

Basalt Fiber and Its Composite Manufacturing and Applications: An Overview

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Abstract

Basalt fiber is a low-cost material obtained from the Basalt rock from earth, and it can be divided into small pieces to form fiber. In this paper dealing with Basalt fiber manufacturing, property of composites and application are reviewed. The results indicate that as compared to glass fibers, carbon fibers and aramide fiber, basalt fiber possesses excellent machine-driven properties such as wave permeability, electrical properties, non-conductive and insulation properties. BFRP has higher flexural strength and better adhesion as related to CFRP and GFRP. When temperature increases thermal and mechanical properties of BFRP reduces considerable. Due to the above advantages, the addition of Basalt fiber and its composites can be used in sound and sound absorption and thermal insulation application.

Keywords: *Basalt Fiber, Application, Manufacturing, Composites, Properties*

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Background to the Study

Basalt is obtained from Basalt rock found around the world. The crushed rock used in industrial and highway engineering. Basalt can be used in manufacturing of fine and ultrafine fibers known as Basalt fibers. These fibers are superior as they possess excellent properties such as sound insulation, heat and vibration and stability [http://basaltfm.com/index/html:dt12/10/2020]. This Basalt fiber is High resistance to High temperature and possesses durability, strength. Basalt consists of SiO_2 , FeO_3 , Al_2O_3 , CO , and is acidic type, Basalt is necessarily for fiber preparations. Basically, Basalt can be found in continuous fibers having unique mechanical and chemical properties, so that it is highly suitable for demanding utilization, requiring resistance against High temp, acid, solvent resistance, durability and low water absorption (Deshamukh, 2007). As is well known due to its significant mechanical properties Basalt is utilized as fiber in the composite materials, and is known as Basalt fiber reinforced polymer composite (BFRP). Basalt is a characteristic materials that is obtained from volcanic rock affected by solidified magma, at. Temperature a round 1500C to 1700C (Militky et al., 2002). It is necessary to design high voltage towers such as steel towers in future. Therefore, it is required to use new type of materials that has high strength, light and minimum risk of corrosion. At present bigger lamp posts and telephone poles have been designed structural designers are looking for new type of materials for building, bridges and windmills (Reykjavik, 2013). The density of basalt is approximately one third of density of steel, which indicates that BFRP is lighter, and a stronger material compared to steel. Further, it is also cheaper, and easier to produce, compared to other fibers such as glass fibers (Foire et al., 2015). Basalt rock can be used to make fibers, strands, basalt filaments, wires and Basalt mesh. Some of important applications include polymer reinforcement, soil strengthening, bridges, highway, industrial floors, heat and sound insulation of industrial buildings, manufacturing of bullet proof vest and rehabilitation of structures (Panchalan, 2005) Fiber reinforcement is gaining popularity due to their performance in terms of ecological cost i.e. US\$ 5 per 1 kilogram, Basalt fiber (BF) is highly potential alternatives compared to US\$ 15 per 1 kilogram of glass fiber and US\$ 30 per 1 kilogram of carbon fiber and better chemical-physical properties (Deak.and Czigany, 2009).

Basalt fibers production

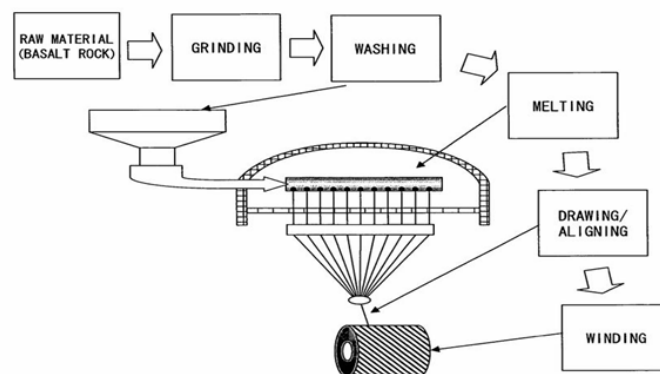


Fig.1: Plant layout of Basalt Fiber Production

In many ways, Basalt fiber production is similar to glass fiber production. The process of Manufacturing of Basalt filament consists of four major steps, melt preparation, Extrusion, Fiber forming, use of lubricants and finally winding. The process of filament manufacturing by heating the Basalt and extruding the molten material through the die in the form of fibers is shown in the Fig.1 (Berozashvili, 2001). Basalt rock (crushed material) is washed and cleaned and allowed to move in the melting bath in the heated furnace to get melt (Basalt) materiel. Temperature is maintained in the furnace around 1400 to 1500C. The second step consists of extrusion process where molten rock is extruded through nozzles to get continuous filaments of Basalt fibers (Basaltex PVT.Ltd). The third step is fiber formation. The fibers obtained from the melt under pressure can be imparted to strand integrity, lubricity, and resin is applied and filaments are collected together to form strand formation. In the final step the Strand formed is wound by automated winding to forming tube. The filament diameter from 7 micron to 17 micron can be produced depending upon the speed of fiber and temperature of melt.

Figure 2 shows flow chart of basalt fiber production.

Figure 3 (a) shows the Basalt porous rock formed by lava; (b) continuous Basalt fibers; (c) Basalt fiber roving; (d) Basalt Mesh

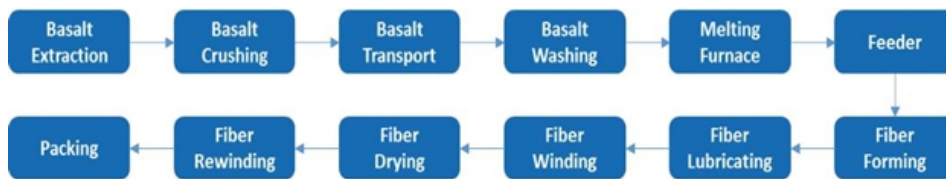


Fig. 2: Flow chart of basalt fiber production

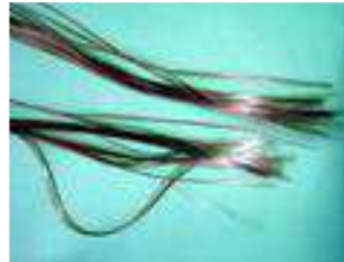


Fig. 3: (a) Basalt porous rock formed by lava

(b) continues Basalt fibers

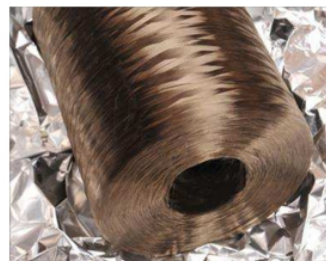


Fig. 3: (c) Basalt fiber roving

(d) Basalt fiber Mesh

Composition of Basalt Fiber

Being rich with oxides of Mg, Ca, Na, K, and Fe, along with traces of alumina and earth crust consists of 33% of Basalt is a copious mineral. And Fig. 4 depicts chemical content of basalt which differs according to topographical distribution. Chemically, these fibers are composed of plagioclase, olivine, and pyroxene and clinopyroxene mineral. Based on the above chemistry; there are different types of basalt like Boninite (rich in magnesium), Alkali basalt (rich in sodium) and Tholeitic basalt (rich in sodium). Figure 4 describes the mineral distribution within basalt and effect of geological changes

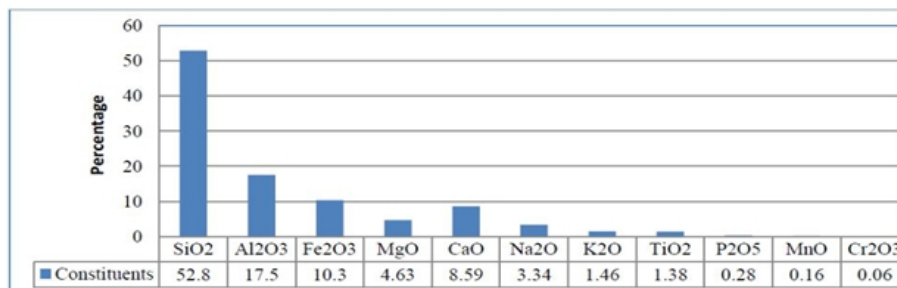


Fig. 4: Chemical Composition of Basalt Fiber

Properties of Basalt Fibers

1. Alkali Résistance

Basalt fibers are less affected. Durability, maintenance under the critical situation and long-term performance are some drawbacks that the composite has to face and most critical being corrosion. Toughness, degradation properties of resin and crack propagation are the factor on which résistance against corrosion depends. The complete mechanism behind degradation of fibers has not been understood completely, but structural and morphological changes arise in Basalt when it is expose to un favorable environment for long period of time (Berozashvili, 2001). Basalt fibers are more stable in salt solution especially in water, but in strong acids they show less stability. In alkaline solutions its tensile strength reduces due to pitting of the fibers in large area. It is also observed that in acids the tensile strength also reduces which is due to damage of chemical constituent of fibers. Finally, the Wight loss is lower in alkali, water, and acids also. (Tengiz). It is observed that Basalt fibers and their composites shows greater resistance to salt and water solutions as compared to glass fiber where as in acidic environment glass beat the basalt fiber. It is also concluded that properties of basalt can be modified using matrix and coupling agent. For example, when Epoxy resins reinforced BFs and glass fibers were tested with a seawater solution, similar degradation was observed in Epoxy based basalt fiber and Glass fiber (Wei et al., 2010, 2011).

2. Thermal Stability

In comparison to E-glass (-60 to 450/460°C) Basalt has wider temperature range -200 to about 650/800°C. Due to mineral composition and presence of huge number of micro pores, BFs are passive to fire protection and thermal insulation applications (Novitskii, 2004; Fiore et al., 2015). The crystallization behavior is key factor in evaluating the heat stability of BFs.It

depends on the heat treatment process and chemical composition of fiber. In Basalt crystallization occurs in two phases first phase in which spinal structure formed due to oxidation of ferrous cat ion. and in second phase the diffusion of divalent cations (Fe^{2+} , Mg^{2+} , Ca^{2+}) takes place where they come to surface to form nano crystalline layers of CaO , $(\text{Mg,Fe})_3\text{O}_4$, MgO (Fiore et al., 2015).

3. Mechanical Strength

Basalt fiber tensile strength varies between 3000-4840Mpa which is higher than glass fibers. It has larger strength and stiffness than E glass fibers. The BF specific gravity varies from 2.6 to 2.8g/cc than other fibers.

4. Corrosion and Fungi Resistance

Basalt fiber has excellent corrosion and fungi resistance. It does not react with air, gases and water. Moisture present in BF exists in the range less than 1%.

5. Abrasion Property

Basalt filaments have hard filaments and hardness varies between 5 to 9 Mohr's scales. A basalt filament possesses better and stronger abrasion property.

6. Ecological Friendliness

BF have usual raw material obtained from basalt extracted from rock. It does not cause any harm to human health. It does not produce any biological hazard and cause the waste disposal problems. Hence this material is considered as friend by the ecosystem (Kumbhar, 2014).

Properties of Basalt Fiber Reinforced Polymer

Basalt is made of basalt fiber that carries load to provide strength and stiffness characteristic whereas Polymer distributes load & protects the fibers from environmental conditions. Polymer can be of different types such as thermo setting (vinyl ester, epoxy), thermoplastic (polypropylene, polyethylene etc. depending on the properties of polymer polyethylene) etc. Depending on the properties of polymer properties of BFRP change.

1. Flexural Behavior

Composites are subjected to various loading conditions during their service life, among which, flexure is predominant. When basalt is mixed with polyester and subjected to three-point flexure test is done and found that the flexural strength and flexural modulus were highest for the composite material with pure stacking of Basalt than it more flexural strength among the other pure glass sample specimen (Amuthakkannan et al., 2014). The effects of surface modification of Basalt fibers and glass fibers with unsaturated polymer matrix in acidic and alkali environment in BFRP laminates shows excellent mechanical properties as compared to GFRP laminates (higher tensile and impact strength of BFRP composite in acidic environment (Manikandan et al., 2012). A comparison was done between BFRP having epoxy matrix and BFRP having tourmaline micro/Nano particles and it was seen that as compared to Basalt fiber epoxy composite, Basalt loaded with different tourmaline percentages showed higher tensile and flexural strength (Subagia et al., 2014)

2. Temperature Variation

When thermal properties of glass fiber are compared to Basalt fiber it was found that tensile modulus of BF was around 60.4 ± 18.9 GPa while tensile strength was found to be 568 ± 267 MPa. There are several properties of basalt that make it remarkable like chemical resistance, thermal resistance, low water absorption and sound insulation ability. When basalt is mixed with thermoplastic and thermoset matrix it can be a very good reinforcing material (Hung et al., 2014). At various temperatures, Basalt fiber demonstrates altered elastic properties because of warm impact. When basalt fiber is tempered at various temperatures of 300, 200, 100 and 50°C it was observed that there was some basic change inside the fiber, which indicates solid ductile properties when the fiber was treated underneath of 300°C at a time of 1 hour. (Militky et al., 2002).

Basalt Fiber Future Prospective and Challenges:

The worldwide market of Basalt fibers is expected to grow at a CAGR over the next five years which will meet millions USD in 2024 from millions of USD in 2019, as per the latest report focuses on basalt fibers in global market in Europe, North America, and Asia-Pacific, South America and Middle East and Africa have also attracted attention. The use of Basalt fiber in industry especially significant in construction area due to its properties such as good compatibility with concrete, easy mixing at high concentration environmentally friendly properties. The basalt fiber is finding increased application in the construction & infrastructure segment due to its high strength and non-corrosive properties. Basalt fiber has larger mechanical strength that is useful in construction at extreme condition... These are available at a much lower price compared to all other alkali-resistant fibers. Hence, construction & infrastructure end-use industry is expected to grow with high CAGR during the forecast period. Demand for non-corrosive products continues to increase in the construction industry as it helps to reduce the cost and increase the life of structure made by using them. The use of corrosion-free basalt fiber composite bars as reinforcement in concrete is one of these developments.

The basalt fibers impart strength to the rebar while the resin holds the fibers firmly. In comparison to steel rebar, BFRP (basalt fiber reinforced plastic) rebar significantly improves the life of civil engineering structures where corrosion is a major factor. There are some technical complexities in the production of basalt fiber which creates difficulties for the product to compete with other matured products. There are a number of advantages of basalt fiber over the conventional glass fiber; however, it is not recommended by the governments and no initiatives have been taken by other agencies to develop this industry. There are very few countries such as Russia, China, the US, Germany, Belgium, and Ukraine which are focusing on the further expansion of basalt fiber but emerging economies such as Brazil, India, and others do not register any initiatives in this market. Manufacturers are trying to promote the use of basalt fiber on their own in various industries by attending several exhibitions and composites conferences.

Applications of basalt fibers

1. Nuclear Power Plant

Basalt fibers are used for eradicative materials in nuclear power plants since they do not absorb radiations. Protective cap using geo-composites in the waste disposal sites, incorporating the basalt materials, can offer best protection against nuclear hazard environment.

2. Concrete Reinforcement

Basalt fibers are used in the construction field especially in civil structures due to their excellent fire resistance properties. These fibers are also used in bridges, tunnels and railways sleepers. The 80% of basalt fibers with epoxy binder that forms basalt rebar gives mechanical strength to reinforced concrete which are less expensive.

3. Building Material

BF can be used as new material for doors, building, Interiors, and sound insulation for buildings. It has excellent sound resistance characteristics. It can perform as fencing in the frequency range up to 1800HZ. These fibers are well applicable as slabs for construction of house such as ceiling. The BF possesses excellent thermal insulating properties which are three times than asbestos. These fabrics are used in blocking material in public transport system.

4. Road Construction

Basalt fibers offer number of advantages over the glass fibers and metal mesh pavement reinforcement. They are eco-friendly and offer resistance to very high temperatures of molten asphalt. They are also safe material in tunnel lining work. The basalt fiber material is suitable for soil and stone built to carry road as stabilization and climate and environment-friendly safety.

5. Abrasion Resistance Basalt Fiber Pipes and Casting

Pipes can be manufactured using filament winding technique with the help of fabrics, and prepegs to saturate with a binder. These pipes are applicable for transporting liquid and gases. The basalt made pipes are used for longer service life 60 to 80 years which is 2 to 3 times longer than conventional metallic pipe. These are also used in chemical, oil and cement industries.

6. Agriculture

BF can be used in various applications like, drainage pipes, pipes for irrigation and hosing. It is also used in agriculture machine construction.

Conclusions

Basalt rock is an alternative raw material used for fiber forming due to its chemical structure, large scale availability, freedom from impurities and great ability to form fibers in molten state. Basalt composite replaces the steel known as reinforced plastics (1kg of steel is equals 9.6 Kg of steel). Basalt can replace almost all applications of asbestos and has three times its heat

insulating property. Alkali resistance, thermal stability of Basalt fiber as well as flexural strength, temperature variation and adhesive nature of Basalt Fiber Reinforced polymer is studied. Basalt composites exhibited higher tensile strength when subjected to higher temperature for different time periods than GFRP. The adhesion between the Basalt fiber and its composites is better as compared to carbon fiber and its composites. Initial cost of basalt fiber depends on chemical composition, quality of raw material leading to formation of different types having different mechanical, thermal and chemical properties. Due to wide application in infrastructure and automobile industry and low-cost basalt fiber can well be the material of future

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