STUDIES ON THE MECHANICAL AND DURABILITY PROPERTIES HIGH STRENGTH SELF COMPACTING CONCRETE INCORPORATING BASALT FIBERS

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ABSTRACT

This paper aims to make high-strength self-compacting concrete by utilizing supplementary cementitious materials (SCMs) in cement partially. The SCMs used in the present work are fly ash, GGBS and Basalt fiber (BF). In the present work, six mixes were prepared. Mix SCCBF0 is cement replaced with fly ash by 20% and 10% of GGBFS in all mixes. The 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% volume of concrete of basalt of fibers were added to the mixes i.e: SCCBF0.1, SCCBF0.2, SCCBF0.3, SCCBF0.4, and SCCBF0.5 respectively. The tests performed are fresh, mechanical, and durable. To find the fresh properties slump flow test, V-funnel test, and L-Box test are performed. To find mechanical properties compressive strength tests at 28 and 56 days, flexural tests at 28 and 56 days, and split tensile tests at 28 and 56 days of curing are performed. In this study the effect on the durability properties of High strength Self Compacting concrete are analyzed by subjecting the specimens to an Acidic environment like Hydrochloric acid (HCL), and Sulfuric acid (H_2SO_4) and in a Base environment like Sodium Hydroxide (NaOH), Magnesium Sulphate ($MgSO_4$), in 5% concentration of each, with a dosage of 0.3% by the volume of concrete and then the properties such as mechanical, dimensional stability and mass loss were determined.

Keywords: supplementary cementitious materials (SCMs), Self Compacting concrete, slump flow test, V-funnel test, L-Box test, fly ash, GGBS and Basalt fiber (BF).

I INTRODUCTION

A. Fiber reinforced self compacting concrete

When fiber is incorporated in concrete as a composite material, it is known as Fiber Reinforced Concrete (FRC). Concrete is a brittle material, with low tensile strength and possesses low stain capacity. Addition of fiber as composite material proves to be a solution to this problem. It forms a bridge across the crack and increases the ductility of concrete. Homogenous tensile concrete is obtained with the addition of steel fiber. Self Compacting concrete is well known for its performance in its fresh stage but in hardened stage it has low tensile strength and shear strength. When fiber is reinforced in self compacting concrete this problem is solved. Such type of concrete is known as Fiber Reinforced Self Compacting Concrete (FRSCC). Structural performance of SCC is increased. All types of fibers can be added in cement matrix but its aspect ratio and volume of fiber in concrete affect the workability of SCC. Hence special care has to taken in mix proportion of FRSCC.

B. Basalt fiber

During recent times, several research works are being carried out on a development of modern continuous fibers from basalt stones. Basalt has its source from volcanic magma and flood volcanoes which are a very hot fluid or semi-fluid material under the earth's crust. It gets solidified in open air. Basalt fiber is a variety of volcanic rocks, which are dark gray in color, and it formed from the molten lava after solidification. Basalt rock-beds with a thickness of 200 m have been found in the East Asian countries. Basalt rock is a volcanic rock which can be divided into small particles. It can then be formed into continuous or chopped fibers called basalt fibers. Basalt is quarried, crushed, washed and then melted at 1500°C. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber.

Basalt fiber has a high working temperature and has a good resistance to chemical attack, impact load, and fire with less poisonous fumes. The above said basalt fibers and basalt composites are used in plastic polymer reinforcement, soil strengthening, bridges, highways, industrial floors, heat, and sound insulation for residential and industrial buildings, bulletproof vests, retrofitting and rehabilitation of structures. Basalt fiber contains extrusive, igneous rock collected of plagioclase, feldspar, pyroxene, and magnetite, with or without olivine and containing not more than 53% SiO_2 and less than 5% total alkalis. Basalt is divided into two types such as alkali basalt and tholeiites. It has a similar absorption of SiO_2, but alkali basalts have a higher content of Na_2O and K_2O than tholeiites. The making of basalt fibers is similar to the manufacture of glass fibers. By industrial production of basalt fibers by new technologies, their cost is equal and even less than the cost of glass fiber.

Figure.1 Basalt fiber

The Basalt fiber is an inorganic fiber material. It is a natural material and originates from volcanic rock. It is commonly known as basalt roving or continuous filament fiber. When the continuous length is chopped into various lengths, it is called as basalt chopped strands fiber which has varying colors such as brown, gold or gray.

II SURVEY OF RESEARCH

Abhijeet B. Revade et al. (2015) studied the effects of short basalt fibers on mechanical properties of concrete. Among four different contents of basalt fibers, 0%, 1%, 1.5%, and 2%, the split tensile and flexural strength increases from 0% to 2.0%, but optimum value of compressive strength is obtained for 1.0% and then it is decreases for 1.5% and 2.0% of fiber content. The results from experimental studies shows that the optimum percentage of basalt fibers for the maximum compressive strength of 36.89 MPa is 1.0 %, which gives 13.19% increase in compressive strength than normal concrete. For maximum split tensile and flexural strength, optimum fiber content is 2% gives the maximum strength of 3.54 MPa and 6.78 MPa which is 20.82% and 35.87% higher than standard concrete. From the research, it was proposed that the usage of basalt fibers in low - cost composites for civil applications gives good mechanical properties like strength and lower cost predicted for basalt fibers.

Elba Helen George et al. (2014) investigated the effect of basalt fiber on mechanical properties of concrete containing fly ash and metakaolin. Based on the studies conducted, it is observed that the basalt fiber inclusion enhanced the split tensile and flexural strength of concrete. Through the SEM analysis, it is confirmed that the rod-like structure of basalt fiber observed at the interface of the cementitious and aggregate matrix could probably be the reason for the increased split tensile and flexural strength of concrete, as it bridges or connects the weak and strong matrix upon loading. However, the quantitative nature of this benefit is difficult to determine as it is required to conduct further studies to prove which is also authors future scope of work, as well.

Mustapha Abdulhadi (2014) underwent a comparative study of basalt and polypropylene fibers reinforced concrete on compressive and tensile behavior. The investigation the fibers Basalt and Polypropylene with various volumes can still be a promising work as there is always need to overcome the problem of brittleness of concrete. Addition of 0.3%, 0.6%, 0.9% and 1.2% resulted in a reduction of strength relative to ordinary concrete by 9%, 19%, 1%, and 18% respectively. The addition of 0.3% and 0.6% volume of basalt fiber increase the tensile strength of concrete by 2.6% and 22.9% respectively; while for 9% and 1.2% volume, the tensile strength of concrete decreased by 11.3% and 19.8% respectively; therefore, the optimum dosage for the split tensile strength of basalt fiber is in the vicinity of 0.6%. Also, addition of 0.3%, 0.6%, and 0.9%, volume of polypropylene fiber increases the splitting tensile strength of concrete by 15.1%, 7.8%, and 5.6% respectively.

Tehmina Ayub et al. (2014) investigated the effect of chopped basalt fibers on the mechanical properties and microstructure of high - performance fiber - reinforced concrete. The use of silica fume (without fibers) increased the compressive strength, splitting tensile strength and flexural strength as high as 15.37% and 28.88%, and 4.81%. In contrast, the addition of metakaolin increased the compressive, splitting tensile and the flexural strength of the concrete as high as 14.83%, 2.13% and 9.44%, respectively. The variation in the average cube and cylindrical strengths of HPFRC containing Basalt fibers was found to be in the range of ±4% when compared to the average cube compressive strength of the control specimens. When Basalt fibers were added as 1%, 2%, and 3% by volume in the concrete mixes, it was found that the average increase in the compressive strain was 4.76%, 9.99% and 12.20%, respectively.

Amuthakkannan et al. (2013) experimented the effect of aspect ratio of the fiber and fiber content on mechanical properties of short basalt fiber reinforced polymer matrix composites. Short Basalt fiber reinforced polymer composites have been investigated with different fiber length and various fiber content. The characterization of the composites reveals that the length of fiber has a significant effect on the mechanical properties of composites. 68 % of fiber and 10 mm length of fiber shows better properties than other lengths of fiber from the result of the tensile strength of the Basalt fiber composites. Flexural strength of composites also exhibits good properties in 68 % of fiber and 10 mm length of fiber. The impact strength of basalt fiber reinforced composite of 50 mm length reveals that the maximum impact energy absorption in all the percentage of fiber.

Palanisamy et al. (2013) have done the performance evaluation and investigation on mechanical properties of polyester fiber reinforced concrete. Experimental investigation were carried out for concrete mixes with a percentages of 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4% and 0.45 of Polyester fibers to find the mechanical properties of concrete with w/c 0.50. The test results show clearly that Polyester fiber reinforced concrete shows significant effects on the properties and quality of the concrete out of all the mixes considered. Concrete with 0.40% of Polyester fiber (R8) was found to be superior to other mixtures for all operating conditions. The addition of fibers in concrete (R8) increases the split tensile strength to 1.41 times when compared to plain concrete (R0). The flexural strength increases by 2.55 times when compared to plain concrete (R0) in the fiber addition of 0.40% in concrete (R8) and it leads to a reduction of crack formation.

Mohsen A. Issa et al. (2016) investigated the shear behavior of basalt fiber reinforced concrete beams with and without basalt FRP stirrups. The concrete beams were made with and without Basalt FRP shear reinforcements. The flexural reinforcement ratios (ρf) ranged from 2.69 to 14.8 times the balanced ratio (ρfb) for shear reinforced (NSR) beams and 1.69 to 6.88 for the shear reinforced (SR) concrete beams. Two different shear span-to-depth ratios were considered for the various beams. The test results are shown regarding crack patterns, failure modes, load-deflection, load-strain behavior, and shear capacity. It was witnessed that for both SR- and NSR beams, the shear capacity improved when the area of Basalt fiber reinforced polymer reinforcement increased for the same span to depth ratio, whereas the shear capacity low when the span to depth ratio increased.

Ranjitsinh K. Patil et al. (2014) experimented the effect of basalt, glass and steel fiber on compressive and flexural strength of concrete. For mechanical properties of reinforced concrete, and beams were tested over an effective span of 900 mm up to a failure of the beam under two-point loading. The fibers were placed in concrete randomly by (0.25%, 0.5%, 0.75%, 1%) of its total volume of concrete. Marek Urbanski et al. (2013) investigated the concrete beams reinforced with basalt rebars as an effective alternative of conventional R/C structures. Basalt bars for concrete reinforcement called BFRP is a new material, so it is essential to find the differences and limitations of their use in the concrete structures about traditional steel reinforcement of concrete structures. This research explained some of the selective results of this study on the simply supported beams under flexure strength, reinforced with BFRP bars, compared to the conventional concrete beams with steel reinforcement. The tested beams were cast of C30/37 concrete and reinforced with basalt bars of 8 mm diameter having and tensile strength was calculated from the tensile tests. The analysis of the beam deflection and cracking behavior has been presented. The results show the different characteristics of the load deflection behavior of the basalt reinforced beams compared to the traditionally steel reinforced beams, at the same time the significant impact type and quality of anchoring on the process of basalt bars tensile process. Deflections of beams with BFRP reinforcement were pointedly higher than the conventional beam deflection, due to the much lower modulus of elasticity of BFRP bars compared to steel bars.

III OBJECTIVES

The objectives of paper are:

- Study on strength characteristics of M80 grade basalt fiber reinforced self compacting concrete with addition of 0.1%, 0.2%, 0.3%, 0.4% and 0.5% basalt fiber in the weight of concrete.
- To determine the fresh properties of self compacting concrete by slump flow, v funnel and l-box test.
- To determine the Harden concrete by compressive, split tensile and flexural strength for 28 and 56days curing.
- To determine the durability properties of basalt fiber reinforced self compacting concrete.

IV METHODOLOGY AND MIX DESIGN

A. Methodology

- Collect the materials (cement, water, basalt fiber, ggbs, fly ash, coarse and fine aggregate).
- Choose the mix design and literature survey (for mix proportions and pending works from past researches).
- Design mix design of M80 grade self compacting concrete.
- Find out the mix proportions for different mix grades.
- Mixing of all dry materials for 2mintues and required quantity of water to add the dry mixed materials and mix it for 3-5mints.
- Freshly prepared concrete test with slump flow, l-box, v funnel test
- Cast the cubes, beams & cylinders moulds based on the requirement.
- Cure the sample in water for 28 and 56 days for cubes, cylinders and beams.
- After curing ages, the samples tested. Compressive strength test for cubes, flexural strength for beams and split tensile strength test for cylinders.
- Durability tests such as acid and base attack test performed for 0% fiber based scc nd optimum dose fiber based scc on the harden properties of concrete.
- Results & discussions
- Conclusions

B. Mix design

Right combination of cement, aggregate, Basalt fiber, fly ash, GGBS water and admixture is required to achieve a self-compacting concrete which satisfies the specification. The purpose of mix proportioning is to obtain a product that will perform according to certain predetermined requirement, the most essential requirement being the workability of fresh concrete, and strength and durability of hardened concrete. Below table shows the mix proportion used for 6 mixes.

Table.1 Mix design

SCC BF %	Cement (Kg/m³)	Fly ash (Kg/m³)	GGBS (Kg/m³)	Water (Kg/m³)	SP (kg/m³)	Coarse aggregate (Kg/m³)	Fine aggregate (Kg/m³)	Basalt fiber (% by volume of concrete)
0	490	70	140	196	5.6	760	780	0
0.1	490	70	140	196	5.6	760	780	2.4
0.2	490	70	140	196	5.6	760	780	4.8
0.3	490	70	140	196	5.6	760	780	7.3
0.4	490	70	140	196	5.6	760	780	9.7
0.5	490	70	140	196	5.6	760	780	12.18

V EXPERIMENTAL WORK

All the required quantities of cement, fly ash, GGBS, basalt fiber, fine aggregate and coarse aggregates weighed separately and mixed in dry condition. The obtained proportion of water and super plasticizer are added to the composite mixture and mix thoroughly until a uniform mixture is formed. The same procedure is repeated for different mixes which includes the addition of basalt fiber. The complete mixing is done by hand mixing. After the concrete is mixed, the fresh concrete tests are to be carried out to measure the workability by using slow flow test, L-box test and V-funnel test.

Standard cube, cylinder and beam specimen was casted for this investigation. The entire specimens were demouled after 24 hours. The specimen was kept in water bath tab until testing. The specimen was air dried before testing.

For cubes compressive strength test, beams flexural strength test and cylinders split tensile strength will performed to knowing its strength by adding different percentages of basalt fiber.

Figure.2 Test setup for compressive strength

Figure.3 Test set up for split tensile strength

Figure.4 Test setup for flexural strength

The durability of concrete by using acid and base attack tests performed. The acid attack test with HCL and H_2SO_4 solutions and base attack test with $MgSO_4$ and NaOH solutions.

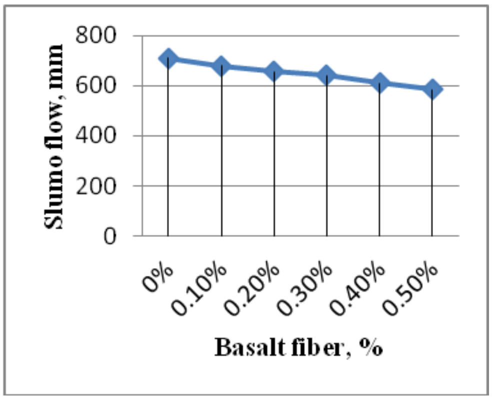
Figure.5 cubes immersed in acid

VI RESULTS AND DISCUSSIONS

A. Fresh properties of self compacting concrete

a. Slump flow

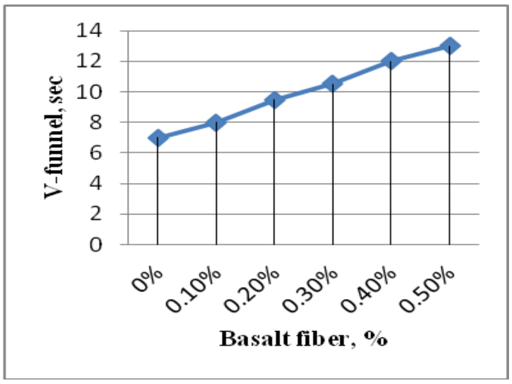
The slump flow values were decreasing with increasing Basalt fiber content in the self compacting concrete. When basalt fibers are added it creates a disturbance to the flow of concrete. Even though the workability slump values reduce but all the slump values are within the limits. Below graph shows the slump flow values of fresh concrete from SCC BF 0% to SCC BF 0.5% in a graphical representation.



Graph.1 Slump flow test results graph

b. V-funnel test

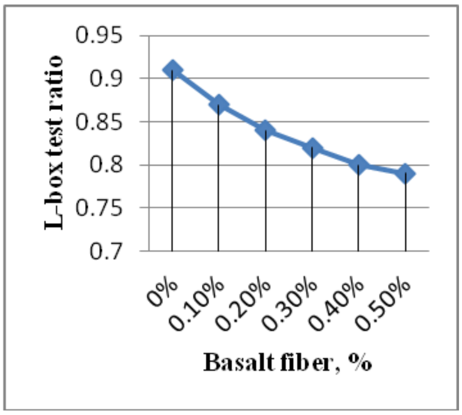
V-funnel time is inversely proportional to slump flow diameter. If slump flow values are more, the workability is good and it requires less time to remove the concrete from V-funnel. As basalt fibers are added to concrete (SCC BF 0.1% to SCC BF 0.5%), the time requires to remove the concrete is more as compared with the control mix (SCC BF 0%). Below graph shows the V-Funnel values of fresh concrete from SCC BF 0% to SCC BF 0.5% in a graphical representation.



Graph.2 V-Funnel test results graph

c. L-box test

L-box H2/H1 ratio is proportional to slump flow diameter values. If H2/H1 ratio values are more the concrete workability is good and it flows through the dense reinforcement fill every corner. A similar trend follows in L-box w.r.t to Slump flow and V-funnel. Below graph shows the L-box ratio values of fresh concrete from SCC BF0% to SCC BF 0.5% in a graphical representation.

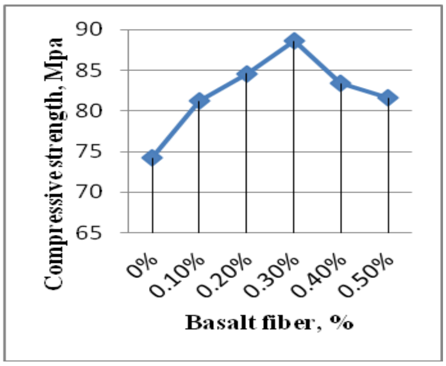


Graph.3 L-box test results graph

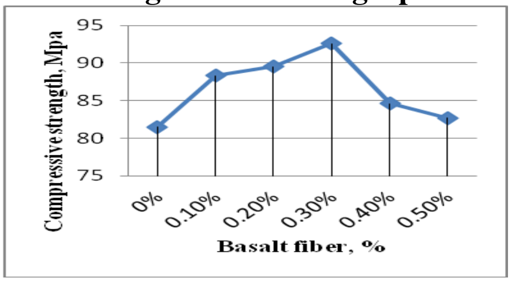
B. Harden properties of self compacting concrete

a. Compressive strength

The compressive strength of Basalt fiber reinforced self compacting concrete test results mentioned in below graph. The highest compressive strength gains for SCC BF 0.3% mix as compare to all other mixes. 0.3% addition of basalt fiber in the weight of concrete give the highest compressive strength as compare to the other dosages.



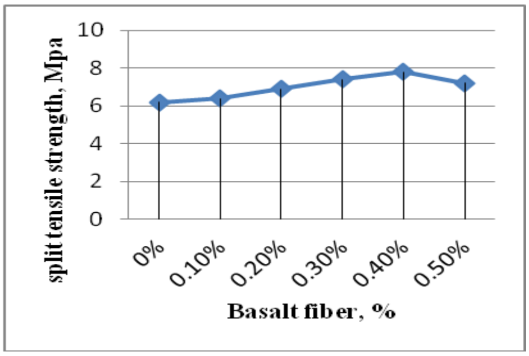
Graph.4 28days compressive strength test results graph



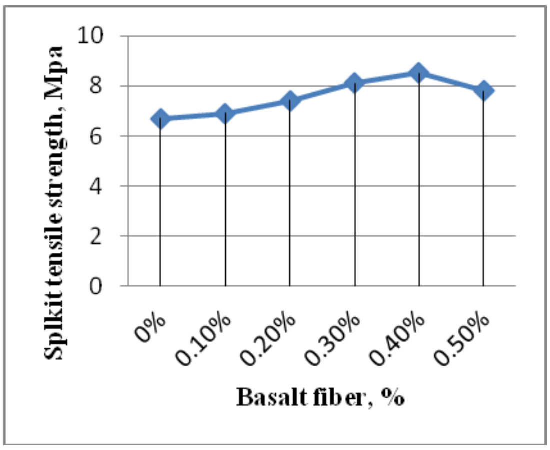
Graph.5 56days compressive strength test results graph

b. Split tensile strength

The split tensile strength of Basalt fiber reinforced self compacting concrete test results mentioned in below graph. The highest split tensile strength gains for SCC BF 0.3% mix as compare to all other mixes. 0.3% addition of basalt fiber in the weight of concrete gives the highest split tensile strength as compare to the other dosages.



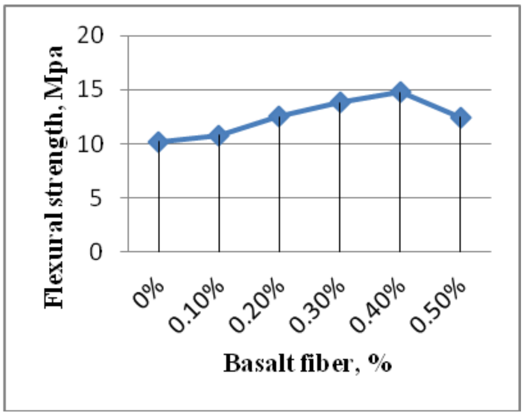
Graph.6 28days Split tensile strength test results graph



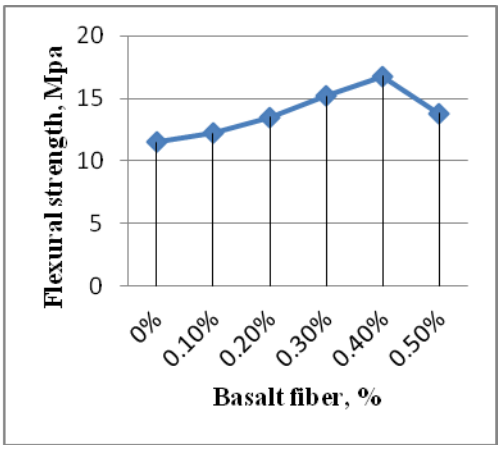
Graph.7 56days Split tensile strength test results graph

c. Flexural strength

The flexural strength of Basalt fiber reinforced self compacting concrete test results mentioned in below graph. The highest flexural strength gains for SCC BF 0.3% mix as compare to all other mixes. 0.3% addition of basalt fiber in the weight of concrete gives the highest flexural strength as compare to the other dosages.



Graph.8 28days Flexural strength test results graph



Graph.9 56days Flexural strength test results graph

C. DURABILITY PROPERTIES OF SELF COMPACTING CONCRETE

a. Acid attack test

The acid attack of concrete with basalt fiber reinforced concrete after the attack was found to be less weight loss when compared to the normal concrete. The variation of test results are shown in table 2. Due to sulphate attack the concrete deteriorated and the strength has reduced.

Table.2 Acid attack test results

Basalt fiber %	HCL	H_2SO_4
0	0.65	1.4
0.3	0.61	1.18

b. Base attack test

The base attack of concrete with basalt fiber reinforced concrete after the attack was found to be less weight loss when compared to the normal concrete. The variation of test results are shown in table 3. Due to base attack the concrete deteriorated and the strength has reduced.

Table.3 Base attack test results

Basalt fiber %	NaOH	$MgSO_4$
0	0.68	0.46
0.3	0.45	0.41

The acid attack causes extensive formation of concrete in the region close to the surface. The regions close to the surface tends to cause disinserting mechanical stresses leading to spalling and lesser exposer of the concrete surface in the concrete prevent spalling. Due to the cohesiveness of the cement hydration products, there is a less loss in mass and strength. The percentage of relative linear expansion can be reduced by adding basalt fiber. Concrete with low permeability is the best protection against sulphate attack. This can be achieved using basalt fiber reinforced concrete. By preventing sulphate attack, the effect of expansive forces generating tensile stresses in concrete is reduced. Deterioration of cement parts by the formation of gypsum reduces pH of the system and loss in the stiffness and strength. This results to expansion, cracking and transformation of non-cohesive mass.

The cohesiveness can be maintained by the addition of basalt fiber.

CONCLUSIONS

- The workability of all mixes of high-strength self-compacting concrete was reduced when basalt fibers were added, due to the movement disrupting the flow of concrete.
- At 28 and 56 days of curing, the compressive strength of the Control Mix SCCBF0 grade obtained 74.2 MPa and 81.5 MPa respectively.
- At 28 and 56 days of curing, the compressive strength of the Mix SCCBF0.3 grade obtained 88.6 MPa and 92.6 MPa respectively. SCCBF0.3 mix has 13.6% more strength compared with the control mix.
- At 28 and 56 days of curing, the split tensile strength of the Control Mix SCCBF0 grade obtained 6.2 MPa and 6.7 MPa respectively.
- At 28 and 56 days of curing, the split tensile strength of the Mix SCCBF0.4 grade obtained 7.8 MPa and 8.5 MPa respectively. SCCBF0.4 mix has 26.8% more strength compared with the control mix.
- At 28 and 56 days of curing, the Flexural strength of the Control Mix SCCBF0 grade obtained 10.2 MPa and 11.5 MPa respectively.
- At 28 and 56 days of curing, the Flexural strength of the Mix SCCBF0.3 grade obtained 14.75 MPa and 16.75 MPa respectively. SCCBF0.4 mix has got 41% more strength compared with the control mix.
- With the consideration of the fibers, the weight reduction was a lot more prominent for the examples submerged in the acids from 1 to 14 days while from 14 to 28 days it showed a sluggish decrement. Out of all H2SO4 affected the examples.
- The maximum dimension loss was found in the specimen of control mix tested under acid attack with H2SO4 i.e., in the acidic environment, when compared to the SCCBF0.3 sample.
- The maximum dimension loss was found in the specimen of control mix tested under acid attack with HCL i.e., in the acidic environment, when compared to the SCCBF0.3 sample.
- The maximum dimension loss was found in the specimen of the control mix tested under base attack with NaOH i.e., in the basic environment, when compared to the SCCBF0.3 sample.
- The maximum dimension loss was found in the specimen of the

control mix tested under base attack with MgSO4 i.e., in the basic environment, when compared to the SCCBF0.3 sample.

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