RESEARCH PAPER | Engineering | Volume - 5 | Issue - 1 | Jan Special Issue - 2015 | ISSN - 2249-555X



Fresh and Hardened Properties of Steel Fiber Reinforced Self Compacting Concrete

KEYWORDS: Self compacting concrete, steel fiber, fresh properties, workability, hardened properties.

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ABSTRACT The development of self-compacting concrete (SCC) is an important revolution towards efficiency at building sites. In this work, the fresh and hardened properties of the self-compacting concrete is studies by adding the steel fibers in order to combine the benefits of SCC in the fresh state and an enhanced performance of fiber reinforced concrete in the hardened state. It is observed that when steel fibers are added to concrete mix, there is significant improvement in the hardened properties of the SCC. With the special characteristics of SFRSCC, the new fields of application can be explored.

I. INTRODUCTION

Self-compacting concrete (SCC) was first developed in Japan (in the mid to late 1980s) as a means to create uniformity in the quality of concrete by controlling the ever present problem of insufficient compaction by a workforce that was losing skilled labor and by the increased. Complexity of designs and reinforcement details in modern structural members. Durability was the main concern and the purpose was to develop a concrete mix that would reduce or eliminate the need for vibration to achieve consolidation. SCC is defined as "concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for additional compaction". Subsequent study by major contractors who developed their own in-house systems improved the mixes and fostered the wide spread use of SCC in Japan. The commercial success of SCC in Japan is underscored by a government –supported plan for SCC usage already has reached 40% of the total concrete placed in Japan. This technology was transferred to Europe during the 1990's with the development of the polycarboxilate generation of high range water reducers (super plasticizer) [1, 4 – 6].

Fibers have been produced in a wide range of materials, shapes and characteristics. They improve the performance (strength and toughness) of brittle cement-based materials by bridging cracks, transmitting stress across a crack and counteracting the crack growth. The steel fiber is the most common fiber type in the building industry; other fiber types like plastic, glass and carbon fibers contribute with a smaller part to the market. Dependent on the type and the content of the fibers the workability of concrete can be significantly affected. Composing SFRSCC with defined performance in the fresh and the hardened state is a complex task. This paper concentrates mainly on studying the fresh properties like slump flow, V-funnel, U-box, L-box of SCC with & without fibers and hardened properties like compressive strength, split tensile strength and flexural strength of SCC mix proportions of M30 and M40 for various fractions (0.25%, 0.50%, 0.75% and 1.0%) of the steel fibers by volume of concrete [3,7].

II. FRESH PROPERTIES OF SCC

Self-consolidation characteristics are related to the fresh properties and more specifically to the rheological properties of the concrete. This implies: (a) high deformability; (b) high flow ability; (c) resistance to segregation, and (d) passing ability to flow through reinforcing bars and other confined spaces. Several test methods have been proposed for evaluating the fresh properties. Although none of these methods has been standardized by the corresponding regulatory bodies, however, the EFNARC standards [2] are mostly followed by the researchers across the world. Table – 1 shows the test methods for checking the fresh properties of SCC, and Table – 2 shows the acceptance criteria for SCC as per EFNARC [2].

III. TEST METHODS

1) Slump Flow Test

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete. Figure – 1 shows typical slump flow apparatus used for the test.

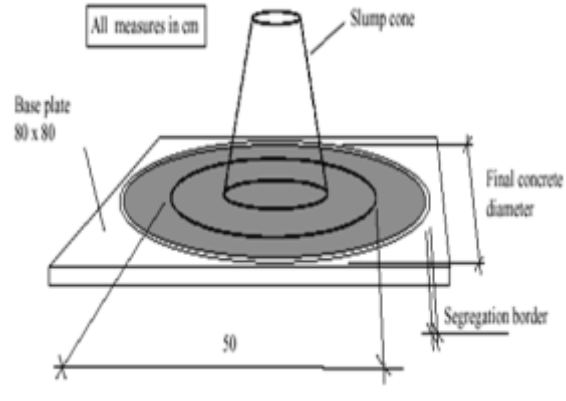

Fig.1

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TABLE I
TEST METHODS FOR FRESH PROPERTIES OF SCC

Sr. No.	Methods	Properties
1	Slump flow by Abrams cone	Filling ability
2	T-50cm slump flow	Filling ability
3	J-Ring	Passing ability
4	V-Funnel	Filling ability
5	V-Funnel at T5 min.	Segregation resistance
6	L-Box	Passing ability
7	U-Box	Passing ability
8	Fill Box	Passing ability
9	GTM screen stability	Segregation resistance
10	Orimet	Filling ability

TABLE II
ACCEPTANCE CRITERIA FOR SCC AS PER EFNARC

Sr. No	Methods	Unit	Typical range of values	
			Mini.	Maxi.
1	Slump flow by Abrams cone	mm	650	800
2	T 50cm slump flow	Sec	2	5
3	J- ring	mm	0	10
4	V- funnel	Sec	6	12
5	V- funnel at T5 min	Sec	0	+3
6	L – box	(h2/h1)	0.8	1.0
7	U – box	(h2-h1) mm	0	30
8	Fill – box	%	90	100
9	GTM screen stability test	%	0	15
10	Orimet	Sec	0	5

2) V-Funnel Test and V-Funnel test at T5 minutes
The V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly. About 12 liter of concrete is needed to perform the test, sampled normally. Figure – 2 shows typical apparatus used for the V – Funnel test.

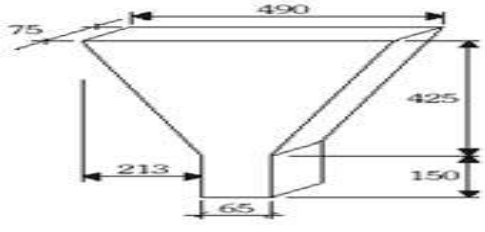

Fig.2 V-funnel apparatus

3) L- Box test method
This is widely is used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. About 14 liter of concrete is needed to perform the test, sampled normally. Figure – 3 shows typical apparatus used for the L – Box test

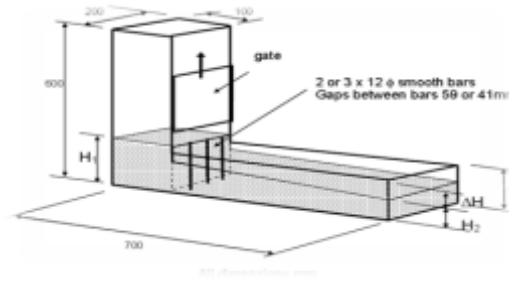

Fig.3 L-Box test Apparatus

4) U- Box test method
This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability-this is literally what the concrete has to do-modified by an unmeasured requirement for passing ability. The 35 mm gap between the sections of reinforcement may be considered too close. The question remains open of what filling height less than 30 cm. is still acceptable. Figure – 4 shows typical apparatus used for the U – Box test

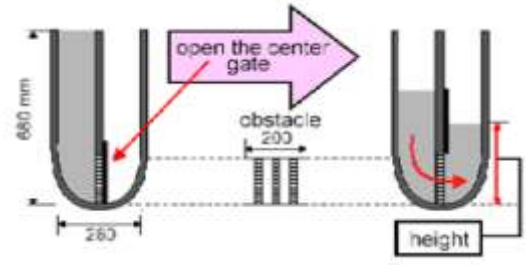

Fig.4 U-Box Apparatus

IV. SPECIMEN PREPARATION AND TESTING
1) Constitute Materials
Cement:
The cement used for making self compacting concrete was Ordinary Portland cement of 53 grade. The physical properties were evaluated as per IS: 4031-1968 and are listed in Table – 3.

TABLE III
PHYSICAL PROPERTIES OF CEMENT

Particulars	Test Results	Requirements as per IS: 12269-1987
Fineness (m^2/kg)	287	225 minimum
Setting time (minutes)		
(a) Initial	120	30 minimum
(b) Final	220	600 maximum
Compressive strength (MPa)		
3 days	40.6	27
7 days	52.0	37
28 days	66.0	53

Fine aggregate:
River sand is used for the fine aggregates and the details of the physical properties are shown in Tables – 4.

TABLE IV
PHYSICAL PROPERTIES OF FINE AGGREGATE

Fineness modulus	2.80
Specific gravity	2.65
Water absorption	1.2

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Coarse aggregate
In SCC, to avoid blocking of concrete, the maximum aggregate size should not be larger than one-fifth of the narrowest dimension of the form in which concrete is to be placed; also, it should not be larger than three-fourths of the maximum clear distance between the reinforcing bars. The maximum aggregate size should generally be limited to 12 – 20 mm. In this study the maximum size of aggregates used was 12mm. The physical properties of the coarse aggregates are shown in Tables – 5.

TABLE V
PHYSICAL PROPERTIES OF COARSE AGGREGATE

Properties	Sample
Specific gravity	2.87
Water absorption	1.15%
Flakiness index	15%
Elongation index	10.30%

Filler:
The Dolomite Powder is used as the filler material and the physical and chemical properties are shown in Table – 6.

TABLE V I
PHYSICAL AND CHEMICAL PROPERTIES OF DOLOMITE

Appearance	White crystalline powder
Sp. Gravity	2.6 – 2.8
Oil absorption	12 - 14
Volatile Content	Max 0.5%
Ph of Slurry	8.5 – 9.5
Coarse Particle	Max 0.5%
Caco3	56.5%
Mgco3	43.0%
Cao	31.5%
Mgo	20.5%
Fe2O3	0.5%
SiO2	1.5%

Admixtures
The admixtures plays very important role in maintaining the flow and workability of the SCC. The properties of the viscosity modifying agent (VMA) and super-plasticizers used in the study are listed as per Table – 7

TABLE V II
PROPERTIES OF ADMIXTURES

Properties	Super-plasticizer GLENIUM SKY 784	VMA Glenium Stream2
Color	Light brown	Transparent
Density	1.10	1.003
Compability	Use for all cement	Use for all cement
PH Value	More than 6	----
Max Dosage	On trial & error basis	On trial & error basis

Fibers
Hooked end steel fibers shown in Figure – 5 available commercially [8] with properties as shown in Table – 9.

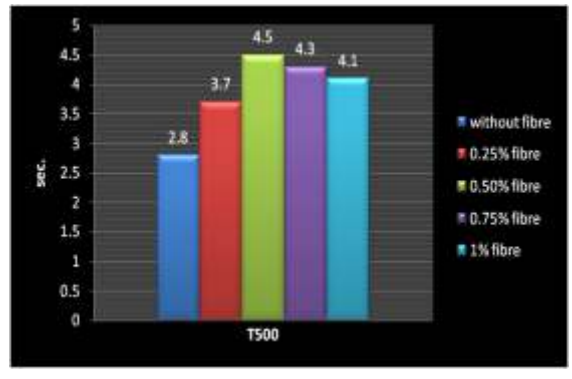


Fig.5 Hooked end Steel fiber

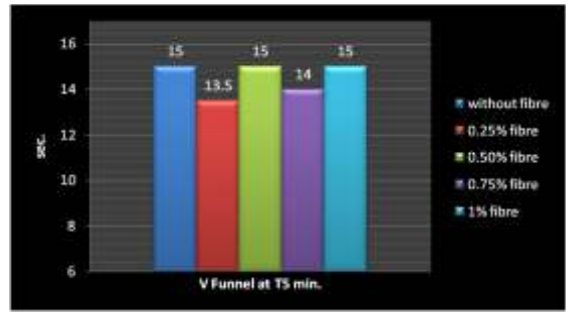
TABLE V II
PROPERTIES OF STEEL FIBRE

Properties	Super-plasticizer GLENIUM SKY 784	VMA Glenium Stream2
Color	Light brown	Transparent
Density	1.10	1.003
Compability	Use for all cement	Use for all cement
PH Value	More than 6	----
Max Dosage	On trial & error basis	On trial & error basis

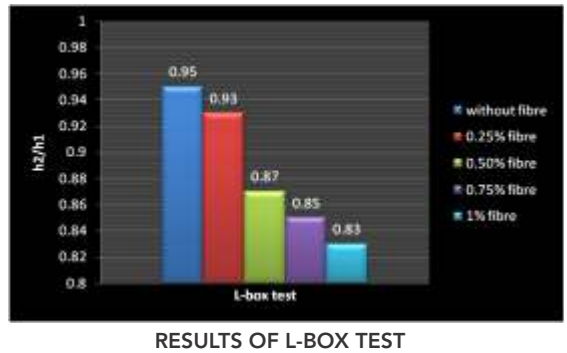
V. RESULTS OF FRESH PROPERTIES



RESULTS OF SLUMP FLOW TEST AT T5 MIN



RESULTS OF V-FUNNEL AT T5 MIN.



RESULTS OF L-BOX TEST

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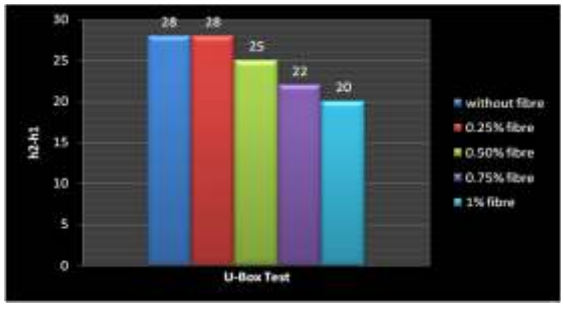
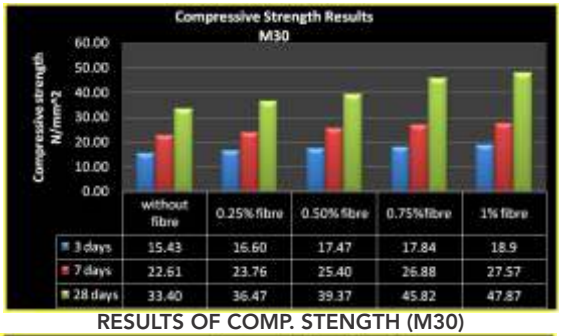


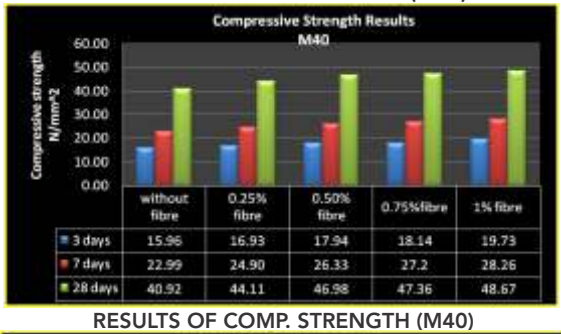
RESULTS OF U-BOX TEST

VI. RESULTS OF HARDENED PROPERTIES



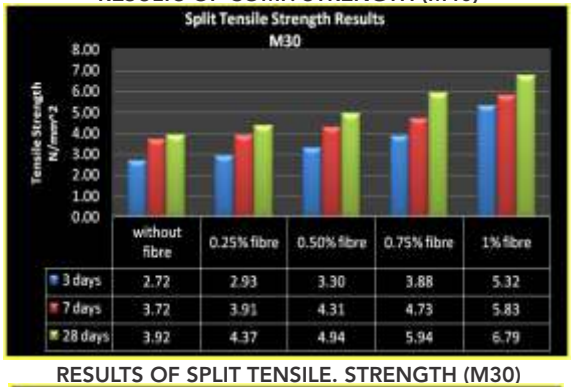
	without fibre	0.25% fibre	0.50% fibre	0.75% fibre	1% fibre
3 days	15.43	16.60	17.47	17.84	18.9
7 days	22.61	23.76	25.40	26.88	27.57
28 days	33.40	36.47	39.37	45.82	47.87

RESULTS OF COMP. STENGTH (M30)



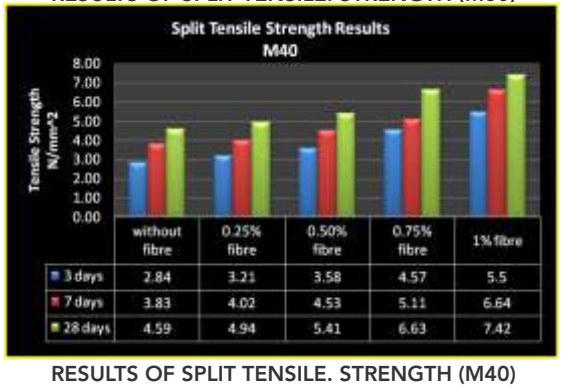
	without fibre	0.25% fibre	0.50% fibre	0.75% fibre	1% fibre
3 days	15.96	16.93	17.94	18.14	19.73
7 days	22.99	24.90	26.33	27.2	28.26
28 days	40.92	44.11	46.98	47.36	48.67

RESULTS OF COMP. STRENGTH (M40)



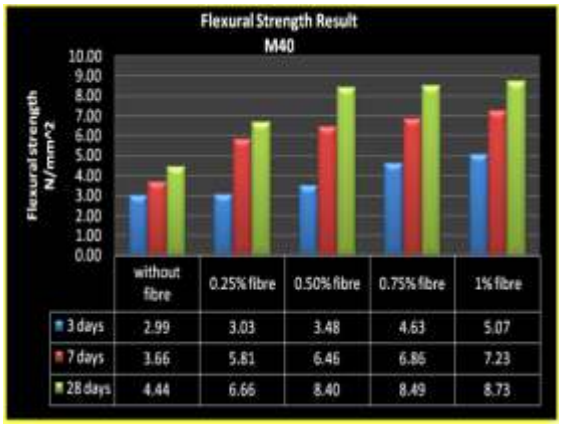
	without fibre	0.25% fibre	0.50% fibre	0.75% fibre	1% fibre
3 days	2.72	2.93	3.30	3.88	5.32
7 days	3.72	3.91	4.31	4.73	5.83
28 days	3.92	4.37	4.94	5.94	6.79

RESULTS OF SPLIT TENSILE. STRENGTH (M30)



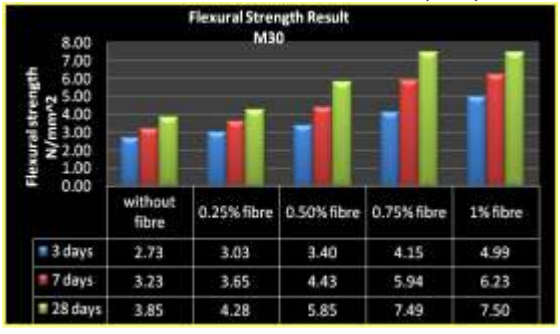
	without fibre	0.25% fibre	0.50% fibre	0.75% fibre	1% fibre
3 days	2.84	3.21	3.58	4.57	5.5
7 days	3.83	4.02	4.53	5.11	6.64
28 days	4.59	4.94	5.41	6.63	7.42

RESULTS OF SPLIT TENSILE. STRENGTH (M40)



	without fibre	0.25% fibre	0.50% fibre	0.75% fibre	1% fibre
3 days	2.99	3.03	3.48	4.63	5.07
7 days	3.66	5.81	6.46	6.86	7.23
28 days	4.44	6.66	8.40	8.49	8.73

RESULTS OF FLEXURE STRENGTH (M30)



	without fibre	0.25% fibre	0.50% fibre	0.75% fibre	1% fibre
3 days	2.73	3.03	3.40	4.15	4.99
7 days	3.23	3.65	4.43	5.94	6.23
28 days	3.85	4.28	5.85	7.49	7.50

RESULTS OF FLEXURE STRENGTH (M40)

VI. DISCUSSIONS

From Table 10, it can be seen that as the % volume of the fiber increases in the SCC, its flow ability reduces and in order to maintain its eligibility as a "flowing concrete" is possible by increasing the content of the super-plasticizer in the mix.

Figures 6 and 7 shows the time required for T 50 cm slump flow and V – Funnel tests respectively. It can be seen that as the % volume of the fiber increases in the SCC, its flow ability reduces, which in turn results in the increase in the time required for the flow. The results for L – Box and U – Box tests are shown in Figures 8 and 9 respectively. It can be observed that as the % volume of the fiber increases in the SCC, its flow ability reduces, which results in the reduction in the (h2 / h1) ratio.

The results of the hardened properties of SFRSCC like compressive strength, split tensile strength and the flexural strength for two mixes (M30 and M40) are shown in Figures 10 to 15. From all these figures, it is clearly seen that as the % fiber content is increased in the SCC, its hardened properties are increased.

VIII. CONCLUSIONS

1. SFRSCC can be developed with high amount of fines and low w/p ratio. This can be done simultaneously by using proper dosage of super-plasticizer and VMA.
2. As the % steel fibers are increased in the SCC, its flow ability reduces. For higher fractions of steel fibers, the dosage of super-plasticizers and VMA should be increases.
3. The U – Box test played crucial role in examining the fresh properties of SFRSCC.
4. At high content of fibers, even with an increase in admixture dosage, the concrete shows less flow ability, because of the binding properties of the fibers, However, it enhances the stability of the mix.
5. As the % fiber content is increased in the SCC, its hardened properties are increased.

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