International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 06 | June - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Experimental Investigation on Strength of Concrete Using Basalt Fiber with Silica Fume

Sanket Mukund Patil[1], Yasin Chand Pathan[2], Misba Afzal Karpude[3], Shailesh Rajabhau Shinde [4], Ujawala Baban sonawane [5],Prof.S.R. Suryawanshi[6]

"1-5-B.E Students in JSPM's Imperial College of Engineering and Research Wagholi, Pune.
6-Assistant Professor in Civil Department of JSPM's Imperial college of Engineering and Research Wagholi, Pune."

Abstract

Concrete is a brittle material with low tensile strength and limited ductility. This study explores the enhancement of concrete strength through the addition of basalt fiber and silica fume. Basalt fibers improve tensile strength, crack resistance, and durability, while silica fume enhances compressive strength and reduces permeability. M40 grade concrete was tested by incorporating basalt fibers at 0.1%, 0.5%, and 1% volume fractions, along with a 10% replacement of cement by silica fume. Compressive and splitting tensile strengths were evaluated at 7, 14, and 28 days. Results indicate up to 30% improvement in 7-day compressive strength and 20% improvement at 28 days with a 1% fiber addition, demonstrating the synergy between basalt fibers and silica fume.

Keywords:
Basalt fiber, Silica fume, Concrete, Compressive strength, Cost analysis.

1. Introduction

In this modern age, civil engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory.

It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of Fiber Reinforced Concrete (FRC) is its superior resistance to cracking and crack propagation.

The weak matrix in concrete, when reinforced with fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water.

Basalt Fiber

Basalt is fine-grained, extrusive, igneous rock composed of plagioclase, feldspar, pyroxene and magnetite, with or without olivine and containing not more than 53 wt% SiO2 and less than 5 wt% total alkalies. Many types of basalt contain phenocrysts of olivine, clinopyroxene and plagioclase feldspar. Basalt is divided into two main types, alkali basalt and tholeiites. They have a similar concentration of SiO2, but alkali basalt's have higher content of NA2O and K2O than tholeiites. The production of basalt fibers is similar to the production of glass fibers. Basalt is quarried, crushed and washed and then melted at 1500° C

Silica Fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys. It primarily consists of amorphous (noncrystalline) silicon dioxide (SiO2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle, silica fume is a very reactive pozzolana when used in concrete. Condensed silica fume is a very fine, amorphous, and reactive mineral admixture. It reacts readily with the calcium hydroxide, which is produced during Portland cement hydration.

2. Literature Review

2.1 General

The chapter will provide the comprehensive me review done relations the determination of properties of basalt fiber reinforced concrete. It presents the various researches on basalt fibre chronologically.

1. C. Colombo,& M. Burman 2012),1165-1170 :

Perfomance Evaluation of 3-DBasah fiber Reinforced Concrete & Basalt Rod Reinforced concrete This report presents the experimental investigation carried out to evaluate the Perfomance characteristics of basalt her reinforcement concrete. It examines the mechanical properties of basalt fiber reinforced concrete for M40 grade of concrete. This was the first test conducted on basalt fibers as a composite material The hardened concrete properties determined were compressive strength, static modulus. flexural strength bad- defection behavior, comparison of kind- deflection curves, ASTM toughness indices, first crack toughness, post crack behavior, Japanese standard method for toughness indices and equivalent flexural strength. The diameter and length of basal fiber used are 12pm and 13mm respectively. The dosages of fibers added to the concrete were 0%, 0.5%, 1%, and 1.5% by volume of concrete respectively. There was a noticeable increase in the post crack energy absorption capacity and ductility due to the addition of basal fibers. The impact resistance increased as the fiber content increased. The study showed that the Perfomance of basalt fiber reinforced concrete is similar to that of the polypropylene fiber reinforced concrete used in the market

2. Enrico Quagliarini & Francesco Monni (2012)372-375:

In the paper experimental investigations on basalt fiber_x0002_reinforced concrete, published in The Institution of Engineers (India) Series A · October 2018 provides review on the use of basalt Fiber as a mineral admixture in the concrete. The review also represented a brief idea of percentage replacement of Basalt Fiber in case of normal and high - strength concrete. In this paper the percentage of basalt Fiber taken for testing as 0%, 0.50%, 1.0%, 1.5% This paper shows the increase in compressive, splitting tensile, flexural strength and elastic modulus of concrete at 28 days having 0.5% volume fraction (13 kg/m3) of basalt Fiber was in the order of 26.79, 42.71, 44.06 and 35.23%, respectively, as compared to conventional concrete.

3. Hao Zhou et.al (2020)

In the paper experimental study on basalt fiber reinforced concrete with partial replacement of cement with quarry dust and metakaolin, published in international journal of innovative research in technology (ijirt) september 2020, volume 7 issue 4. In this paper work, an experimental investigation is carried out to obtain the optimum replacement of basalt fibers by testing the mechanical properties of the concrete. In this paper 0.5%, 1%, 1.5%, 2%, 2.5% and 3%. Percentage of basalt fiber taken for testing with different percentages of quarry dust and metakaolin. Paper also shows the enhancement of 15.31% in compressive strength, 18.29% split tensile strength and 21.02% flexural strength compared to conventional concrete.

4. Sai charan, ch. L. K murthy gupta (2016)

In the paper a comparative study on mechanical properties of basalt fiber reinforced concrete with partial replacement of cement with ggbs published in international journal of engineering research & technology (ijert), vol. 5 issue 06, june-2016. In this paper basalt fibers are taken in four different proportions 0.5%, 1%, 1.5%, 2% & 2.5% respectively to the volume of concrete & tested at 7 & 28 days. 35% of compressive strength has increased, 69% of split tensile

strength & 65% flexural strength increased when basalt fiber added to concrete volume & tested against conventional concrete. Naraindas Bheel (2021) published in Springer, In the paper basalt fbre-reinforced concrete: review of fresh and mechanical,12 February 2021.

5. Naraindas Bheel (2021)

published in Springer, In the paper basalt fbre-reinforced concrete: review of fresh and mechanical,12 February 2021. In this paper basalt fibers are taken in different proportion for different test. For flexural test as 0% to 5%, 0% to 1.5% for split tensile & 0% to 3% for compression test. The crushing strength proliferated up to a certain amount after this; the crushing strength gradually decreases. Compressive & flexural strength increases with adding basalt fiber.

6. Ranjitsinh k. Patil , d. B. Kulkarni (2018)

paper studied comparative study of effect of basalt, glass and steel fiber on compressive and flexural strength of concrete published in international journal of research in engineering and technology (ijret). The experimental programme consist of casting and testing of reinforced concrete beams and cubes with (0.25%, 0.5%, 0.75%, 1%) of its total volume. They have compared three types of fibers (basalt fibers, glass fibers, steel fibers). Basalt fibers from them basalt fiber has got maximum compressive and flexural strength. The first crack was observed at a load of about 60% of total load carrying capacity.

7. Krassowska and Lapko(2018)

concluded that the test results of models of BFRC beams showed a distinct increase in flexural and shear capacity as compared to the beams without fibers.

3. Materials and Objective

3.1 Materials

- Cement: OPC 53 grade.
- Fine Aggregates: Crushed sand.
- Coarse Aggregates: 20mm nominal size.
- Basalt Fibers: Diameter 6mm, length 12mm, tensile strength 4150-4800 MPa.
- Silica Fume: Diameter 0.15 µm, specific gravity 2.22.

3.2 Objective :

To perform laboratory test by using different percentage of basalt fiber and silica fume in the concrete & compare the following test results with conventional concrete.

1. To investigate the effects of basalt fiber and silica fume on the compressive strength of concrete.
2. To evaluate compressive strength of concrete using basalt fibre, silica fume with different proportion for M40 concrete .
3. To compare strength of conventional concrete with basalt fibre with silica fumes.
4. To compare the costs of conventional concrete with concrete modified by basalt fiber and silica fume in order to make an informed decision based on economic factors.

4. METHODOLOGY

The structure of the project consists of : Material Collection

To check physical properties of Cement, Fine aggregates and Coarse aggregates Casting of specimens(M40)

Curing of specimens for 7 days, 14 days and 28 days

Tests to be conducted on specimens

7 days, 14 days and 28 days testing (C.S 67%),

Result and Analysis

Conclusion

4.1 Mix Design of M40 grade concrete

M40 grade concrete mix was designed with a water-cement ratio of 0.45. Cement content was partially replaced with 10% silica fume. Basalt fibers were added at volume fractions of 0.1%, 0.5%, and 1.0%.

1) Target Strength for Mix Proportioning:

The target mean compressive (Fck) strength at 28 days is given by Fck' = Fck+1.65 S where Fck = target average compressive strength at 28 days,

Fck = characteristic compressive strength at 28 days, and

S = standard deviation From Table I of IS: 10262, standard deviation S = 5N / mm 2 Therefore, target strength Fck= 40+ (1.65×5) fck = 48.25MPa .

2) Selection of Water-Cement Ratio:

From Table 5 of IS: 456, maximum water-cement ratio = 0.45. Based on experience, adopt W/C ratio of 0.45. Hence O.K.

3) Selection of Water Content:

From Table 2 of IS: 10262, for 20mm aggregate .

Maximum Water content per cubic metre of concrete = 186 lit.

Estimated Water content for 100mm slump = 186 + (3 + 3) / 100 =197 lit.

4) Calculation of Cement and Silica Fume Content:

Water-cement ratio = 0.45

Cementitious material (cement + Silica Fume) content = 197/0.45 = 437.77 kg / m 3 From Table 5 of IS: 456 - 2000 Minimum cement content for 'severe exposure conditions = 380kg/m3 From Table 6 of IS: 456-2000, Adjustment to minimum cement content for 20mm nominal maximum aggregate size

= 380 + 40 = 420 kg / m3

437kg / m x 3 > 420 kg / m3 , O.K. Now,

to proportion a mix containing Silica Fume the following steps are suggested:

Cementitious material content = 437 kg/m3 Water content = 197 kg/m3

So, water-cement ratio = 197/437=0.45.

Silica Fume at 10% of total cementitious material content

= 437 x10\% = 43.7 kg / m.3

Cement (OPC) content = 437 - 43.7 = 393.3 kg / m3 Silica Fume content (Saving of cement) = 43.7 kg / m 3

5) Proportion of Volume of Coarse Aggregate and Fine Aggregate Content:

From Table 3 of IS: 10262,

Volume of coarse aggregate corresponding to 10mm size aggregate and fine aggregate (Zone 1) for water- cement ratio of 0.50 0.60

In the present case water-cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (at the rate of ± 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate = 0.64 +0.01 = 0.65 Volume of fine aggregate content = 1-0.65=0.35

6) Mix Calculations:

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m3

b) Volume of cement = Mass of cement/(Specific gravity of cement-1000) = 349 / (3.15 x 1000) = 0.1107m

c) Volume of Silica Fume - Mass of Silica Fume /(Specific gravity of Silica Fume x1000 = 43.7 / (2.25 x 1000) = 0.01942 m3.

d) Volume of water = Mass of water/(Specific gravity of water x 1000) = 197 / (1 x 1000) = 0.197 m3.

e) Volume of all in aggregates = a (b + c + d) = 1 - (0.1107 + 0.03687 + 0.197) = 0.6535 m3

1) Mass of coarse aggregate volume of all in aggregates volume of coarse aggregate Sp. gr. of coarse aggregate 1000 -0.6535 x 0.65x 2.94 x 1000 = 1248.83 kg.

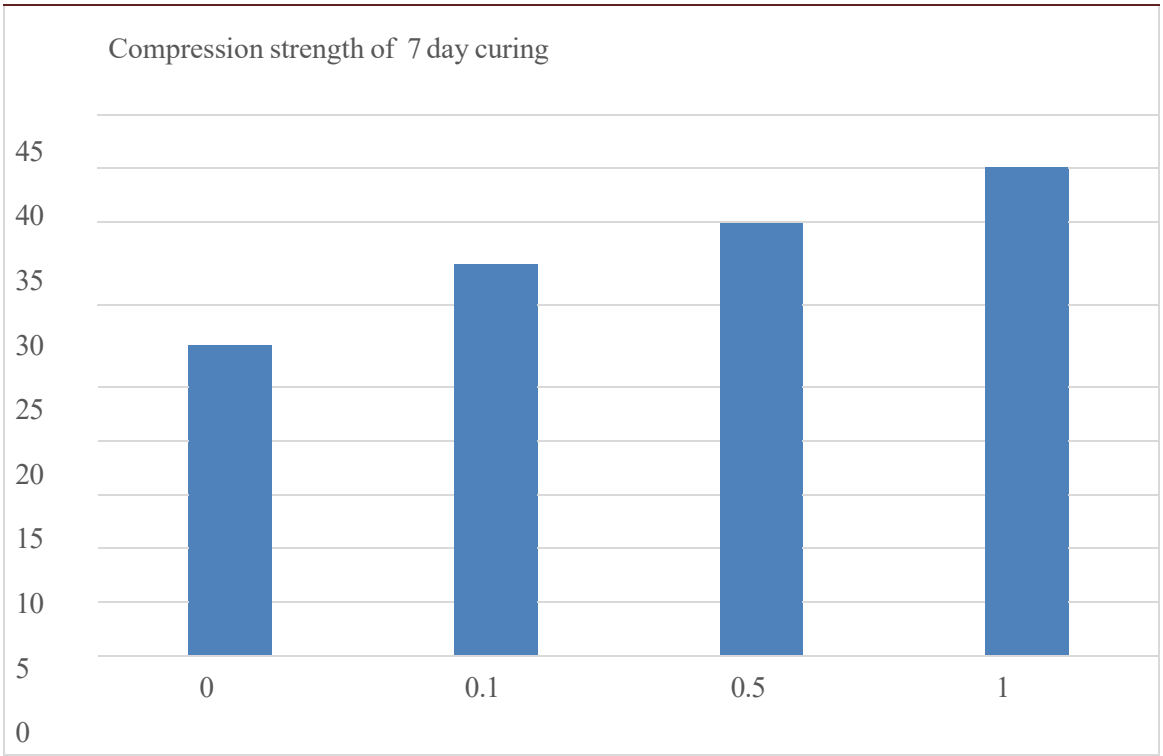
g) Mass of fine aggregate = volume of all in aggregates volume of fine aggregate - Sp. gr. of fine aggregate 1000 0.6535x0.35 2.74 1000-626.70 kg

5. Results and conclusion

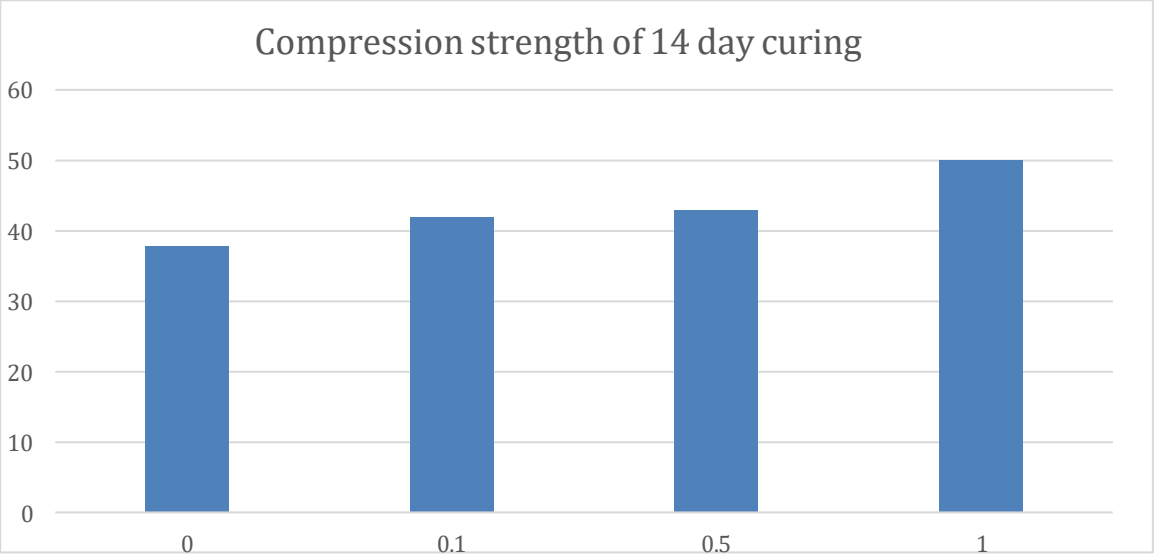
5.1 Compressive Strength

- 7 Days: Strength increased from 27.4 MPa (control) to 40.49 MPa (0.1% fiber and 5% sillics fume).
- 14 Days: Strength increased from 37.77 MPa (control) to 49.99 MPa (0.5% fiber and 10% sillics fume).
- 28 Days: Strength increased from 41.3 MPa (control) to 52.91 MPa (1% fiber and 15% sillics fume).

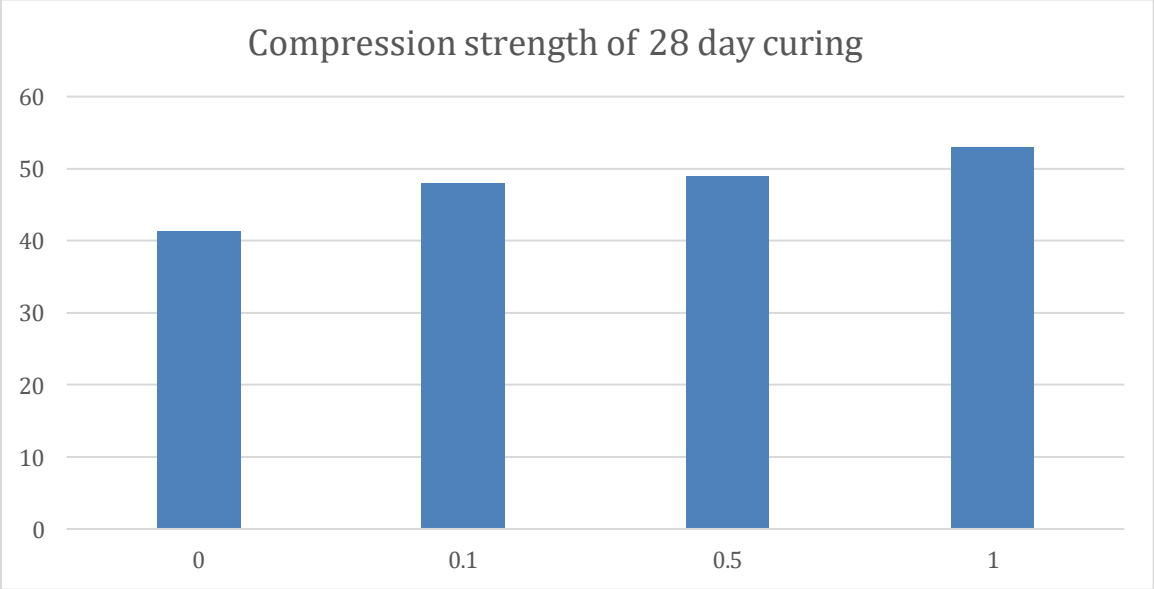
5.2 Compression strength of 7 day curing



5.3 Compression strength of 14 day curing



5.4 Compression strength of 28 day curing



Cost Analysis

The cost analysis indicated an increase in material costs with basalt fiber and silica fume addition. However, the enhanced performance and durability can justify the cost for high-performance applications.

MATERIALS	TOTAL COST	% CHANGE IN COST
M40 Cube	7539.8 Rs	100 %
Silica fume 5% Basalt fiber 0.1%	10213 Rs	35.45 %
Silica fume 10% Basalt fiber 0.5%	18201.2 Rs	141.40 %
Silica fume 15% Basalt fiber 1%	. 27713.12 Rs	267.55%

Conclusion

1) There is an increment up to 30% in the average 7 days compressive strength for 1.0 % volume fraction of basalt fiber with silica Fume as compared to control concrete. The average 28 days compressive strength increase up to 20% for the same dosage of basalt fiber and silica fume. This shows basalt fiber gives high early strength. The compressive strength increases to the 1 % further it decreases.

2) In all test performed in this report shows the increase in strength after add basalt fiber and silica fume,

have the peak value at 1%.

3) It has been seen that with increasing more percentage of basalt fiber with silica fume strength of that specimen increases.

4) From the table No. 5.11 We May Include Cost of 1m3 Concrete Mix is Increased by

35.45 % Using Basalt Fibre 0.1% and Sillica Fume 5%.

5) From the table No. 5.11 We May Include Cost of 1m3 Concrete Mix is Increased by

141.40 % Using Basalt Fibre 0.5% and Sillica Fume 10%.

6) From the table No. 5.11 We May Include Cost of 1m3 Concrete Mix is Increased by 267.55% Using Basalt Fibre 1% and Sillica Fume 15%.

References

1. C. Colombo, & M. Burman (2012),1165-1170 "Performance Evaluation of 3-DBasah fiber Reinforced Concrete & Basalt Rod Reinforced concrete".

2. Enrico Quagliarini & Francesco Monni (2012)372-375 In the paper "experimental investigations on basalt fiber_x0002_reinforced concrete", published in The Institution of Engineers (India) Series A

3. Hao Zhou et.al (2020) in the paper "experimental study on basalt fiber reinforced concrete with partial replacement of cement with quarry dust and metakaolin", published in international journal of innovative research in technology (IJERT).

4. Krassowska and Lapko(2018) "concluded that the test results of models of BFRC beams showed a distinct increase in flexural and shear capacity as compared to the beams without fibers."

5. Naraindas Bheel (2021) published in Springer, "In the paper basalt fbre-reinforced concrete: review of fresh and mechanical",12 February 2021.

6. Ranjitsinh k. Patil , d. B. Kulkarni (2018) paper "studied comparative study of effect of basalt, glass and steel fiber on compressive and flexural strength of concrete" published in international journal of research in engineering and technology (IJERT).

7. Sai charan, ch. L. K murthy gupta (2016) in the paper "a comparative study on mechanical properties of basalt fiber reinforced concrete with partial replacement of cement with ggbs" published in international journal of engineering research & technology (IJERT).