Experimental Investigation on Properties of High Volume Fly Ash High Strength Self Compacting Concrete with Steel Fibers

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Abstract – *Self compacting concrete (SCC) has gained popularity in recent years for the fact that it needs very little or no compaction and flows into every corner under its own self-weight. This is a special kind of high performance concrete which has good flowability, passing ability and resistance to segregation. This paper concentrates on the variation in the fresh and hardened properties of high volume fly ash high strength self-compacting concrete (HVFAHSSCC) with the inclusion of steel fibers into the concrete mix. Conventional SCC involves high material costs and hence a high percentage of cement has been replaced with mineral admixtures like fly ash, ground granulated blast furnace slag, silica fumes etc. In its fresh state the concrete is characterized as SCC if it satisfies the EFNARC guidelines. Passing ability and flowability considerably reduced with the increase in volume fraction of steel fibers in the mix for high volume fly ash high strength SCC of M60 grade concret. There was marginal increase in compressive strength with increase in percentage of steel fibers up to 1.5% volume fraction. Flexural strength increased significantly with addition of steel fibers. A 33.91% increase in flexural strength was observed for 1.5% volume fraction of steel fibers compared to reference mix.*

Key Words: *HVFAHSSC, Fly ash, Steel fibers, M-sand, Compressive strength, Flexural strength.*

1. INTRODUCTION

Self-Compacting Concrete (SCC) has gained popularity because of the ease of placing and compaction in areas of congested reinforcement. Self-Compacting Concrete is mostly used in high rise structures (1). Since this is a special type of high performance concrete the cost involved is high as the binder content is higher compared to conventional concrete. To make the concrete economical, varying percentage of cement is replaced with fly ash, ground granulated blast furnace slag, silica fumes etc. In this study SCC of M60 grade was proportioned by replacing high volumes of Portland cement by fly ash (50%) so as to make the concrete economical and incorporate waste materials in the concrete to reduce the impact on use fresh raw materials (2). Nan-Su, Kung-Chung Hsu, His-Wen Chai (2001) developed mix design procedures for SCC. Primarily the aggregate quantity is calculated there after the binder paste fills the voids of aggregates to produce concrete with flow ability, passing ability, filling ability and self-compatibility within EFNARC limits of SCC (3). B.H.V Pai (2014) found SCC with GGBS exhibited better mechanical properties compared to SCC with silica fumes (4).

1.1 HVFA Self-Compacting Concrete (SCC)

HVFA self-compacting concrete has some promising characteristics such as high fluidity, better segregation resistance and high self-compacting ability without the need of any vibration and compaction during placing (4). Most important task involves in arriving at the mix design as the standard methods are not applicable for proportioning materials for High Strength SCC. In the current study Nan-Su method was used to attain the final mix proportion for High Strength SCC (3). For SCC it is vital to use super plasticizers in order to achieve required workability. In addition to chemical admixtures viscosity modifying agents are also used to enhance it (2).

1.1.1 Properties of Self-Compacting Concrete

Table 1: General acceptance criteria for self-compacting concrete

Test Method	Property	Permissible Limits	
		Min.	Max.
Slump flow	Flow ability	500mm	800mm
V-funnel	Flow ability	8sec	12sec
L-box	Passing ability	0.8	1.0
U-box	Passing ability	0mm	30mm

2. METHODOLOGY

The mix proportioning of SCC in the present study was carried out by using Nan-su method.

- The volume ratio of aggregate 52-58%.
- Voids ratio in the loose aggregate must be in the range of 42-48%.
- Total powdered content must be in the range of 400-600kg/m³.
- Fine aggregates content could be higher than 38% of the total volume.

- Coarse aggregates content must be in the range of 28-35% of the total volume (3).

Table 2: Mix design as per powdered content

Water	M-sand		Fine aggregate		Coarse aggregate	Super plasticizer
	Cement	Fly ash	M-sand	Natural sand		
0.32	1		1.67		1.33	0.011

2.1 Materials

- Cement: In this experimental work OPC 53 grade was used. The mentioned cement was confirming to IS 12269: 2013 (6). The specific gravity of cement was determined to be 3.15 in accordance with (IS: 2720 part 3) (7).

- Fine aggregates (M-Sand and Natural sand): The most commonly known fine aggregate is river sand, which was used in the experimental work. It was obtained from a local source. Specific gravity was found to be 2.65. The most common alternative for river sand is M-sand. It was obtained from a local source. Specific gravity was found to be 2.74.

- Coarse aggregates: 12.5 mm down size aggregates were used in this experimental work, which were obtained from locally available sources. The specific gravity was experimentally determined to be 2.78.

- Mineral admixture: In this experimental work Fly ash was used as mineral admixture of specific gravity 2.11.

- Water: Potable tap water was used for experimental works and also for curing specimens.

- Super-plasticizer: Conplast SP 430 was used to achieve the required flowability. Specific gravity 1.20 to 1.21. Without any chloride amount.

- Steel fibers

- Length: 25mm, thickness: 0.75mm, aspect ratio: 33, density: 7850 (Kg/m^3).

3. RESULT AND DISCUSSION

3.1 Effect on workability due to variation of steel fibers

Table 3: Variation of workability for percentage variation of steel fibers for M-Sand optimized SCC

Sr. no	Tests	EFNARC limits	Reference mix	Percentage variation of volume fraction of steel fiber			
			0%	0.5%	1%	1.5%	2%
1	Slump flow	500-800mm	670	630	605	570	515
2	V-funnel	8-12sec	10	10	11	12	15
3	U-Box	0-30mm	25	26	27	30	36
4	L-Box	0.8-1.0	0.91	0.9	0.87	0.82	0.7

The addition of steel fibers in the concrete reduces the workability considerably (Slump flow, V-Funnel, U-Box and L-Box) as shown in Table 3. At 2.0% volume fraction of steel fiber the slump flow is 515mm, other test values do not satisfy the guidelines provided in EFNARC for SCC. As the fresh concrete properties at 2.0% volume fraction do not satisfy EFNARC guidelines the optimum dosage was found to be 1.5% volume fraction of steel fibers. The fibers do not blend in well into the concrete matrix resulting in reduction in workability. Fibers have a tendency to stick out as a result there is greater reduction in flowability of SCC as that of the reference mix (0% steel fibers by volume fraction). As the fiber percentage increased from 0% to 2.0% a slump loss of about 155mm was observed. Workability is also governed by aspect ratio, shape and length of the fibers. Figure 1 and Figure 2 portray the reduction in workability due to percentage variation of steel fibers.

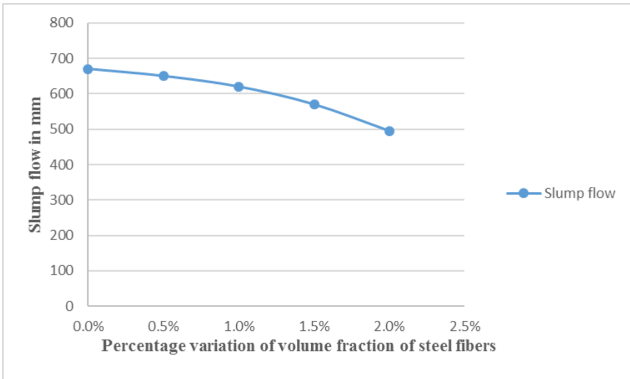

Figure 1: Slump flow for percentage variation of volume fraction of steel fibers

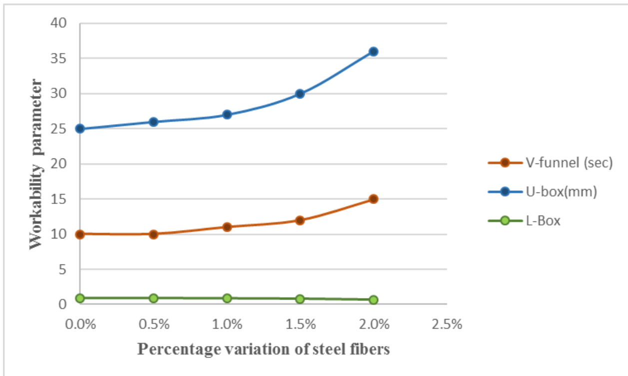

Figure 2: Workability parameter (L-Box, V-Funnel, and U-Box) for percentage variation of steel fibers

3.2 Effect of variation of steel fibers on compressive strength of HVFAHSSCC

Table 4: Variation of compressive strength for percentage variation of volume fraction of steel fibers for M-Sand optimized SCC

Sr.no	Percentage variation of volume fraction of steel fibers	Compressive strength in N/mm2	
		7days	28days
1	0	34.47	62.67
2	0.5	34.82	63.85
3	1.0	35.61	64.74
4	1.5	35.96	65.93
5	2.0	36.71	66.96

The addition of about 1.5% steel fibers in the concrete leads to marginal increase in compressive strength in comparison to reference mix as shown in Table 4. Steel fibers were added at an interval of 0.5% from 0% to 2.0% volume fraction. It is observed that the maximum compressive strength at 7days and 28 days of curing was 35.96 N/mm2 and 65.93 N/mm^2 for 1.5% volume fraction of steel fibers. As the fresh concrete properties at 2.0% volume fraction do not satisfy EFNARC guidelines the optimum dosage was found to be 1.5% volume fraction of steel fibers. Inclusion of steel fibers may lead to the increase in density hence marginal increase in strength was observed. The concrete so formed may possess lesser permeability. Figure 3 portrays the difference in compressive strength with percentage variation of steel fibers.

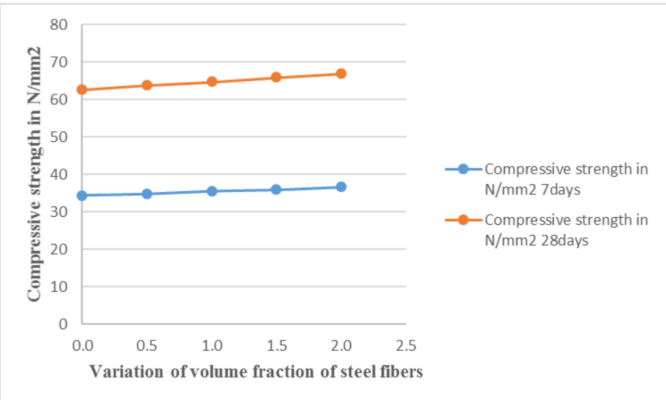

Figure 3: Variation of compressive strength for percentage variation of volume fraction of steel fibers for M-Sand optimized SCC

3.3 Effect of variation of steel fibers on flexural strength of HVFAHSSCC

Table 5: Variation of flexural strength due to percentage variation of steel fibers for M-Sand optimized SCC

Sr.no	Percentage variation of volume fraction of steel fibers	Flexural strength(N/mm^2)
1	0.0	5.47
2	0.5	5.87
3	1.0	6.00
4	1.5	7.27
5	2.0	7.80

Addition of steel fiber significantly increases the flexural strength of SCC as shown in Table 5. There was a significant increase in flexural strength with the increase in steel fiber percentage. For 1.5% percent volume fraction of steel fiber maximum flexural strength 7.27 N/mm2 was observed. In addition to increase in the flexural strength the width of the cracks also reduced significantly. The failure pattern was observed to be in a ductile manner after the inclusion of steel fibers to the mix. Increased flexural strength could be due to the fact that steel fibers influence the way cracks are developed in concrete, also impart better crack growth resistance and increase in surface roughness of cracks. For 1.5% volume fraction of steel fibers 42.59% increase in flexural strength was observed from reference mix (mix without fibers). Figure 4 shows variation of flexural strength for different volume fraction of steel fibers.

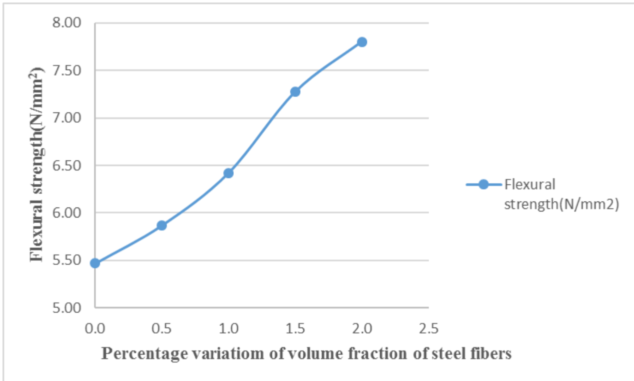

Figure 4: Variation of flexural strength due to percentage variation of steel fibers for M-Sand optimized SCC

4. REGRESSION AND CORRELATION

The following table given below represents compressive strength obtained from experimental and analytical methods for different percentage of steel fibers. Regression equation and coefficient of correlation for mix tested at normal temperature.

$$y = -1E\text{-}13x^2 + 2.132x + 62.698$$

Where, x = Percentage of steel fibers, y = Compressive strength (N/mm^2).

R^2 = 0.9985

R = Coefficient of correlation.

Table 6: 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	62.67	62.69	0.03
0.5	63.85	63.73	0.14
1.0	64.74	64.83	0.14
1.5	65.93	65.89	0.06
2.0	66.96	66.96	0

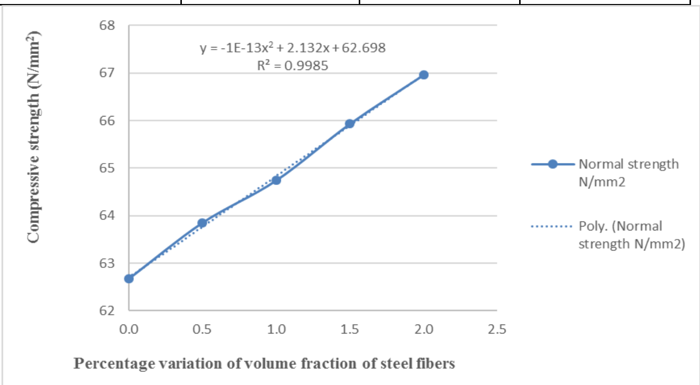

Figure 5: Best fit curve for compressive strength

5. CONCLUSIONS

- Passing ability and flowability considerably reduced with the inclusion of steel fibers in the mix.
- There was marginal increase in compressive strength with increase in percentage of steel fibers up to 1.5% volume fraction.
- Flexural strength increased significantly with addition of steel fibers. The maximum flexural strength of 7.27 N/mm2 was observed for 1.5% volume fraction of steel fibers. For 1.5% volume fraction of steel fibers 33.91% increase in flexural strength was observed from reference mix (mix without fibers).

6. REFERENCES

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