Strength Evaluation of Steel Fiber Reinforced-Self Compacting Concrete

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***Abstract*— Self-compacting concrete (SCC) offers several economic and technical benefits; the use of steel fibers extends its possibilities. Steel fibers acts as a bridge to retard their cracks propagation, and improve several characteristics and properties of the concrete. Fibers are known to significantly affect the workability of concrete, but to compensate the effect of workability, dosage of super-plasticizer was increased. Therefore, an investigation was performed to compare the properties of normal self-compacting concrete and SCC with steel fiber. SCC [1, 2, 3] was developed in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions. The main motive was to compare the strength aspects between normal SCC and the fiber reinforced SCC. Fiber content was varied from .35 to 1 percent by weight of cement. The dosage of viscosity modifying agent (VMA) was varied from .1 to .2% by weight of cement. The workability was measured with slump-flow test, L-Box test and V-funnel test. The results indicated that high-volume of fly ash can be used to produce Steel fiber reinforced self-compacting concrete (SFR-SCC), even though there is some increase in the concrete strength because of the use of steel fiber and high-volume of fly ash.**

Keywords—Workability, Volume fraction of Fibers, Split Tensile Strength, Viscosity modifying agents (VMA), Super-Plasticizer.

I. INTRODUCTION

Cement concrete is the most extensively used construction material in the world. The reason for its extensive use is that it provides good workability and can be molded in any shape. In this modern age, civil engineering constructions have their own structural and durability requirements, every structure are intended to meet this purpose and hence modification in the conventional concrete has become mandatory. The proclivity of present engineers is to target the existing problems associated with concrete and with meager resources, so as to define the new standards and methods.

Fiber reinforced concrete (FRC) is defined as concrete made with cement containing fine and coarse aggregate and corrugated steel fibers. In FRC, thousands of small fibers are dispersed and distributed randomly in concrete during mixing and thus improves concrete properties. Consequently, it improves tensile and compressive strength, energy absorbing capacity and ductility of concrete. Tests have shown that use of 0.25% - 1% steel fibers by weight of cement can produce concrete with better performance characteristics.

The present work deals with experimental research of M25 grade Self-Compacting Concrete (SCC) with corrugated steel fibers of 1 mm diameter and 30 mm length at different fiber volume fractions as mentioned above. The dosage of super-plasticizer (Glenium-51) was varied from 1% to 1.6% by weight of cement and that of viscosity modifying agent [4] (VMA) was varied from 0.1% to 0.2% by weight of cement. The effect of steel fibers on the properties of fresh and hardened concrete was investigated and results obtained are presented.

A. Material Requirements for Concrete

The constituent materials, used for the production of Self-Compacting Concrete (SCC) shall generally comply with the requirements of EN 206. The materials shall be suitable for the intended use in concrete and not contain harmful ingredients in such quantities that may be detrimental to the quality or the durability of the concrete, or cause corrosion of the reinforcement.

General suitability is established for cement conforming to EN 197-1. Aggregates shall conform to EN 12620. The moisture content should be closely monitored and must be taken into account in order to produce SCC of constant quality. Suitability is established for mixing water and for recycled water from concrete production conforming to EN 1008. Admixtures used shall comply with EN 934-2: 2000 (including Annex A), where appropriate.

Finely-divided inorganic material is used in concrete in order to improve certain properties or to achieve special properties. This specification refers to two types of inorganic additions (i) nearly inert additions (Type I), (ii) Pozzolonic or latent hydraulic additions (Type II). General suitability as Type I (semi-inert) addition is established for filler aggregate conforming to EN 12620, pigments conforming to EN 12878. General suitability as Type II (Pozzolonic or latent hydraulic) addition is established for fly ash conforming to EN 450, silica fume conforming to EN 13263 ground granulated blast furnace slag conforming to BS 6699.

II. EXPERIMENTAL PROGRAM

Mix design of M25 of concrete was carried out using NAN-SU method. Ordinary Portland cement of 43 grade conforming to IS 8112 was used. Fine aggregate of fineness modulus 2.57 and specific gravity 2.61 was used along with the coarse aggregate of fineness modulus 6.55 and specific gravity of 2.72 conforming to IS 383. Fly ash was used as a substitute for cement replacement. Steel fibers were varied from 0.35% to 1% by weight of cement. The quantity of super-plasticizer (Glenium-51) was varied from 1% to 1.6% by weight of cement. The properties of steel fibers and fly ash are given in Tables 1 and 2 respectively. The cement content, coarse aggregate, fine aggregate, fly ash content was kept constant for all the mix, the detail of which is given in Table 3. The details of the mix prepared are given in Table 4. Firstly, the coarse aggregates were added to the mix, and then fine aggregates, cement and fly ash were added and dry mixed for about one minute. Then two-third of water was added to the mix to obtain uniform wet mix. Finally the super plasticizer was added to the remaining one-third water and added to the wet mix. The total mixing time was about five minutes. In case of SFR-SCC, the steel fibers were added to the wet mix by sprinkling uniformly through hands, to avoid balling of steel fibers. Finally the super plasticizer and VMA were added to the remaining one-third water and fed into the mixer. The mixing time for SFR-SCC was increased by one minute to facilitate the uniform mixing of steel fibers. Cubes of sizes 150 x 150 mm for compressive strength and beams of 500 mm x 100 mm x 100 mm for flexural strength were cast. All the specimens were water cured and tested at 3, 7 and 28 days of curing. The workability was measured with the slump cone test, L-box and V-funnel test

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TABLE 1 Physical Properties of Steel fibers

S.No.	PROPERTIES	
1.	Diameter	: 1mm
2.	Length	: 30mm
3.	Tensile Strengt	: 400 MPa
4.	Appearance	: Bright in clean wire
5.	Modulus of Elasticity	: 200 GPa
6.	Specific Gravity	: 7.850

TABLE 2 Physical Properties of Fly Ash

S.No.	**PROPERTIES**	
1.	Type	: Class F
2.	Particle Size	: 1-100□
3.	Colour	: Greyish
4.	Density	: 2200-2400 kg/m^3
5.	Blain's Value	: 3500-5000 cm^2/gm
6.	Specific Gravity	: 2.14-2.42

TABLE 3 Constituents of Mix

Cement	250 kg
Fine Aggregates	980 kg
Coarse Aggregates	730 kg
Fly Ash	200 kg
Water	200 liters

TABLE 4 Detail of Mix

Mix	Fiber Content (%age of weight of cement)	Super Plasticizer (kg)	Viscosity Modifying Agent (ml)
SCC	0%	2.5	0
SFR-SCC .35	.35%	3	250
SFR-SCC .70	.70%	3.5	600
SFR-SCC 1.0	1%	4	840

III. TESTS CONDUCTED ON CONCRETE

In the present work, slump flow, L-box and V-funnel tests have been performed to check the workability of SCC & SFR-SCC. Strength evaluation has been done based on the compressive strength test and flexural strength test for SCC & SFR-SCC. The experimental set up for various tests and their results are described below:

A. Workability

Specifications for the four workability tests performed in the laboratory according to the EFNARC, 2006 are:

- SLUMP FLOW TEST
  T_{500} = 2 -5 sec
  Flow Spread = 650 – 800 mm
- V-FUNNEL TEST
  Time = 6 – 12 sec
- L-BOX TEST
  PA = H_2/H_1 = 0.8 – 1.0

The various workability test results for SCC & SFR-SCC are represented in Table 5.

WORKABILITY TESTS	RESULTS			
	SCC	*SFR-SCC .35*	*SFR-SCC .70*	*SFR-SCC 1.0*
T_{50} (sec)	2.6	3.2	3.8	4.1
Flow spread (mm)	780	720	690	680
V-funnel Time (sec)	8	10	11.2	12
L- box PA =H_2/H_1	1	0.91	.87	0.82

TABLE 5 Results for Workability Test

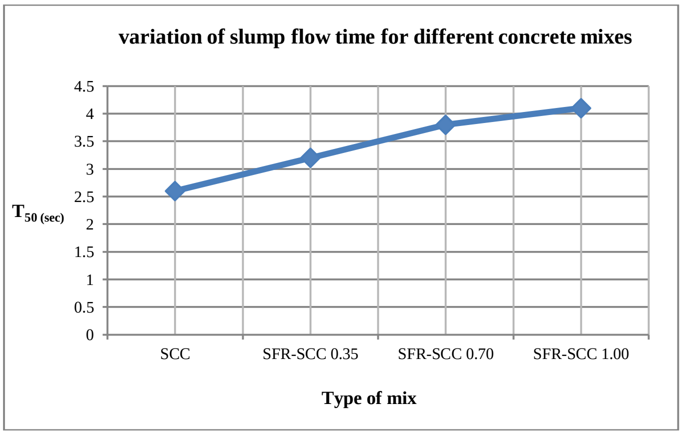

Fig. 1 Variation of slump flow time for different concrete mixes

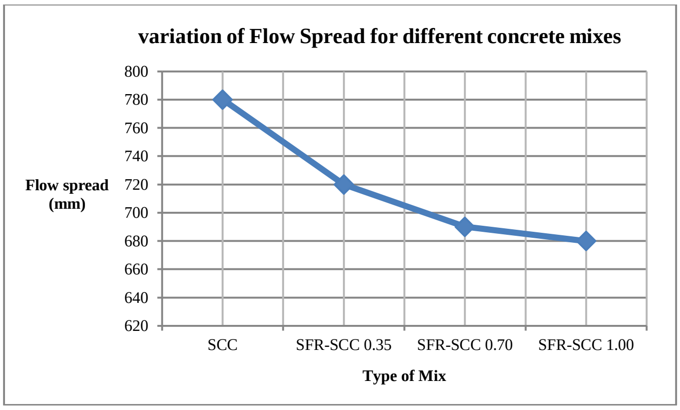

Fig. 2 Variation of Flow Spread for different concrete mixes

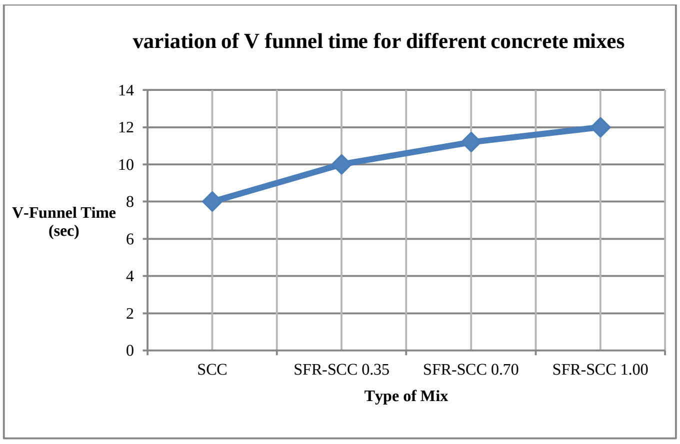

Fig. 3 Variation of V funnel time for different concrete mixes

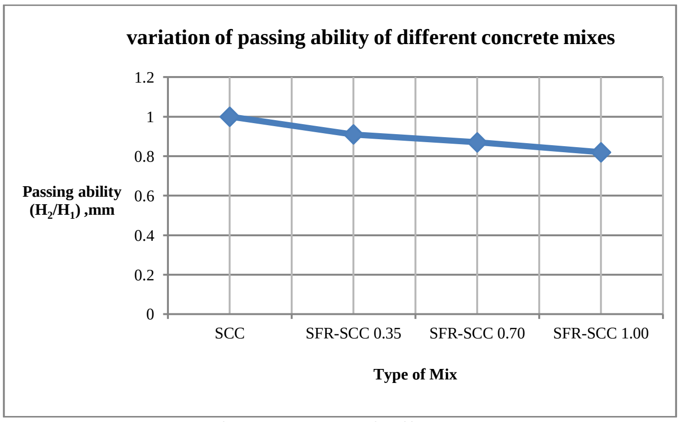

Fig.4 Variation of passing ability of different concrete mixes

B. *Compressive Strength*

Cubes compression tests were performed on standard cube of size 150 x 150x 150 mm after 3, 7 and 28 days curing as per IS 516-1959. The compressive strength of specimen is obtained by dividing the load taken by the concrete cube before the appearance of first crack to the area of block. The results are shown in table 6.

The compressive strength is calculated by the following formula:

$$f_{cu} = P_c/A$$

Where, f_{cu} = compressive strength of specimen, N/mm^2
P_c = Failure Load in compression, KN
A = Loaded area of cube, mm^2

TABLE 6 Compressive Strength Results

Mix	3 Days	7 Days	28 Days
SCC	12	15.9	22.5
SFR-SCC .35	15	16.9	25.6
SFR-SCC .70	16	18.1	26.6
SFR-SCC 1.0	18.4	20.4	30.2

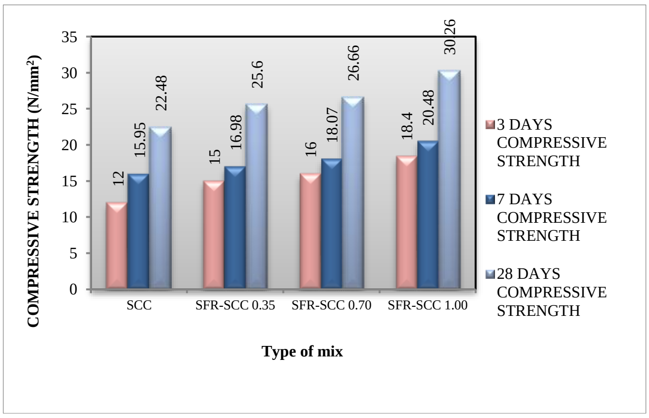

Fig. 5 Compressive strength test results for different concrete mixes

C. *Flexural Strength Test*

Flexural strengths tests were performed on beam specimens according to IS 516:1959. Standard beams of size 500 mm x 100mm x 100 mm were subjected to two pints loading till failure of specimen. It was performed after 28 days of curing on a flexural testing machine of capacity 25kN. The results are shown in table 7. To obtain load-displacement graphs some beam samples were also tested on a 100 kN capacity servo-controlled computerized flexural testing machine and is calculate by using formula:

$$\sigma = .45\ P$$

Where, σ = Flexural strength, MPa
P = Load at failure, N

TABLE 7 Flexural Strength Results

Mix	**28-Days (N/mm^2)**
SCC	3.66
SFR-SCC .35	4.78
SFR-SCC .70	5.81
SFR-SCC 1.0	7.24

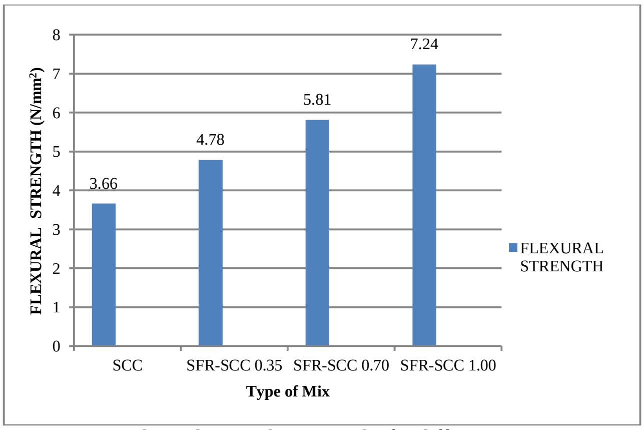

Fig. 6 Flexural Strength Test results for different concrete mixes

IV. CONCLUSIONS

From the results of the workability tests for SCC and SFR-SCC, it can be seen that with the increase in the quantity of fibers the flowing ability and passing ability of the concrete decreases due to interlocking of fibers and hence the time taken by the concrete to reach a particular point increases. Therefore, to enhance the Flowing ability of the concrete, the dosage of the Super Plasticizer is to be increased along with the quantity of the fibers.

It is observed that 3, 7, 28 day compressive strength in case of .35% steel fiber[12] is more than that of SCC and same is observed in the case of .70 and 1.00. It has also been observed that with increase in steel fiber the compressive strength also increases i.e. compressive strength of SFR-SCC .70 mixes at any day is more than that of .35 and compressive strength of SFR-SCC 1.00 mix is more than that of .35 and .70 mixes. So it is noticed that with increase in fiber content, compressive strength also increases.

The increase in flexural strength for SFR-SCC 1.00, SFR-SCC 0.70 and SFR-SCC .35 is 100%, 61% and 33% over SCC. The maximum increase is for SFR-SCC 1.00.

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