STRENGTH AND WORKABILITY OF HIGH VOLUME FLY ASH SELF-COMPACTING CONCRETE WITH BASALT FIBERS

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Abstract–*Self-Compacting Concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Fine aggregate content is increased higher than coarse aggregates to make concrete highly flowable. It is desirable to replace river sand by M-sand due to high fine aggregate content. High Volume Fly Ash SCC was designed based on Nan-Su trial and error mix design procedure. The fresh properties of SCC are characterized by EFNARC guidelines. The present work deals with workability and strength studies on basalt fiber reinforced High Volume Fly Ash SCC of grade M30. Here Ordinary Portland Cement is replaced with 50% of fly ash. Basalt fibers were added in the mix by 0%, 0.25%, 0.5%, 0.75% and 1%. Compressive and flexural strength tests were conducted for all percentages of basalt fibers. The experimental test results showed marginal increase in compression and considerable increase in flexural strength.*

Key Words: **EFNARC, Fly Ash, M-sand, SCC, Basalt fibers, Compressive strength and Flexural strength.**

1. INTRODUCTION

Ongoing advancements in the concrete technology have set up new courses for enhancing the mechanical and durability properties of concrete. One of the satisfactory methods for improving the properties of concrete is by addition of natural/artificial fibers like Basalt, Steel, Glass, Jute, Nylon, polypropylene in to concrete matrix. Structural behaviour of concrete members is enhanced by adding basalt fibers in concrete structures [1]. Many extensive researches have been carried out all over the world since the beginning of SCC era to understand the fresh and hardened concrete properties of SCC. SCC is categorised as Powder based SCC, VMA based and combination of both [2]. SCC requires high slump which is attained by adding superplasticizer to concrete mixture. To avoid segregation resistance on superplasticizer addition fine aggregate content is increased more than coarse aggregates which lead to usage of high volume of cement. More amount of cement results in higher temperature rise and an increased cost. Superplasticizer dosage can be reduced to obtain similar slump flow compared to concrete made with Portland cement only by using fly ash and blast furnace slag in SCC. Use of fly ash improves rheological properties and cracking of concrete is reduced due to heat of hydration of the cement. A 28-day compressive strength of approximately 35MPa was achieved by SCC made with 50% replacement of cement by fly ash [3]. Nan-Su method of mix design was used as a basis to arrive at the mix design for High Volume Fly Ash SCC in this study [4]. Final mix design was arrived at through trial and error method. SCC has large part of fine aggregate in comparison with coarse aggregates and now a days due to scarcity of natural sand, M-sand has become a new generation fine aggregates replacement for natural sand. In the present study natural sand was partially replaced by 30% of M-sand [5]. Basalt fibers were added to SCC mix at an interval of 0.25% from 0% to 1%. Marginal increase in compressive strength and considerable increase in flexural strength was observed [6].

1.1 High Volume Fly Ash SCC

Self-compacting concrete (SCC) in general contains an extensive amount of powder materials, a superplasticizer and/or viscosity modifying admixtures [7]. Using high cement content in the production of SCC leads to shrinkage of concrete and also increases the cost. Reduction of cement content in SCC is possible by partial replacement of cement with fly ash. The utilization of fly ash enhances filling ability and passing ability of SCC while maintaining segregation. Also SCC with higher fly ash content as cement replacement tends to reduce both drying and autogenous shrinkage [8].

2. OBJECTIVES OF THE STUDY

Following are the objectives of this experimental study:

- To study the variation of workability parameters of High Volume Fly ash SCC with the inclusion of basalt fibres in the mix.
- To study the compressive strength of High Volume Fly ash SCC with the inclusion of basalt fibres in the mix.
- To study the flexural strength of High Volume Fly ash SCC with the inclusion of basalt fibres in the mix.

3. METHODOLOGY

3.1 MIX DESIGN

High Volume Fly Ash SCC of grade M30 satisfying EFNARC guidelines in fresh state was designed using Nan-Su method of mix design.

Table 1: Mix Proportion of High Volume Fly Ash SCC					
CA	FA	Cement	Fly Ash	Water	Super Plasticizer
830	1000	230	230	172.6	3.68

3.2 MATERIALS

1. Cement: Ordinary Portland cement of grade 43 with specific gravity 3.15 conforming to IS: 12269-1987 was used in the investigation.

2. Fine aggregates:

a) Natural sand: River sand obtained from local source was used as fine aggregates in this experimental work. It was conforming to zone II and specific gravity was determined to be 2.64.

b) Manufactured sand: Manufactured sand was procured from local source. It was confirming to zone II and specific gravity was determined to be 2.74.

3. Coarse aggregates: Locally available crushed angular coarse aggregates were used in the present work. 12.5mm down sized aggregates were used and s specific gravity was determined to be 2.78.

4. Fly ash: In this experimental work fly ash is used as the filler material and cement is replaced with 50% of fly ash. Specific gravity was found to be 2.1. It was obtained from Raichur Thermal Power Station, Shaktinagar, Raichur.

5. Water: Potable tap water was used for casting specimens as well as for curing purpose.

6. Superplasticizer: Conplast SP 430 admixture was used in this experimental work which confirms to IS 4103:1999. Specific gravity was found to be 1.20.

7. Basalt fibers: Chopped basalt fibers were used. The thickness and length were 24μ and 12mm respectively.

4. CASTING AND TESTING OF SPECIMENS

Cube specimens of size 150×150×150mm were casted for compression strength test and cured for 28 days. For determining flexural strength beams of standard size 500×100×100mm were casted and cured for 28 days. After 28 days the specimens were removed from curing tank and were dried in room temperature. Specimens were weighed before testing and then were tested to find the compressive strength and flexural strength.

5. RESULTS AND DISCUSSIONS

5.1 FRESH PROPERTIES

The fresh property tests such as slump flow test, L- box test, U- box test, V- Funnel tests were conducted and results of all these tests were compared with the requirements of EFNARC-2005 guidelines for SCC. The fresh properties results are shown in Table 1 and various plots are drawn and compared with reference mix.

Table 2: Fresh Properties of SCC for different percentage of Basalt fibers						
Tests	EFNARC Limits	Reference mix	Percentage variation of volume fraction of basalt fibers			
		0%	0.25%	0.5%	0.75%	1%
Slump Flow	600-800mm	680	667	635	606	571
V-funnel	8-12 secs	10	11	13	14	17
L-Box	0.8-1.0	0.96	0.933	0.87	0.84	0.77
U-Box	0-30mm	26	28	30	33	37

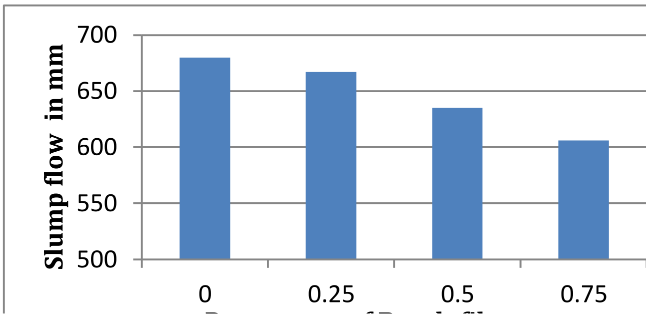

Chart 1: Slump flow test results

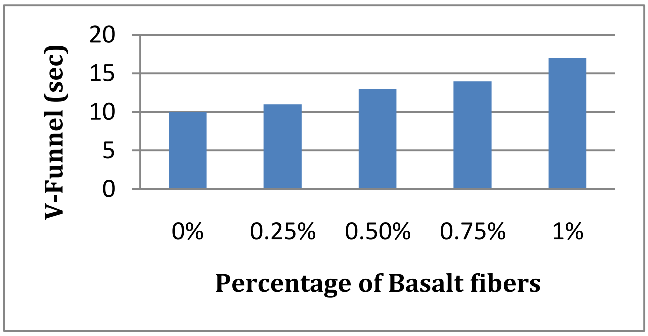

Chart 2: V-funnel test results

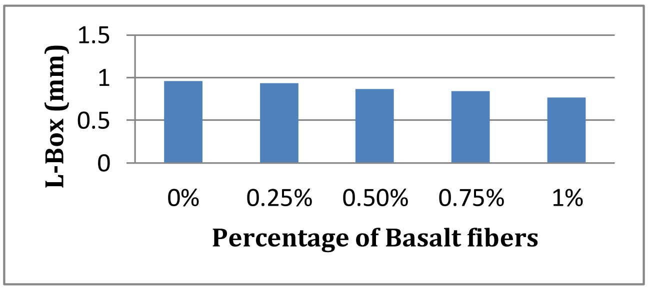

Chart 3: L-Box test results

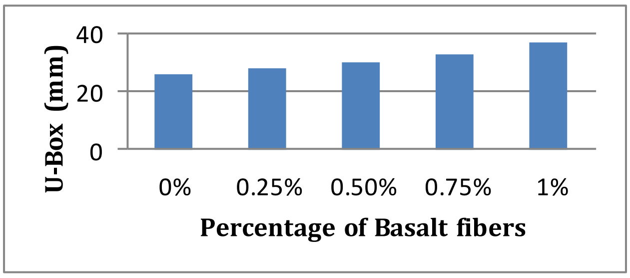

Chart 4: U-Box test results

Addition of basalt fibers leads to considerable reduction in workability parameters (Slump flow, V-funnel, L-Box and U-Box). Slump flow is 571mm for 1% volume fraction of basalt fibers which is very low according to EFNARC guidelines. Fibers do not blend in well into the mix which causes reduction in workability. Fibers tend to stand out which leads to major reduction in flowability of SCC from that of reference mix i.e. 0% volume fraction of basalt fibers. Slump loss of about 109mm was observed as the fibers were increased from 0% to 1%.

5.2 HARDENED PROPERTIES

a. Compressive Strength

The following table given below represents compressive strength of HVFA SCC at 28days for different percentage of basalt fibers.

Table 3: Compressive strength results at 28 days

Sl. No	Percentage of Basalt fibers	Compressive Strength in MPa
1.	0	35.96
2.	0.25	37.77
3.	0.5	38.81
4.	0.75	40.14
5.	1	41.2

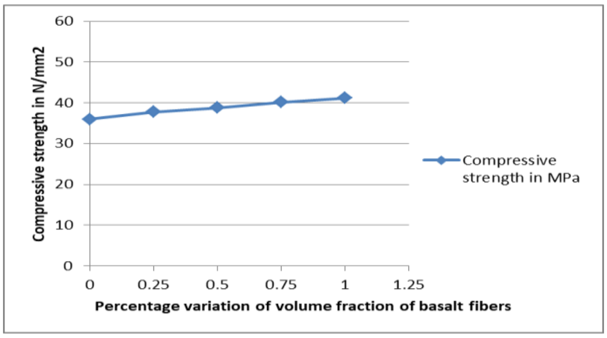

Chart 5: Variation of Compressive strength for percentage variation of volume fraction of basalt fibers

From Table 3 marginal increase in compressive strength was observed due to addition of basalt fibers in the mix. 0.75% volume fraction of basalt fibers was found to be optimum dosage. Increase in density of concrete due to addition of basalt fibers leads to increase in compressive strength. For 0.75% volume fraction of basalt fibers 11.62% increase in compressive strength was observed from reference mix (mix without fibers).

b. Flexural Strength

The following table given below represents flexural strength of HVFA SCC at 28days for different percentage of basalt fibers.

Table 4: Flexural strength results at 28 days

Sl. No	Percentage of Basalt fibers	Flexural Strength in MPa
1.	0	3.66
2.	0.25	4.12
3.	0.5	4.42
4.	0.75	4.73
5.	1	4.86

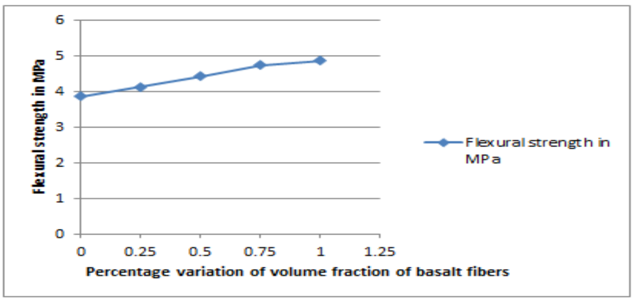

Chart 6: Variation of Flexural strength for percentage variation of volume fraction of basalt fibers

From Table 4 it is observed that addition of basalt fibers significantly increased the flexural strength of SCC. The maximum flexural strength was found to be 4.86 N/mm² for 1% volume fraction of basalt fibers. But since workability properties were not satisfied as per EFNARC guidelines, 1% volume fraction of basalt fibers is not considered to be optimum dosage. 0.75% volume fraction of basalt fibers was found to be optimum dosage. Width of cracks also reduced considerably. Inclusion of basalt fibers to the mix lead to more ductile type of failure. For 0.75% volume fraction of basalt fibers 29.23% increase in flexural strength was observed from reference mix (mix without fibers).

6. REGRESSION AND CORRELATION

The following table given below represents compressive strength obtained from experimental and analytical methods for different percentage of basalt fibers.

Table 5: Compressive strength obtained from Experimental and Analytical Methods

Percentage of basalt fibers	Compressive strength in MPa		
	Experimental Results	Predicted from Equations	% Error in prediction
0	35.96	36.03	0.20
0.25	37.77	37.57	0.52
0.5	38.81	38.94	0.33
0.75	40.14	40.14	0
1	41.2	41.17	0.07

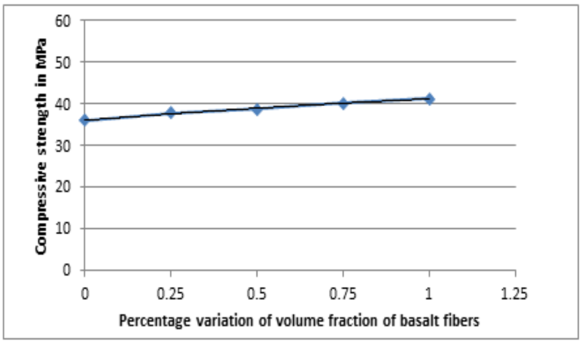

Chart 7: Best fit curve for Compression strength

From Table 5 and Chart 7, it is observed that best fit polynomial equation satisfies the experimental values for compressive strength at 28 days for different volume fraction of basalt fibers. Regression equation for compressive strength is as given below:

$$y = -1.3829x^2 + 6.5229x + 36.033$$

Where, y = Compressive strength,

x = Percentage variation of basalt fibers.

Coefficient of correlation, $r^2 = 0.9963$

7. CONCLUSIONS

1. Passing ability and flowability reduced considerably with the inclusion of basalt fibers in the mix. All fresh property tests satisfied EFNARC guidelines till 0.75% of basalt fibers. Hence 0.75% of basalt fibers is considered to be optimum dosage.

2. Marginal increase in compressive strength with increase in percentage of basalt fibers up to 1% volume fraction was found.

3. Flexural strength increased considerably with inclusion of basalt fibers. Inclusion of basalt fibers to the mix lead to more ductile type of failure.

4. From regression and correlation analysis it can be concluded that best fit polynomial curve was found to be satisfied for compression strength for different volume fraction of basalt fibers.

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