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# Fabrication of Helmet using Basalt Fiber and Analysis of Stress, Strain : Total Deformation between Basalt Fiber and Polystyrene

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## Abstract

Basalt fiber is artificial fiber which is made from basalt rock which is similar to glass fiber and carbon fiber. Basalt originates from volcanic eruptions after they get solidified. Basalt mainly consists of olivine, clino-pyroxene, plagioclase and opaque metal oxides. Raw materials are found easily and it has very easy manufacturing process. It has better physiomechanical properties and cheaper. This fiber has high hardness and good thermal properties. It has high stiffness and strength than glass fiber. These have many field applications and can replace many costly materials. These fibers have high potential to solve problems in cement and concrete industries. This project deal with fabricating of the component using basalt fiber and epoxy resin LY556 and hardener HY951 to the shape of component.

**Keywords:** Basalt fiber • Volcanic eruptions • Good thermal properties

## Introduction

Basalt fiber is a type of igneous rock formed when rapid cooling of lava takes place on the surface of the earth's crust [1]. This basalt rock characteristic varies with conditions like source of lava, cooling rate and historical exposure of the elements from several years [2]. Generally high quality fibers are obtained from basalt deposits with uniform chemical process [3]. These fibers produced from basalt rock are selected based on the rock with rich chemical proprieties and use of quality tests like crushing the rocks and melting them to high temperatures (Figure 1 and Table 1) [4].

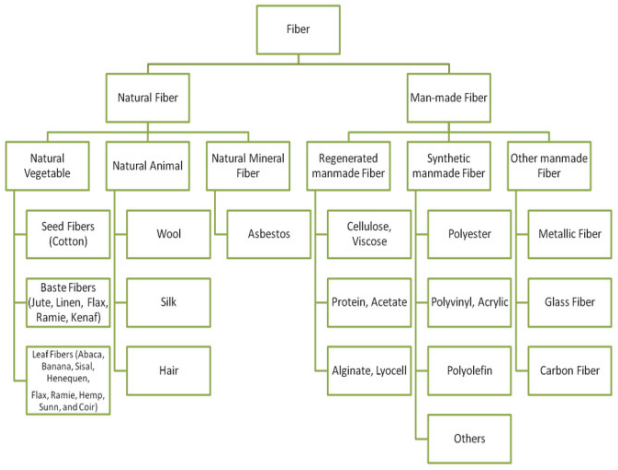


**Figure 1.** Image showing the different types of fibres.

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**Table 1**. Difference between natural fibre and synthetic fibre.

| Natural fiber | Synthetic fiber |
|---|---|
| These are naturally obtained | These are chemically composed |
| Colors of these are obtained naturally | Colors of these are artificially obtained |
| These are eco-friendly | These are generally not eco-friendly |
| These are comparatively less durable than synthetic fibers | These are more durable than natural fibers |

## Materials and Methods

Significant growth is observed in the field of composite world. Basalt fiber is a huge performance non-metallic fiber made from basalt rock melted at high temperature. It originates from volcanic magma. A very hot fluid or semi hot fluid material under solidified in open air. It is resistant to alkalis and acids, it is thermally, electrically and sound insulated. Its tensile strength can be greater than large-tow carbon fiber, its elongation is better than small carbon fiber. Basalt has a 3-dimensional molecule and when compared with single infiltrating linear polymeric fibers [5-10]. It is cost effectiveness, anti-aging, as well as other excellent characteristics (Figure 2).

**Figure 2.** Basalt fiber.

## Epoxy resin

Epoxy resin is a polymerizable thermosetting resin and occurs in various viscosities including liquids and solids [11]. There are many different types of epoxies that are used widely in preparation of materials and structural adhesives. Epoxies have advantages like high strength, low levels of volatiles, excellent adhesion, and low shrinkage of fiber, good chemical resistance and ease of processing it. Major disadvantages are brittleness with the quantity of the resin used and the reduction of properties in the presence of moisture. Processing techniques are autoclave molding, filament winding, press molding, vacuum bag molding, resin transfer molding, and pultrusion. The most common cure temperatures range between 250°C and 350°F (120°C-180°C) (Figures 3 and 4) [12].


**Figure 3.** Epoxy resin LY556.

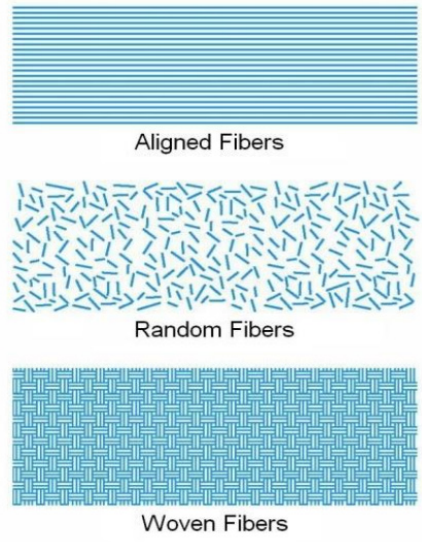


**Figure 4.** Alignment of fibers.

**Aligned fiber:** These are aligned in same order so that it may have equal thickness in every cross section of the material.

**Random fiber:** These are arranged in the zigzag manner so that this won't have the strength equal in all areas.

**Woven fiber:** These are very impressive alignment because this is so strong in all the parts of the material.

Study of mechanical properties of hybrid natural fiber composite Mayur Thombre, Animesh Agarwal, Chandrajeet, Sandeep Nair, Mechanical engineering, Shri Shankaracharya Institute of Technology and Management Bhilai, India.

It has studied the effect of Fatigue resistance of basalt fibers reinforced laminates. Hand layup process is used to prepare the epoxy laminates were carbon, basalt, and E-glass balanced woven fabrics has been utilized. Mechanical characterization of laminates reinforced with fabrics having the same areal density demonstrated that basalt Fiber composites possess an elastic modulus higher than the corresponding glass fiber laminates, while their tensile strength approaches that of corresponding carbon fibers laminates. The investigation of the fatigue behavior confirmed the better performances of basalt Fiber laminates with respect to the corresponding glass fiber laminates, with higher stiffness retention at low fatigue loads and better damping properties. It was concluded that the potential of basalt fiber as replacement of glass fibers for the production of structural composites combining good mechanical performances and interesting energy dissipation capabilities.

Wang, et al. has studied the low velocity impact properties of 3D woven basalt/aramid hybrid composites. Inter ply and intra ply hybrid composites has been fabricated by using Aramid, basalt fibers, and epoxy resin. Impact test has been carried out in the composite at 2 m/s and 3 m/s impact velocities along warp and weft directions. Due to a layer-by-layer fracture mode for the inter ply hybrid composite the inter ply hybrid composite showed higher ductile indices (8%-220%), lower peak load (5%-45%), and higher specific energy absorption (9%-67%) in both warp and weft directions than that of the intra ply hybrid composite.

## Production of basalt fiber

**From lava to rock:** Basalt fiber is a type of igneous rock formed when rapid cooling of lava takes place on surface of earth's crust. Basalt rock characteristics vary from source of lava, cooling rate, and historical exposure to the elements.

Millions of years ago, eruptions from the center of the Earth expelled an enormous quantity of lava in the planet surface. The earth's mantle consists of a thin layer called sphere, when this thin lava get in contact with superficies, this creates basalt Rock. This occurs with long years of earth center temperature and pressure stabilization.

Even though high quality basalt found abundance in the nature, volcanoes throws tons of lava in earth atmosphere which reinforces the concept of advanced basalt fiber as a high technology and green composite.

**From rock to fiber:** The process of producing fibers from basalt is based on selecting the richest chemical properties basalt rocks with the use of quality tests, crushing the rocks and melting to high temperatures. The melted basalt is send from a specific hole where the temperature is gradually decreased from a yarn where thickness reduces over the cooling process where it gets rolled in a roving machine.

The continuous basalt fiber, which is made using the natural volcanic rock as the raw material, these are put in the furnace under 1450 P0P-1500 P0P after crushing them into power and then these are produced by the platinum rhodium drawing filament laminate in the process. Compared to the carbon fiber which has many unique advantages. Such as the physical property, the high temperature resistance, good acid and alkali-resistance, the good UV resistance, the low hygroscopic property, the environmental resistance and sound insulation, high temperature filter-ability, it offers radiation resistance , excellent wave-adsorption and wave-penetration and so on (Figure 5).

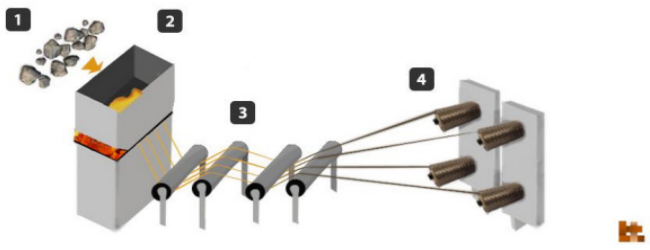


**Figure 5.** Production of basalt fiber.

Crushed basalt rock is the only raw material used in manufacturing of the fiber. It is a continuous fiber produced from igneous basalt rock melt and drawn about 2,700°F (1,500°C).

## Results and Discussion

The lava rocks are melted in the furnace. After it reaches the molten state this material is send to the extrusion process to form finer threads. These are continues fibers (Tables 2 and 3).

Advantages of composites

- Light weight
- High strength
- Strength related to weight
- Corrosion resistance
- High impact strength
- Design flexibility
- Nonconductive and nonmagnetic
- Durable

**Table 2**. Properties of basalt fiber.

| Chemical composition of basalt rocks | % |
|---|---|
| $SiO_2$ | 52.8 |
| $Al_2O_3$ | 17.5 |
| $Fe_2O_3$ | 10.3 |
| MgO | 4.63 |
| CaO | 8.59 |
| $Na_2O$ | 3.34 |
| $K_2O$ | 1.46 |
| $TiO_2$ | 1.38 |
| $P_2O_5$ | 0.28 |
| MnO | 0.16 |
| $Cr_2O_3$ | 0.06 |

The physical appearance of basalt fiber is usually grey in colour (Table 3).

**Table 3**. Mechanical properties of basalt fiber.

| Density (gm/cm3) | Tensile modulus (GPa) | Tensile strength (MPa) | Elongation at break (%) | Coefficient of thermal expansion (10-6 m/mK) |
|---|---|---|---|---|
| 2.66 | 93 | 4500 | 3.1 | 8 |

### Fabrication of helmet

This helmet consists of the woven fiber alignment. Procedure for fabricating helmet is:

Required materials are basalt fiber, epoxy resin LY556, hardener HY951, wax, paint brush. Taking the helmet model for the impression. Applying the wax for the model to reduce the adhesion on the helmet.

Add the resin and hardener in the 1:10 ratio. Mix it and apply as soon as possible on the helmet surface to avoid the hardening of the mixture. This will harden at the normal room temperature. Apply the resin on the wax. Keep the layer of the fabric mat on the surface.

- Follow this process for required amount of the thickness.
- Let it get harden for 4 to 5 days in room temperature.
- Remove the material carefully from the mould without damaging.
- Surface finish is done if required (Figures 6 and 7).

**Figure 6.** Basalt fiber mat.

**Figure 7.** Helmet fabricated.

### Applications of basalt

**Nuclear power stations:** It is used as the nuclear shields and insulators in the nuclear power plants.

**Construction sites:** Basalt fiber is added in the concrete for the construction of the buildings, houses, etc.

**Electro-technical purposes:** These are used as the insulators of the electricity. This can replace the glass materials in many conditions.

**Industrial applications:** As these are brittle in the nature these are used in the hard materials category in many fields.

**Hot gas filtration:** The development of the new high temperature synthetic fibers like basalt has led to increased use of hot gas filtration for the industrial applications. Glass fiber material can be operated at 30°C-260°C. But basalt fiber can reach up to 600°C to 800°C (Figures 8-10 and Table 4).

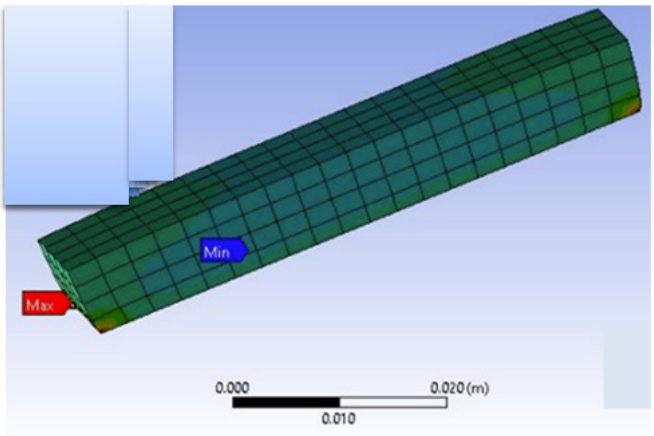


**Figure 8.** A-static structure of strain. **Note:** (▬) 0.00072736 Max, (▬) 0.00026281 Min.

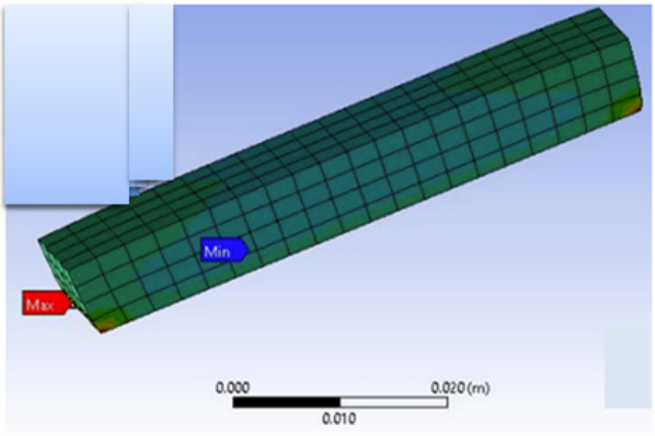


**Figure 9.** A-static structure of stress. **Note:** (▬) 5.8189e7 Max, (▬) 2.0946e7 Min.

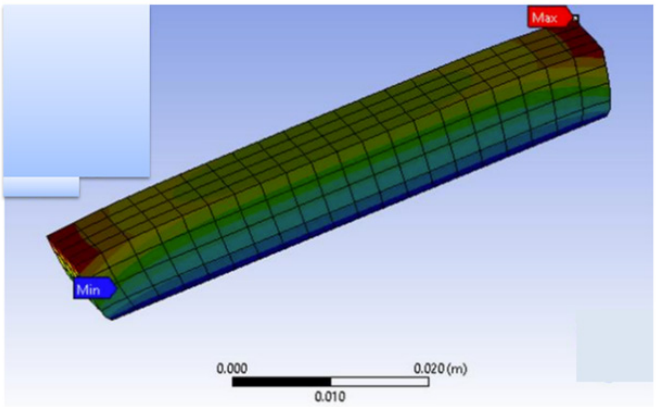


**Figure 10.** A-static structure of total determination. **Note:** (▬) 5.0979e-6 Max, (▬) 0 Min.

**Table 4**. Properties of A-static structure.

| **Bounding box** | |
|---|---|
| Length X | 5.4999e-002 m |
| Length Y | 1.e-002 m |
| Length Z | 1.e-002 m |
| **Properties** | |
| Volume | 5.5e-006 m³ |
| Mass | 1.4575e-002 kg |
| Scale factor value | 1 |
| Object name | Solid |
| State | Meshed |
| **Graphics properties** | |
| Visible | Yes |
| Transparency | 1 |
| **Definition** | |
| Suppressed | No |
| Stiffness behavior | Flexible |
| Coordinate system | Default coordinate system |
| Reference Temperature | By environment |
| **Material** | |
| Assignment | Basalt fiber |
| Nonlinear effects | Yes |
| Thermal strain effects | Yes |
| **Bounding box** | |
| Length X | 5.4999e-002 m |
| Length Y | 1.e-002 m |
| Length Z | 1.e-002 m |
| **Properties** | |
| Volume | 5.5e-006 m³ |
| Mass | 1.4575e-002 kg |
| Centroid X | -15.789 m |
| Centroid Y | -3.6633 m |
| Centroid Z | 5.e-003 m |
| Moment of inertia Ip1 | 2.4291e-007 kg·m² |
| Moment of inertia Ip2 | 3.7954e-006 kg·m² |
| Moment of inertia Ip3 | 3.7954e-006 kg·m² |
| **Statistics** | |
| Nodes | 1865 |
| Elements | 320 |
| Mesh metric | None |

## Conclusion

From the above literature by comparing two different materials like basalt and high impact polystyrene, we can conclude that in many of the cases like weight, temperature resistance, volume are better in the basalt than in hips. We can also understand that by adding the basalt fiber we can increase the tensile strength in different applications and it is used in different applications. Composite materials have good mechanical, electrical, chemical properties, where we can use these composite material in various industries. Several parts of automobile and aerospace components are manufactured by composite materials as they have good properties. Composite materials are used in domestic purpose like furniture, windows, doors, civil construction etc.

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