Basalt – technical fiber for civil applications

This article gives information about the forms and applications of volcanic rock fiber (basalt fibers) for civil applications. Volcanic lava solidifies to produce basalt rock. The crushing of volcanic rock gives basalt fiber. Basalt fiber is light weight, has high strength and requires high temperature to melt. These inherent characteristics of basalt fiber make it more suitable for use in civil applications such as building bridges, highways and residential housing, and in the construction industry etc. Basalt is well known as a rock found in virtually every country round the flora and fauna. Basalt rock is more prolific in India (especially in Maharashtra), and the basalt fiber is available at a cheaper cost as compared to other raw materials such as synthetic and high-performance fibers.

Ranjit N. Turukmane, Sujit S. Gulhane, Amarjeet M. Daberao
SVKM'S NMIM'S, Maharashtra/India

Basalt fiber is a textile innovation developed to be utilized in fiber-reinforced composites and structural applications. It has a similar chemical composition as glass fiber, but has better quality attributes, and is dissimilar to most glass filaments as it is impervious to basic, acidic and salt attack. This makes it a decent possibility for solid, civil framework and shoreline structures [1]. Certain polymer-based composites use sisal fiber as a reinforced material, but these are not viable compare to basalt fiber [2, 3]. It is advantageous compared to aromatic polyamide fibers and high temperature resistant fibers like aramid and carbon to withstand at higher temperature for a wider temperature range of -269 °C to +650 °C as it possess higher oxidation resistance, higher radiation resistance, higher compression strength, and higher shear strength. The manufacturing of basalt and glass fibers is somewhat similar to its manufacturing cost, which is less compared to S-glass. It is a persistent fiber delivered through volcanic basalt shake dissolve drawing at around 1,500 °C. Basalt fiber is very much similar to carbon and fiber glass, and has better physico-mechanical properties and is cheaper. 1 kg of basalt reinforcement is equal to 9.6 kg of steel. There are many areas of application and the fiber can replace many costly and rare materials. Its manufacturing process is very simple and raw materials are found in virtually every country [4].

Manufacturing of basalt fiber

Basalt rock enters the furnace chamber as crushed particles where the material is converted in to liquid form at a temperature of 1,500 °C. Basalt fiber melting temperature is as good as glass fiber temperature i.e. between 1,400 and 1,600 °C. Basalt fiber is almost as transparent as glass fiber and it absorbs and emits infrared energy. It would therefore not be melted in the same furnace which is used for melting of silica because continuous burning and mixing is required in basalt fiber production [5].
The basalt fractions are reduced into raw material form up to 5-20 mm in dimensions which is fed into a melting furnace at a temperature of 1,400-16,000 °C. This is then passed through the die holes from the bushing, having a continuous length 9-15 mm in diameter. The winding unit takes the continuous length of basalt fiber on the spool which is rewound into the bundle of basalt roving.

Properties of basalt fiber

Physical Properties

- Color: golden or brown.
- Diameter: approx. 5.8 µm and a length of 6-12 mm.
- Density: 2.75 g/cm^3
- Coefficient of friction: 0.42-0.50.

Chemical Properties

- Stability increases in strong alkali.
- Weight loss is found in boiling water, alkali and acid.
- Good resistance to alkaline environment with pH of 13-14.

Fig. 1
Manufacturing of basalt fiber

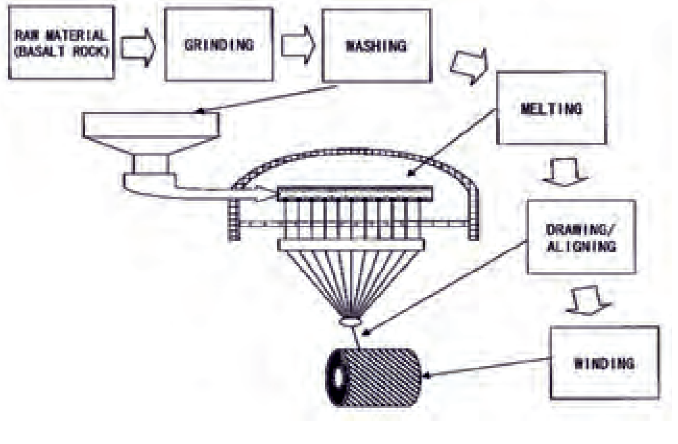

Fig. 2
Concrete made from basalt fiber

Thermal Properties

A wide thermal temperature range between 260-982 °C, a high melting temperature of about 1,450 °C and the special low conductive nature of basalt fiber allow it to be used for firefighter protection, industrial and civil applications. The thermal behavior of basalt fiber is far superior to other high-performance fibers, having 3 times better thermal efficiency than asbestos fiber without the health issues. It comes under the non-combustible and non-exploding category of fibers.

Mechanical Properties

Basalt fiber is a unique fiber having high tenacity and specific rupture properties at certain load. These properties allow its use in many applications, as it is many times stronger than steel. It has no hygroscopicity with non-capillary action which gives it more resistance to moisture [6].
Basalt products are available in various forms such as fibers, nonwovens and mesh.

Application of basalt fibers in civil engineering

Basalt-cement materials

Tensile strength properties of basalt fibers are suitable for mixing in cement material. This basically enhances the performance of cement and increases the life of the construction. The coarse and chopped roving fibers that are consistently used for mixing may vary in proportion from 15:85. It has been advised to use Portland cement which increases inter cohesion properties of basalt fiber to improve tensile, flexural and impact properties. It was found that strength, fatigue and flexural properties of the Portland cement were increased 2 to 4 times compared to conventional cement [7].

Basalt fiber-reinforced concrete

The stability and strength of the concrete was increased with the composition of Portland cement, river sand, coarse basalt fibers, and 30 % water. This has properties like radio transparency and high damping. It is also found to be economical due to its low cost which has resulted in its application in manufacturing a large assortment of high-strength, fire-resistant structures [8].

Geo-composites

Geo-composites consist of different types of geo-synthetics. As most of the individual components are thermoplastic they can be thermally laminated, but adhesive bonding and needle punching are also used. Examples include: geotextile-geo-net; geotextile-geogrid; geo-net-geomembrane; or what is termed a geo-synthetic clay liner (GCL). Advancement in the basalt fiber-reinforced polymer composites improved its potential for use for civil applications [9]. There is almost no limit to the variety of geo-composites that are possible and the development of these materials results from the anticipated usefulness of their multi-functionalities and the opportunity for more rapid installation than by using the individual components. The main geo-composite material types are: drainage geo-composites, reinforcement geo-composites and fluid barrier geo-composites. Control of water is critical to the stability of most geotechnical constructions and drainage geo-composites have become important materials for such a requirement. Common configurations of drainage geo-composites are of a geo-net sandwiched between 2 nonwovens geotextile filters or a sandwiched thick or thin preformed core (panel drain, edge drain or wick drain). Blanket drains are commonly used as liquid collection – removal layers [10].
Reinforcement geo-composites are structures in which a spun-bonded or melt blown nonwovens are incorporated into a knitted geogrid by the stich-knit action of holding yarns or bonded by needle punching to one or both sides of a woven or knitted geogrid. The nonwovens add separation and filtration functions to the geo-grid reinforcement to give the multi-functionality of the geo-composite [11]. Nano-technology helps to improve the properties of reinforced fibers which is highly beneficial to civil and construction engineering [12].
Both woven and nonwoven geotextiles can serve as moisture barriers when impregnated with bituminous, rubber-bitumen, or polymeric mixtures. Such impregnation reduces both the cross-plane and in-plane flow capacity of the geotextiles to a minimum. However, for liquid containment applications what is referred to as a geosynthetic clay liner will be more effective [13].
Geosynthetic clay liners (GCLs) are geo-composites that are typically prefabricated with a sodium bentonite clay layer sandwiched between 2 geotextile layers; 2 needle-punched nonwovens layers or 1 needle-punched non-

Fig. 3
Bricks made of basalt fiber

Fig. 4
Basalt application in geo-composites

woven and 1 woven layer. The process commonly involves attaching the top and bottom layers by stitching or needle-punching through the bentonite core which also gives the structure its internal shear resistance. When hydrated the bentonite core swells and becomes an effective barrier to liquid or gas. Developed basalt fibers have composite properties permitting them as a replacement for asbestos, high strength glass, silica, chemical resistant glass and other special fibers in many civil and construction applications [14].

Basalt geo-mesh is advantageous than the glass and metals which can be used for pavement reinforcement. It is proved that basalt fiber is ecofriendly and does not have any adverse effect on the health of human beings, unlike asbestos, and can withstand higher temperature. The basalt geo-grids are lighter and chemically safer than metal. These are considered as one of the best alternatives to metal matrix composites and are used for soil stabilization, reinforcement in road construction and building construction.

Construction

The ideal use of basalt fiber in construction mainly encompassed reinforcement material for bridges, reinforced concrete as fiber bars, non-corrosive concrete columns, building constructions, soft roofing, reusable shutters, internal waste pipes, reinforced structures, heat-supply systems, cable conduits and hydraulic construction. Basalt fiber can also be found in road construction and the reinforcement of concrete and asphalt runways, as well as in the construction of sound-absorbing barriers for highways, railways etc.

Basalt-plastic pipes

Basalt-plastic pipes can be used in shaft lining, land reclamation, agriculture (to carry gases and water), and also as a protection shield during geological or geophysical works. The wrapping which is impregnated with basalt fibers is used as plastic composite pipes for structural support. The equipment used for the manufacturing of glass-reinforced plastic tubes should be adequate for basalt-plastic composite pipes [15].

Advantages

Advantages of basalt fibers in civil applications are:

- high mechanical properties and chemical resistance in both acid and alkali environment (better than E-glass)
- extended temperature range (up to 580 °C)
- environmental friendliness
- easy recycling of basalt fiber reinforced plastics (BFRP) in comparison with GFRP (glass fiber reinforced plastics)
- production cost of basalt fibers is very low compared to other types of fibers, i.e. it is cost-effective.

Conclusion

Basalt fiber-reinforced composites and reinforced concrete are being consistently used in civil applications, the reason being improved properties without delaminating at high temperature, its cost effectiveness and its higher tensile strength compare to steel. The advanced sustainable properties of basalt fiber limit the use of fiber glass, carbon fiber and steel rods in civil engineering and the construction industry. ■

References

[1] Kumbhar, V.P.: An Overview: Basalt Rock Fibers-New Construction Material, Acta Engineering International (2014) 11-18

[2] Turukmane, R.N.; Nadiger, V.G.; Bhongade, A.L.; Borkar, S.P.: Studies on Treated Sunnhemp and Treated Jute Fiber Reinforced Epoxy Composites, International Journal of Advanced Engineering Research and Science 3 (2016) 10, 13-16

[3] Turukmane, R.N.; Bhongade, A.L.; Borkar, S.P.; Daberao, A.M.: Studies on Inter fiber cohesion Properties of Sisal Fiber reinforced Polypropylene Composite. International Journal on Textile Engineering and Processes 3 (2017) 1, 46-50

[4] Sheldon, G.L.: Forming fibers from basalt rock, Platinum Metals Review 21 (1977) 18-24

[5] Singha, K.: A short review on basalt fiber, International Journal of Textile Science 4 (2012) 19-28

[6] Palmieri, A.; Matthys, S.; Tierens, M.: Basalt fibers: Mechanical properties and applications for concrete structures, in: Concrete solutions: Proceedings of the International Conference on Concrete Solutions (2009) p.165-169

[7] Li, Weimin; Xu, Jinyu: Mechanical properties of basalt fiber reinforced geopolymeric concrete under impact loading, Materials Science and Engineering. 505 (2009) 178-186

[8] Vladimir B.: Brik Research & Technology, Inc. Madison, Wisconsin, Basalt Fiber "Composite Reinforcement For Concrete", IDEA Program Transportation Research Board National Research Council March 1997

[9] Wu, Z.; Wang, X.; Wu, G.: Advancement of structural safety and sustainability with basalt fiber reinforced polymers, Proceedings of 6th International conference on FRP composites in civil engineering (CICE2012), Rome/Italy (2012)

[10] Patnaik, A.: Applications of basalt fiber reinforced polymer (BFRP) reinforcement for transportation infrastructure, Department of Civil Engineering, University of Akron, OH44325-3905 (2009)

[11] Fiore, V.; Scalici, T.; Di Bella, G.; Valenza, A.: A review on basalt fiber and its composites, Composites Part B: Engineering 74 (2015) 74-94

[12] Turukmane, R.N.; Daberao, A.M.; Kolte, P.P.; Nadiger, V.G.: A Review – Nano Technology in Textile composites, International Journal on Textile Engineering and Processes 2 (2016) 3, 19-22

[13] Murray, A.D.: Basalt Fibers for high-performance composites, Allied Composite Technologies LLC, Lecture held at Automotive Composites Conference & Exhibition (ACCE) 2008 in Troy, MI/USA

[14] Thorhallsson, E.; Konradsson, A.; Kubens, S.: Concrete Cylinders Confined with Basalt Fiber Reinforced Polymer, Basalt Today, 2016

[15] Wagner, J. (ed.): Karst landscapes and karst features in the Philippines, Wagner (2013)