Mechanical Properties of Glass/Basalt Hybrid Composite Reinforced Epoxy Composites

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Abstract : In this study Mechanical properties of basalt (B)/glass (G) reinforced epoxy composites was investigated. Composite laminates were fabricated by using hand layup process. Each laminate consists of five layers of fabrics and resin mixture as per stacking sequence. Six different kinds of laminates were prepared with filler materials (coconut shell powder and aerosel).Different kinds of laminates were prepared in the following stacking sequence B/B/B/B/B, G/G/G/G/G, and B/G/B/G/B with coconut shell powder, B/B/B/B, G/G/G/G/G, and B/G/B/G/B with filler aerosel. The Specimen preparation and test was carried out as per ASTM standards. Mechanical properties like tensile strength, impact strength were evaluated and compared. It was observed that maximum tensile and impact strength was accrued in hybrid composite laminate 6 with aerosel filler materials.

***IndexTerms* - Basalt fabrics, Glass fabrics, Coconut shell powder, Aerosel powder Polyester Matrix Composites.**

I. INTRODUCTION

Glass fibers and basalt fibers are the most commonly used for polymeric matrix reinforcement composites. Glass and basalt fibers have their low cost, high tensile strength, high chemical resistance, and insulating properties.

In recent years, the usage of natural fibers as a replacement for synthetic fibers such as carbon and glass fibers in composite materials has gained interest among researchers throughout the world. Extensive studies on natural fibers, such as sisal [1], jute [2,3] and flax [4,5], showed natural fibers has the potential to be an effective reinforcement for composite materials. The renewed interest of natural fibers over synthetic fibers was that they are abundant in nature and are also renewable raw materials. The usage of natural fibers also provided a healthier working condition than that of glass fibers [6]. Furthermore, natural fibers offer good thermal properties and excellent acoustic performance. These advantages made natural fibers gain applications in automotive, packaging and construction industries [7]. However, the products made from natural fiber composite were still limited to the non-structure or sub-structure applications, for example, the interiors of cars due to their relatively poor mechanical properties [8]. Different approaches have been attempted to increase the mechanical properties of natural fiber reinforced composites, such as chemical or physical modifications of the matrix, fibers or both of the components. Mohanty et al. [9] found that alkali treatment increased the bending strength of jute/biopol composites by 30%. Xie et al. [10] reviewed the influence of silane coupling agents used for natural fiber/polymer composites. Besides, hybridizing the natural fibers with a stronger synthetic fiber could significantly improve the strength and stiffness of the natural fiber reinforced composite. Perm kumarnaik et al. [11] studied Mechanical Properties of Sisal/Banana Hybrid Composite Reinforced Polyester Composites, he concluded that maximum impact strength absorbed in laminate 4 is 198.62 J/m and maximum hardness observed in laminate 4 is 13.8Kgf/mm2.

Above review shows that there is a limited work has been done on stacking sequence by using hand layup process. Hence in this research work mainly focused on influence of various stacking sequences on mechanical properties of hybrid combination of basalt and glass fabrics with and without filler materials.

II. MATERIALS

Epoxy resin were used as a thermosetting materials. E-glass and basalt fiber were used as reinforcing material.

2.1 POLYESTER RESIN: Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group. Epoxy LY556 resins with HY951 hardener was used for the fabrication of basalt-glass reinforced hybrid composite and also it has high versatility, excellent adhesive characteristic, lesser amount of shrinkage and low cost. Which is used here for binding the materials such as two different fabrics table 1 shows that properties of epoxy resin.

Table 1: *properties of Epoxy resin*

Material	Density in g/m3 x106	Modulus of elasticity in GPa	Poisson's ratio
Epoxy	1.15	2.65	0.35

2.2 ***COCONUT SHELL POWDER:*** Coconut shell particles were used as filler material for this investigation. Shell particles of size between 200-800μm are prepared by using grinding machine. Coconut shell particles are potential candidates for the development of new composites because of their high strength and modulus properties, approximate value of coconut shell particle density was 1.60 g/cm^3. Coconut shell powder as shown in figure1.

2.3 Aerosel powder : In this research work aerosel powder was used as filler materials. Aerosel powder can be found, for instance, in the cosmetics industry, where it increases the temperature stability of lipsticks. It is also used in the production of offshore yachts and in the electronics industry. Aerosel powder can be found in any bathtub, aerosel powder having pyrogenic oxides result in thixotropy, low moisture absorption, mechanical stability and the optimization of rheological properties. Aerosel powder as shown in figure 2.

(a) (b)

Figure1.a.Coconut shell powder. b. Aerosel powder

2.3 Glass fiber : There are variety of glass fibers used in different applications such as E-glass fiber (Electrical application), S-glass (Structural application have high temperature) and C-glass (Corrosive environment). The glass fibers are existing in many forms such as woven fabrics and continuous chop etc. Glass fibers are accessible commercially are generally preparing in the form of long continuous fibers, chopped strands, and woven roving (cloth). In chopped strand, the continuous fibers are slice to the short piece and fibers are arranged in the appearance of bundle. S-glass has greater modulus, higher tensile strength and higher elongation at failure compared to the E-glass. The mainly used of S-glass where strength is a primary concern along with weight e.g. tail wings of airplane, airplane fuselage, ship hulls, pipes for carrying aqueous liquid etc. But its primary issue is its cost because it is restrict in its use in general applications such as sports items namely window frame, fiber glass door, bath tub, hockey sticks, arrow of archery, hockey, and household appliances[12]. Figure 2 shows E glass fibers and fabrics.

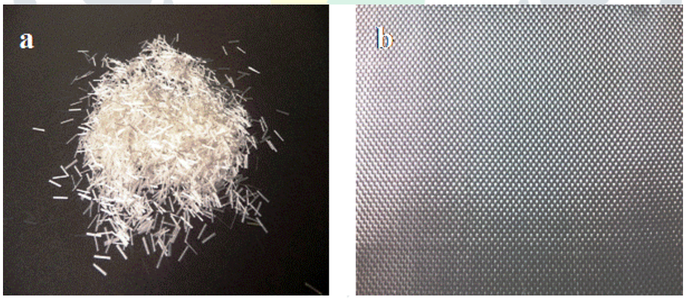


Figure 2: a) E-glass fiber, b) E-glass fabric

In E-glass fiber, "E" indicates the electric, which is form from alumina - borosilicate glass having oxides of alkali, which is < 1 percentage by weight. The C-glass having higher percentage of boron oxide, whereas S-glass having high percentage of magnesium oxide with aluminum and silica oxide[13]. E-glass is the lowest price comparing to all commercially available reinforcing fibers, for this reason, it is uses in widespread for the FRP industries. For this reason, E-glass fabrics was used for our research work.

2.4 Basalt fiber: Basalt fabrics was used for our research work. Basalt fibers are dark colored materials, which are prepare from fine fibers of basalt (volcanic rock) which are composed of basic minerals like plagioclase ($Na/CaAlSi_3O_8$), pyroxene ((NaCa)(Mg, Fe, Al)(Al, Si)$_2$O$_6$) and olivine (Mg^{2+}, Fe^{2+})$_2$SiO$_4$. Basalt rock originating from flood volcanoes and volcanic magma which is very hot fluid or semi-fluid material present under the earth's crust. Once it comes out on earth surface, it will be solidify due to atmospheric temperature. Although fiber of basalt materials are not biodegradable but even though it will considered as natural materials, because it is form from basaltic (volcanic) rocks. It is found in nature and virtually in observe in every country around the globe and environmentally friendly in nature. High acidity with low iron content of basalts is mainly considerable for production of fibers. This type of fibers is prepared from single materials, crushed basalt from the quarry source. Figure 2 shows basalt rock and basalt fabrics.

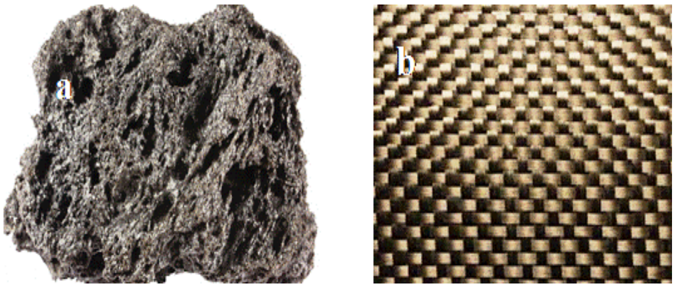


Figure 2 : a) Basaltic rock, b) Basaltic fabric

Fibers of basalt are typically produced by two different methods: Junkers method and spinneret technology [14]. This is the only fibers which are not adding of any materials while its production. It required only washed simply and then melted the basalt materials at about 1500 ^{o}C. These types of fibers are similar to fiber-glass with better physic-mechanical properties and also cheaper than carbon fiber. Usually, this fibers are using in the field of fire-proof textile, automotive and aerospace industries.

III. Composite Preparation

The composite laminates were prepared according to ASTM standard; the composite laminates were prepared 300 x 300 x 3 mm^3 using by hand lay-up process. The layer of fabrics is placed one by one on the mold which is flat and then the epoxy resin is used after each layer followed by hand lay-up technique. Epoxy LY556 resin and the HY951 hardener were mixed in the rate of 10:1 Weight fraction is calculated by using Equations 1[11]. A hydraulic cold press was used for the preparation of composite laminates, mould was placed inside the hydraulic press, 8N load were applied on mould, then laminates were cured at that pressure for 24 hours. After that laminate are separate from mould box. Staking sequence of laminates as shown in table 2.

$$Wf = wf/(wf + wm) \text{ and } Wm = wm/(wf + wm) \ldots\ldots.(1)$$

Wf = Weight of fiber

Wm = weight of matrix

Table 2. Stacking sequence of laminates

laminates	Staking sequence
L1	G/G/G/G/G
L2	B/B/B/B/B,
L3	B/G/B/G/B
L4	G/G/G/G/G,
L5	B/B/B/B/B
L6	B/G/B/G/B

3.1 Experimental Procedure:

a. Tensile test: The tensile strength test of the prepared composites is studied using a computerized Universal testing machine (UTM). Tensile testing of the specimen prepared according to ASTM standard (D-638) dimension of tensile test sample 216 X 19 X 3mm^3. A sample was tested using computerized tensile testing machine with cross head speed of 5 mm/min and 50mm of gauge length. The tensile modulus and its elongation at the break of the composites were calculated from the stress strain curve, five specimens were tested for the sample each value were recorded, compared and tabulated. Dimension of tensile test specimen as shown in figure 3.

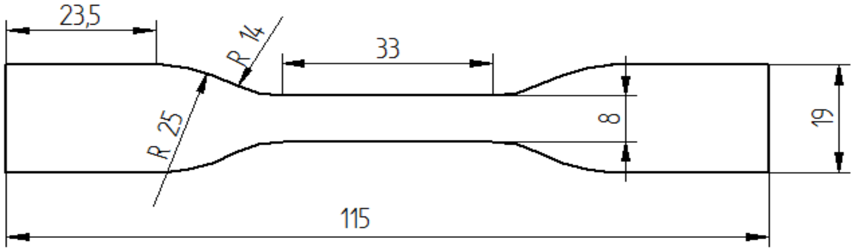


Figure 3: Dimension of tensile test specimen.

b. Impact Strength Test: Impact strength is the ability of a material to withstand suddenly applied load. Izod impact test is one of the most common test used to estimate the impact resistance as specified by ASTM D256 standard. Izod impact test specimens are prepared according to ASTM standard D256. Dimensions of izode impact sample are shown in figure 4.

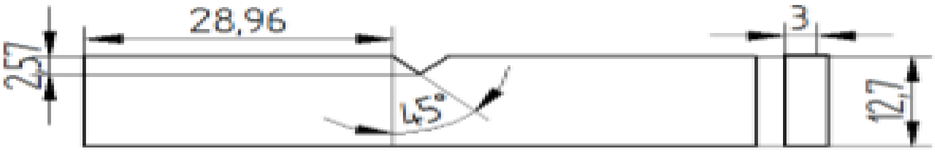
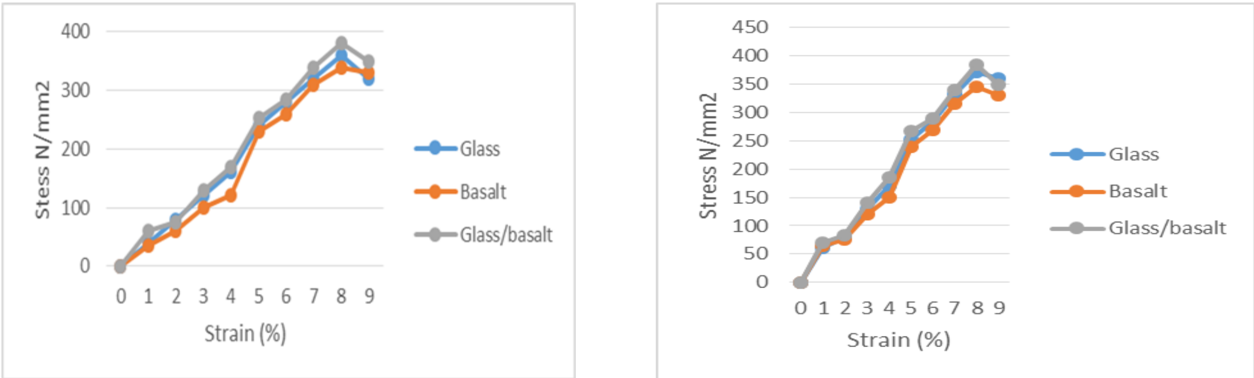


Figure 4. Dimension Izod impact test specimen

IV. Results and Discussion

The ultimate tensile strength, maximum impact strength of the specimens are determined and discussed below.

4.1 Tensile test results:



(a) (b)

Figure 5. a. composite laminate with coconut shell powder. b. composite laminate with aerosel powder.

The tensile strength of the composites was studied using a computerized Universal testing machine (UTM) for all samples in that maximum stress strain and ultimate tensile load was reported. Figure 4 shows that stress strain curve for the E-Glass and coconut shell powder combination. Three test was carried out for each laminates and average stress stain values are recorded as shown in figure 4.It was absorbed that maximum stress value found in hybrid composite laminate 3 is 380 N/mm^2 compared to laminate 1 and laminate 2, further it was observed that ultimate tensile load was 31.13kN and ultimate tensile strength 387.2Mpa.

Figure 5 shows that stress strain curve for the basalt fabrics and aerosel powder combination. Three test was carried out for each laminates and average stress stain values are recorded as shown in figure 5.It was absorbed that maximum stress value found in hybrid composite laminate 6 is 385 N/mm^2 compared to all other laminates further it was observed that ultimate tensile load was 38.5kN and ultimate tensile strength 476.34Mpa.further it was observed that fabrics with aerosel powder combination found maximum value compared to coconut shell powder combination.

4.2 Impact Test: The impact strength of different fabricated composite laminates was estimated on Izod impact tester. For each laminate three tests were conducted and the average of the impact strength are presented in Table 3.

From figure 6 it was observed from the results that hybrid (Laminat6) composite laminate with aerosel powder combination exhibit enhanced impact strength compared to other composite laminates. Increase in the impact strength is due to better bonding, adhesion and uniform dispersion of the fiber in the matrix. It is absorbed that hybrid Laminate 6 with aerosel powder combination exhibits better impact strength is12.2 J/mm^2.

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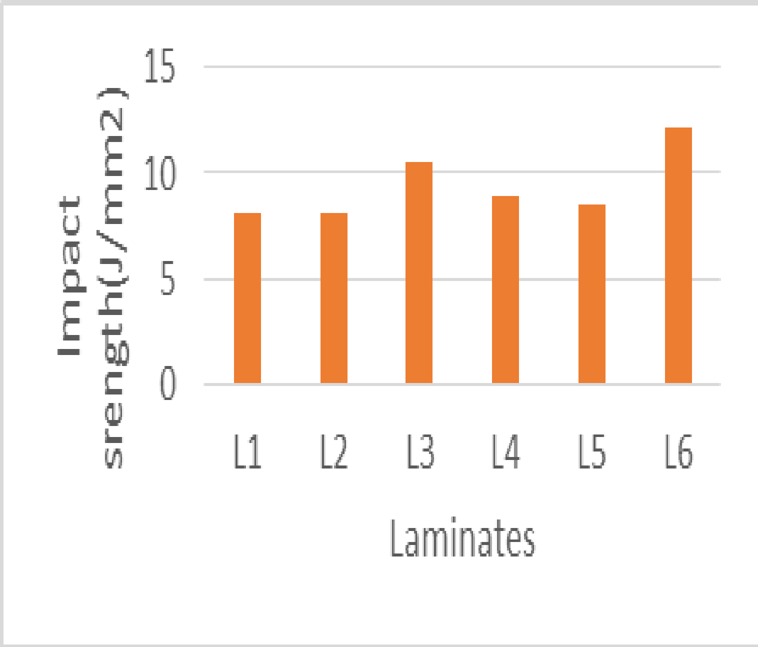

Figure 6. Average Impact strength of different laminates

V Conclusion

A multilayered hybrid composite has been fabricated successfully by reinforcing low cost, light weight, eco-friendly glass fibres with basalt fibers with filler materials, using epoxy resin matrix. It is noticed that hybrid combination glass- Basalt with aerosel powde combination of laminate 3 exhibit maximum ultimate strength and exhibits maximum impact strength as compared to other composite laminates. It is clearly observed that Maximum ultimate strength was exhibits in Laminate 6 is 476.34 Mpa, Due to better bonding, adhesion and uniform dispersion of the fiber in the matrix. Maximum impact strength was exhibits in laminate 6 is 12.2 J/mm^2. Due to better bonding, adhesion and uniform dispersion of the fiber in the matrix.

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