.65	1500
E-Glass	2600	3.0%	72	2.55	840
Kevlar-29	3300	4.2%	70	1.44	550

The process of weaving is achieved by passing the weft 90° yarns over and underneath the warp 0° yarns [15]. Plain weave gives the tightly compacted structure with less complexity and manufacturing time than the Twill and Satin weave as shown in fig. 1. Previous studies conducted on hybridization of woven fibre composites mainly focused on stacking sequence of fabric materials, arranged in different layers to offer a distinct property in each ply, with less emphasis on achieving high strength and stiffness in a single ply. This leads to the development of interwoven fabric of carbon and basalt which can done by replacing alternate yarns (either warp and weft) with the yarns showing good strength and resisting many of this disadvantages. This will increase the uniformity of materials composition in both of the directions.

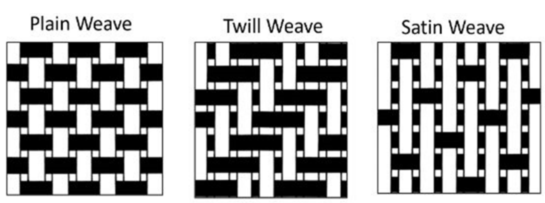

Fig. 1 Weaving Pattern [18]

B. Matrix Selection

Different kinds of organic polymers make up the continuous phase in polymer matrix composites (PMC), whereas reinforced fibres make up the dispersed phase. In order to effectively transfer load between the fibres, the continuous phase acts as a matrix to hold the fibres together. The medium viscosity and chemical resistance of the thermosetting epoxy resin LY 556 make it a popular choice for use as a reinforcing material with hardener HY 951 at a given mix ratio of 100:10 at room temperature. The epoxy resin (LY556) 1kg & hardener (HY951) 100 grams was supplied by Herenba Instruments & Engineers, Chennai.

TABLE II
Specification of Epoxy and Hardener[24]

Properties	Epoxy LY556	Hardener HY951
Visual appearance	Medium Viscosity, Colorless clear liquid.	Brownish yellow colour liquid
Yield strength	9000-12000 MPa	500-1000 MPa
Density at room temperature	1.13-1.16 gm/cc	0.946 gm/cc

C. Fabrication Method

The fabrication of the composite is done by hand lay-up approach. This manufacturing process requires manually applying individual layers or plies for reinforcement. It consists of thousands of fibres that have been resin-impregnated and bundled into tows woven together. The fiber and epoxy percentage are set to be 70% and 30% respectively. This fabric is layered with the epoxy carefully to reduce the bubble formation which can cause catastrophic defect and later on which can affect the whole composite. This process is continued up to four layers such that thickness of the specimen is about 3 mm as per the ASTM standards. The laminates are then allowed to cure in typical air conditions for 24hrs.

TABLE III
Specification of specimen prepared after fabrication

	Interwoven Hybrid Carbon-Basalt A1	Interwoven Hybrid Carbon-Basalt A2	Interwoven Hybrid Carbon-Basalt A3
Fabric Weight (gm)	89	91	92
Fabric Thickness (mm)	3.08	3.17	3.36
Resin Weight (gm)	38	39	40

III. RESULTS

A. Microstructure Analysis

A concentrated electron beam is utilized by a Scanning Electron Microscope (SEM) to scan a sample's surface and produce a high resolution image. Images from SEM can provide details about a material's surface chemistry and topography. SEM has been carried out on the manufactured composite which shows the results in the following fig. 2.

Fig. 2 SEM images of fabricated composite

The composite morphology illustrated by the SEM micrograph in figures shows some indication of fibre pull-out and fibre debonding. Thus, signifying a comparatively weak bond between the fibres and matrix due to hand-weaving process. The SEM micrograph also revealed that the fibre bundles are not completely attached to the matrix, which indicates that the slightly higher viscosity epoxy resin penetrates the interwoven fabric. However, the bonding observed between both the fibers seems to be good.

B. Tensile Strength

The ASTM D3039 test technique is the industry standard for determining a polymer matrix composite material's tensile characteristics. It is used to calculate the amount of force needed to break a polymer composite specimen as well as how far the specimen can stretch or elongate before breaking. A stress-strain diagram generated by tensile tests is presented in fig. 5. The results obtained in the tensile test carried out according to the ASTM D3039 (250x25mm) are depicted in the table IV.

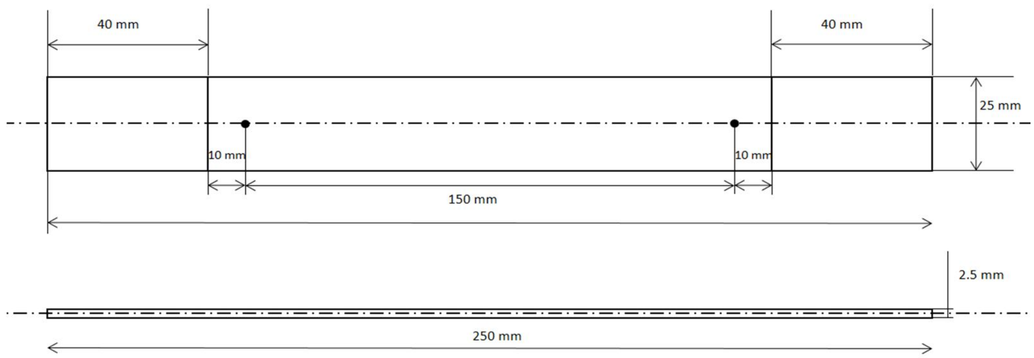

Fig. 3 ASTM D3039 specimen sizing [23]

Fig. 4 Specimen section according to ASTM D3039

TABLE IV
Tensile Strength per Sample

Sample ID	Tensile Strength (N/mm^2)
A-1	335.86
A-2	288.27
A-3	260.29

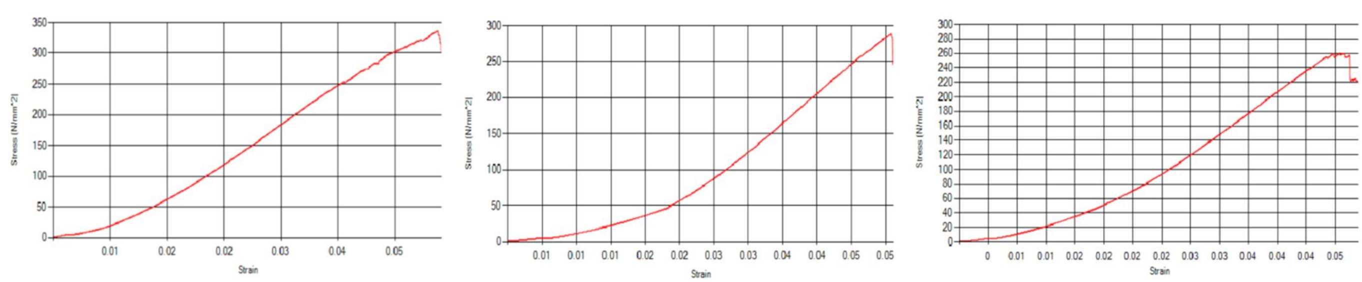

Fig.5 Stress vs. Strain graph for specimen A1, A2 & A3

C. Flexural Strength

The hybrid polymer matrix composite specimen for flexural investigation was prepared according to the ASTM D790 standard. Three point loading is used to assess the stiffness and flexural strength of a composite construction. Table V shows the flexural strength of each specimen. The dimensions are taken as according to the testing standard (125x13mm). The load vs. displacement graph for each specimen is given in fig. 6.

TABLE V
Flexural Strength per Sample

Sample ID	Flexural Strength (N/mm^2)
A-1	245.88
A-2	363.03
A-3	338.97

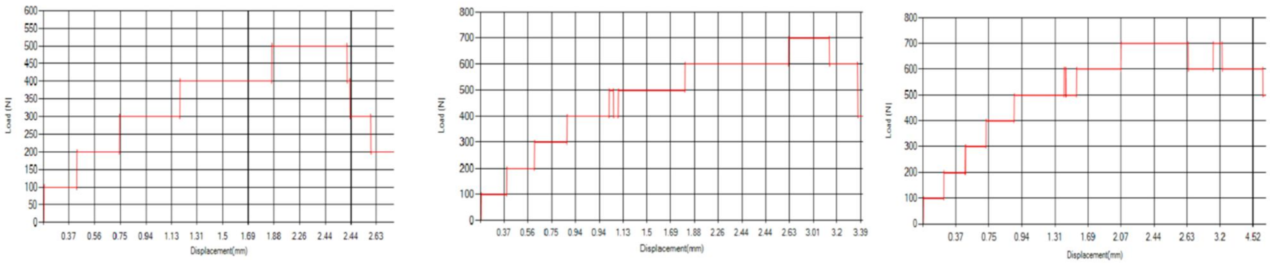

Fig. 6 Load vs. Displacement graph for specimen A1, A2, A3

D. Impact Energy

Impact test is used to simply describe the amount of energy absorbed by the specimen. Izod impact test has been carried out on given interwoven composite as per the ASTM D256 (63x13mm) standard as shown in fig. 7. The impact energy has been found for each of the test sample as given in the table VI below.

Fig. 7 Specimen section according to ASTM D256

TABLE VI
Impact Energy per Sample

Sample ID	Impact Energy
A-1	4.2
A-2	3.4
A-3	2.8

E. Hardness Number

Durometer Hardness test (Shore D) has been carried out on give interwoven composite as per the ASTM D2240 standard. Due to the impression on the hybrid composite, the hardness of composite materials is primarily determined by the outer surface of the laminates. The Hardness Number has been found for each of the test sample as given in the table VII.

TABLE VII
Hardness Number per Sample

Sample ID	1	2	3	4	5	Mean
A-1	87	84	89	86	88	86.8
A-2	89	87	89	86	91	88.6
A-3	92	90	93	92	90	91.4

IV. CONCLUSION

The fabrication of hand weaved interwoven hybrid fabric of carbon and basalt was done by hand lay-up technique. Tensile, flexural, impact and hardness tests were carried out on the composite in accordance with ASTM standards to determine its mechanical properties.

1) Results for the hybrid composite made with hand weaving are obtained.
2) The maximum tensile strength obtained from sample A-1 was 335.86 MPa. The average of the three samples with the same composition is 294.80 MPa.
3) The greatest flexural strength measured from sample A-2 was 363.03 MPa. 315.96 MPa is the average value for all three samples of the same composition.
4) The sample A-1 yielded 4.2 J as the recorded maximum impact energy. The three samples with the same composition had average impact energy of 3.46 J.
5) The sample A-3's sample has the highest observed hardness number of 91.4. The three samples with the identical composition had an average value of 88.93.
6) SEM analysis was done to examine the hybrid polymer matrix composite's microstructure.

The current study was conducted using simple hand weaving and hand lay-up techniques. However, the work can be continued to expand by considering machine weaving and other composite fabrication methods. The effect of manufacturing techniques on composite performance can also be investigated. The mechanical properties are discussed in detail inside this paper study. As a result, there is a lot of room to discover other properties of hybrid polymer composites, such as physical and water absorption properties.

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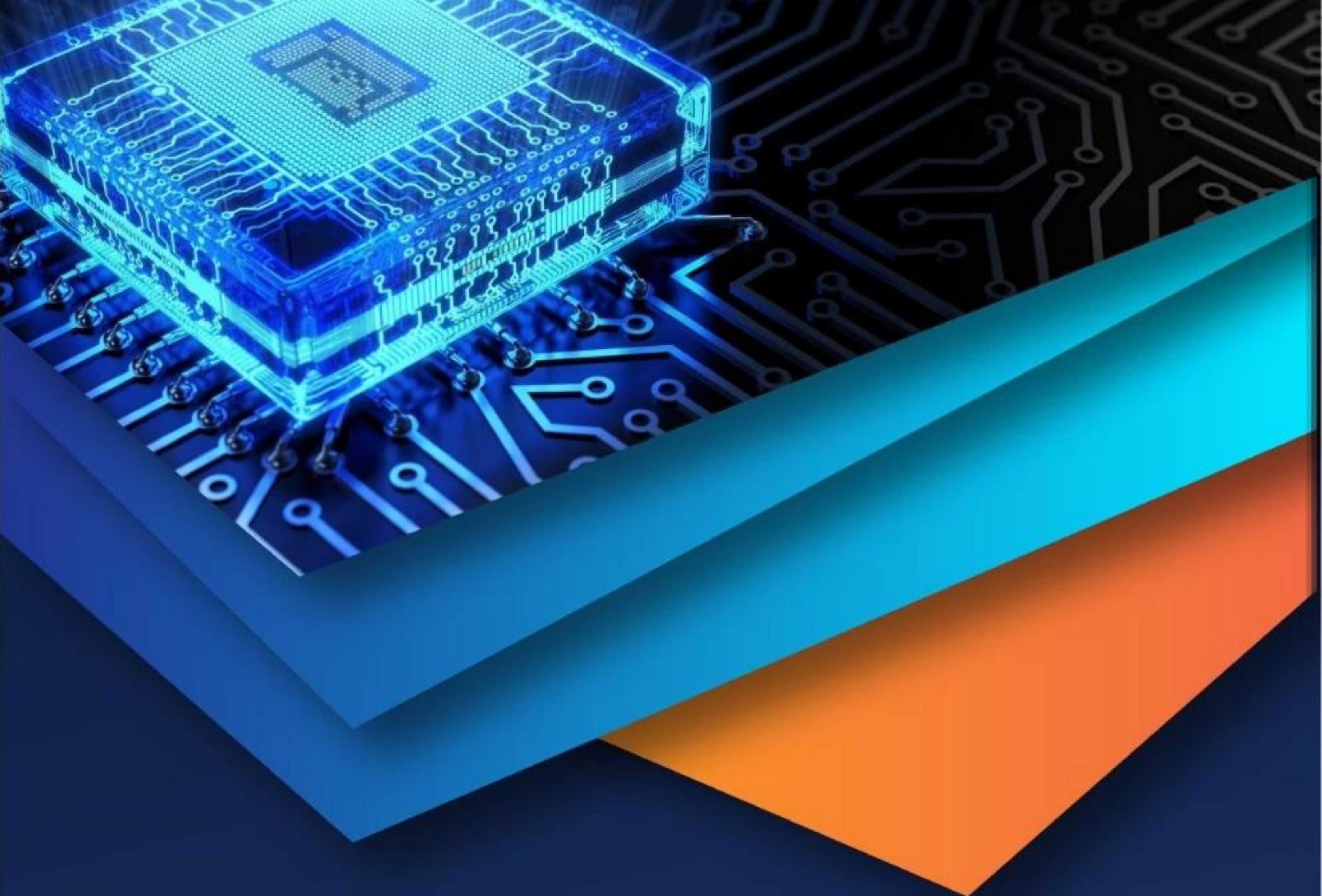

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