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Fabrication and Testing of Unidirectional Basalt and Carbon Fiber Composites

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ABSTRACT: Present work progress a methodology to fabricate a unidirectional composite material with carbon, Basalt materials to analyze its mechanical properties such as Tensile test, compression test and Flexural test, impact test by using experimental method Maximum Tensile strength obtained at carbon+basalt 00 specimen. Maximum compressive strength obtained at carbon+basalt 00 specimen. Maximum flexuralstrength obtained for carbon+basalt 00 specimen. And maximum impact strength obtained carbon+basalt00, carbon+basalt 600

Keywords—Hybrid Composite, carbon, Basalt, Epoxy Resin (LY556) And Hardener (HY951),

I. INTRODUCTION

The development of composite materials and related design and manufacturing technologies is one of the most important advances in the history of materials. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be tailored to meet the requirements of a particular application. Many composites also exhibit great resistance to high-temperature corrosion and oxidation and wear. These unique characteristics provide the mechanical engineer with design opportunities not possible with conventional monolithic (unreinforced) materials. Composites technology also makes possible the use of an entire class of solid materials, ceramics, in applications for which monolithic versions are unsuited because of their great strength scatter and poor resistance to mechanical and thermal shock. Further, many manufacturing processes for composites are well adapted to the fabrication of large, complex structures, which allows consolidation of parts, reducing manufacturing costs.

Originating from early agricultural societies and being almost forgotten after centuries, a true revival started of using lightweight composite structures for many technical solutions during the second half of the 20th century. After being solely used for their electromagnetic properties (insulators and radar-domes), using composites to improve the structural performance of spacecraft and military aircraft became popular in the last two decades of the previous century. First at any costs, with development of improved materials with increasing costs, nowadays cost reduction during manufacturing and operation are the main technology drivers. Latest development is the use of composites to protect man against fire and impact and a tendency to a more environmental friendly design, leading to the reintroduction of natural fibres in the composite technology. Increasingly nowadays, the success of composites in applications, by volume and by numbers, can be ranked by accessibility and reproducibility of the applied manufacturing techniques. Some examples of natural fibers.

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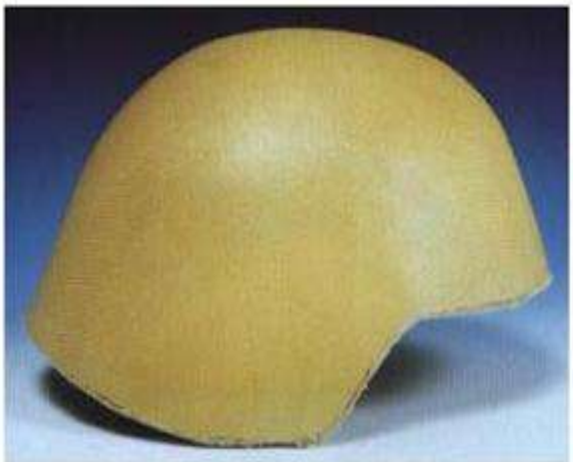

Composite materials constitute a group of materials formed by putting together two different materials. A reinforced car body and a body of a rocket are examples of such materials. The aim of this three-dimensional composition is to obtain a property which none of the constituents possesses: In other words, the target is to produce a material that possesses higher performance properties for a particular purpose than its constituent parts. Some of these properties are mechanical strength, corrosion resistance, high temperature resistance, heat conductibility, stiffness, lightness, and appearance. In accordance with this definition, there are several conditions that must be satisfied by the composite material. It must be man-made and not natural. It must comprise at least two different materials with different chemical components separated by distinct interfaces. Different materials must be put together in a three-dimensional unity. It must possess properties which none of the constituents possesses alone and that must be the aim of its production. The material must behave as a whole, e.g. the fiber and the matrix material (material surrounding the fibers) must be perfectly bonded.

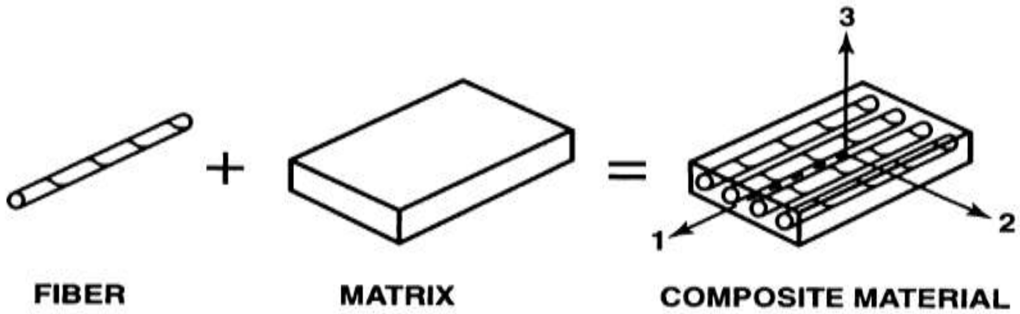

Fig. 1.2 composite material

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired.

Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat. Fibers fall short of ideal performance due to several factors. The performance of a fiber composite is judged by its length, shape, and orientation, composition of the fibers and the mechanical properties of the matrix.

The orientation of the fiber in the matrix is an indication of the strength of the composite and the strength is greatest along the longitudinal directional of fiber. This doesn’t mean the longitudinal fibers can take the same quantum of load irrespective of the direction in which it is applied. Optimum performance from longitudinal fibers can be obtained if the load is applied along its direction. The slightest shift in the angle of loading may drastically reduce the strength of the composite.

Unidirectional loading is found in few structures and hence it is prudent to give a mix of orientations for fibers in composites particularly where the load is expected to be the heaviest. There are many types of fibers are present, those are

- **Glass Fibres:** Over 95% of the fibers used in reinforced plastics are glass fibers, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics with which they are reinforced.
- **Carbon Fibres:** They are characterized by a combination of high strength, high stiffness and light weight. They are produced by polymeric fibre percursors or pitch fibre precursors. The advantages of carbon fibres are their very high tensile strength to weight ratio, high tensile modulus to weight ratio, very low coefficient of thermal expansion and high fatigue strength. The disadvantages are their low impact resistance and high electrical conductivity. Due to high cost, the use of carbon fibres is justified only in weight critical structures.
- **Ceramic Fibres** The glass-types typically contain about 50 to 70% silica. Silica glass is a purer glass fiber that can be made by treating fiberglass in an acid bath, which removes all impurities without affecting the silica. The final product contains 93 to 99% silica. Quartz is even more pure, and quartz fibers are made from natural quartz crystals that contain 99.9% silica, possessing nearly all the properties of pure solid quartz. Alumina aluminum oxide fibers, basically developed for use in metal matrices are considered a potential resin-matrix composite reinforcement. It offers good compressive strength rather than tensile strength. It's important property is it's high melting point of about 2000ºC and the composite can be successfully used at temperature up to about 1000ºC.
- **Aramid Fibres:** Kevlar aramid is made of carbon, hydrogen, oxygen and nitrogen and is essentially an aromatic organic compound. Its advantages are low density, high tensile strength and low cost. The main disadvantages are low compressive strength and difficulty in cutting or machining.

Boron Fibres: These are characterized by their very high tensile modulus. They have relatively large diameters and due to this they are capable of withstanding large compressive strength and providing excellent resistance to buckling. The main disadvantage is that it is costly.

There are two classification systems of composite materials. One of them is based on the matrix material metal, ceramic, polymer and the second is based on the material structure:

1.4.1 Classification of composites I

(based on matrix material)

1.4.2 Metal Matrix Composites (MMC)

MetalMatrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

1.4.3 Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and embedded fibersof other ceramic material (dispersed phase).

1.4.4 Polymer Matrix Composites (PMC)

Polymer MatrixComposites are composed of a matrix from thermoset Unsaturated Polyeste(UP) Epoxiy(EP)
or thermoplastic,Polycarbonate(PC), Polyvinylchloride, Nylon,
Polysterene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

1.4.5 Classification of composite materials II

(based on reinforcing material structure

1.4.6 Particulate Composites

Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.

1. Composites with random orientation of particles.
2. Composites with preferred orientation of particles. Dispersed phase of these materials

consists of two-dimensional flat platelets (flakes), laid parallel to each other.

1.4.7 Fibrous Composites

1. Short-fiber reinforced composites. Short-fiber reinforced composites consist of
2. a matrix reinforced by a dispersed phase in form of discontinuous fibers (length

< 100*diameter).

I. Composites with random orientation of fibers.
II. Composites with preferred orientation of fibers.

3. Long-fiber reinforced composites. Long-fiber reinforced composites consist of

a matrix reinforced by a dispersed phase in form of continuous fibers.

I. Unidirectional orientation of fibers.
II. Bidirectional orientation of fibers (woven).

1.4.8 Laminate Composites

When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite

1.5 Basaltfiber

Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene,and olivine.It is similar to fiberglass, having better physicomechanical properties than fiberglass, but being significantly cheaper thancarbon fiber. It is used as a fireproof textile in the aerospace and automotive industries and can also be used as a composite to produce products such as camera tripods.

The technology of production of BCF(Basalt Continuous Fiber) is a one-stage process: melting, homogenization of basalt and extraction of fibers. Basalt is heated only once. Further processing of BCF into materials is carried out using "cold technologies" with low energy costs.

Fig Basalt fiber

1.6 Carbon fiber

Carbon fibers or carbon fibres are fibers about 5–10 micrometres in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared with similar fibers, such as glass fibers or plastic fibers

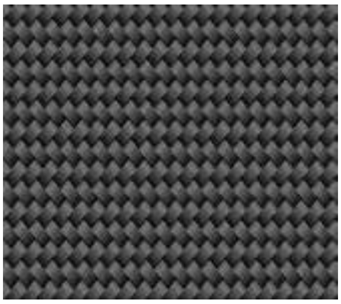

Fig carbon fiber

1.7 Epoxy resin

Epoxy refers to any of the basic components or cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group.[1] Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide

Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols (usually called mercaptans). These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing.

Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with favorable mechanical properties and high thermal and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics/electrical components/LEDs, high tension electrical insulators, paint brush manufacturing, fiber-reinforced plastic materials, and adhesives for structural and other purposes.

II. METHDOLOGY

Fabrication of laminates

The composite panels have been fabricated by hand lay-up system. This fabrication procedure is completed

Table for Fabrication of composite materials

Composites	Composition
Basalt+carbon **0^0, +30^0,-30^0,-0^0**	Basalt+carbon+LY556+HY951
Basalt+ carbon **0^0, +45^0,-45^0,-0^0**	Basalt+carbon+LY556+HY951
Basalt+carbon **0^0, +60^0,-60^0,-0^0**	Basalt+carbon+LY556+HY951
Basalt+carbon **0^0, +0^0,+0^0,+0^0**	Basalt+carbon+LY556+HY951

Hand layup technique

Initially the fibers were weighed and accordingly the resin and hardeners were weighed. Epoxy and hardener were mixed by using glass rod in a bowl. Care was taken to avoid formation of bubbles. Because the air bubbles were trapped in matrix may result failure in the material. The specimens were fabricated by using hand lay-up process. Hand lay uptechnique is the simplest method of composite processing. The infrastructural requirement of this method is also minimaland the procedure was as follows. The fibers are cut for required dimensions to remove extra fiber. Then a polythene A3 sheet is placed on a plane surface, over which the layers of the fibers has to be placed. Epoxy Resin(Araldite LY 556) was then mixed with the Hardener (Aradur HY 951) in the proportionate ratio and stirred well and then applied over the surface of the polythene A3 sheet. Then the first specimen is prepared by using a layers of jute , chpped, & basalt fibers is placed over the layer of resin and again a layer of resin mixture is applied over the fibers over which the roller is rolled in order to remove air if any trapped between those layers. Then a 20 k.gf weight was applied on the composite. It was left for 24 hours to allow sufficient time for curing and subsequent hardening.

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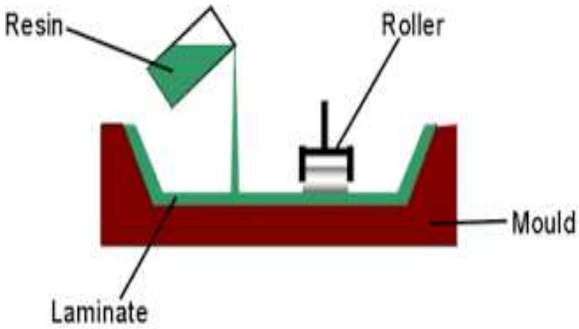


III. PROCEDURE:

- First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface and to remove dust particles wherever found.
- Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product.
- Reinforcement in the form of woven mats are cut as per the mold size and placed at the surface of mold.
- Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold.
- The Epoxy Resin and hardener are taken in the ratio of 10:1
- The polymer is uniformly spread with the help of brush.
- The basalt and carbon mat has taken unidirectional angles 0^0,-0^0,30^0,-30^0,45^0, -45^0,60^0,-60^0
- Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present.
- The process is repeated for each layer of polymer and mat, till the required layers are stacked.
- After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied.
- After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed.
- The time of curing depends on type of polymer used for composite processing.

For epoxy based system, normal curing time at room temperature is 24-48 hours

Cutting of specimens according to the dimensions

A cutting machine was used to cut each laminate into smaller pieces, for various experiments:

- **Tensile test:** Sample was cut into dumbell shape (200*25*3mm)
- **compressive test:** Sample was cut into flat bar shape (200*25*3)
- **Impact test:** sample was cut into flat bar shape (55*10*3)
- **Flexural test:** sample was cut into rectangle shape (30*30*3)

Fig:3.9 tensile test specimen

Fig Compressive Test Specimen

Tensile Test (ASTM STANDARD D3019)

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The commonly used specimen for tensile test is the flat rectangular type. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is(200*25*3)mm. Typical points of interest when testing a material include: ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) and results are analyzed to calculate the tensile strength of compositesamples.

Fig Universal testing machine

CompressiveTesting(ASTMSTANDARD D3410)

Compressive properties describe the behavior of a material when it is subjected to a compressive load. Loading is at a relatively low and uniform rate. Compressive strength and modulus are the two most common values produced. The specimen is placed between compressive plates parallel to the surface. The specimen is then compressed at a uniform rate. The maximum load is recorded along with stress-strain data. An extensometer attached to the front of the fixture is used to determine modulus.

- Compressive strength and modulus are two useful calculations.
- Compressive strength
- maximum compressive load

Impact Test(ASTM STANDARD D256)

Impact test is to determine the behavior of materials when subjected to high rates of (sudden) loading. It measures the energy absorbed in breaking the specimen by a single blow or impact. Charpy impact test is conducted for the composite. A pendulum type single blow impact test is used in the charpy impact test. During this test, the notched specimen is supported at both ends, as a simple beam in simply supported orientation, and is broken by a falling pendulum on the face opposite to and immediately behind the notch. The energy absorbed as determined by the subsequent rise of pendulum, is a measure of impact strength or material toughness and is expressed in terms of Joules. **Conclusion**

The study on the mechanical properties of hybrid polymer composites leads to the following

Fig impact test machine

Flexural Strength(ASTM STANDARD D709)

Flexural strength determines the ability of the composite under vertical loading. A bending test is performed on actual beam cross section by using the three points loading systems as Fig.3.12. The bending fixture is supported on the platform. The loading is held in the middle of the specimen when specimen under test is supported with knife edge points. At a particular load the deflection at the centre of the beam is determined.

Where F is axial load
b is width
d is depth or thickness
L is length of the support span

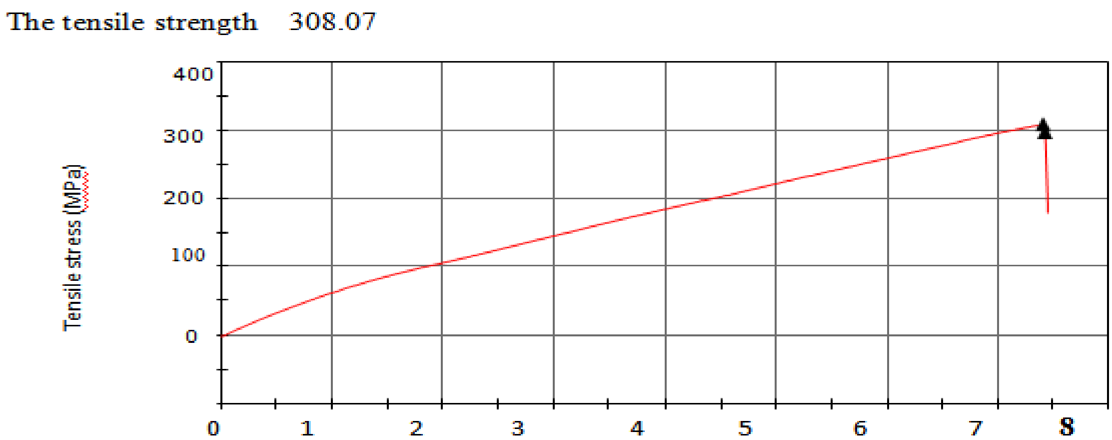
Flexural modulus is known as the ratio of stress to strain in flexural deformation. Formula for flexural modulus is

$E = \frac{FL^3}{4wdh^3}$ (KN/mm^2) or GPa

Where F is force
L is length of the support span
w is width
d is deflection
h is height or thickness

IV. RESULT

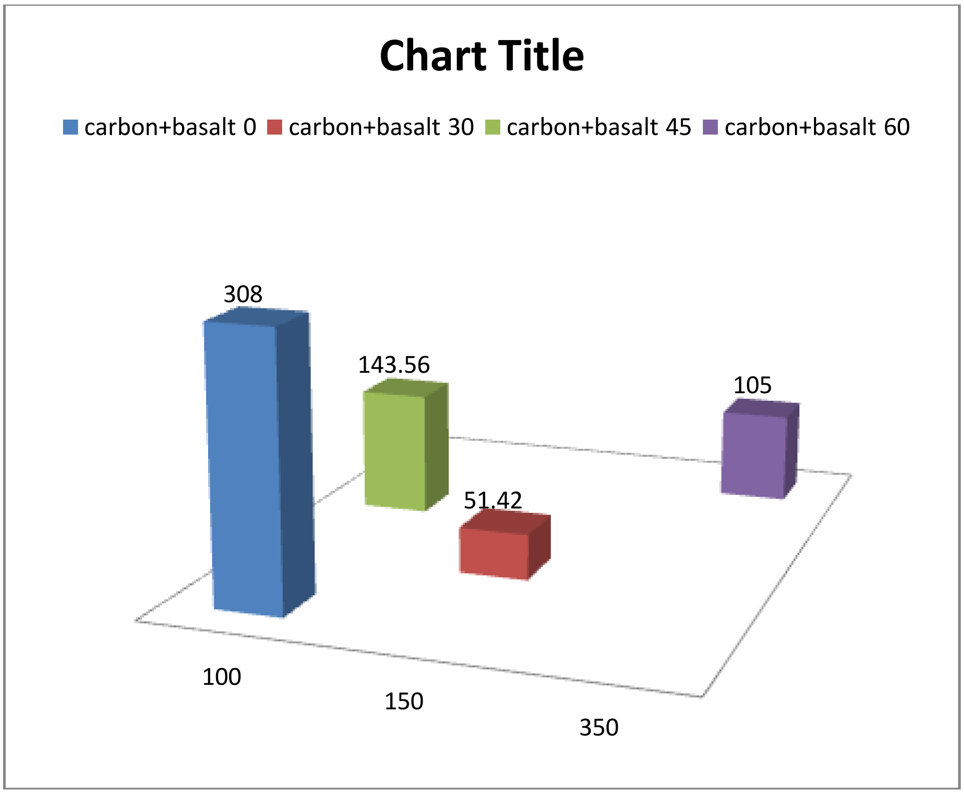
Tensile tests were performed on the specimens of carbon, and basalt combination specimens .The graph hs taken from specimen carbon and basalt angle -0^0 and +0^0



Graph: Stress –Strain curve for carbon+basalt specimen

specimen	Tensile strength(M.Pa)
Carbon + basalt at angle 0^0	308.07
Carbon + basalt at angle 30^0	105.94
Carbon + basalt at angle 45^0	51.47
Carbon + basalt at angle 60^0	143.56

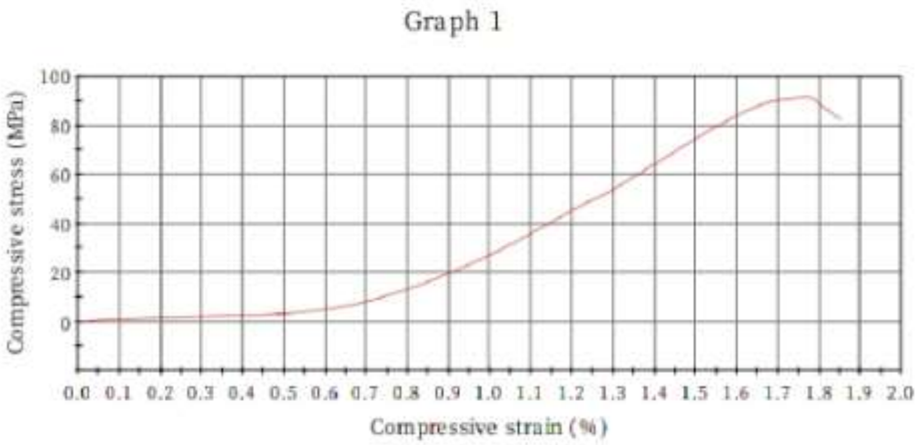
Table Tesnile Strenth



Graph Tensile test result

Compressive Test

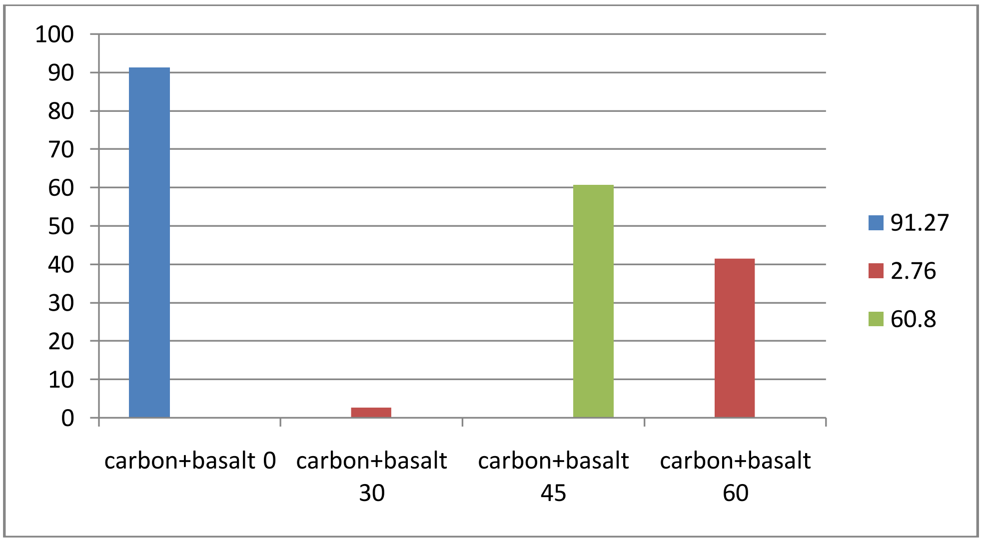
Compressive tests were performed on the specimens of carbon and basalt combination specimens
The graph hs taken from specimen carbon and basalt angle -0^0 and $+0^0$
The compressive strength 91.27



Graph compressive Stress –Strain curve for carbon+basalt specimen

specimen	critical load(KN)	compressive strength(M.Pa)
Carbon + basalt at angle 0^0	8.21	91.27
Carbon + basalt at angle 30^0	0.2	2.76
Carbon + basalt at angle 45^0	5.47	60.80
Carbon + basalt at angle 60^0	3.74	41.6

Table : Compressive Test Results



Graph: compressive strength comparison graph.

Flexural test

Flexural tests were performed on the specimens of carbon and basalt combination specimens
The graph hs taken from specimen carbon and basalt angle -0^0 and $+0^0$
The flexural strength 248.84

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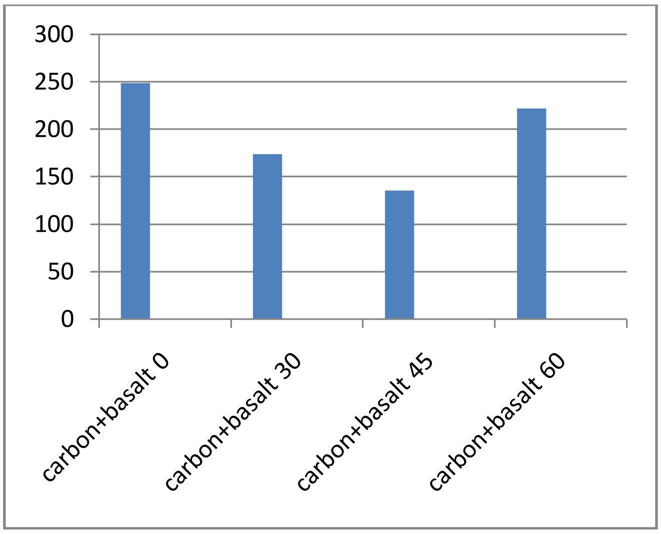
specimen	**Load**	**Flexural strenth**
Carbon + basalt at angle 0^0	0.45	248.84
Carbon + basalt at angle 30^0	0.31	174.17
Carbon + basalt at angle 45^0	0.24	135.67
Carbon + basalt at angle 60^0	0.40	222.12

Table Flexural test result



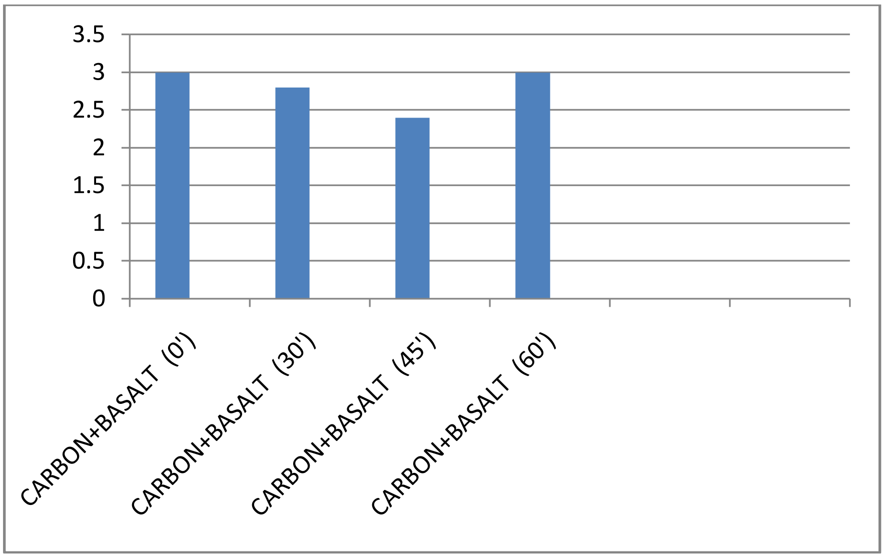
Graph Flexural Test result

Impact test

Impact tests were performed on the specimens of carbon and basalt combination specimens

specimen	Impact strenth
Carbon + basalt at angle 0^0	3
Carbon + basalt at angle 30^0	2.8
Carbon + basalt at angle 45^0	2.4
Carbon + basalt at angle 60^0	3

Table Impact Test Result



Graph Impact test result

V. CONCLUSIONS:

Fabrication of hybrid polymer composites has been done successfully.

Mechanical properties of Carbon,Basalt and combination of these fibers are observed.

- Maximum Tensile strength obtained at Carbon+basalt 0^0 specimen
- Maximum compressive strength obtained at Carbon+basalt 0^0 specimen
- Maximum flexurialstrenth obtained for carbon+basalt 0^0 specimen.
- And maximum impact strenth obtained carbon+basalt0^0 ,carbon+basalt 60^0
- The present study on hybrid polymer unidirectional composites leaves a wide scope for future to find many other aspects of these composites. Few recommendations for the future investigation are:
- The present study has been carried out using simple hand lay-up technique. However, the work can be extended further by considering other methods of composite fabrication and the effect of manufacturing techniques on the performance of composites can similarly be analyzed.

The paper study explains about the mechanical properties. So there is a lot of scope to find other properties of hybrid polymer composite like physical, water absorption properties etc.

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