Performance Evaluation of High Strength Basalt Fibre Reinforced Concrete

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Abstract: ***The use of discontinuous fibres that are spaced in an ad hoc manner helps to reduce the width of fractures and inhibit the propagation of micro and macro cracks. As a result, the permeability of the concrete will decrease. It has been demonstrated that the addition of fibres to concrete improves its mechanical properties, including its resistance to fracture, impact, and dynamic load. In recent years, the use of composite materials, especially fiber-reinforced plastics, has experienced tremendous increase (FRP). As a direct result of the spread of FRP technology, the creation of new types of fibres, such as basalt fibre, has become increasingly important. The ease with which basalt fibre may be manufactured, as well as its resistance to severe temperatures and capacity to endure the effects of freezing and thawing, have led to its increasing popularity. This field of investigation focuses on the mechanical and elastic properties of concrete coupled with chopped basalt fibre. To cast basalt fibre examples, chopped basalt fibres of different lengths (12 mm, 18 mm, and 24 mm) and dosages (4 kg/m^3, 8 kg/m^3, and 12 kg/m^3 of concrete volume) were utilised. The results indicated that basalt fibre with a length of 18 mm and a dose of 8 kg per cubic metre offered the highest compressive strength in compared to ordinary concrete. The ideal flexural and split tensile strengths were provided by basalt fibres with a length of 24 mm and a dosage of 12 kg per cubic metre. In terms of elastic properties, basalt fibre with a length of 24 mm has showed superior performance than basalt fibre with a length of 12 mm, basalt fibre with a length of 18 mm, and plain concrete.***

Keywords: basalt, fibre, reinforced concrete

1. Introduction

Concrete is the most regularly used and most widely utilised building material in the world because it is the most durable and adaptable construction material that can be moulded into a variety of different shapes. However, concrete is brittle when subjected to tension because it includes a high number of minute fissures. When a load is applied to the matrix, microcracks begin to develop throughout the structure. Therefore, without reinforcement concrete members will not be able to sustain the tensile stress created by the force applied in the tensile zone. Continuous reinforcing is incapable of halting or even slowing the spread of micro and macro cracks. Both of these circumstances cannot be managed. The insertion of randomly spaced discontinuous fibres, on the other hand, decreases the fracture breadth and the rate at which micro and macro cracks spread throughout the material, hence reducing the crack width. Consequently, the permeability of the concrete is decreased. It has been demonstrated that the addition of fibres to concrete improves its mechanical properties, including its resistance to fracture, impact, and dynamic load.

In recent years, the use of composite materials, especially fiber-reinforced plastics, has experienced tremendous increase (FRP). Due to deterioration caused by elements such as corrosion of steel reinforcement and other similar types of damage, the service life of concrete has been reduced. Due to its non-corrosive nature, high specific strength, and high specific stiffness, the application of FRP is acquiring a great deal of popularity. This is so that it can improve the performance and strength of concrete. Concrete is currently manufactured using a variety of commercial fibres, including steel fibres, glass fibres, polypropylene fibres, and carbon fibres. As a direct result of the spread of FRP technology, the creation of new types of fibres, such as basalt fibre, has become increasingly important.

The ease with which basalt fibre may be manufactured, as well as its resistance to severe temperatures and capacity to endure the effects of freezing and thawing, have led to its increasing popularity. It has been demonstrated that the performance of basalt fibre in acidic environments is superior to that of glass fibre. The fatigue performance of basalt fibre is better, and it is applicable in settings with temperatures ranging from extremely low to extremely high. The vast bulk of research undertaken on this material has been on the fundamental mechanical properties of basalt fibre, such as its compressive strength, tensile strength, and flexural strength. Basalt fibre can be processed into a number of products for use in civil engineering construction applications, such as basalt fibre reinforced polymer rebars, textiles, meshes, and chopped fibres.

The material known as basalt fibre is an organic product derived from the basalt rock type. The manufacture of basalt fibres does not generate any environmentally hazardous waste, and it can be utilized without risk. Due to its great tensile strength, good thermal strength, and stability in all adverse situations, basalt fibre is an exceptional building material. There are two unique types of basalt fibres, called respectively as filaments and bundled fibres. It has been demonstrated that basalt fibre composites have potential applications in numerous fields, including national defence, aerospace, civil construction, transport infrastructure, energy infrastructure, petrochemical, fire protection, automobile manufacturing, shipbuilding, water conservation, and hydropower.

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2. Basalt Fibre Reinforced Concrete

2.1. Basalt Fibre

Basalt is a black, igneous rock composed of extremely tiny granules. A wide range of dark brown to black volcanic rocks is referred to as "basalt." When molten lava from deep below the earth's crust rises to the surface and cools, it forms these rocks. Granite is a coarse-grained rock, whereas basalt is a fine-grained rock with a greater iron and magnesium concentration. The majority of the makeup of the ocean floor is basalt. The majority of basalt on Earth was formed in rock-forming conditions, namely: a) Oceanic divergent boundaries; b) Oceanic hotspots; and c) Plumes and hotspots in the mantle.

For a very long time, it has been recognised that basalt rock is renowned for its thermal qualities, strength, and durability. The density of basalt is 2.80 grammes per cubic centimetre. Crushed basalt is used as filter stone in drain fields in addition to the creation of road foundation, concrete aggregate, asphalt pavement aggregate, and rail road ballast. Due to basalt's high abrasion resistance, thin, polished basalt slabs are commonly utilised to produce floor tiles, building veneer, and monuments. Basalt filaments are produced by melting volcanic basalt rock at temperatures between 1400oC and 1700oC for approximately six hours. The molten substance is then extruded through a specific platinum bushing to create basalt fibre filaments. The three most common methods for producing basalt filaments are centrifugal blowing, centrifugal multi-rolling, and die blowing. The fibre solidifies into hexagonal chains, resulting in a robust structure far stronger than steel or glass fibres. Its production generates no environmental waste.

Basalt roving is a collection of continuous, complex, one-directional basalt fibres. Basalt fibre provides higher electrical insulation and chemical resilience to glass fibre, especially in strong alkalis. It reduces the risk of environmental contamination caused by the production of diverse glass fibre, which generates significant levels of harmful metals and oxides. Basalt fibre offers greater rigidity and strength than glass fibre. Using a drum-chopping machine, basalt fibres are manufactured from a continuous roving. As the density of basalt fibre is less than that of steel fibre, the addition of basalt fibre does not raise the composite's dead load relative to steel fibre composite. In addition to being resistant to corrosion, basalt fibre possesses exceptional temperature resistance, anti-oxidation, and anti-radiation properties.

Basal Fibre 12 mm in length

Basalt fibre 18 mm in length

Basalt fibre 24 mm in length

Figure 1: Basalt fibre use in praposed work

2.2. Methodology

A total of 90-CYLINDER specimens, 60 cube specimens, and 60 beam specimens underwent casting and testing. Each batch yielded six cube-shaped specimens that were cast for the compression test (3 specimens each for 7 days and 28 days). For each batch, elastic characteristics such as plastic shrinkage, modulus of elasticity, and Poisson's ratio were determined by casting three specimens. In each batch, three cylinders were manufactured for the split tensile test. After seven days, three specimens were tested, and after 28 days, three specimens were tested. Six beams were constructed for flexural testing for each batch (3 specimens each for 7 days and 28 days). In all mixtures, the ratio of water to cement remained constant at 0.42. The creation of each basalt fibre-mixed concrete specimen required the use of a comparable mix proportion. Cube, beam, and cylinder examples of basalt fibre mixed concrete were formed using basalt fibres with diameters of 16 mm, lengths of 12, 18, and 24 mm, and doses of 4, 8, and 12 kg per cubic metre of concrete volume, respectively.

At 7 days of age and 28 days of age, flexural strength, compressive strength, and split tensile strength tests were conducted. In accordance with the IS regulation, the third-point loading technique was used to determine the flexural strength of the specimen beams. First, the compressive strength of cube specimens was determined using the IS code, followed by the split tensile strength of cylinder specimens. The plastic shrinkage, modulus of elasticity, and Poisson's ratio were measured at the age of 28 days. The test results were then statistically and graphically analysed so that conclusions could be reached.

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2.3. Mix Design

IS 10262 – 2009 is used in the mix design process in order to generate M40 grade concrete. The coarse aggregate was tested using the reference number IS: 2386 – 1963. Coarse aggregate is calculated to have a fineness modulus of 2.75 and a specific gravity of 3.02. Using the standard IS: 2386 (Part III) – 1963, the amount of water that coarse aggregate can absorb was determined to be 20.6%. For the goal of determining the aggregate's level of toughness, an impact test was conducted, and the resulting impact value was 46.5%. The compressive strength of coarse aggregate was determined using crushing experiments, and the result was found to be 30.3%. The sand utilised is easily accessible river sand with a bulk density of 1860 g/m3 and a specific gravity of 2.78. Typically, river sand has a fineness modulus of 2.69. In the experimental examination conducted in compliance with IS: 12269 – 2013, 43 different grades of ordinary Portland cement (OPC) were utilised. To find the proper mix proportions for concrete mix design, a variety of processes, calculations, and laboratory tests are required. This process is utilised for the manufacturing of higher-grade concrete, such as M25 and above. The proper balance of components, which results in more cost-effective concrete structures, is one of the advantages of meticulously creating the concrete mix.

Table 1: Test matrix

Specimen Name	Length of Fibre (MM)	Fibre quantity (Kg/m^3)
PC	–	–
BF1204	12	4
BF1208	12	8
BF1212	12	12
BF1804	18	4
BF1808	18	8
BF1812	18	12
BF2404	24	4
BF2408	24	8
BF2412	24	12
Where, PC = Plain concrete, BF = Basalt Fibre		

3. Result and Discussion

3.1. Compressive strength

After testing cube specimens for compressive strength, it was observed that there is tremendous increase in compressive strength of basalt fibre mixed concrete specimens as compared to that of plain concrete. 12 mm basalt fibre specimen with dosage of 4 kg/m^3 and 18 mm basalt fibre specimen with dosage of 8 kg/m^3 has greater compressive strength as compared to other specimens after 28 days.

Based on the findings presented in figures 2, it is clear that as days pass, basalt fibre performs more effectively when combined with expanded clay. During the course of this experiment, it was discovered that the crack appearance on the concrete and the fibre reinforced concrete is practically non-visible. This is due to the compatibility of basalt fibre with the expanded clay as well as the high strength of the expanded clay as well as basalt fibre. The expanded clay works extremely effectively as a binder both within the concrete mixtures and during the compression process.

Table 2: Mix design for M40 grade concrete

Ingredient	Cement	Fine aggregate	Coarse aggregate	Water
Quantity Kg/m^3	440.00	761.50	1359.48	176.00
Ratio	1.00	1.73	3.09	0.40

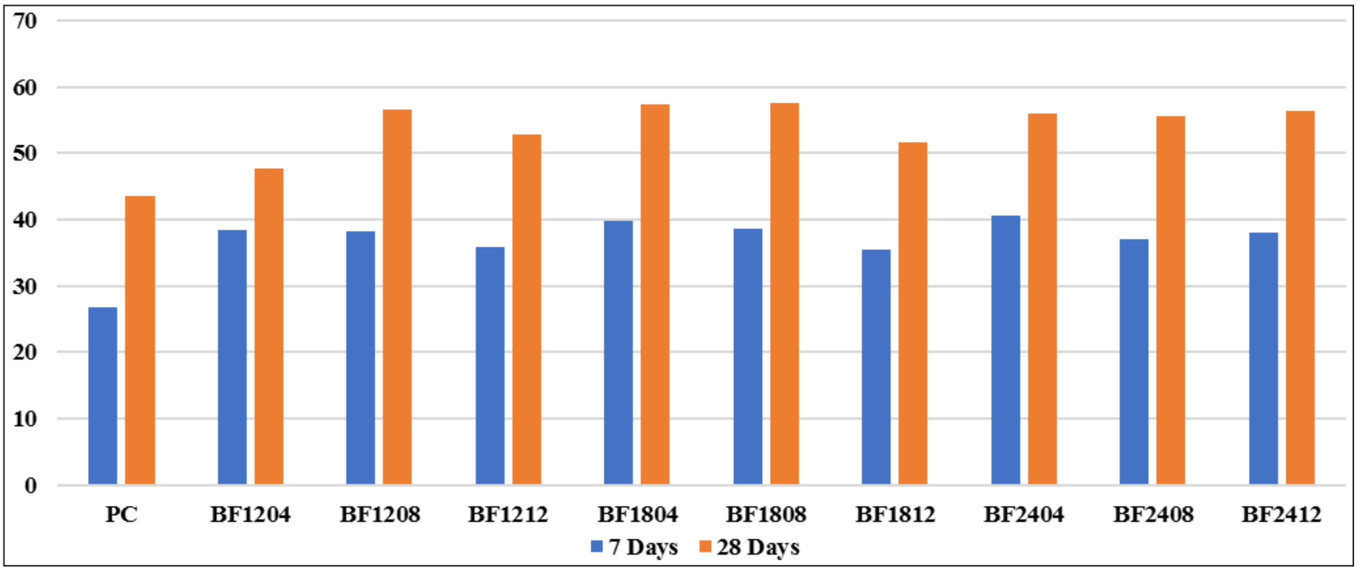

Figure 2: Compressive strength of basalt fibre mixed concrete specimens of various lengths and dosage

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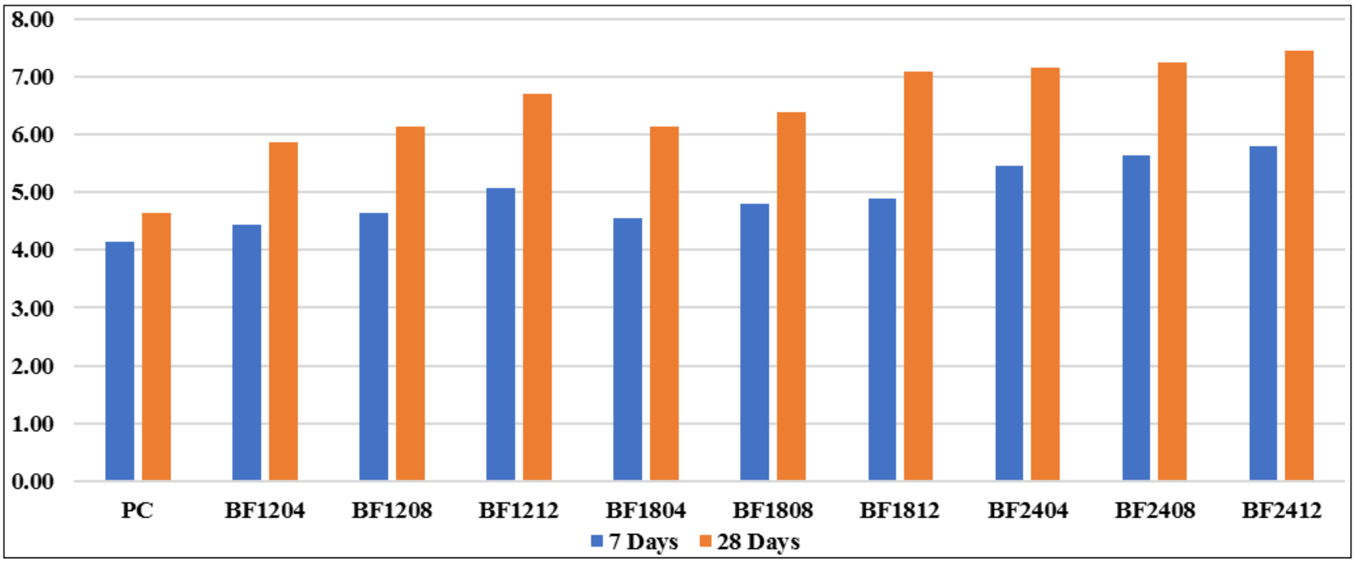

Figure 3: Tensile strength of basalt fibre mixed concrete specimens of various lengths and dosage

3.2. Split Tensile Strength

Even though concrete is very weak when it is put under stress, it is vital to understand the tensile strength of concrete in order to calculate the load at which cracks will begin to appear. The test results basalt fibre mixed concrete of various lengths and dosage are represented in Figure 3 for this load plays a role in the development of cracks as well as their spread to the tension side of the concrete and to adjacent concrete members. The fracture width is decreased when basalt fibres are used to reinforce concrete, which results in an increase in the concrete's strength and longevity. According to the findings that were acquired, it was discovered that the tensile strength of concrete that was reinforced with basalt fibres improves as the curing time passes. Tensile tests on concrete were carried out on concrete samples that were either reinforced with basalt fibres or left unreinforced. After 7 days, 7 and 28 days of curing in water, the specimens were evaluated. According to the findings, the tensile strength of concrete steadily improves as its ages throughout the curing process. The tensile strength of concrete rises in proportion to the length of the basalt fibres that have been pre-soaked. The author conducted research to determine how the tensile strength of concrete will be affected by the utilisation of basalt fibres with lengths of 12, 18, and 24 mm. According to the findings, basalt fibre with a diameter of 24 mm attained the highest possible tensile strength. The following inferences and conclusions can be made based on the findings. Reinforcing concrete with basalt fibres of 12, 18 and 24 mm in length and 20 - 55% content increases the tensile strength significantly, increasing it by 56 %. This results in higher concrete tensile strength of the BF2412 class, which is the result of using basalt fibres with a diameter of 24mm and a content of 56%. There was not a discernible difference in tensile strength when utilising either 12 mm or 18 mm fibre lengths, despite the fact that most fibre lengths reached a higher value.

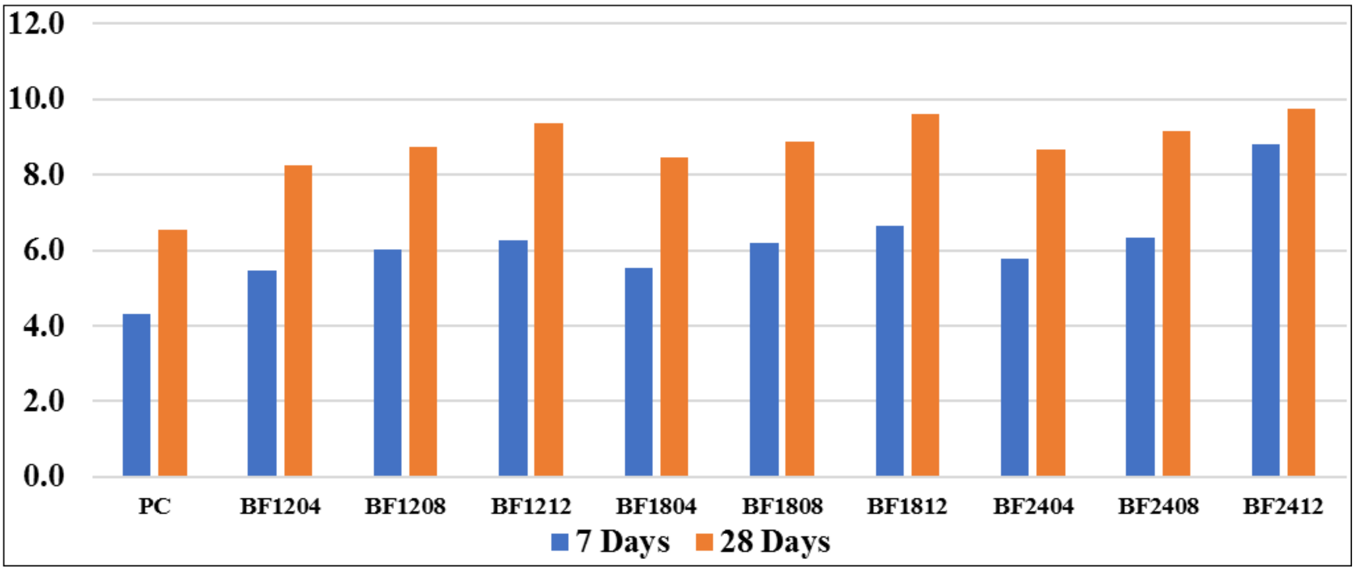

Figure 4: Flexural strength of basalt fibre mixed concrete specimens of various lengths and dosage

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3.3. Flexural Strength

In the fields of construction and engineering, it is vital to have a working knowledge of certain words, such as the flexural strength of the material. This is done to ensure that the material is robust enough to be utilised in the construction of various structures. The ability of a material to withstand deformation in the presence of a load is refers to as the flexural strength of the material. Test provides two useful main parameters: the first crack strength that the material can withstand and the ultimate flexural strength or modulus of rupture, which is determined by the maximum load that can be attained. Both of these parameters are useful in determining the ultimate flexural strength or modulus of rupture. The flexural strength of concrete was tested after it had been allowed to cure for 7 days and 28 days, both with and without the addition of basalt fibres. According to the findings, the flexural strength of concrete suffers when even just 1% of basalt fibre is added to the mixture. Reinforcing concrete with non-dipping chopped basalt with a length of 12, 18 and 24 mm, and using different doses of 4 kg/m^3, 8 kg/m^3, and 012 kg/m^3. According to the findings, the flexural strength of the concrete improved as the percentage of basalt fibres in the mix grew, and it attained its utmost potential when the of basalt fibres in the mix was BF2412. The findings of an experiment that the flexural strength of concrete improves along with an increase in the percentage of basalt fibres present in the mixture. The author conducted laboratory tests with various basalt fibre contents, utilising a variety of concrete prisms. When the results were compared with those of a typical concrete mixture, it became abundantly clear that the addition of basalt fibres to the concrete mixture increased the mechanical properties in general, including the flexural strength.

3.4. Elastic Modulus

Elastic modulus of plain concrete and basalt fibre mixed concrete (with different fibre lengths and different fibre dosages) was computed by testing cylinder specimens at the age of 28 days. A stress – strain curve plotted are as follow.

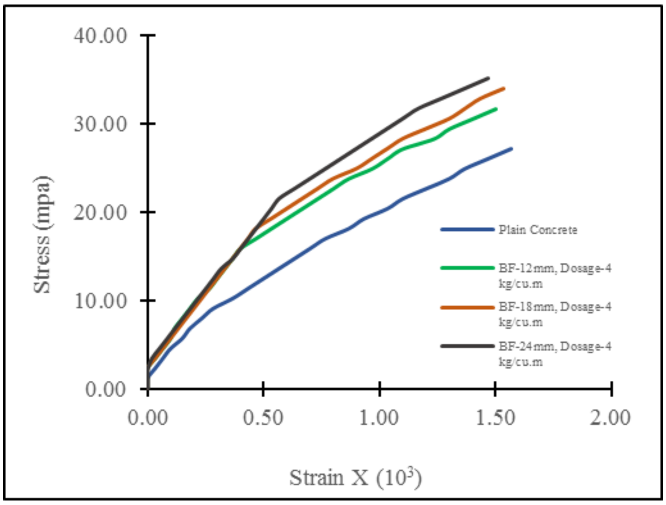

Figure 5: Stress – strain curve of basalt fibre mixed concrete of various lengths of dosage 4 kg/m3

After testing cylinder specimens for elastic modulus, it is observed that results of elastic modulus of basalt fibre mixed concrete specimens are greater than that of plain concrete specimen. From stress – strain curve it is observed that basalt fibre mixed concrete specimen of 24 mm length has greater results as compared to plain concrete and basalt fibre mixed concrete specimens of 12mm and 18mm length. It is also found that there is no big difference in results of 12mm and 18mm length basalt fibre mixed concrete specimens.

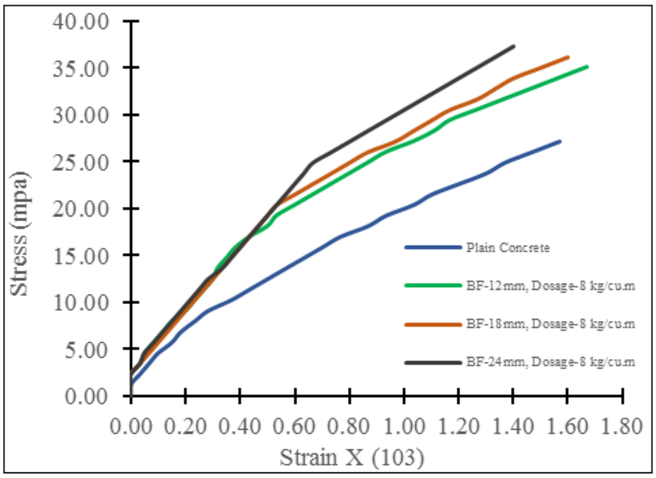

Figure 6: Stress – strain curve of basalt fibre mixed concrete of various lengths of dosage 8 kg/m3

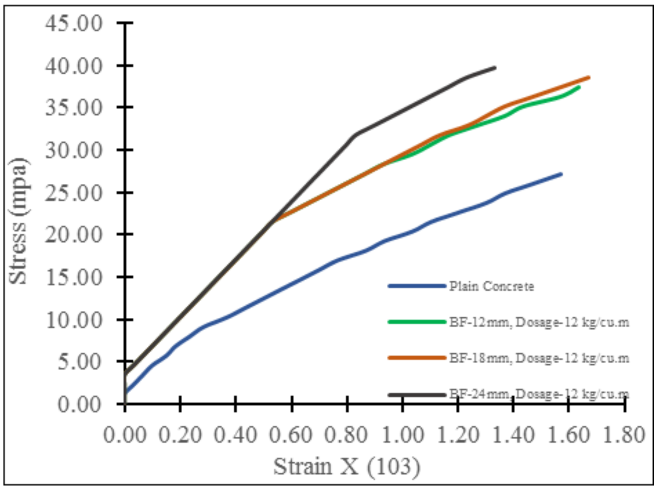

Figure 7: Stress – strain curve of basalt fibre mixed concrete of various lengths of dosage 12 kg/m3

The rigidity of a material, as well as its propensity to deform elastically, can be measured using something called the elastic modulus. The modulus of elasticity, also known as Young's modulus, can be represented by the slope of the stress strain diagram. This definition comes from Hook's law and states that the modulus of elasticity is defined as the ratio of the stress to the strain. Researchers from a wide variety of institutions have looked at the effect that incorporating basalt fibres into concrete at varying quantities and lengths can have on the material's elastic modulus. Experimentally, discovered that increasing the percentage of basalt fibre dosage in concrete from 4 kg/m3 to 12 kg/m3 results in a considerable increase in the material's modulus of elasticity. In particular, the highest modulus of elasticity was accomplished when the basalt fibre content was 4 kg/m3, and

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it started to drop when the basalt fibre dosage reached 12 kg/m3. According to the Figure 5, 6 and 7, the slope of the stress strain curve for the control mix is significantly steeper than the slope of the curves for the mixes reinforced by basalt fibres. According to the result, basalt fibres were fully active and exhibited remarkable resistance to the spread of cracks in concrete. According to the result who investigated the effect of adding different basalt fibre dosage of 4 kg/m3, 8 kg/m3 and 12 kg/m3 into the concrete stress strain curves, adding basalt fibre content of 0.2% achieves the highest stress strain resistance values. This was discovered by finding that adding basalt fibre content of 0.06% achieved the lowest stress strain resistance values.

4. Conclusions

1) It is found that the basalt fibre mixed concrete containing 24mm length basalt fibre with dosage of 4 kg/m^3 has highest compressive strength at the age of 7 days and basalt fibre mixed concrete containing 18mm length basalt fibre with dosage of 8 kg/m^3 has highest compressive strength at the age of 28 days. From result analysis it is found that there is almost 32% increase in the compressive strength in comparison with plain concrete.
2) It is found that the basalt fibre mixed concrete containing 24mm length basalt fibre with dosage of 12 kg/m^3 has highest tensile strength at the age of 7 days as well as at the age of 28 days. From result analysis it is found that there is almost 18% increase in the tensile strength in comparison with plain concrete.
3) It is found that the basalt fibre mixed concrete containing 24mm length basalt fibre with dosage of 12 kg/m^3 has highest tensile strength at the age of 7 days as well as at the age of 28 days. From result analysis it is found that there is almost 49% increase in the tensile strength in comparison with plain concrete.
4) It is found that basalt fibre mixed concrete has low plastic shrinkage as compared to plain concrete. Basalt fibre mixed concrete containing 24 mm length basalt fibre has comparatively low shrinkage than that of 12mm and 18 mm basalt fibre mixed concrete specimens at the age of 28 days.
5) After plotting stress – strain curve it is observed that basalt fibre mixed concrete has high elastic modulus in comparison with plain concrete. Basalt fibre mixed concrete containing 24mm length basalt fibre has comparatively high elastic modulus at the age of 28 days. It is found that basalt fibre mixed concrete containing 12mm and 18mm length has no big difference in stress – strain curve at the age of 28 days.

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