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# Comparative Study on Different Properties of Various Basalt Fibre and Its Composites: A Review

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**Abstract**

A high-tech fibre product without environmental pollution, basalt fibre is green, healthful, and environmentally friendly. BF (basalt fiber) has an excellent temperature resistance, high mechanical strength, low energy consumption and good chemical stability. This paper review the method used to manufacture basalt fibre, physical property of BF, mechanical properties, and thermal properties. Based on the reviews, basalt fibre is better to carbon, glass, and aramid fibres in terms of mechanical properties, sound insulation performance, and non-conduciveness. Based on the above qualities, adding basalt fibre to a substrate can enhance the material's properties. In the field of heat and sound insulation, basalt fiber and its composites can produce high- and low-temperature protective clothing and materials for sound insulation. Finally, this review showed some ideas that should be investigated in this area as well as possible areas for future research.

**Keywords**: - Basalt Fiber, composite material, mechanical properties, physical properties and thermal properties

## 1. Background

Over the past 25 years, the use of plastic in passenger cars has doubled. One factor for this is the tendency toward less weight and more complicated auto parts, but economic factors have also played a role[1]. Today, composite materials are used in a variety of automotive components, including fuel tanks, bumpers, and interior panels[2]. Compounds containing glass fibres are challenging to recycle because they are difficult to separate. The European Community requires member nations to reuse and recover at least 95% of all end-of-life (EOL) vehicles by 2015, in accordance with Directive 2000/53/EC[3].

Today, Automobile industries are facing two major challenges; reducing weight of vehicle in order to get more fuel efficiency without compromising the strength of the vehicle, and getting more environment friendly design of the vehicle. For years' synthetic fiber based composite materials (like Glass Fiber Composites and Carbon Fiber composites) are being used widely. Of course, they provide very high strength and other mechanical properties but they are very expensive and less environment friendly. So natural fiber based composites or hybrid composites are now gaining attention as they provide better formability, abundant, renewable, cost-effective and eco-friendly features. Different types of natural fibers are available; like Hemp, Banana leaf, Bamboo, Jute, Kenaf, Palm, Pineapple, Sisal, Areca, Human hair, and Basalt Fibers from basalt rocks.

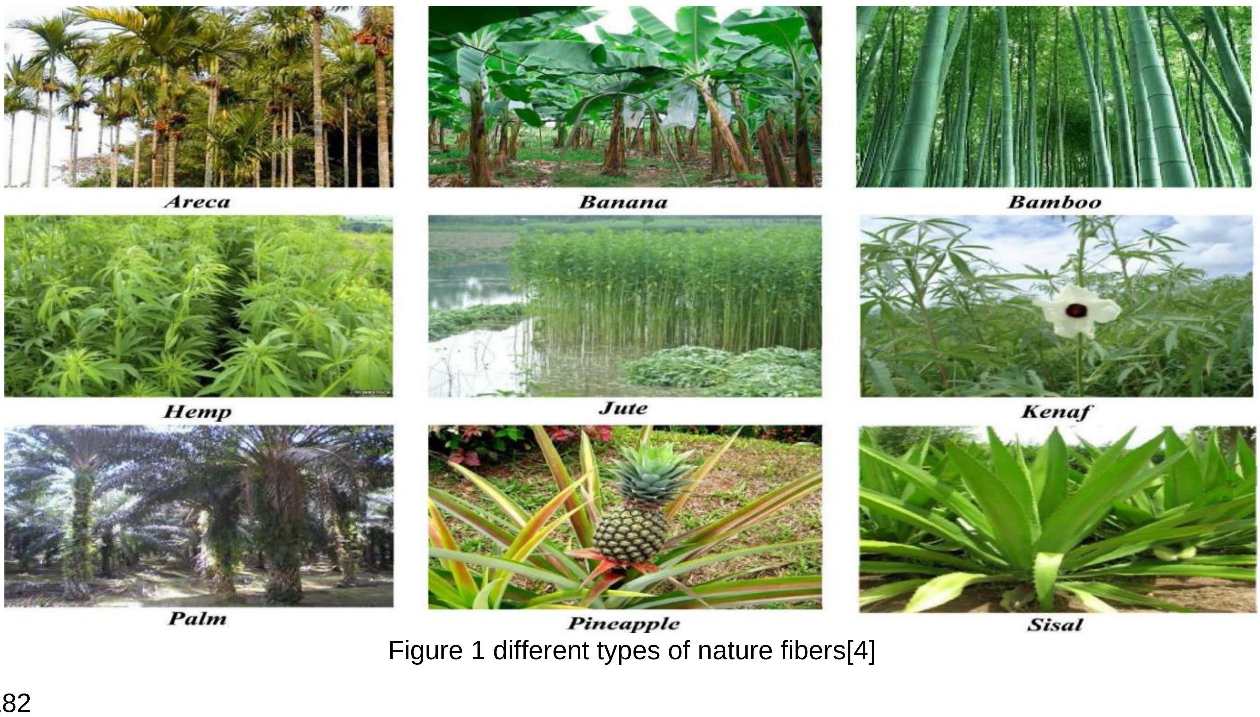


Figure 1 different types of nature fibers[4]

The study of basalt fibre and its composite materials' performance in India has significant theoretical value and strategic importance. Research on basalt fibre is still in its initial stages. Grinding

## 2. Introduction

The first production vehicle made of natural fibres was the Trabant from Eastern Germany, produced between 1950 and 1990. The oldest components added to plastic composites are likely sawdust and natural fibres. They have been used since bakelite, the first plastic, when they were employed to improve impact resistance, cut costs, and manage shrinkage. It featured with a cotton chassis enclosed in a polyester matrix. Up until recently, fibreglass or thermoplastics reinforced by mineral materials were employed by automobile manufacturers[5].

Paul Dhé, a Frenchman, developed the Basalt fibre manufacturing process in 1922, but no actual production actually occurred[6]. The Soviet Union successfully recovered BF from basalt ore in 1954[7]. Since the 20th century, the use of composite materials has increased dramatically and is increasingly replacing traditional building materials. Basalt fibre is a high-performance inorganic silicate fibre that is produced by melting and drawing natural basalt rock at high temperatures. It is a type of green fibre that does not harm the environment or increase the risk of cancer[8][9]. Traditional GF (glass fiber) is better to BF (basalt fiber), which has superior mechanical properties and corrosion and high-temperature resistance[10]. The best option to replace GF and CF is BF (basalt fibre), which is less expensive than CF (carbon fibre)[11][12].Furthermore, basalt fiber-reinforced polymers have found extensive use in a variety of industries, including petrochemical, construction, aerospace, automotive, shipbuilding, and others[13][14]. In general, the composite materials utilised in the construction sector are made of reinforcing elements implanted in a hardened matrix; the reinforcing element is selected for its compatibility with thermal strain as well as its non-reactive nature with the hardened matrix[15]. In terms of performance and cost-effectiveness, basalt fibre reinforced thermoplastic polymer composites can be positioned between Glass fiber reinforced thermoplastic polymer composites and Carbon fiber reinforced thermoplastic polymer composites. The fibre matrix interface's ability to facilitate effective load transfer from the matrix to the fibre will determine the mechanical performance of the Basalt fiber reinforced thermoplastic polymer. The fibre matrix interface's ability to provide effective load transmission from the matrix to the fibre will determine the mechanical performance of the BFRP. Basalt fibres are often inert by nature and require treatments to increase their adherence to polymeric matrices.

The basalt fibre is a novel material that finds extensive use in both military and non-military sectors, including aircraft, architecture, the chemical industry, healthcare, electronics, and agriculture. It is regarded as the fresh material for the twenty-first century. The only healthy and environmentally friendly glass fibre product is basalt fibre. Basalt fibre is becoming better understood and used by people as the social economy continues to develop, and both the market demand for basalt fibre and the demand for its products are increasing rapidly.[16].

## 3. Basalt fibre and the method used to manufacture Basalt fibre

One of the most promising materials for use in the automobile sector is that based on basalt fibres. Continuous basalt fibres, explosive-reinforced composite materials, heat- and sound-insulating materials, protective coatings, and silencers that are heat- and sound-insulated are some examples of these materials. When basalt stone is melted at a temperature between 1450 and 1500 degrees via a platinum-rhodium alloy bushing, the result is a continuous fibre. The "volcano rock silk" of the twenty-first century is a brand-new fibre that protects the environment. It is also referred to as "golden fibre" due to its golden-brown hue.

The four primary steps for the manufacturing of BF are as follows: selecting the materials, as shown in figure, melting, grinding, and wire drawing.

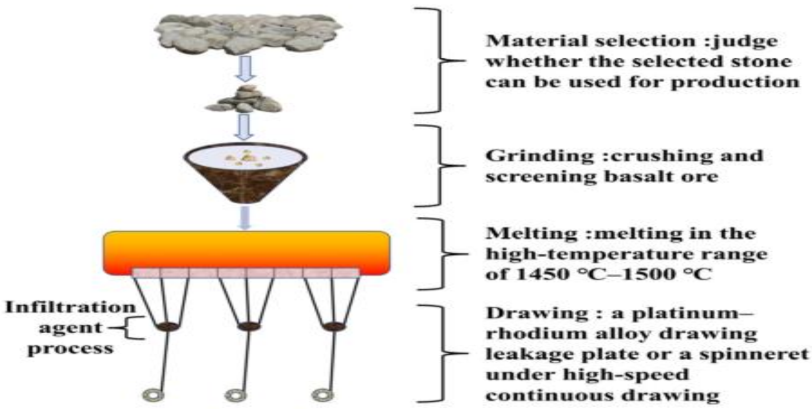


Figure 2 Manufacturing of Basalt fibre[17][18]

The output quality has increased as a result of ongoing process optimization at BF. The industrial process has essentially gone through two periods of development. The primary technique employed in the first stage is the crucible method, sometimes referred to as the two-step method. The procedure begins by melting a specific quantity of raw materials at a high temperature in order to create a spherical drawing material. The spherical material is re - melted in a crucible in a subsequent phase, homogenised, and drawn into the finished product. The technique used at the manufacturing facility is complex, time-consuming, and labour-intensive, but the homogenization effect is better and less likely to clog the leakage plate. The tank kiln method, commonly referred to as the one-step method, which completes melting and wire drawing jointly, is primarily used in the second stage. This methodology is comparable to how GF is made, however it uses less energy, doesn't require additives, and is less expensive than carbon fibre or glass fibre[19].

## 4. Properties of Basalt fiber and Comparison with common fiber

a. Physical property of BF

As performance is compared, the continuous basalt fibre is not the strongest among all fibres, but none of the other fibres can match the continuous basalt fibber's strength.

Table 1 Physical properties of various fibers[20]

| Property | E-GF | Advantex | S-GF | CBF | Kevlar 49 | CF |
|---|---|---|---|---|---|---|
| Density/(g·cm$^{-3}$) | 2.55-2.62 | 2.62 | 2.462.49 | 2.8 | 1.44 | 1.78 |
| tensile strength/MPa | 3100-3800 | 3100-3800 | 4590-4830 | 4840 | 2758-3034 | 2500-3500 |
| Elastic module/GPa | 76-78 | 80-81 | 88-91 | 89 | 124-131 | 2.3-2.4 |
| Elongation at break/% | 4.7 | 4.6 | 5.6 | 3.1 | 2.3 | 1.2 |
| coefficient of linear expansion (20-00℃)/℃·106 | 5.4 | 6 | 2.9 | 8 | - | - |
| Softening point /℃(η=107.6 dPaS) | 850 | 916 | 1056 | - | - | - |
| Temperature/℃ | (-60 -350 ) | - | (-60 -300 ) | (-260 -880 ) | <250 | <2000 |

b. Mechanical Properties

The elongation at break, elastic modulus, tensile strength, and other metrics are all mechanical characteristics of fibers. The table illustrates that the elastic modulus and tensile strength of BF are much higher than those of E-glass fiber, which differ slightly from those of S-glass fiber. Continuous BF has a slightly higher elongation at break than CF and aramid fibre, which is less than S- glass[21].

Table 2 Mechanical properties comparison of BF and other fibres[22][23]

| Fiber Type | Basal Diameter ( m) | Density (g cm$^{-3}$) | Tensile strength (Mpa) | Modulus of Elasticity (Gpa) | Elongation at Break (%) | Price (USD.Kg$^{-1}$) |
|---|---|---|---|---|---|---|
| Basalt fiber | 6 to 21 | 2.65 to 3.00 | 3000 to 4840 | 79.3 to 93.1 | 3.1 | 2.5 to 3.5 |
| E-glass fiber | 6 to 21 | 2.55 to 2.62 | 3100 to 3800 | 72.5 to 75.5 | 4.7 | 0.75 to 1.2 |
| S-glass fiber | 6 to 21 | 2.46 to 2.49 | 4590 to 4830 | 88 to 91 | 5.6 | 5.-7 |
| Carbon fiber | 5 to 15 | 1.78 | 3500 to 6000 | 230 to 600 | 1.5 to 2.0 | 30 |
| Aramid fiber | 5 to 15 | 1.44 | 2900 to 3400 | 70 to 140 | 2.8 to 3.6 | 25 |

c. Thermal Properties

Table shows that basalt fiber has a greater thermal expansion coefficient and softening point than E-glass fiber. While BF can withstand temperatures over 700°C and below -260°C, GF and CF can only withstand high temperatures of 380 °C and 500°C, respectively, at the maximum service temperatures. Because of its unique characteristic, BF can be used in specific products like fire insulation and aerospace[24].

Table 3 Thermal properties comparison of BF and other fibres[22][23]

| Fiber Type | Maximum Working Temperature (˚C) | Softening point (˚C) | Thermal Conductivity (W m1 K1) | Thermal Expansion Coefficient (10-6. ˚C-1) | Heat loss rate (%) |
|---|---|---|---|---|---|
| Basalt fiber | 700 | 960 | 0.031 to 0.038 | 8 | 1.91 |
| E-glass fiber | 380 | 850 | 0.034 to 0.040 | 5.4 | 0.32 |
| S-glass fiber | 300 | 1056 | 0.034 to 0.040 | 29 | - |
| Carbon fiber | 500 | - | 5 to 185 | 0.05 | - |

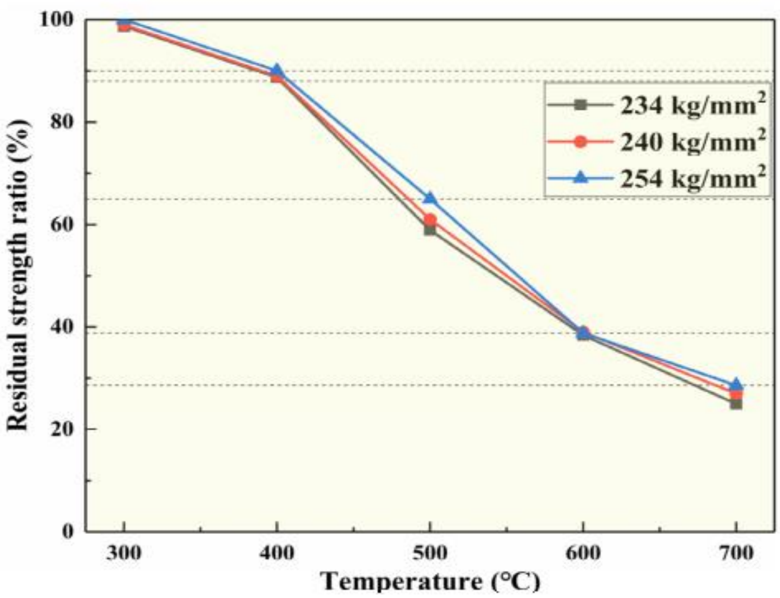


Figure 3 Residual strength ratio of basalt fiber at various temperatures[23]

The residual strength ratio of various BF fabric types at various temperatures has also been studied and the results are shown in figure[25]. When the continuous working temperature reached 400 ˚C, the BF was still able to keep its residual strength ratio between 88% and 90%. The residual strength fraction could reach 65.0%, 38.8%, and 28.6% at 500 ˚C, 600 ˚C, and 700 ˚C, respectively. This completely demonstrates the outstanding heat resistance of BF[23].

## 5. Conclusion and Future work

Basalt fiber (BF) is currently a preferred choice among material scientists in place of steel and carbon fibre. because of its great rigidity and minimum extension or elongation at break. Basalt fibres composite materials may be the solution to the problem of weight reduction without sacrificing mechanical properties or environmental friendliness. Excellent tensile strength and elastic modulus are two mechanical properties of basalt fibre that are commonly used in reinforced composites. Basalt fibre is widely used in adiabatic insulation due to its low thermal conductivity, superior seismic performance and large working range. Excellent compatibility with, plastic, carbon fibre, metal, and other materials: A composite made of continuous fibres of basalt and different types of resin has a better bonding strength than glass fibre and carbon fibre. In the future, attention must be paid to stabilising techniques and the methods by which the great properties of BF are formed, in addition to a variety of other important aspects in the BF-making processes. The mass manufacturing of BF still has a number of technological problems, and the products' stability must be improved.

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