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EVOLUTION OF MECHANICAL PROPERTIES OF HYBRID COMPOSITES

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Abstract
Fiber reinforced polymer (FRP) composite materials are gradually substituting conventional metallic materials because of their high specific strength and better corrosion resistance. However, the cost of the composites is still higher than the traditional materials. Different fibers like glass, carbon, aramid and basalt are used in polymer matrix composites. Some of the fibers like carbon the cost is very high and some other fibers like glass the cost is very less. So most of the researchers concentrate on hybrid composites to reduce the cost of the composites and also to improve the mechanical properties. Hybrid (glass/Basalt) composites are widely in bridges, aircraft landing runway, printed circuit boards, fire protection structures, brake pad, power and radar. In this paper, glass and basalt fiber of different orientations of fixed composition (60% matrix and 40% fiber by weight) laminated composites are fabricated by using hand lay-up technique and evaluated the mechanical properties. The fractured specimen microstructure was observed by using Scanning Electron Microscope (SEM) for understanding the bonding strength of fibers. It is found that the BGB composite has better properties than the GBG like tensile, compression and flexural strength.

Keywords: FRP, glass fiber, Basalt fiber, composite materials, mechanical properties, tensile, flexural.

1. Introduction

Nowadays, FRP composites have gained increasing interest due to their eco-friendly properties. Fiber reinforced plastic (FRP) composite materials are made of fibers to introduce the directional properties where the load is received, and polymer resin matrix for bonding the fibers. Fibers used are generally glass, basalt, carbon, and aramid with polymers for bonding like polyester, epoxy, and vinyl ester as matrix materials. In general the matrix material is soft and reinforcing material is hard. The interfacial bond strength has to be sufficient for load to be transferred from the matrix to the fibers if the composite is stronger than the unreinforced matrix. Polymer composites exhibit superior properties such as strength, heat resistance, toughness and abrasion resistance and are lighter than conventional materials such as metals and alloys. FRP composite materials are commonly used in aeronautical, Automobile and ship building industries. One of the major challenge for the composite engineers is to develop stronger, light weight and less cost materials. So for improving the performance of the composites hybridization of two or more fiber (synthetic fiber with another synthetic fiber) in a single polymeric matrix. Glass fiber reinforced composites (GFRP) and Carbon fiber reinforced composites (CFRP) are having their own importance in its applications, but hybridization of fibers overcome the drawbacks of both the composites i.e less

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cost and strength increases. Glass fibers are less cost and more tensile strength and carbon fibers are more costly, but high compressive and flexural strength. Basalt fibers are less cost compared to carbon and more cost compared to glass, but it has good mechanical properties, acid alkali resistance, excellent electrical properties, high wave permeability, nonconductive and excellent sound insulation and insulation characteristics. G. Marom et al. [1] studied the hybridization i.e. positive or negative hybrid effect of a selected mechanical property from the rule of mixture behavior of carbon/carbon/epoxy and glass/carbon composites. None of the mechanical properties, excluding the fracture energies show signs of a positive hybrid effect. P.W. Manders and M.G. Bader [2] studied hybrid effect and failure strain enhancement of up to 50% for the glass/carbon fiber composite. They selected different glass/carbon ratios and states of dispersion of the two phases. The failure strain of the carbon fiber increased as the relative proportion of carbon fiber was decreased, and as the carbon fibers were more finely dispersed. C. S.Yerramalli and A, M Waas [3] have selected carbon/glass hybrid composite with the fiber volume fraction of 30%. by varying the carbon/glass fiber ratios, maintaining same fiber volume fraction, ranging from pure glass to pure carbon including hybrid laminates were tested for compression loading to study the failure mechanisms. To study the failure mechanisms, modeling like iso-stress and iso-strain models were considered. Splitting and kinking failures were noted while loading the hybrid laminates under static and dynamic loading rates. J. Zhang et al.[4] studied mechanical performance for a hybrid composites made of carbon/glass reinforcements, and the fabricated by using wet lay-up method.

2. Materials

2.1 Basalt Fiber

Basalt fiber is a continuous fiber made of melting basalt stone at 1450^{o}C to 1500^{o}C through platinum rhodium alloy bushing. It is a new environmental protection fiber which is known as the twenty first century ‘volcano rock silk’. It is also called golden fiber because its colour is golden brown. Basalt fibers are present in basalt based ingenuous molten volcanic rock found in lava is obtained using extrusion process. Basalt fiber extrusion process is simpler and energy efficient than of any other competing fibers. Dimensions of fibers are range of 10 μm to 20 μm. It is used as fire proof material in textile, aerospace and automotive industries and can also used as a composite to produce products like brake pads, radar, printed circuit boards and camera tripods. Compared with other types of fiber materials, basalt continuous fiber have stronger affinity with other materials such as various resins and inorganic materials. Tensile and Compressive mechanical properties are better for basalt compared to glass and cheaper than carbon counterparts. Hence, basalt fibers grab high attention as novel type of reinforcement material for hybrid composite fabrication.

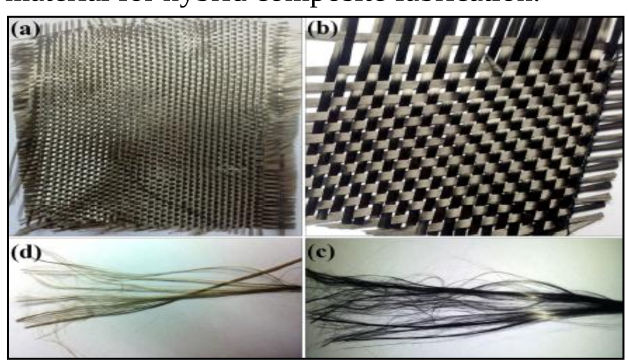

Figure 1. Basalt Fiber

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Properties

The tensile strength of basalt fiber ranges from 2.8 to 3.1 GPa. Where as the elastic modulus of the fibers varies in between 85 and 87 GPa. The break elongation is 3.15%. The density of Basalt fiber is 2.67gm/cm^3. The aerial density of basalt is 300 GSM.

2.2 Glass Fiber:

Glass fiber is a type material which consists of numerous `extremely small diameter fibers of glass. These fibers are made by cooling pure silica which is heated to extremely high temperatures (around

1700^{o}C). Since the surface area to weight ratio is low, the thermal conductivity of this fibers is around 0.05W/(m.K) which is very low. Hence these are used as thermal

insulators.

Glass Fiber Reinforced Polymer

Properties:

Density of glass fiber is ranges between 2.55 to 2.6 gm/m^3 and bulk Module is of glass fiber ranges between 43 to 50 GPa and the tensile strength of glass fiber ranges between 1950 to 2050 MPa and the elastic limit of glass fiber ranges between 2750 to 2875 MPa and young's module of glass fiber ranges between 72 to 85 GPa. The aerial density of Glass is 300 GSM.

As mentioned above the promising properties, effective mechanical properties and economically better of basalt fibers could make basalt a better reinforcement fiber in place of carbon fiber based composite materials.

2.3 Resin and Hardener

Epoxy resin is extensively used to give great bonding strength properties between the fiber face sheets to form the matrix. The Epoxy resin should be used at room temperature is considered as LY 556. The epoxy is chosen as the polymer matrix amidst other matrices because of its better properties of mechanical strength, chemical resistance and service temperature requirements. Hardener (HY 951) is used or employed in fabrication of composite materials to improve the interfacial adhesion and impart strength to the composite. Here the resin and hardener mixture of 10:1 is used to obtain optimum matrix composition.

Epoxy Resin and Hardener

Method of Manufacturing

Hand layup

Hand layup technique is one of the simplest fabrication methods used in manufacturing reinforced stacked plastic.

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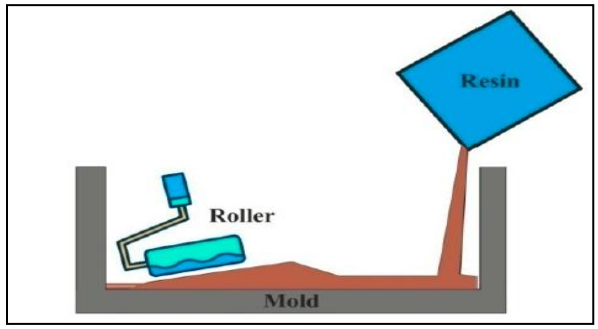
The cost of the production technique is very low; the costlier piece of hand layup technique is typically a spray gun for resin and application of get coat on the composite. Some of the fabricators brush the resin onto the composite or pour the resin onto the composite. There are no limitations of the size of the part using hand layup fabrication process. This fabrication of the composite is very simple where the resin and the reinforcing agents are placed against the surface on the open side of the mould and it is allowed to cure at room temperature which is sprayed on the mold with a spray gun. Gel coating is applied to improve the surface profile. The gel coating on the fiber reinforcement composites are about 0.4 – 0.7 mm thickness which helps in corrosive resistance for the composites, which is usually seen in the outer shell of the boats. This method is used to produce epoxy resin parts such as boat hulls, pickup trucks canopies, vessels and tanks. Here two different stacking sequence and fixed composition (60 :40 by weight) composites are fabricated. One composite is four basalt and four glass and four basalt (BGB) and other one is four glass and four basalt and four glass (GBG) having a thickness of 3 mm.



Hand layup Technique

Results and Discussion

Tensile Strength:

To perform the tensile tests of each laminated specimen three pieces are prepared according to ASTM - D3039 as shown in figure 5. The specimens of 165 mm gauge length, 19 mm wide and 3 mm thickness are prepared as shown in figure 5. The average tensile strength is of GBG is 1452.18 MPa and the average tensile strength is of BGB is 1828.06 MPa.as shown in table 1 & 2 respectively and load vs deflection shown in figure 8.

Tensile strength results (GBG)

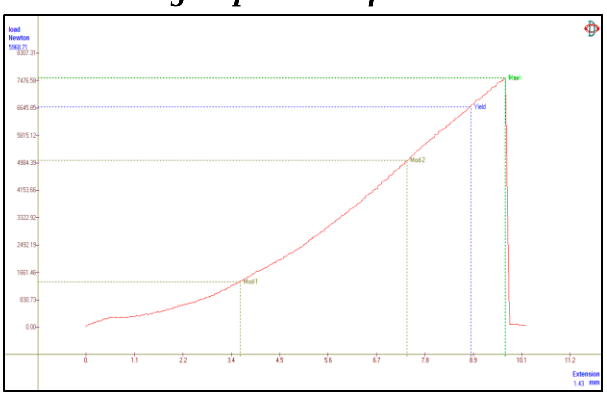
Ref. Standard	ASTM 3039		
Specimen code	**GBG-01**	**GBG-02**	**GBG-03**
Yield Force (N)	6186.48	8372.41	7476.03
Tensile Strength at Max ($N/_{mm}^2$)	212.83	262.31	259.90
Max Force (N)	6827.39	9180.99	8093.43
Max Elongation (mm)	9.69	10.37	11.65
Modulus of Elasticity ($N/_{mm}^2$)	1336.07	1533.24	1487.25
Average Tensile Strength	**245.01 MPa**		
Average Modulus of Elasticity	**1452.18 MPa.**		

Tensile strength results (BGB)

Ref. Standard	ASTM 3039		
Specimen code	**BGB-01**	**BGB-02**	**BGB-03**
Yield Force (N)	6675.00	4867.36	6345.69
Tensile Strength at Max ($N/_{mm}{}^2$)	287.53	186.78	247.86
Max Force (N)	7552.10	5299.51	7104.92
Max Elongation (mm)	9.67	11.21	5.87
Modulus of Elasticity ($N/_{mm}{}^2$)	1819.89	1612.96	2051.34
Average Tensile Strength	**240.72 MPa**		
Average Modulus of Elasticity	**1828.06 MPa.**		

UTM for Tensile Strength Test

Tensile strength specimen after Test



Load vs Deflection Curve

4.2 Compressive strength

The basalt specimen compressive strength tests are done on universal testing grip holders of the UTM machine. The specimens are load of 5 mm/min at uniform rate. The basalt fiber testing pieces are of gauge length about 50 mm, about 12 mm and 14 mm wide and about 3mm thickness for different combinations of test specimens like BGB and GBG composite specimens respectively. The average compressive strength is of GBG is 12.54 MPa.. and the average compressive strength is of BGB is 17.77 MPa. As shown in tables 3 & 4 respectively and the load vs deflection shown in figure 10.

Compressive testing on (BGB) Specimen

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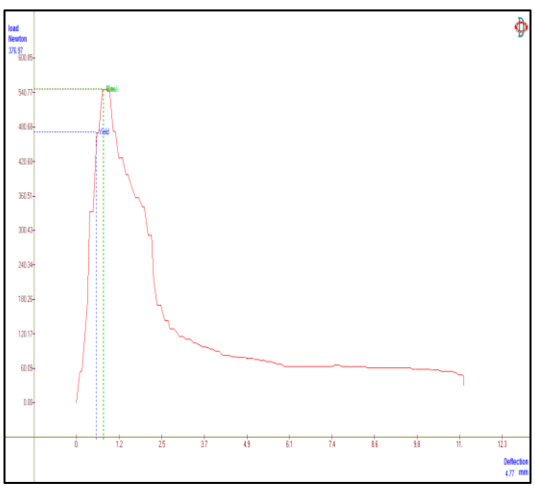
Table 3: Compressive strength (GBG)

Ref. Standard	ASTM D695		
Specimen code	**GBG-01**	**GBG-02**	**GBG-03**
Area	34.20	33.40	30.72
Max. force	439.34	289.86	494.26
Max. deflection	0.47	0.3	0.84
Compression Strength	12.85	8.68	16.09
Average Compression Strength	**12.54 MPa**		

4 Compressive strength (BGB)

Ref. Standard	ASTM D695		
Specimen code	**BGB-01**	**BGB-02**	**BGB-03**
Area	24.57	27.61	24.42
Max. force	547.25	452.09	357.94
Max. deflection	0.77	0.58	0.37
Compression Strength	22.28	16.37	14.66
Average Compression Strength	**17.77 MPa.**		



Load Vs Deflection curve

4.3 Flexural strength

Flexural tests are conducted to check for each laminated composite material properties against the bending forces with rectangular samples according to ASTM D - 790 using a universal testing machine (Figure 11), fitted with a 3-point bending fixture at the cross-head of the Universal Testing fed with a speed of 2mm/min. The flexural strength specimen specification details are shown in Figure 12. The average flexural strength is GBG is 191.857 MPa. and the average flexural strength is of BGB is 278.23 MPa. As shown tables 5 & 6 respectively and the load vs deflection shown in figure 13.

Flexural Strength Specimen details

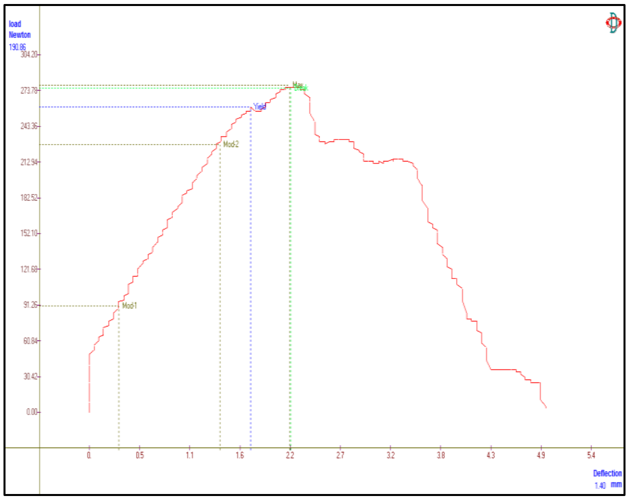
Figure 12: Flexural strength testing machine

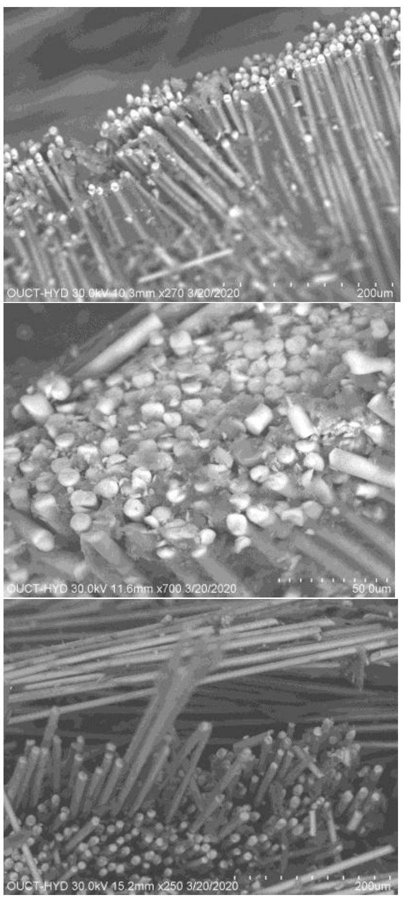
Table 5: Flexural Strength (GBG)

Ref. Standard	**ASTM D790**		
Specimen code	**GBG-01**	**GBG-02**	**GBG-03**
Yield Force (N)	288.93	219.744	156.96
Yield Deflection (mm)	2.22	2.38	1.53
Max Force (N)	306	226.5	167.7
Flexural Strength @ Max (MPa)	251.51	186.2147824	137.8473064
Flexural Strain	0.025034808	0.036866186	0.021285639
Flexural Modulus at 1% Strain (MPa)	25648.43	18989.7	14057.31
FLEXURAL MODULUS OF ELASTICITY ($N/_{mm}{}^2$)	9537.131056	6849.649149	5070.5195
Average Flexural Strength (MPa)	**191.857 MPa**		

Table 6: Flexural Strength (BGB)

Ref. Standard	**ASTM D790**		
Specimen code	**BGB-01**	**BGB-02**	**BGB-03**
Yield Force (N)	300.75	259.965	359.1239681
Yield Deflection (mm)	1.91	1.74	2.04
Max Force (N)	317.7	278.5	397.2
Flexural Strength @ Max (MPa)	266.940251	233.9846644	333.6753137
Flexural Strain	0.021391028	0.021990024	0.024673973
Flexural Modulus at 1% Strain (MPa)	26366.61	23111.47	32958.26
FLEXURAL MODULUS OF ELASTICITY ($N/_{mm}{}^2$)	11096.26568	7510.912262	10713.53457
Average Flexural Strength (MPa)	**278.23 MPa**		





Glass-Basalt-Glass

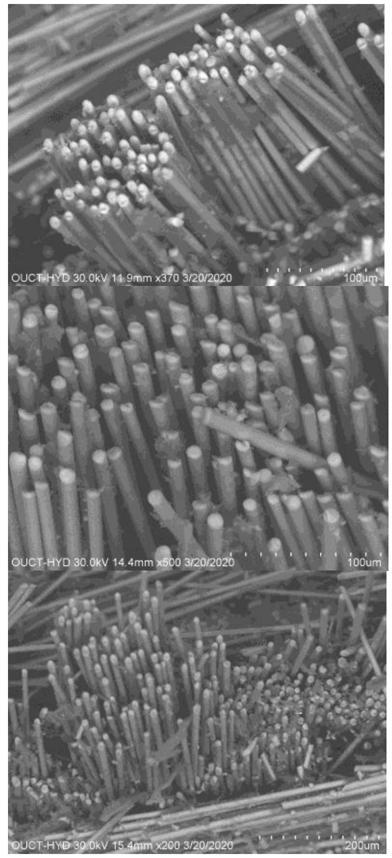


Figure15: Basalt-Glass-Basalt

5. Conclusion:

In this paper, GBG and BGB Hybrid composites are prepared by using hand layup technique and their mechanical properties like tensile strength, flexural strength, and compressive strength are investigated. Scanning Electron Microscope (SEM) analysis also conducted for testing the bonding strength of fibers.

The following conclusions are drawn from the test results

1. The Average Tensile Strength of BGB (240.72 MPa) is slightly lesser than that of the specimen with GBG (245.01 MPa) composite.
2. The Average Compression Strength of BGB (17.77 MPa) is more than that of the specimen with GBG (12.54 MPa) composite.

3. The Average Flexural Strength of BGB (278.23 MPa) is more than that of the specimen with GBG (191.857 MPa) composite.
4. From the observation of SEM images it should be concluded that the bonding of the fibers in the Hybrid Composite is appreciably great with basalt and glass fibers.

From the above experimental results, it is observed that Basalt-Glass-Basalt (BGB) composites are stronger than the Glass – Basalt-Glass (GBG) composites.

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