DESIGN AND STRENGTH ANALYSIS OF A HYBRID COMPOSITE OF CARBON, GLASS AND BASALT FIBER

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Abstract

Composite materials have a very long history and its applications are increasing day by day. Its properties make it focus and replacing many materials of the present use with the composite materials. In the present work, a hybrid composite of carbon, basalt, and glass fibers are bind with the help of the epoxy resin matrix. These fibers are selected because of their unique properties. Vacuum resin infusion method is used to produce the hybrid composite. Many properties were tested like Tensile strength, Compressive strength, Hardness, Bending strength, Impact load strength, Water absorption capacity, Acid corrosion and Soil degradation rate as per ASTM standard. It is concluded from the result that the present composite is not suitable for corrosive environment and strength of the composite will be increased by replacing glass or basalt fiber with any other natural or artificial fiber. The hybrid will also make corrosive resistance by surface coating. The properties of the present hybrid composite make suitable for many application like spacecraft, Automobile, Safety equipment etc.

Introduction

A composite material is a mixture of two or more metal with different chemical and physical properties that were joining by some bonding materials. In this composition, individual materials have different properties but when it was mixed with other materials it gives a unique property as a whole material. These sole components remain heterogeneous at the microscopic level but homogeneous at the macroscopic level. The new materials provide strength, light in weight, or less expensive when compared to traditional materials. These features of composite materials make essentials for making building blocks, swimming pool panel, boat hulls etc. Now a day's composite materials are also used for clothing.

A material shall be considered as a composite material if it satisfies the following conditions:

1. It is manufactured i.e., excluding naturally available composites.

2. It consists of two or more physically and/or chemically distinct, suitably arranged or distributed phases with an interface separating them.

3. It has characteristics that are not the replica of any of the components taken individually.

Factors that control the properties of fibers

(a) Length: The fibers can be long or short. Long, continuous fibers are easy to orient and process, but short fibers cannot be controlled fully for proper orientation. Long fibers provide many benefits over short fibers. These include high strength, impact resistance, low shrinkage, improved surface finish, and dimensional stability. However, short fibers provide low cost, easy to Filament Strand.

(b) Orientation: Fibers oriented in one direction give very high stiffness and strength in that direction. If the fibers are oriented in more than one direction, such as in a mat, there will be high stiffness and strength in the directions of the fiber orientations. Hence the fibers are usually oriented in directions where high stiffness and strength are required.

(c) Shape: Due to easiness in handling and manufacturing fibers, the most common shape of fibers is circular. But fibers are available in the form of square and rectangle also.

(d) Material: The material of the fiber directly influences the mechanical performance of a composite. Fibers are generally expected to have high elastic moduli and strength than the matrix materials. The fibers will also good functional properties like high thermal resistance, fatigue resistance, and impact resistance

History

Composite materials are not modern materials it has a thousand of years history. After the discovery of the wheel, production of continuous yarns by spinning is probably the most important development of mankind, helping him to survive outside the tropical zone and dissemination across the earth. Many flexible fibers like jute, cotton, flax replace the animal's skin. Many natural resources also used, soon a composite was invented in 1500 B.C. when early Egyptians and Mesopotamian colonist used a composite of mud and straw to create strong and durable buildings

Later, in 1200 AD, the use of composite was found by the Mongols to create a bow. A composition of wood, bone, and "animal glue," bows were pressed and sheathed with birch bark. These bows were powerful and accurate. Composite Mongolian bows helped to ensure Genghis Khan's military sovereignty.

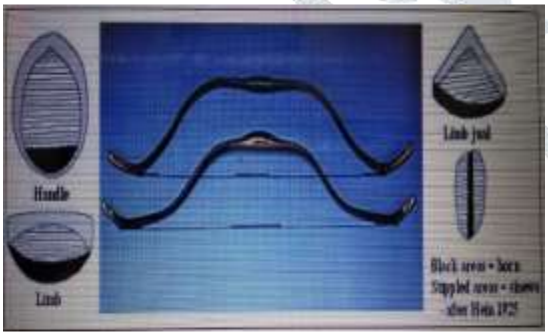

Fig.1- First bow of composite (1200AD)

Fig. 1.2- World first evidence of composite (2500BC)

2.Experimental Study

2.1 Matrix Material Used

There is the large number of fiber like carbon, jute, glass, flax etc present in the market but in this work a hybrid of carbon fiber, **glass fiber, basalt** that are joined together by **epoxy** resin. These fibers are selected by analyzing the recent study and the properties are providing by these fibers. These fibers have different properties and play a specific role in our work.

2.2 Uses of Epoxy Resin

An epoxy resin is defined as a molecule with more than one epoxy group, which can be hardened in a useful plastic. The epoxy group, which is also called the glycidyl group, has through its characteristic appearance given the name to epoxy. Epoxy resins are a family of thermoset plastic materials which do not give off reaction products when they cure and so have low cure shrinkage. They also have good adhesion to other materials, good chemical and environmental resistance, good chemical properties and good insulating properties. The epoxy resins are generally manufactured by reacting epichlorohydrin with bisphenol. Different resins are formed by varying proportions of the two: as the proportion of epichlorohydrin is reduced the molecular weight of the resin is increased.

2.3 Glass Fibre

Glass fiber is a material consisting of numerous extremely fine fibers of glass. Glass Fibers are among the most versatile industrial materials known today. They are readily produced from raw materials, which are available in virtually unlimited supply. All glass fibers described in this article are derived from compositions containing silica. They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability, and inertness, as well as desirable fiber properties such as strength, flexibility, and stiffness. Glass fibers are used in the manufacture of structural composites, printed circuit boards and a wide range of special-purpose products.

2.4 Carbon fiber

Carbon fiber is composed of carbon atoms bonded together to form a long chain. The fibers are extremely stiff, strong, and light, and are used in many processes to create excellent building materials. Carbon fiber material comes in a variety of "raw" building-blocks, including yarns, unidirectional, weaves, braids, and several others, which are in turn used to create composite parts.

Fig. 7 Plain Carbon Fiber Weave **Fig. 8 Carbon Fiber Twill Weave**

2.5 Basalt Fiber & its Properties

Basalt fiber is a relative newcomer to fiber reinforced polymers (FRPs) and structural composites. It has a similar chemical composition as glass fiber but has better strength characteristics, and unlike most glass fibers is highly resistant to alkaline, acidic and salt attack making it a good candidate for concrete, bridge and shoreline structures.

Fig.9 Basalt Fiber Spool

Compared to carbon and aramid fiber, it has the features of wider application temperature range -452° F to 1,200° F (-269° C to +650° C), higher oxidation resistance, higher radiation resistance, higher compression strength, and higher shear strength. (Note that application temperatures of FRPs are limited by the glass transition temperature of the matrix, which is lower than the application temperature of the fibers.

Producing fibers from basalt was researched during the cold war by the old Soviet Union and limited commercial research and production was done in the U.S. during the same period. The Soviets researched basalt as a source of fiber for ballistic resistant textiles.

The price of fibers made from basalt is higher than those made of E-glass, but less than S-glass, aramid or carbon fiber and as worldwide production increases, its cost of production should reduce further.

2.8 Technical data sheet of Matrix used

Basalt Fiber Fabric 320 GSM Plain

Fiber type	Wrap	6K
	Wrap	6K
Woven pattern		plain
Linear density (10mm)	Wrap	4K
	Welt	4K
Size (mm)	Width	1000
	Thickness	0.38
Area weight (g/m^2)		320

Table 1 Design of Basalt fiber

Carbon fiber 200GSM

Characteristic	Specification	Tolerance	Test method
Area (g/m^2)	200	+/-3%	ASTM D3801
Width (mm)	1000	-0/+10mm	ASTM D3774
Dry fabric thickness(mm)	0.2	+/-0.03	ASTM D1777

Table 2

Sr. no	Property	Unit	Epoxy resin	Hardener
1	Type		Solvent modified resin	polyamine
2	Appearance		Color less liquid	Clear liquid
3	Max viscosity	MPa-s	650(+/-)100	

4	Specific gravity	g/cc	1.15-1.18	0.98+/-.1
5	Pot life@27^{0}C	hours	1.5-2	
6	Storage stability	months	12 months	6 months

Table 3(a)

GSM Glass fibre fabric (7 mil)

	Specification	Tolerance	Test Method
Weave	Plain		
Glass Fibre Type			
Warp	ECG37531/0		
Weft	ECG37531/0		
Aerial Weight (GSM)	210	±353)	ASTM3D3801
Dry Fabric Thickness(mm)	0.183d783milx	±30.03	ASTM3D1777
Fabric Width (mm)	1250	±35	ASTM3D3774
Roll Length (meters)	50	± 0.5	
Finish	Untreated		
Size Compatibility	Epoxy		

Table3(b)

3. Experimental setup

3.1 Tensile Test

Tensile testing, also known as tension testing, is a fundamental material science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are the ultimate tensile strength, breaking strength, maximum elongation, and reduction in area. From these measurements, the following properties can also be determined: Young's modulus, Poisson'sratio, yield strength, and strain-hardening characteristics cs .

Process

The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section is recorded against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the *engineering strain*, ε, using the following equation

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

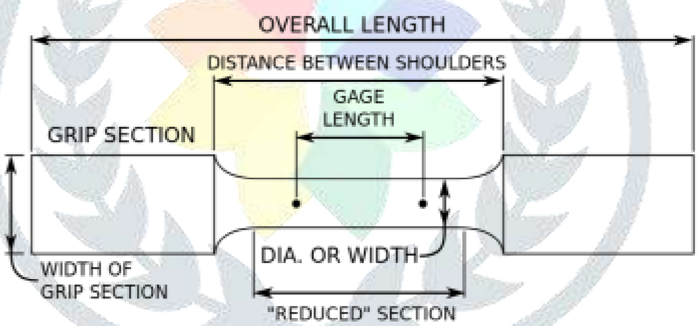

Fig 3.10 Specimen for Tensile Testing

Where ΔL is the change in gauge length, L_0 is the initial gauge length, and L is the final length. The force measurement is used to calculate the *engineering stress*, σ, using the following equation:

$$\sigma = \frac{F_n}{A}$$

Where F is the tensile force and A is the nominal cross-section of the specimen. The machine does these calculations as the force increases, so that the data points can be graphed into a *stress–strain curve*.

3.2 Flexural test

Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample.

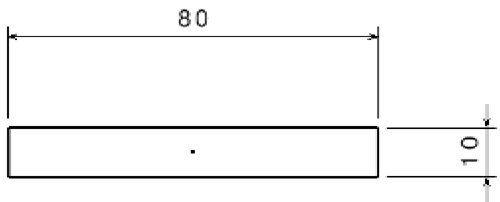

Fig 11. Specimen for Flexural test (ASTM D 790)

3.3 Hardness Test

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation.

More simply put, when using a fixed force (load)* and a given indenter, the smaller the indentation, the harder the material. Indentation hardness value is obtained by measuring the depth or the area of the indentation using one of over 12 different test methods.

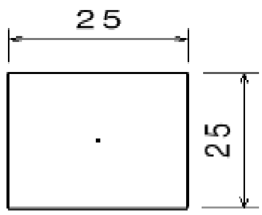

Fig. 12 Specimen for Hardness test (ASTM D785)

4. Result

4.1 Tensile Test

To find the tensile strength of the material a specimen (Dimension 200*20*03 mm) was use. All dimension of the specimen was ensured with the help of Vernier caliper. UTM was use for testing of the material

Fig.13 Specimen After tensile testing (Camera Shot).

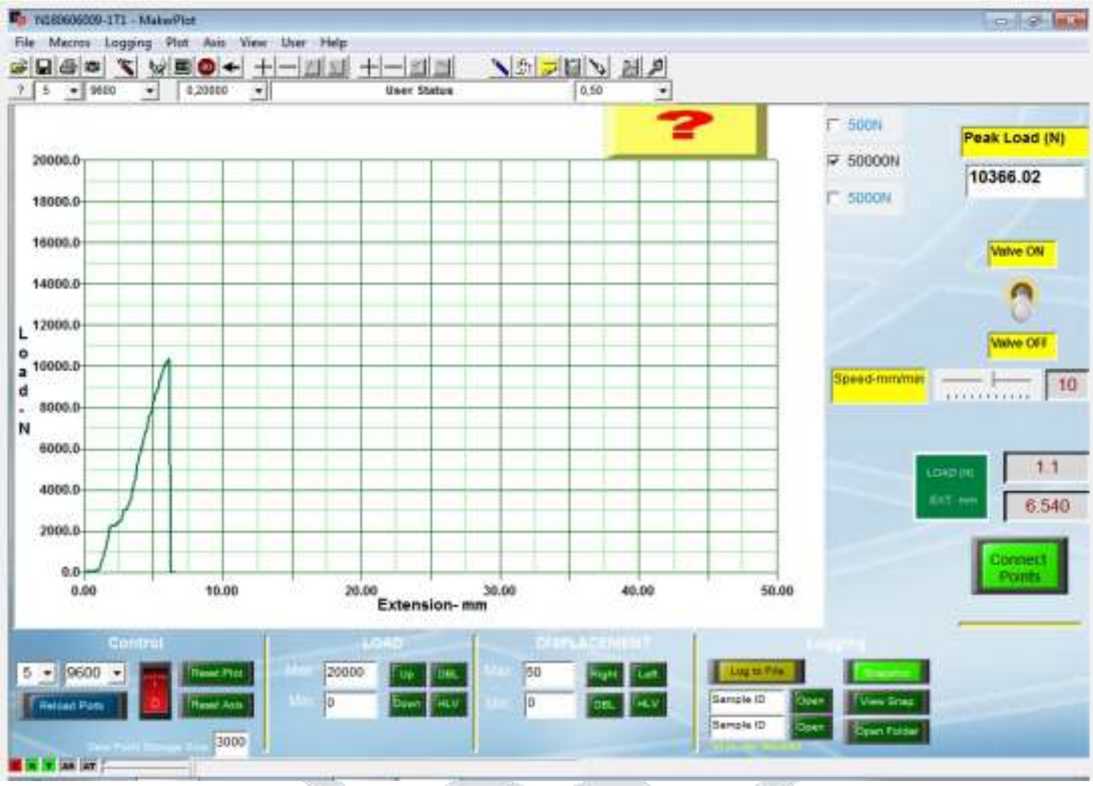

Fig.14 Screen shot of computer software for tensile testing.

Peak load-10366.02 N

Speed-10mm/min

Extension-6.540mm

To find the stress we apply Basic strength of material equation which is mentioned in Chapter 3.

Name of test	Results	Test Method
Tensile Strength N/mm^2	200.0	ISO: 527-2002

Table.4 Tensile test result

4.2 Flexural Test

Specimen use for flexural test was designed according to ASTM standard and all the Flexural test related information was already discussed..

Fig. 15 Specimen after Flexural test.

Result

Peak load- 613.29 N

Speed- -10mm/min

Extension-9.090mm

Name of test	Results	Test Method
Flexural Strength, N/mm^2	414	ISO-180-2000 (Notched)

Table.5 Flexural test result

4.3 Barcol hardness

Hardness value- 90B

Name of test	Results	Test Method
Barcol Hardness	90B	ASTMD-2583-1981

Table.6 Barcol hardness test

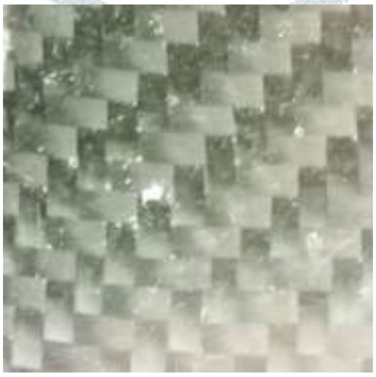

Fig.16 Specimen after Barcol Hardness test(Camera Shot).

Conclusion

The aim of present work to find out the behavior of hybrid composite of Glass, Basalt, Carbon fiber, on various scale like tensile strength, compressive strength, indentation loading.it is observed that the strength of material can be increase by replacing the basalt,glass fiber with carbon and natural fiber. Hardness of the composite may be increased by surface treatment or providing a coating of hard fiber.

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