Experimental Study on Mechanical properties of Steel Fibre Reinforced Self Compacting Concrete

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Abstract: Self-compacting concrete (SCC) is defined as 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. To improve the performance of SCC, polymers are mixed with SCC. It has been observed that steel fibre modified concrete has improved mechanical performance than conventional self-compacting concrete due to superior strength. This study aims to focus on the possibility of using steel fibre in a preparation of self-compacting concrete. The use of the steel fibre was proposed in different percentage as an addition of cement for production of steel fibre modified self-compacting concrete.

KEYWORDS: Self-Compacting Concrete, Steel fibre, Compressive Strength

INTRODUCTION

Self-compacting concrete (SCC) is an important development in concrete technology over the last decades [5,10,18,29,33,35]. SCC may be defined as a concrete that flows under its own weight without the need to any vibration for placing and compaction in the presence of congested reinforcement [13,17,20,22,33,35]. SCC was first developed in 1986 by Okamura [2]. This technology is considered a vital solution to get a concrete that can flow under its own weight without needing any mechanical vibration and complexity of the formwork. Given its wide applicability, SCC has been explored for its potential in building construction and structural works in numerous countries, such as Japan, Canada, and the United States of America (M. M. [27,31]). SCC has many advantages, including high productivity, simple production, and high structure quality [2].

Steel Fibre

This study focuses on steel fibre (SF). They operate as crack arrestor in concrete. Steel fibre length ranges from 1/4 to 3 inches (1.5 to 75 mm) and aspect ratio ranges from 24 to 100.

Types of steel fibre

Fibres are in a range of sizes and shapes. Round steel fibre prepared up of low-carbon steel or stainless steel, having diameters in the range of 0.25 to 1 mm. Flat steel fibre, formed by shearing sheet or flattening round wire and are accessible in thicknesses ranging from 0.15 to 0.41 mm. Crimped and deformed steel fibre are obtainable both in full length or crimped at the ends simply. A typical volume fraction of steel fibre is 0.25 to 1.5% (of the volume of concrete).

Steel Fiber Modified Self Compacting Concrete

Steel fibre self-compacting concrete (SFSCC) mixture shows an improved performance in the fresh and hardened states compared with normal vibrated concrete because of the adding of the fibres [21]. SF addition in concrete mixtures is a nonconventional mass reinforcement that improves the mechanical properties of concrete, ductility, toughness and offers crack propagation control [14,15,19,21,23,24,34,36].

In this dissertation work, steel fibre modified self-compacting concrete compositions containing 0.5%, 0.75% and 1% SF by weight of cement were prepared. Concrete cubes, cylinders and beams were cast to perform compressive strength, split tensile strength and flexural strength tests.

Material used and their properties

- **Cement**

Portland Pozzolana Cement manufactured was used throughout the Experimental investigation. The quality of the cement was confirmed as per IS 4031-1988 and all the quality tests were conducted conforming to the specifications of 12269-1987. Results of the various test are tabulated in Table 1.

Table 1: **Physical Properties of Ordinary Portland cement:**

Characteristics	Observed Value
Normal Consistency	32%
Initial Setting Time	75 minutes
Final Setting Time	525 minutes
Specific Gravity	2.9

Compressive Strength at 28 days	35.5 Mpa

- **Fine Aggregate**

The Fine Aggregate used was locally available coarse Sand. The test procedure as per IS 383: 1970 was carried out to determine the properties of Fine aggregate. The results of the various test are tabulated in Table 2.

Table 2: Physical Properties of Fine Aggregate:

Characteristics	Observed Value
Grade Zone	III
Fineness Modulus	2.26
Specific Gravity	2.62
Silt Content	1.67%

- **Coarse Aggregate**

The Coarse Aggregate used was locally available. The test procedure as per IS 383: 1970 was carried out to determine the properties of Coarse aggregate. The Results of the various test are tabulated in Table 3.

Table 3: Physical Properties of Coarse Aggregate:

Characteristics	Observed Value
Fineness modulus	6.96
Specific Gravity	2.67
Water Absorption	0.40%

- **Steel Fiber**

Corrugated SFs (Fig. 1) with a volume fraction (Vf) of 0.5%, 0.75% and 1% were used. This SF volume represents a typical value and is used in several experimental investigations. Table 4 summarizes the properties of the SF material.

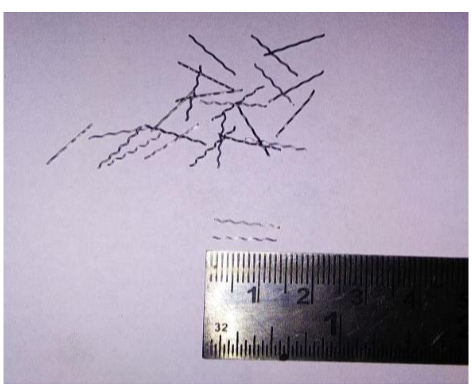

Fig. 1. Image of Steel Fiber Used in Experiment

Table 4: Physical properties of Steel Fiber

S.No	Physical properties of Steel Fiber	Value
1	Length (mm)	12
2	Diameter (mm)	0.5
3	Aspect Ratio	24

- **Super plasticizer (SP)**

Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation. Sika superplasticiser is utilized in this project, which is a product of Sika Company having a specific gravity of 1.14. Super plasticizer is a chemical compound used to increase the workability without adding more water. It was used to provide necessary workability. Properties of Sika superplasticizer are tabulated in Table 5.

Table 5: Properties of admixture

Characteristics	Sika Superplasticiser
Specific Gravity	1.14
Role in Concrete	Improves workability & flow properties, Produces concrete of very high strength

- **Mix Proportioning**

The mix proportion was done based on the method proposed by EFNARC guidelines. Table 6 gives the quantities required for concrete Mix. Table 7 shows the mix composition for steel fibre self compacting concrete. The mix was checked for self-compact ability by flow test, J ring test, V funnel test and L-Box test. Flow test and V-funnel tests for checking the filling ability and L-box test, J ring test for the passing ability (Fig. 2-5). The mixes were checked for the SCC acceptance criteria given in Table 6 & 7

Table 6: Mix Design Trial of Self-Compacting Concrete for 1 m^3 of Concrete

Trial	Steel fibre%	Cement (kg)	W/C ratio	F.A (kg)	C.A (kg)	Admixture %	Admixture (kg)	Slump value (mm)	V funnel (sec)	L box (H2/H1)	J ring (mm)	Remark
SCC 1	1.0	440	0.45	1001.37	725.13	1.0	6.60	430	7	0.8	16	Bleeding
SCC 2	1.0	440	0.45	1002.00	725.55	1.2	6.16	475	7	0.6	18	Segregation
SCC 3	1.0	440	0.45	1002.53	726.00	1.6	5.72	850	8	0.5	11	Flow is more
SCC4	1.0	440	0.45	1003.11	726.39	1.4	5.28	700	10	0.9	9	Flow is good

Table 7: Mix design trial of steel fibre self-compacting concrete for 1 m^3 of concrete

Trial	Cement (kg)	W/C ratio	F.A (kg)	C.A (kg)	C.A/F.A ratio	Admixture %	Admixture (kg)	Slump value (mm)	V funnel (sec)	L box (H2/H1)	J ring (mm)
SCC 1	440	0.45	1003.71	726.82	0.7241	0.5	2.20	452	14	0.6	15
SCC 2	440	0.45	1003.11	726.39	0.7241	0.7	3.08	477	14	0.6	18
SCC 3	440	0.45	1002.53	726.00	0.7241	0.8	3.52	535	12	0.8	11
SCC 4	440	0.45	1002.00	725.55	0.7241	1.0	4.40	611	12	1.0	7
SCC 5	440	0.45	1001.37	725.13	0.7241	1.1	4.84	690	10	0.9	9

Table 8: SCC - Acceptance Criteria

Method	Properties	Range of values
Flow value	Filling ability	650-800 mm
V-funnel	Viscosity	8-12 sec
L-box	Passing ability	0.8-1.0
J ring	Passing ability	0-10

Fig. 2. Slump Test for SCC

Fig. 3. J-Ring test for SCC

Fig. 4. V-funnel test for SCC

Fig. 5. L-box test for SCC

Mixes

The basic mix proportion of SCC is cement, fine aggregate, coarse aggregate, water and admixture. Mix 1 contains 0.5% steel fiber. Mix 2 contain 0.75% steel fiber, then 3, contains 1% of steel fiber. Total 4 mixes were studied. Details of replacements are tabulated in the Table 9 below.

Table 9: Mix composition

Types of mix	Steel Fibre %	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Steel Fibre (kg)	Water (kg)	Admixture (kg)
M1	0	440	1003.11	726.39	0	198	4.40
M2	0.5	440	1003.11	726.39	22	198	5.28

M3	0.75	440	1003.11	726.39	33	198	5.72
M4	1.0	440	1003.11	726.39	44	198	6.16

Compressive Strength

Compressive strength test was performed according to IS 516: 1959. Cubes of specimen of size 150 mm x 150 mm x 150 mm were prepared for each mix. Result Table 10 for compressive strength of cube at 28 days is given below and plotted graphically (Fig 6).

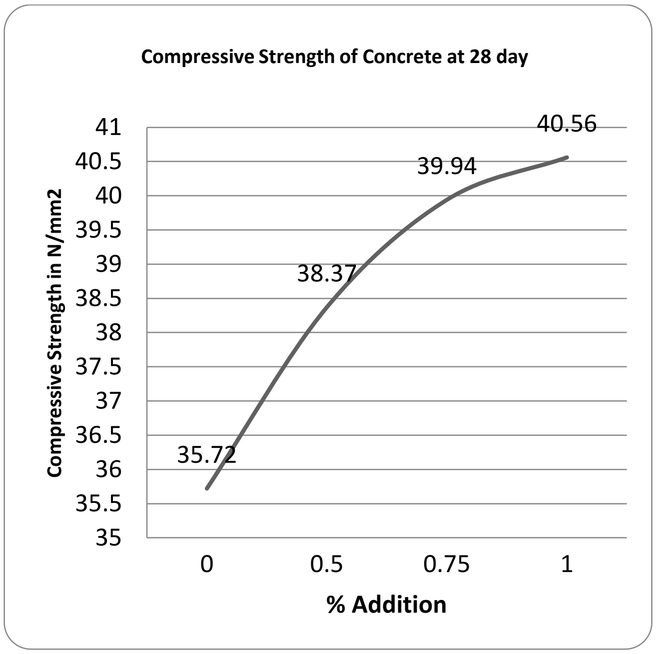

Fig. 6 Compressive strength of steel fibre SCC concrete mix

Table 10: Compressive Strength of concrete at 28 days

	Types of mix	% of Steel Fibre	Compressive strength in MPa
Mix Grade M25	M1	0	35.72
	M2	0.5	38.37
	M3	0.75	39.94
	M4	1.0	40.56

Split Tensile Strength

The test were performed according to the procedure adopted in IS 5816: 1999. Cylinder of size 150 mm x 300 mm were prepared for each mixes. Result Table 11 for Split Tensile strength of cylinder at 28 days is given below and plotted graphically (Fig. 7)

Table 11: Split Tensile Strength of concrete at 28 days

	Types of mix	% of Steel Fibre	Split tensile strength in MPa
Mix Grade M25	M1	0	4.78
	M2	0.5	4.94
	M3	0.75	5.36
	M4	1.0	5.42

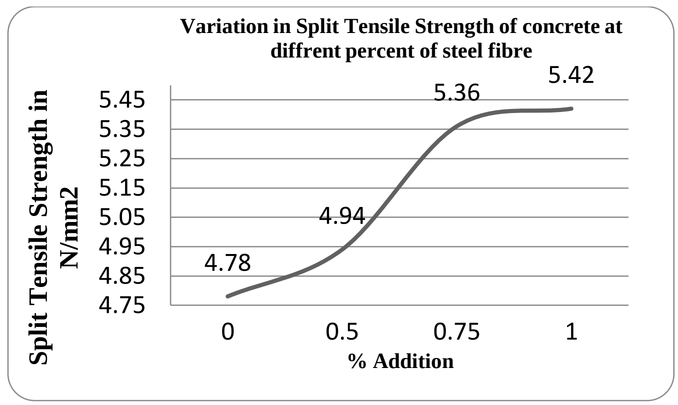

Fig. 7 Split tensile strength of steel fibre SCC concrete mix

Flexural Strength

Flexural strength test was performed according to IS 516:1979. Beams of specimen of size 500 mm x 100 mm x 100 mm were prepared for each mix. Result Table 12 for flexural strength of beam at 28 days is given below and plotted graphically (Fig. 8).

Table 12: Flexural Strength of concrete at 28 days

	Types of mix	% of Steel Fibre	Flexural strength in MPa
Mix Grade M25	M1	0	12.28
	M2	0.5	12.32
	M3	0.75	13.08
	M4	1.0	13.29

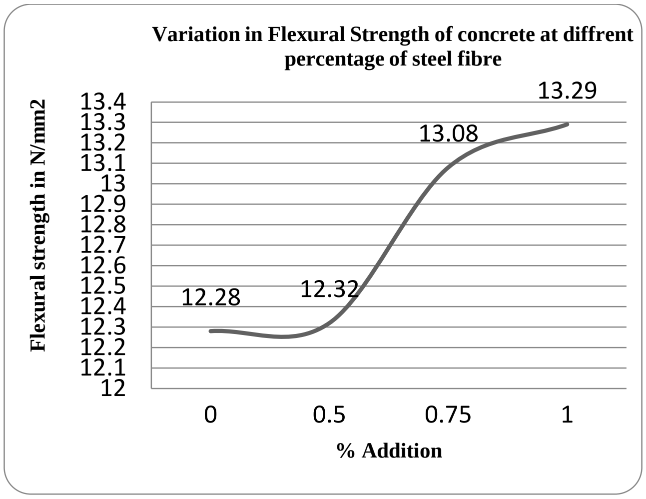

Fig. 8 Flexural strength of steel fibre SCC concrete mixes

CONCLUSION

The strength and durability characteristics of Self compacting concrete (SCC) and steel fibres content 0.5, 0.75, 1.0% by volume, have been computed. The inclusion steel fibres improved the concrete properties in fresh state i.e. deformability, passing ability, filling ability and segregation resistance as well as in hardened state i.e. mechanical and durability properties. The improvement in properties of SCC is because of enhancement in interfacial or bond strength of steel fibres in the concrete. The indices shown in Fig 9 were used to provide suitable addition percentage of Steel fibre. The nomenclature followed in mechanical indices is such that values higher than 1 indicate better performance of respective SCC mix.

Based on the experimental study on concrete mixes, the following conclusions could be made:

1) The present results show that it is possible to design a SCC mix incorporating steel fibres up to 1% by volume. With increase of steel fibre content by volume fractions the workability decreased.

2) It has been found that compressive strength, split tensile strength & flexural strength have their maximum values for 1% Steel Fibre. The compressive strength is increased by13.5% , split tensile strength by 13.38% & flexural strength by 8.22% when compared to their nominal strength..

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