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Investigations on Mechanical Strength of Hybrid Basalt/Glass Polyester Composites

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Abstract

This study focused on tensile, flexural and impact properties of plain woven basalt, plain woven glass and basalt-glass polyester hybrid composites manufactured using hand lay-up method with different layering arrangement. It was observed that, the hybrid composites showed intermediate tensile and flexural properties between plain basalt and plain glass polyester composites while for impact properties for hybrid composite showed higher value than plain basalt and plain glass polyester composite. Additionally it was observed that by controlling the stacking sequence mechanical properties can be improved.

Keywords: Basalt fiber, Glass fiber, Hybridisation, Layering arrangement, Mechanical Strength.

INTRODUCTION

Composite comprises of different materials with distinct properties to create a superior and unique material. Composites are grouped by reinforcement or by types of matrix in which reinforcements are load carrying element whereas matrix material help them to keep in desired location and become load transfer medium between reinforcement and matrix [1]. Fiber reinforce composites are gaining interest in various application, but their growth is limited due to toughness. Hybridisation of fibre is an approach to make composites toughen by combining different kind of fiber and these hybrid composites offer good mechanical properties compare to non-hybrids composites. Mingling of fiber in unit matrix, hybrid fibre reinforced composites offer wide range of mechanical properties [2, 3]. Hybrid composites have several three main advantages over composites which made of using one type of fiber reinforcement. First, they provide new liberty to designer with some unique properties. Second, effective cost utilisation of expensive fibers can be fetched by partially swapping them to least expensive fibers. Third, they provide diverse combination of mechanical properties like ductility, strength and stiffness. Also, hybrid composites are weight saving, improvement of fractural toughness, reduction in notch sensitivity, good impact resistance, longer fatigue life compared to composite which made of single reinforcement. [4]

With advance increase in usage of polymer reinforced along with synthetic fiber has lead to great demand in field of defence, automobile, sport zone etc. The reason behind is optimisation of cost effectiveness of structures & components to achieve peak values of mechanical strength and stiffness [5]. Synthetic fibers (Glass, Kevlar, Carbon, Nylon etc.) are mainly used for making composites, but these fibers are not environment friendly. Recently there is significant growth in environment awareness and new regulation boosted the use of fibers which are environment friendly [6]. Therefore, Basalt fiber is taking as a primary reinforcement for this investigation. Basalt rock is a dense, hard, igneous rock, which is hard volcanic lava. Basalt rocks have 52.8% of SiO_2, 17.5% of Al_2O_3, 10.3% of Fe_2O_3, 8.59% of CaO, 4.63% of MgO, 3.34% of Na_2O_3 and other chemical composition like K_2O, TiO_2, P_2O_5, MnO, Cr_2O_3. Basalt fiber can be made from basalt rocks by melting and extrusion process in a single step. Basalt fiber offers similar performance to S-2 Glass Fiber and also price of the basalt fiber is in between price of S-2 glass and E-glass Fiber. Basalt fiber is a standby of steel and carbon fiber having low elongation and high rigidity [7]. Basalt fiber has some properties like High Tensile Strength, Good corrosion resistance, Dimensional Stability, High Heat Resistance, Fire Resistance, Excellent Fiber-Resin Adhesion, Good Thermal Conductivity, Good Chemical Resistance, Durability, Do not contain other additives, Larger strain to failure, Non- toxic [8]. But one major disadvantage of basalt fiber is it has higher cost compare to E-glass fiber. So that taking E-glass fiber is a secondary reinforcement for this investigation is a good choice, not only this reason but E-glass fiber shows some good mechanical properties as well [9]. There are very less literatures which show hybridisation with basalt fiber. Wei et al. [8] have investigated on degradation of Glass-Basalt with epoxy resin in seawater and they proved that hybrid material experiences some physical damage or irreversible chemical degradation while hybrid composites put in the sea-water for long time. Alexander et al. [10] have investigated about mechanical characterisation on hybridisation of Basalt-sisal-glass fibers and they gave result that combining sisal-basalt fibers gives good performance

compare to sisal-glass fibers, therefore sisal-basalt-epoxy can be best combination for aircraft structural applications. Density, young modulus and tensile strength of basalt fiber can increase by using polypropylene resin instead of thermoset composites also these composites are greatly useful for aerospace or armour structure application [11]. There are numerous studies available on the mechanical characterization of hybrid composites in combination with E glass such as T700S carbon fibres [12], sisal [13], caraua [14], coir [15], Jute [16], banana and hemp [17], bamboo [18] fibers. The constituents of a composite, such as fibers and matrix, influence the mechanisms operating in the composites throughout loading, damage progress, failure types and eventually the strength [19]. Mechanical behaviour of hybrid fiber composites depends on content of fiber, weight and volume fraction of reinforcement, L/D ratio and orientation angles of fibers, different kind of fibers, chemical treatment of reinforcement, stacking sequences and many others [16, 20]. Composites containing transversely and random oriented fibers shows lesser mechanical properties than longitudinal oriented composites, but woven fabric mat shows higher mechanical properties compare to other [21].

The aim of this study was to produce woven basalt-glass polyester hybrid composite with eight different kind of stacking sequence of woven fiber and to study their effect on tensile, flexural and impact properties.

MATERIALS AND METHODS

- **Composite specimen preparation**

Woven basalt fiber and woven glass fiber as a reinforcement and polyester resin as matrix used to fabricate hybrid composite. Woven basalt mat procured from Nickunj eximp entp. pvt. Ltd. Mumbai, India and woven glass fiber procured from Basnsari composites, vidhyanagar, Gujarat, India was used as reinforcement. The matrix material consists of Polyester Resin (Vimal polyester industries, Ahmedabad, Gujarat), Methyl ethyl ketone peroxide (MEKP) catalyst and cobalt Nitrate accelerator was used. Figure 1 and 2 respectively shows woven basalt fiber and woven glass fiber which were cut with require dimension (300mm x 300mm). The tensile properties of woven fibers were tested using IS 1969 which are revealed in Table 1.

Table 1 Tensile properties of woven basalt and woven glass

Fiber Fabric	Tensile Strength (N)		Tensile Elongation (%)	
	Warpwise	Weftwise	Warpwise	Weftwise
Basalt	3632.67	3868.8	2.45	2.51
Glass	520	513.6	1.33	1.35

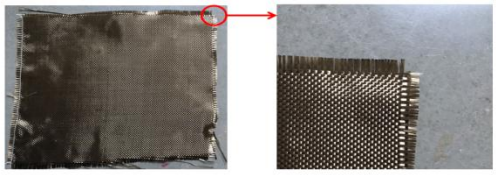

Figure 1 Woven basalt fiber

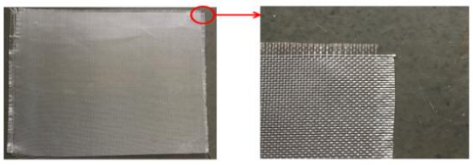

Figure 2 Woven glass fiber

Using the hand lay-up methodology plain Basalt-polyester, plain Glass-polyester and Basalt-glass-polyester hybrid composites with six different stacking sequences were made-up. The matrix material consisting of unsaturated polyester, accelerator and catalyst in the ratio of 1:0.03:0.012. Put woven Basalt Fibre or E-glass fibre as per the stacking sequence and apply matrix material on each layer of fabric with the help of Brush which was used for forcing Resin into Fabrics. Composite was cured for 8-10 hours at room temperature. The same procedure was repeatedly followed to make other composite as per different stacking sequences. The detail arrangements of stacking sequence are shown in table 2.

Table 2 Details of fiber layering arrangements

Sr. No.	Composite plate number	Stacking Sequences
1	P1	GGGBBBBBBGGG
2	P2	BBBGGGGGGBBB
3	P3	BGBGBGGBGBGB
4	P4	GBGBGBBGBGBG
5	P5	GGBGBBBBGBGG
6	P6	BBGBGGGGBGBB
7	P7	BBBBBBBBBBBB
8	P8	GGGGGGGGGGGG

MECHANICAL CHARACTERISATION

- **Tensile testing**

Samples for tensile test were slice into the composite laminates by using VMC (Vertical Machining Centre). Tests were performed on Universal Testing Machine (model:- L series H50KL, cross head movement:- up to 1100 mm, capacity:- 5 tons) at a continuous cross-head speed of 5 mm/min as per D638 ASTM standard. Samples were placed between the grippers and pulled until failure. Five samples to each composite laminates were tested as per D638 ASTM standard and then mean of the result was reported. Figure 3 shows the experimental setup for tensile testing.

Figure 3 Experimental setup for tensile testing

- **Flexural testing**

The flexural test was performed on rectangular specimens which were cut from composite laminate using Universal Testing Machine as per ASTM D790. The flexural test was originated by load applying at the centre of specimen with the specific rate and the deflections were measured and then mean of that result was reported. Figure 4 shows the experimental setup for flexural testing.

Figure 4 Experimental setup for flexural testing

- **Impact testing**

Impact test was performing for how much amount of energy used to break specimen. A notch Izod impact test was used for measuring impact energy as per ASTM D256. Five samples for each composite were examined and the mean of the value was reported. Figure 5 shows the experimental setup for impact testing.

Figure 5 Experimental setup for impact testing

RESULTS AND DISCUSSION

- **Effect of Stacking Sequence on Tensile test**

Tensile strength and tensile modulus for various composite specimens are shows in Table 3.

Figure 6 shows how tensile strength changes with different layering arrangement. It can able to be seen that plain basalt polyester composite shows higher tensile strength compare to plain glass polyester composites. Having different arrangement of basalt and glass fiber shows different result in that we have noticed that the value of tensile strength lies between 246.2 MPa to 292.6 MPa, which is greater than plain glass polyester composite but smaller than basalt polyester composite.

Four basalt layer at centre i.e. GGBGBBBBGBGG layering arrangement gives higher tensile strength compare to other hybrid composites because basalt fiber has higher modulus that glass fiber.

Figure 7 shows stress-strain tensile curves for hybrid composites with different stacking sequence. It is noticed that plain basalt polyester composite has greater strain because basalt fibers are stronger and have higher modulus than glass fibers. Hybrid composites have in-between behaviour between plain basalt and plain glass polyester composite.

Table 3 Tensile properties

Sr. No.	Composite plate number	Tensile Strength (MPa)	Tensile Modulus (MPa)
1	P1	264.6	2300
2	P2	263.6	1790
3	P3	246.2	1830
4	P4	249.4	1970
5	P5	292.6	1960
6	P6	249	2180
7	P7	333.8	2510
8	P8	191.6	1970

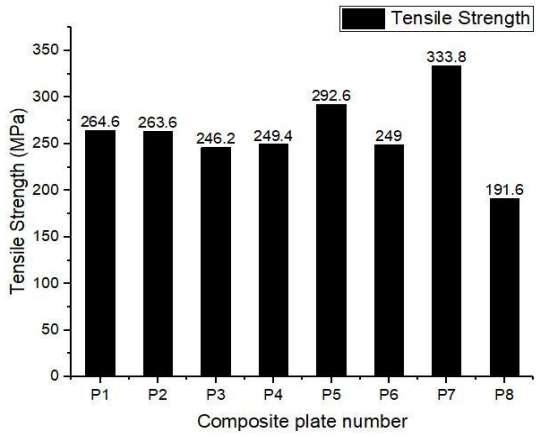

Figure 6 Difference in tensile strength with diverse layering arrangements

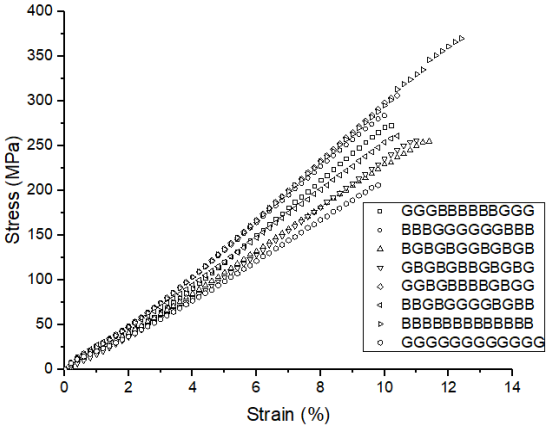

Figure 7 Typical stress-strain tensile curves for various composite

- **Effect of Stacking Sequence on Flexural test**

Table 4 shows flexural strength and flexural modulus of different composite specimens.

Flexural strength varies with different layering arrangements shown in figure 8. It is clearly seen that plain glass polyester composite has higher flexural strength compare to plain basalt polyester composite. Composite with the layering arrangement of BGBGBGGBGBGB showed higher flexural strength compare to other hybrid composites.

It was clearly noticed that higher flexural modulus of hybrid composite H3 (BGBGBGGBGBGB) shows higher flexural strength (302 MPa) and lower flexural modulus of hybrid composite H1 (GGGBBBBBBGGG) shows lower flexural strength (199 MPa).

- **Effect of Stacking Sequence on Impact test**

Table 5 and figure 9 shows that how impact strength varies with different layering arrangements which carried out with notch Izod impact test.

Impact strength of plain basalt polyester composite gives higher value compare to plain glass polyester composite. But In the case of impact strength, composite with layering arrangement of GGGBBBBBBGGG shows higher value than plain basalt polyester composite while other hybrid shows intermediate behaviour between plain basalt and plain glass polyester composite.

Table 4 Flexural Properties

Sr. No.	Composite plate number	Flexural Strength (MPa)	Flexural Modulus (MPa)
1	P1	199	7930
2	P2	204	9970
3	P3	302	13900
4	P4	251	12200
5	P5	201	7200
6	P6	270	13000
7	P7	328	18900
8	P8	361	15900

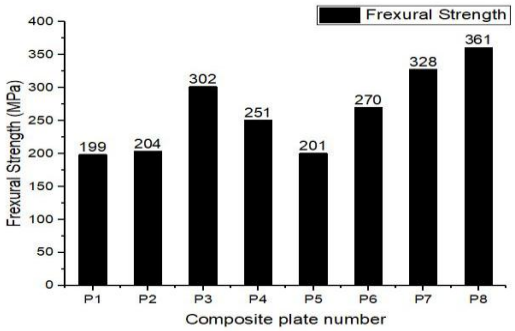

Figure 8 Difference in flexural strength with diverse layering arrangements

Table 5 Impact properties

Sr. No.	Composite plate number	Impact Strength (J/M)
1	P1	1917.16
2	P2	1547.04
3	P3	1581.24
4	P4	1446.33
5	P5	1409.60
6	P6	1556.24
7	P7	1840.16
8	P8	595.72

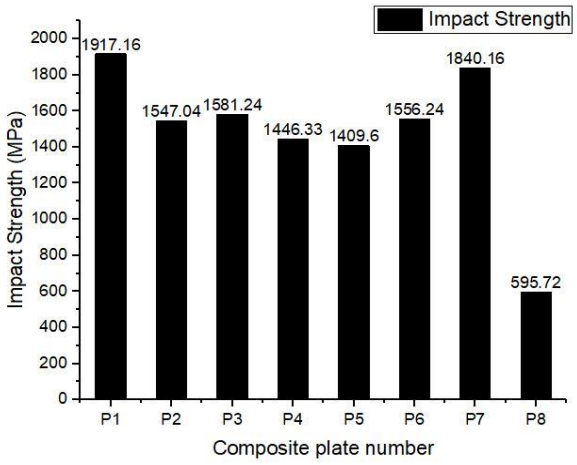

Figure 9 Difference in impact strength with diverse layering arrangements

CONCLUSIONS

The effect of stacking sequence on tensile, flexural and impact properties for basalt-glass polyester hybrid composites was investigated in this study. Hand lay-up method used to fabricating basalt-glass polyester hybrid composite.

For tensile and flexural properties, the hybrid composites showed intermediate properties between plain basalt and plain glass polyester composites while for impact property hybrid composite (GGGBBBBBBGGG) showed higher value than plain basalt and plain glass polyester composite.

In order to obtain good tensile strength for basalt-glass hybrid polyester composites, there must be four basalt fiber layers at centre places as GGBGBBBBGBGG stacking sequence gives maximum tensile strength.

In order to obtain good flexural strength for basalt-glass hybrid polyester composites, there must be basalt fiber layer at extreme places as BGBGBGGBGBGB stacking sequence gives maximum flexural strength.

To get maximum impact strength for basalt-glass hybrid polyester composites, GGGBBBBBBGGG stacking sequence gives maximum impact strength.

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