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Basalt Rock Fiber: New Approach in Concrete Strength

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Abstract:

Concrete is a fundamental unit of the construction which is used in formation of building, marine construction and so on. The demand of those materials that can provide the high strength to the construction. Different types of fibers are added in particular amount in the concrete by which the mechanical properties, durability and serviceability of the structure are improved. The most important properties of Fiber Reinforcement Concrete is the resistance to cracking and crack propagation. Fibrous materials are contained by fiber reinforced concrete (FRC) that increase the structural integrity. Various types of fibers i.e., steel, glass fibers, natural fibers and synthetic fiber are used which provide varying properties to the concrete. Still, steel is used for the construction as constituent of concrete but it is very heavy material that increase the weight of concrete. Another drawback, it gets corrode easily within a short period of time. In the recent time, Civil engineering has found solution to overcome this problem by the use of basalt fiber that replace the steel, glass fiber and carbon fiber because of their properties. This paper study about Basalt fiber with its properties that make it a suitable material for the concrete. Basalt fiber has many application, discussed in this paper.

Keywords: *Concrete, Basalt Fiber, Fiber Reinforcement Concrete, Mechanical Properties*

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Introduction

The world's most common used material in man-made constriction is concrete. It is assumed that steel is most common strengthening material for Reinforced Concrete (RC). This reinforcing material has many advantages like high tension strength, high modulus of elasticity. The material properties of steel is very stable because of their production process which is also very stable. With the advantages, the steel reinforcement has some disadvantages such as corrode as the time pass, low fire resistance, and the high cost which is increasing over last years.

The civil and structural engineers face a challenge as to provide a sustainable, financially feasible and environmental friendly to a society. Fiber reinforcement polymers (FRP) also have some drawbacks by which they are prevented from the use as a structural applications. Different types of FRP's are used like FRPs composed of carbon called CFRP which have high elastic modulus and good tensile strength. While it is less desirable in case of fire testing and it is prohibited because of the high cost in the use. Another FRP is fiberglass, called GFRP that have good mechanical characteristics but have same issue 'cost'.

Melted basalt rock fibers is a new development of FRP which create an excitement in the construction industry. Basalt is naturally occurring material and it is most abundant on earth. In 1920s, the production methods of FRP that composed basalt were found in the United State but large scale of production was not achieved until 1980s. The conventional concrete is not able to bring the steel at its tensile strength completely in use. This problem can be reduced by the use of BFRP and GFRP as these are more flexible than steel (Saad, Patel and Pethani, 2014).

Basalt Fiber

Basalt rock is a type of volcanic rock found in every country all over the world which is spilt into small particles and formed continues or chopped fibers (fine, superfine and ultra-fine fiber) by different process. Basalt fiber has various characteristics such as high temperature, high résistance to chemical attack, fire with less poisonous fumes and impact load. It is also not give any toxic reaction with air and water and it is non-combustible and explosive proof as when it comes in the contact with the chemical substance, do not produce any chemical products which may damage the health and environment. Phenocrysts of olivine, Clinopyroxene and plagioclase feldspar are contained by many types of basalt. Basically, basalt is categorized into two types; alkali basalt and tholeiites. These both types have similar concentration of SiO_2 but the difference is in the concentration of NA_2O and K_2O. These two compound is higher in alkali basalts compared to tholeiites.

Because of these characteristics these basalt fiber has potential applications. The basalt rock is used as a crushed rock in construction, industrial and highway engineering work. Asbestos's applications can be replaced by the use of basalt because it has three times greater insulation properties. Basalt based composites also replace the steel and all known reinforced plastics. According to the report 1 kg basalt reinforcement is equal to 9.6 kg steel.

Basalt fibers have higher value compare to other fibers in the terms of thermal stability, heat, and sound insulation properties and durability because of the single-ingredient raw material melt. New range of composite materials and products are offered by Basalt continuous fibers. The basalt fiber pipes' life is as a minimum 50 years without any care or protection electrically and technically. The mixture of basalt fibers and carbon or ceramic fibers with different metals have an excited and advanced area of applications as they are able to produce a new hybrid composite materials and technologies. The use of basalt special properties improve the performance as well reduce the cost of products.

Russia have been developed and patented more than hundred unique techniques of manufacturing using the basalt fiber materials and products. The largest problem relating to cement and concrete industry, and any cracking and structural failure of concrete can be solved by low cost and high performance fibers. The basalt fibers replace the fiberglass, steel fiber, propethylene, polypropylene, polyester, products of carbon fibers and aramid products because of the higher performance and low cost production (Sharma, 2016; Irine, 2014).

Production of Basalt Fiber

Crushed lava rocks create basalt fiber with particular chemical compositions. The basalt fiber has a similar method of production as glass fibers but do not have any other materials. Basalt have many steps like quarried, crushed and washed and then it is melt at

the temperature around 1,450 °C. After that, molten rock is passed through the small cavities with different speeds by which the fibers of basalt is produced. The filament diameter of fibers is ranged from 9 to 20 µm.

Conversion of Rock to Fiber

The materials is liquefied (conversion of solid into liquid) at 1500°C when the crushed basalt enters into the furnace. The infrared energy is absorbed by the opaque basalt instead of transmission unlike glass. Hence, the uniformly heat to the basalt is become very difficult for overhead gas burners which is used in conventional glass furnaces. For providing the homogenous temperature, the melting basalt should be contained in the reservoir with overhead gas for long period of time (Several hours). There are various strategies that are applied to promote uniform heating by basalt producer like immersion of electrodes in the bath. Two-stage heating scheme is engaged in which feature separate zones are equipped with the controlled heating systems.

Platinum-rhodium bushing, agents are used in the formation of basalt filaments like glass filaments. As the filament cool, a sizing agent is applied and then, speed controlled fiber stretching equipment and winding equipment are used in which filaments are passed and fiber is spooled (Sharma, 2016).

Table 1: Chemical Composition of Basalt Rock (Singha, 2012)

Chemical Composition	**%**
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

Properties of Basalt Fibers

These are some properties which are inbuilts in the basalt fiber that give stregth to the concrete.

Physical Properties:

- Diameter: The basalt fibers have different diameter. 5.8 µ is an example.
- Length: It is available in different length like 6mm, 14mm and so on.
- Color: Generally, basalt fibers are present in golden brown color.
- Density: 2.75g/cm is the density of basalt fiber.
- Coefficient of Friction: The range of coefficient of friction lies between 0.42 and 0.50.

Chemical Properties

- The stability of basalt is very high in strong alkali.
- There is a significant change in the weight loss of basalt in boiling water, acid and alkali. Lightly decrease in the weight.
- Basalt fiber have resistance to UV-light, and biological and fungal contamination.
- Phenolic resin has compatible nature with basalt fiber.
- There is very less absorption of humidity.

Mechanical Properties

- It has a specific tenacity (Capacity to rapture stress to density ratio) that exceeds from the steel many times.

- It gives good moisture resistance because of non-capillary and non-hygroscopic.

- Shot content is contained by basalt, it is generally less than 3%.

Thermal Properties

Thermal range of basalt fiber is from -260°C to 982°C with the melting point 1450°C. The thermal conductivity is very low ranging from 0.031 to 0.038w/mk. Because of these properties, basalt fibers are perfect model for fire protection and applications of insulation. Compare to other high-temper materials such as E-glass, silica, ceramics, stainless steel and carboy, basalt fibers are most cost effective that prevent from rapid overheating and also improve brake life. Another properties is that the exposition less than 400°C, initial strength of basalt fiber is lost while E-glass loss more than 50% strength (Rathod, Gonbare and Pujari, 2013; Patil and Ogale, 2017).

Applications of Basalt Fiber

In roman time, the basalt materials were used in natural form in the formation of building as a paving and building stones. Basalt is famous for its mechanical properties like moisture absorption resistance, corrosive liquids resistance and environment resistance, and have high durability and versatility. There are many fields such as civil engineering, boat building, automotive, sporting things and turbine blades in which basalt fibers and its products are used because of their properties in construction materials.

- It is used in tubes, bars, pipes fittings, sound insulation and internal heat of floor, walls, frame walls, tanks, boiler shells, fire protection structures and chimneys.

- In the production of cylinders of CNG, pads for brake, mufflers, headliners and other parts of automobile, high-quality basalt roving, fabrics and chopped strands are used.

- Basalt chopped strands are good for the preparation of friction materials because of the high friction coefficient.

- Filler for car mufflers is used for great silencing properties made by the basalt fibers which also have good resistance for thermal cycling.

- Chemical and wear-resistant protective coating on tanks, pipelines and high pressure vessels corrosion resistant tank and pipes, and waste water filters is done by the products of basalt. The pipes of basalt are able to contain the petroleum products, gases, aggressive liquids, hot and cold water, and loose materials and easily transported.

- The radioactive radiations are not absorbed by the basalt materials due to which basalt materials are used for the production and transformation of radioactive materials in nuclear power plants.

- Basalt fiber is used as a sewing thread for stitching of filter bags because of the high temperature application. Automobile, aircraft, ship and household appliances also contained the some part of basalt with thermosetting resin like epoxy and phenolic resins.

- The use of hot gas filtration has been increased in industrial applications because of basalt. For cleaning corrosive hot gases and waste air containing hot particles that have the temperature above 800°C, basalt composite filter fabrics can be used positively (Jamshaid, 2017; Singha, 2012).

Review of Literature

According to Singha, (2012) the use of carbon and steel can be reduced or replaced by the incorporation of basalt fiber because of the high rigidity and low elongation. He proposed that basalt is a very useful reinforcement material for present as well as future.

Joshi, Rangari and Shitole, (2014) stated that the concrete workability is decreased as the amount of fiber increase. Up to 0.07% use of basalt, the strength of beams increase after that increasing from 0.07% it again decrease the flexural strength. When the concrete comes to post cracking stage, the fibers are used as they can increase the ductility and hardiness of concrete.

Ketan and Kulkarni, (2013) concluded that the strength of concrete is decreased on 7 days and 14

days but the strength is gained after 28 days with the addition of basalt in the concrete. They discussed different points about the basalt fiber; it can replace the reinforce plastics (1kg basalt = 9.6 kg steel), replace the asbestos because of high heat insulating properties, low cost of basalt compare to other raw materials for fiberglass, more availability of basalt than other raw material and have low melting point due which low energy consumption.

Ansari and Chandak, (2015) studied about the strength of concrete that contain basalt fiber and concluded that the compressive strength of concrete containing basalt fiber is more (1%) compare to plain concrete. In the same way, split tensile strength of basalt fiber concrete is 1% more than the plain concrete. The use of 1% basalt fiber in the concrete mix design is an optimum value by which compressive and tensile strength increase.

Elshafie and Whittleston, (2015) the basalt fiber has an effect on the workability in the form of decrement in the collapsing as the content of basalt fibers increase but only up to optimum limit. The length of basalt is more effective compare to content in case of tensile and compressive strength and in case of flexural strength, length and content of basalt fiber, both are important.

Sureshkumar *et al.*, (2016) stated that the basalt fiber has many properties such as low thermal conductivity, high softening, high oxidation resistance and better fire resistance compared to glass fiber. Because of these characteristics it is more suitable for the reinforcement of concrete structures such as reinforcement concrete bridge grinders. In the end of paper, they concluded that basalt fibers are good alternative strengthening material compare to glass fibers, carbon fibers etc.

Regar and Amjad, (2016) focused on the positive aspects of basalt fibers. Basalt fibers has few deficiencies like the instability in the basalt fiber properties, low stretching properties, defects in the production process, defect in the end product such as the produced fiber can be affected by heterogeneity of basalt melt. So, there is an important to modify the material before putting it into use.

Vijayaraghavan *et al.*, (2017) proposed that the construction industry has a high demand of fiber reinforced concrete (FRC). Basalt fiber has a great composition in FRC because of their non-corrosive, good flexural strength and high heat resistant properties. The compressive and flexural strength are increased by 12% and 38% respectively by the addition of basalt fiber. It gain high strength within 28 days compare to other traditional FRC. Basalt materials can be used in structural members like beam column joints and tension and compression members.

Bhatt *et al.*, (2017) discussed about the advantages of basalt fiber such as high strength, light weight, and also non-corrosive in nature. Because of these advantages, it is considered as a best material in concrete structure like in marine structure. The strength is three times greater than the traditional steel bars. The volcanic eruption is source of the basalt rock that contains good thermal resistance, an important factor for Reinforced Cement Concrete (RCC) building.

Anthithya, Saravanan and Satheesh, (2017) investigate the mechanical behavior of concrete that contain chopped strands fibers of basalt. They found that the tensile, flexural and compressive strength of the concrete is increased by the addition of basalt fiber as the concrete has the capacity to hold the crack of concrete and resist the concrete beams from falling apart by the help of basalt fibers. The concrete is a principle unit of construction. The improvement in the mechanical properties of concrete by the incorporation of basalt fiber can increase the durability of building in future. In the field of construction materials, basalt fiber opens a new era.

Conclusion

Basalt rock is solid and compact, formed from volcanic lava eruption proceed by the natural cooling process. Basalt covers many parts of the world. Fibers of basalt rock have different properties like mechanical, chemical and thermal. Because of their properties such as highly resistance to alkali, acid and salt attack, low thermal conductivity etc. it becomes attractive for electro-technical (Insulation material and flame retardant) and construction purposes. Basalt replace the asbestos, steel and carbon in different applications. This paper concludes that basalt rock fiber is a best choice as concrete material because of the high tensile strength, compressive strength and flexural strength as well as high rigidity and low elongation or extension at break.

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