An Experimental Investigation on Concrete with Basalt Rock Fibers

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Abstract. Basalt fibre is formed from basalt rock when melted at a high temperature making it a non-metallic fibre. Basalt fibre reinforced concrete are good fire resistance, strength and light weight. These properties making it highly advantageous in the future to the construction business. There are many applications of basalt fibre like industrial, bridges, residential and highway etc. Fibres of basalt rock are used to make Basalt fibre, is cheaper and have improved physicomechanical properties which is very similar to the fibre glass and the carbon. They can replace many expensive materials resulting in wide range of applications in the field. The raw materials are available in all countries, making their production very simple. The biggest difficulties of the concrete and cement industry’s can be solved by the usage of basalt fibres. It is also used as composite and in the aerospace, automotive industries and fibre proof textile. Basalt fibres have no hazardous reactions with water or air and are explosion-proof and non-combustible. No chemical reaction will be produced that may damage environment or health when in contact with other chemicals. Reinforced plastics and steel maybe replaced by the basalt base composites. One kg of basalt reinforces equals to 9.6 kg of steel. Differences in compressive strength and split tensile test for concrete with and without basalt fibre by using cubes and cylinders are studied in this paper.

1. Introduction

Certain characteristics are seen in Concrete which is made with Portland cement. The use of Concrete which is made with Portland cement is limited since it is brittle and relatively strong in compression but weak in tension. As soon as it is poured, cracks appear before it has set fully which is another fundamental flaw in this concrete. Concrete weakness is due to these cracks, in large worksite applications. This results in lack of durability, failure and fracture. The weakness in tension can be avoided by including certain fibres of sufficient volume and by using conventional rod reinforcement.

A composite material consisting of mortar, mixtures of cement, or suitable fibres that are uniformly dispersed and discrete, are called as Fibre reinforced concrete. It can be flat or circular. The ratio of length to diameter of a fibre is called Fibre Aspect Ratio. Aspect ratio typically varies from 20 to 150. Egyptians first used fibres to reinforce materials which were brittle. Egyptians used straw to reinforce sun baked bricks and plaster was reinforced by horsehair. In the beginning of 20th century, Asbestos fibres were used in concrete. Concrete reinforced by steel fibre may have begun in 1960’s, glass fibres by 1980’s and from 1990’s we can see use of carbon fibres in reinforcement of concrete. Many types of fibres are being used in construction material these days.
1.1 Basalt Fiber

- Basalt is igneous rock primarily composed of pyroxene minerals. It is dark in colour and fine-grained.
- It is extrusive rock that is formed on the surface of the Earth from lava.
- It is manufactured by melting crushed and washed basalt rock which is then extruded through small nozzles to get continuous basalt fibre filaments.
- It is not toxic and also safe for the environment.
- It has elastic structure and has high heat stability.
- Owing to the high resistance to corrosion, high ductility and durability, fibre reinforced concrete is used extensively.

![Figure 1. Basalt Fiber](image)

1.2 Properties of Basalt Fiber

1.2.1 Physical Properties:

- Colour- Golden brown.
- Density- 2.75g/cm3.
- Coefficient of friction - Between 0.42 to 0.50.
- Length- Available in 6mm, 8mm, 12mm etc.
- Diameter- Available in different diameters like 5.8 micron.

1.2.2 Chemical Properties:

- UV-light resistant
- Fungal & biological contamination resistant
- Basalts are more stable in strong alkalis
- Lower weight loss in Alkali, boiling water and acids.
- Less Absorption of humidity

1.2.3 Thermal Properties:

- Thermal range of -260 C to 982 C
- Melt point of 1415 C
- Low thermal conductivity 0.031-0.038 w/m
- It is a solution for asbestos replacement
- Fire resistant and used in insulation applications
- Cost effective than the other high temper materials.
• Improves life span
• explosion proof and non – combustible

1.2.4 Mechanical Properties:
• The rupture stress to density ratio (Specific tenacity) of basalt fibre exceed that of steel.
• Gives good moisture resistance and is non-hygroscopic and non-capillary.

1.2.5 Applications
• Water retaining structures
• Pavement, Flooring, Roads, Bridges, Airport Runways
• RCC & PCC – Slabs, Beams, Columns & Lintels
• Pre-Cast Concrete Structure

1.2.6 Advantages
• At point of inception crack occurrence will be prevented.
• Increases Flexural, impact strength and compression will be increased.
• Reduces Water permeability is reduced resulting in less porous surface.
• Surface finish will be improved.
• Impact/wear/ shock/ abrasion load resistance will be increased
• Life of structures are Enhanced.

1.2.7 Disadvantages
• The price of fibre made from E-glass is lesser than those made of basalt.
• Specific design guidance for the use of Basalt fibre have not provided by International Federation for Structural Concrete, Canadian Standard Association, The American Concrete Institute, and other internationally recognized engineering code authorities.

1.2.8 Need for the Study
• For the improvement of structural strength
• For the improvement ductility behavior of a structure
• For improving durability of inwater retaining structures by reduction and control the crack width.
• For improving tensile strength without increasing steel reinforcement
• For improving the performance of concrete.
• For increasing the split tensile strength, flexural strength and compressive strength of concrete.
• For increasing the lifespan of the structure.

2. Estimation of Concrete Mix

2.1 For Cube:
Volume of cube = 150 x 150 x 150 mm = 3375000 x 10⁻⁹ = 0.003375 m³Volume of cement = 0.003375 x 413 = 1.393 Kg
Cement content = 413 Kg/m³
Total no.of cubes = 24
Volume of concrete required for 24 cubes = 24 x 1.393 = 33.4 Kg

2.2 For Cylinder:
Volume of cylinder = \(\pi \times R^2h = \pi \times 50^2 \times 20 = 1.570 \times 10^{-3} \text{ m}^3\) (d = 100 mm, h = 200)
Volume of cement = Volume of cylinder x cement content = 1.570 x 10^{-3} x 413 = 0.648 Kg.
Kg. Total no.of cylinder = 24
Volume of concrete required for 24 cylinders = 24 x 0.648 = 15.5 Kg

2.3 For Beams:
Volume of beam = 500 x 100 x 100 mm = 0.005 m³
Volume of cement = Volume of beam x Cement content = 0.005 x 413 = 2.06 Kg
Total no.of beams = 12
Volume of concrete required for 12 beams = 12 x 2.06 = 24.7 Kg

3. Procedure for Concrete Mix
➢ The quantities required for concrete mix like, coarse aggregate, cement, water, fine aggregate and basalt fiber are weighed.
➢ Specimen details of cube: 150 mm x 150 mm x 150 mm
➢ Specimen details of cylinder of size 100 mm dia x 200 mm height
➢ Using M30 grade, the mix ratio is (1:1.87:3.29:0.5).
➢ Mix the concrete with different percentages like 0%, 0.5%, 0.75% and 1% by using concrete mixing machine.
➢ After mixing the concrete pour the concrete into the moulds and for eliminating the voids by using vibrating machine.
➢ Cast the specimen and dry it for 24 hours and demould the specimen.
➢ For 7 days and 28 days the specimen is cured in water.
➢ Remove the specimen from water and dry it for 4-5 hours.
➢ Find compressive strength, tensile strength after drying of cubes and cylinders.

4. Results and Discussions
4.1 Compressive Strength Test
For cubes, Compressive Strength = P/A

| Percentage of Basalt fiber (%) | Ultimate load (kN) | Compressive Strength(N/mm²) |
|-------------------------------|-------------------|-----------------------------|
| 0%(CC)                        | 451               | 20.06                       |
| 0.5%                          | 522               | 23.20                       |
| 0.75%                         | 494               | 21.95                       |
| 1%                            | 462               | 20.53                       |
Table 2: After testing the average results of specimen at 28 days

| Percentage of Basalt fiber (%) | Ultimate load (kN) | Compressive Strength(N/mm²) |
|-------------------------------|--------------------|----------------------------|
| 0%                            | 864                | 38.40                      |
| 0.5%                          | 993                | 44.1                       |
| 0.75%                         | 952                | 42.3                       |
| 1%                            | 912                | 40.5                       |

Figure 2. Compressive Strength Results on 7th and 28th day

4.2 Split Tensile Strength Test

For Cylinders, Split tensile strength = \( 2p/\pi dh \)

Table 3. After testing the average results of specimen at 7 days

| Percentage of Basalt fiber (%) | Ultimate load (kN) | Split Tensile Strength(N/mm²) |
|-------------------------------|--------------------|------------------------------|
| 0%(CC)                        | 72                 | 2.29                         |
| 0.5%                          | 112                | 3.56                         |
| 0.75%                         | 91                 | 2.89                         |
| 1%                            | 81                 | 2.58                         |

Table 4. After testing the average results of specimen at 28 days

| Percentage of Basalt fiber (%) | Ultimate load (kN) | Split Tensile Strength(N/mm²) |
|-------------------------------|--------------------|------------------------------|
| 0%                            | 90                 | 2.86                         |
| 0.5%                          | 138                | 4.39                         |
| 0.75%                         | 129                | 4.10                         |
| 1%                            | 119                | 3.80                         |
4.3 Split Tensile Strength Test

For beams, Flexural Strength = $P_l/P_d^2$

Table 5: After testing the average results of specimen at 28 days

| Percentage of Basalt fiber (%) | Ultimate load (kN) | Flexural Strength(N/mm$^2$) |
|--------------------------------|-------------------|-----------------------------|
| 0%(CC)                         | 7.7               | 3.85                        |
| 0.5%                           | 12                | 6                           |
| 0.75%                          | 10.6              | 5.3                         |

5. Conclusions

Basalt rock fibers have no toxic reaction with air or water, are non-combustible and explosion proof. Basalt rock fibers have new range of material in building construction, road construction, concrete industry. They have potential to high performance and cost effectively replace of glass fibers, carbon and steel fibers. One Kg of basalt reinforces is equals to 9.6Kg of the steel.

The compressive and split tensile strengths are increased with 0.5% addition of basalt fiber to the concrete at 7 days and 28 days, and gradually decreased for the further percentages. The flexural strength increased with 0.5% addition of basalt fiber to the concrete at 28 days, and gradually decreased for the further percentages.
6. References

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