Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 06, June-2020

Application of Basalt and it's Products in Civil Engineering

Juby Elsa Sunny[1], Riya Ann Varghese[2], Sagar S[3], Sujin P John[4], Reshma Kassim[5]
[1,2,3,4] UG Scholar, Department of Civil Engineering, SAINTGITS college of Engineering, Kerala, India
[5] Assistant Professor, Department of Civil Engineering, SAINTGITS college of Engineering, Kerala, India

***Abstract* - Basalt is a common rock that is found abundant in world wide. The good mechanical properties of basalt make it particularly suitable for many applications. High strength and non-corrosive nature of basalt make it more applicable in reinforced concrete structures in marine environment. The products made from basalt can be also used effectively in the construction of bridges, highways, residential and industrial buildings. This paper deals with the study of the basalt rock products such as aggregate, fiber, mesh and rebars and its wide application in the construction field. Also, this paper compares the performance of these products with conventional building materials. These products have the potential to solve large problems in civil engineering and makes the construction easy and economic.**

Keywords : Basalt, Concrete, Reinforcement, Rebar, Fiber, Aggregate, Mesh

1.INTRODUCTION

Basalt is an extrusive igneous rock forms from the cooling and crystallization of magma. Due to the high amount of magnesium oxides and calcium oxide and very low amounts of lighter colored silicate minerals, it is generally black in color. Occasionally some orange or red colors can appear in basalts due to rusting iron compound on that particular basalt. There is also some light-colored basalt found, which form when basalt magma contains higher amount of calcium and sodium mineral. Basalt rock can be used to make various products such as basalt rebars, basalt fabrics, chopped basalt fiber strands, continuous basalt filament wires and basalt mesh. Some of the potential application of these basalt composites are soil strengthening, bridges and highways, industrial floors, plastic polymer reinforcement, retrofitting and rehabilitation of structures.

In this paper, it focusses on the study of some application of basalt and its products. In marine environment the chances of corrosion in concrete structure is very high. In such situations, it can make the concrete surface hardened, cement dissolved and crack appearance, which leads to decrease the strength and adversely affects its reliability and durability of concrete structure. By the use of non-corrosive, non-metallic basalt products may be fully reducing this problem. They are non-toxic and environmentally safe.

2. LITERATURE REVIEW

Sudha et al. (2019) studied the mechanical properties like compressive strength, split tensile strength of basalt reinforced concrete in beam column joint. The behavior of beam column joint with 0.75%, 1% and 1.25% basalt fiber were studied under cyclic loading. The results showed that the beam column joint shows better performance by the addition of basalt fibers. The study concluded that addition of basalt fiber into the concrete will enhance the flexural, compressive, split tensile strength and toughness of the concrete. Also, it will reduce the size of cracks during failure [1].

Rathod et al. (2013) studied the flexural strength and compressive strength behavior of basalt fiber reinforced concrete and normal concrete. Separate specimens were cast with 1 % and 2 % of basalt fiber. The results show that the flexural strength and compressive strength of specimens with basalt fiber is higher compared with normal concrete. Also, by the addition of 2% of fiber, the 14 days flexural strength increased about 40% to 50%- and 28-days compressive strength increased about 83% to 92% [2].

Kishore et al. (2015) focused on the effect of basalt aggregate content and its combination with limestone aggregate in concrete mix. Different percentage combination of basalt and limestone aggregate were used in this study. Compressive strength, workability, specific gravity, Los Angeles abrasion tests were performed to evaluate the performance of basalt aggregate in concrete mixes. The test results concluded that concrete mix with basalt aggregate are more workable than limestone aggregate and also the higher strength is obtained by the introduction of basalt aggregate in concrete mixes [3].

Lokesh et al. (2015) evaluate the performance characteristics of steel rebar and basalt rebar in concrete beams. Tests were performed to find the flexural and shear capacity of beam. From the comparative study between steel and basalt reinforced beam, it was found that the beams with BFRP bars shows less deflection and have higher flexural strength and stiffness than beams with steel rebars. The bond between basalt rebar and concrete was also good. The test results confirm that BFRP bars can be used as an excellent alternative to steel bars in concrete beams [4].

Urbanski et al. (2013) identifies the difference and limitations of basalt rebar in concrete structures in relation to steel reinforcement. In this study, the deflection and crack pattern of simply supported basalt reinforced beam and steel reinforced beams were compared. It was found that the failure of basalt reinforced beam did not occur suddenly and it has significantly higher deflection compared with steel reinforced beam due to the lower modulus of BFRP bars. Also, the average crack width is 3 to 4 times higher than steel reinforced beam. This study also points out that deflection and crack width are the major factors to be considered in the design of basalt reinforced concrete beams [5].

Hulin et al. (2013) investigate the influence of BFRP mesh on the fire behavior of thin high-performance concrete plates. The performance of samples with BFRP meshes were

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 06, June-2020

compared with samples having no meshes, sample with steel mesh and samples displaying a full sandwich structure. HPC specimens kept in furnace were exposed to fire load on one side of the specimen. Test results showed that specimens with BFRP mesh have better resistance to high temperature and it reduces the possibility of HPC spalling. But it decreases the mechanical strength of HPC exposed to fire [6].

3. PRODUCTS

3.1 Basalt Fiber

Basalt fiber is a high-performance non-metallic material made up of very fine fibers of basalt. Its composition consists of mineral plagioclase, pyroxene and olivine. It is manufactured by melting the quarried basalt rock to about 1400 degree Celsius. The fiber is then extruded through small nozzles to produce continuous filaments of basalt fiber. There are three manufacturing techniques, which are centrifugal-blowing, centrifugal-multiroll and die blowing. These continuous basalt fibers have some proven technical characteristics and performance specifications.

Properties

- Basalt fiber typically has a filament diameter of 9-12 micro-meter
- Specific gravity: 2.65
- It has high thermal resistance and low flammability
- It has excellent adhesion to polymer resins and rubbers
- The co-efficient of friction may is between 0.42 to 0.50
- Basalt fibers has a high elastic modulus, that resulting in an excellent specific tenacity, that is three times that of steel.
- It has high chemical resistance, especially to concentrated acid-based materials
- Basalt fibers have significant capability of acoustic and heat resistance
- It has better tensile strength than E-glass fibers and also greater failure strain than carbon fibers
- Basalt fibers are more expensive than E-glass fibers, but cheaper than carbon fibers

Applications

- Basalt fiber is used as a textile for fireproofing in aerospace and automotive applications
- Basalt composite pipes can be used to transport corrosive gases and liquids
- It can also used as a composite reinforcement in various structures, including concrete reinforcement and in the construction of building, road and runways
- Basalt fiber is a unique material used for the manufacture of porous, foamed and aerated concrete, when it is adding into dry construction mixes, it increases their plasticity, water resistant and adhesive properties
- Basalt fiber reinforced concrete is mainly used for the construction of hydraulic structure, earth- quake proof structure, reservoirs.

Table 1: Basalt Fiber Applications

Type of concrete structure, application	**Quantity of fiber in mix**	**Length and diameter of fiber**
Screed floor, industrial floors on a solid prepared base	1% of cement weight (replacement of metal mesh)	12 – 24 mm 16-17 µm
Heavy loaded industrial floors on unprepared base	1% of cement weight (in combination with rebar and mesh)	12 – 24 mm 16-23 µm
Intermediate slabs, columns, reinforced concrete frame	1.5 kg per cubic meter	12 – 24 mm 16-23 µm
Buildings and structures foundations	1.5 кг – 2 kg per cubic meter	12 – 24 mm 16-23 µm
Road construction, sites	1% (replacement of metal mesh)	12 – 24 mm 16-23 µm
Plastering solutions	0.6 %	6 mm 16 µm
Cellular concrete products (foam blocks, gas blocks)	0.25 – 0.4 %	6- 12 mm 16 µm

3.2 Basalt Rebar

Basalt rebar made from basalt rock is a material with wide range of acceptance in the construction field for past few decades, due to its non-corrosive nature. These non-corrosive rebars have the potential to replace steel in reinforced concrete and can also increase the durability of concrete structures.

Manufacturing Process

Basalt rebars are made from basalt rock by the process of fiberization and pultrusion. These bars consist of about 80% of basalt fiber. Basalt rock is crushed into finer pieces and allowed to melt in a very large furnace. Thin filaments are drawn from this molten rock by using high speed winders. By varying the speed of drawing, fibers of wide range size can be easily produced. The fiber then subsequently cooled to get hardened filaments. The filaments are then converted into rebars by using pultrusion process. In this process, the fibers are initially pulled through resin bath and then through heated die. Pullers or tractors are used to control the pulling process. Then it is sawn into required length by incline saw.

Properties of BFRP bars

- Basalt rebars has much higher tensile strength than steel bars of same diameter. These bars are two times stronger than steel bars.
- From various research studies, it was clear that the flexural load carrying capacity of basalt reinforced concrete specimens are higher than that of steel reinforced specimens
- BFRP bars are 89% lighter than steel rebars
- The stress – strain relationship of these rebars are linear and has lower modulus of elasticity than that of steel
- The bond strength of basalt rebar is good
- As these rebars are made from basalt rock, it is naturally resistant to acid, alkali and corrosive environments
- It has good thermal stability and does not conduct electricity

Applications

- BFRP bars can be used for structures in highly corrosive environments, such as:
  - ✓ Chemical plant
  - ✓ Off shore structures
  - ✓ Channel pipes
- It can be used as a sealine reinforcement
- Also, it can be used in the construction of swimming pools, bridges and domes

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 06, June-2020

Practical Example

Swimming pool constructed with basalt rebar, Rhode Island

The figure 1 shows a swimming pool in Rhode Island which is constructed using basalt rebars. This swimming pool contains hundreds of feet of rebar. Which was made vertically and horizontally. The non-corrosive nature of basalt rebars gives endless resistance to corrosion that could occur if steel is used. And also, the reinforcement is unmoved by pool chemicals.

Fig 1. Swimming pool constructed with basalt rebar

3.3 Basalt Reinforcing Mesh

The reinforcing mesh is made of basalt roving with acrylic impregnation and polyster thread. It is an excellent alternative to a traditional steel mesh due to its high strength, low thermal conductivity and long-term retention of its qualities in aggressive environment, load and temperature changes.

Basalt reinforcing mesh is mainly designed for reinforcing roads to increase the pavement lifespan by reducing the effects of reflective cracking caused by traffic loads, age hardening and temperature cycling. It is economically feasible when compared to normal steel reinforcing mesh. The basalt reinforcing mesh can be classified onto 2 types.

- Mesh with close cell
- Mesh with open cell

Reinforcing mesh for roads with closed cell is created for simple and quick use. Mesh with closed cell is produced with texturized basalt roving. It allows to prevent the stickiness of the bitumen to the drum of the machine. The size of closed mesh window is 30mm*30mm and roll length is 100m. Figure 2 and figure 3 shows reinforcing mesh with closed cells and open cells respectively.

Fig 2. Reinforcing mesh with closed cells

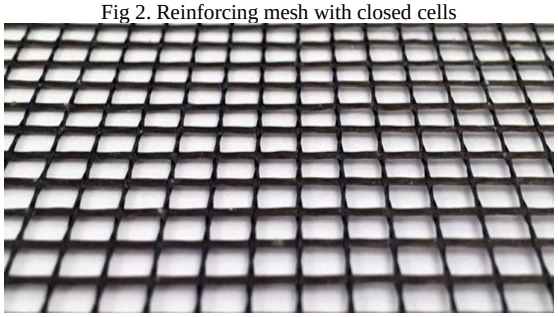

Fig 3. Reinforcing mesh with open cells

Properties of Basalt Reinforcing Mesh

- High strength and resistance to stretches bars when subjected to high loads
- High resistance to deformation at high load as a result of impacts
- It distributes the load evenly over the entire surface of the coating
- High resistance to corrosion: basalt mesh shows high resistance to corrosion in acid and alkaline media hence reduces the crack width. So, it can be effectively used in the design of pavement in bridges
- It is having excellent drainage qualities
- It shows high fire safety and fire resistance
- It shows resistance to fungal spores and small rodents.
- It is very light weight product so transportation of the material is very simple. It is an ecofriendly product
- The installation and dismantling process is very simple
- By using basalt reinforcing mesh we can reduce thickness of asphalt concrete pavement up to 20%
- The pavements designed using basalt geogrids show long service life (Reaching 35-40 years)
- It shows resistance to seasonal temperature fluctuations
- It has higher electrical resistance compared to steel. The melting point of basalt fibers is 1450 degree Celsius

Applications

1. Pavement Design

The basalt geogrids can be successfully used in construction, repair and reconstruction of roads as a reinforcing layer. The main function of this material is the uniform distribution of external load on the road over the entire surface, removal of internal stresses of asphalt concrete. Pavements designed with basalt mesh offers good resistance to fungal spores and small rodents.

2. Construction of Industrial and Civil Buildings in Seismic Regions

Due to its various advantages basalt reinforcing mesh can effectively use in construction of industrial and civil building in seismic regions. In those type of building reinforcing mesh can used to:

- General block construction and connection of ceramic foam block with facing brick work (Figure 4)

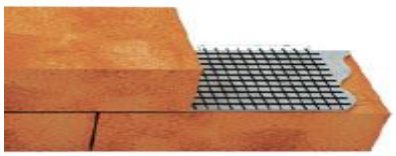

Fig 4. General block construction

- Masonry reinforcement (Figure 5)

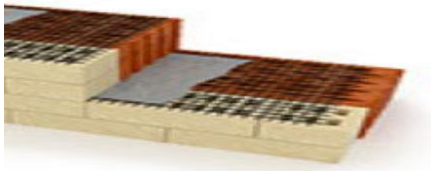

Fig 5. Masonry reinforcement

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 06, June-2020

- Reinforcing plastering (Figure 6)

Fig 6. Reinforcing plastering

Practical Example

Domes with Basalt Mesh, Soldotna, Alaska

Alaska is highly prone to earthquakes. Alaska is the highest earthquake zone. The figure 6 shows a dome in Alaska. This dome is made by using basalt mesh as the choice of reinforcement material. The monolithic Dome church in Soldotna, Alaska has a height of 27 feet and diameter of 80 feet. In 1995, with its congregation of 100 standing in worship and singing, the church successfully faced a severe earthquake.

Fig 6. Domes with basalt mesh in Soldotna

3.4 Basalt Aggregate

Crushed form of basalt is used as aggregates. Basaltic aggregates are dense and fine-grained rocks that are black or very dark color – green and are formed when molten lava from earth's crust rises up and solidifies. Crushed and graded aggregate, essentially free of moisture. Basalt aggregates are similar to limestone aggregates in many aspects. It is essentially used for many applications in the fields of civil engineering. Because of its unique properties it offers more strength to the concrete mixes compared to conventional aggregates.

Properties

- It has high specific gravity
- Basalt aggregate has lower absorption
- It is having a lower abrasion loss value
- It offers a higher strength to the concrete mix over conventional mix
- It is dense and more durable
- Basalt aggregate content mix has higher workability, which reduce the cost of labor.
- It is a natural aggregate available in plenty at low cost and are economical.

Properties of basalt aggregate with limestone

Table 2: Chemical Composition of Basaltic aggregate [3]

COMPOUND	PERCENT
Silicon dioxide	48.0
Aluminium oxide	14.4
Iron oxide	15.1
Calcium oxide	6.18
Magnesium oxide	5.95
Sodium oxide	4.05
Potassium oxide	2.29
Titanium oxide	2.29
Other oxides	1.74

Applications

- Basalt aggregate is used extensively as an engineering material for road base, concrete aggregate asphalt pavement aggregate, railroad ballast, filter stone in drain fields.
- It is also used for the construction of air field pavement, rock fill for dams and breakwaters.
- It is mainly used in concrete mix as it enhances the mix strength over the conventional limestone mix.

4. CONCLUSIONS

From the above study it can be concluded that:

1. The requirement of the moderate strengthening in the civil structures can be met with the use of basalt rock products as it is more available than other raw material.
2. Basalt is an excellent raw material for fiber forming because of its relative homogeneous chemical structure, its large-scale availability and its ability to form fibers in the molten state.
3. The basalt rebar consists of 80% of basalt fiber that offers better mechanical property to the reinforced concrete. It can be used as an alternative to steel bars where corrosion is a major problem.
4. Also higher workability of basalt aggregate reduces the cost of labor. Basalt aggregate is a natural aggregate, which is available in plenty at low cost and also relatively high strength concrete is obtained by basalt aggregate as coarse aggregate.
5. It is most commonly crushed for use as an aggregate in construction projects. Crushed form of basalt is used for concrete aggregate, road base, railroad ballast, asphalt pavement aggregate, filter stone in drain fields, and may other purposes. Basalt is also cut into dimension stone. Thin slabs of basalt are cut and sometimes polished for floor tiles, building veneer, monuments, and other stone.

REFERENCES

[1] Sudha. C, and Mohan. G. S, (2019), "Behaviour of fibre reinforced concrete using basalt fibre in beam column joint under cyclic loading", ARPN Journal of Engineering and Applied Science, volume 14, ISSN 1819-6608.

[2] N. Rathod, M. Gonbare, and M. Pujari, "Basalt Fiber Reinforced Concrete", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064

[3] Kishore. S, Mounika. L, Maruthi. P, and Harikrishna, (2015), "Experimental study on the use of basalt aggregate in concrete mixes",SSRG International Journal of Civil Engineering, volume 12, issue 4.

[4] S. Lokesh, R. Gokilapriya Dharshini, and G. Suresh, "Experimental Comparative Study on Basalt and Steel Reinforcement in RC Beam" Journal of Civil Engineering and Environmental Technology Print

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 06, June-2020

ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 2, Number 7; April-June, 2015 pp. 626-629

[5] M. Urbanski, A. Lapko, A. Garbacz, "Investigation on Concrete Beams Reinforced with Basalt Rebars as an Effective Alternative of Conventional R/C Structures" , 11th International Conference on Modern Building Materials, Structures and Techniques, MBMST 2013, Procedia Engineering 57 (2013) 1183 – 1191

[6] T. Hulin, Hodicky. Kamil. Schmidt, J. Wittrup, Nielsen, J Henrik, Stang, Henrik, "Fire performance of basalt FRP mesh reinforced HPC thin plates", In Proceedings of the 4th Asia-Pacific Conference on FRP in Structures (APFIS 2013) Swinburne University of Technology.