Study on Flexural and Shear Behaviour of Hybrid Fibre Reinforced Self-Compacting Concrete Containing Silica Fume and M-Sand

Hannah B K
M. Tech Student
Dept. of Civil Engineering
YCET, Kollam, India

Mr. Sreejith R
Assistant Professor
Dept. of Civil Engineering
YCET, Kollam, India

Abstract **- Self-Compacting Concrete (SCC) is a high performance concrete that does not require any vibration for placing and compaction. It is able to flow under its own weight and achieves full compaction. Addition of fibres improves the residual load bearing capacity of concrete and this improvement is influenced by the type, content and orientation of the fibres. The use of fibres may extend the possible fields of application of self compacting concrete. Nowadays, the availability of natural river sand is limited due to high cost and scarcity. At present M- sand is the most commonly used fine aggregate. In this thesis, the SCC is made with 25% replacement of cement with silica fume, polypropylene fibre (0%, 0.1%,0.2% to the total volume of concrete), steel fibre (0%, 0.75%, 1.5% to the total volume of concrete) and M-sand (manufactured sand) as fine aggregate. The main focus of this study is on investigating flexural and shear strength behaviour of this hybrid fibre reinforced self compacting concrete containing silica fume and M-sand.**

Keywords-Hybrid fibre, Steel fibre, Polypropylene fibre, Silica fume

I. INTRODUCTION

Concrete is a widely used construction material around the world. In the recent two or three decades, a lot of researches were carried out to improve the performance of concrete in terms of strength and durability. Studies from macro to micro level in the enhancement of strength and durability properties were done. Insufficient vibration or consolidation of concrete leads to poor material quality which eventually reduces the durability of concrete structures. So studies related to high workability and self compactability of concrete to improve the strength and durability are of great significance. The development of self- compacting concrete (SCC) has recently been one of the most important developments in the building industry. It is a kind of concrete that can flow through and fill gaps of reinforcement and corners of moulds without any need of vibrations and compactions during the pouring process, thereby decreasing human effort. The technology was first discovered in 1986 by Japanese researchers to increase the durability by increasing the workability of concrete and thus by increasing the construction quality. SCC must satisfy the following workability performance criteria such as flow ability (ease of flow of fresh concrete when unconfined by formwork and/or reinforcement), viscosity (resistance to flow of a material), passing ability (ability of fresh concrete to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking) and stability (the ability of SCC to remain homogenous by resisting segregation, bleeding, and air popping during transport, placement, and after placement).

Concrete is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks in the early stage concrete is due to the drying shrinkage, these are a basically micro crack which increases in size and magnitude as the time elapses. To avoid these problems tensile reinforcement is provided to increase the strength of concrete. However cracks in reinforced concrete members extend freely until encountering are bar. Thus there arises need for multi directional closely spaced reinforcement which is practically impossible. Fibre reinforcement concrete gives solution for this problem. These fibres are uniformly distributed and randomly arranged which will arrest the formation of cracks thereby increasing flexural strength of concrete.

In this thesis, the SCC is made with 25% replacement of cement with silica fume, polypropylene fibre (0%, 0.1%,0.2% to the total volume of concrete), steel fibre (0%, 0.75%, 1.5% to the total volume of concrete) and M-sand (manufactured sand) as fine aggregate.

II. PRELIMINARY EXPERIMENTAL INVESTIGATION

The aim of preliminary investigation studies was to obtain the mix proportions for Self Compacting Concrete. For that purpose a mix design method proposed by Okumara and Ozawa was adopted. Then the properties of constituent materials were determined.

A. Materials

Cement: Ordinary portland cement of 53 grade confirming to IS 12269 was used for the study. The Specific gravity was obtained as 3.14.

Silica fume: It is a byproduct obtained during the production of silicon metal or ferrosilicon alloys. The specific gravity of silica fume used for this study was found to be 2.2.

Fine aggregate: Commercially available M – Sand with 4.75 mm maximum size was used. The specific gravity was obtained as 2.63.

Coarse aggregate: Coarse aggregate of size less than 20mm from local source was used. The physical property determinations and sieve analysis were done for coarse aggregate. The sieve analysis results shows that the Coarse Aggregate is confirming to zone II as per IS 383:1970.

Super plasticizer: Super plasticizer is also known as high range water reducing admixture The super plasticizer used is cera hyper plast XR W40. Cera hyper plast XR W40 is an acrylic polymer based new range water reducing admixture.

Viscosity Modifying Agent (VMA): Ceraplast-300 is used as viscosity modifying admixture.

Polypropylene fibre: Polypropylene acts as secondary reinforcement in concrete which arrests cracks and increases resistance to impact.

Steel Fibre: Crimped steel fibre having diameter 0.5 mm and length 30 mm were used for the study.

Water: Potable water is generally considered as being acceptable. Hence clean drinking water available in the local water supply system was used for casting.

Reinforcing bars: Main reinforcement consists of 10 mm and 8 mm diameter steel bars, 6mm diameter steel bars will be used as stirrups.

B. Mix proportioning of Self Compacting Concrete

Self compactability can be largely affected by the characteristics of materials and the mix proportion. There are various mix design methods available for the self compacting concrete. Okamura and Ozawa proposed a simple method for the mix design of self compacting concrete.

TABLE 1: DETAILS OF MIX

Mix (M_{30})	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Silica Fume (kg/m^3)	Viscosity modifying agent (kg/m^3)	w/p	Water (kg/m^3)
SCC	347.19	928.654	758.25	115.73	0.2	0.45	208.32

TABLE 2: DETAILS OF DIFFERENT MIX DESIGNATIONS

Mix Designation	Cement (%)	Silica fume (%)	Fine Aggregate (%)	Coarse Aggregate (%)	Polypropylene fibre(%)	Steel fibre(%)
SCC - 1	75	25	100	100	-	-
SCC - 2	75	25	100	100	0.1	-
SCC - 3	75	25	100	100	0.2	-
SCC - 4	75	25	100	100	-	0.75
SCC - 5	75	25	100	100	-	1.5
SCC - 6	75	25	100	100	0.1	0.75
SCC - 7	75	25	100	100	0.2	1.5

III. EXPERIMENTAL INVESTIGATION

A. *Specimen details*

TABLE 3: DETAILS OF NUMBER OF SPECIMENS

Sl. No.	Specimen	Property	Size	Numbers
1	Cube	Compressive strength	150 mm × 150 mm × 150 mm	42
2	Cylinder	Splitting tensile strength	300 mm height and 150 mm diameter	21
3	Beam	Flexural strength	500 mm × 100 mm × 100 mm	21
4	Large beam	Flexural and shear behaviour	1200 mm × 100 mm × 150 mm	28
Total number of specimens				112

B. *Preparation and casting of Test Specimens*

For each mix 6 concrete cubes of size 150X150X150 mm for compressive strength test, 2 cylinders of 150mm diameter and 300mm height for splitting tensile strength of each specimen, 2 beams of size 500X100X100 mm for flexural strength and atotal of 28 beams of size 1200X100X150 mm for finding flexural and shear behaviour of beams.

Mixing was done in a standard type drum mixer of capacity about 0.06 m^3. For the preparation of specimens first aggregates were mixed with the cement properly using the mixer. Admixtures and water were added later and was mixed until a uniform mix was obtained. Later the mix was placed in the moulds and levelled up to the brim properly. The specimens were demoulded after 24 hours and were transferred to the curing tank.

TABLE 4: MIX DESIGNATION FOR LARGE BEAMS

Sl. No.	Beam Designation		Polypropylene fibre(%)	Steel fibre(%)
	Flexure	Shear		
1	SCCF1	SCCS1	-	-
2	SCCF2	SCCS2	0.1	-
3	SCCF3	SCCS3	0.2	-
4	SCCF4	SCCS4	-	0.75
5	SCCF5	SCCS5	-	1.5
6	SCCF6	SCCS6	0.1	0.75
7	SCCF7	SCCS7	0.2	1.5

C. *Tests on specimens*

The experimental investigation carried out was divided into 3 main headings. They are as follows

1. Study on workability
   - Slump test
   - v-funnel test
   - J- ring test
   - L-box test
2. Study on strength
   - Compressive strength
   - Splitting tensile strength
   - Flexural strength test
3. Study on flexural crack pattern
4. Study on Shear crack pattern

D. *Test setup*

A two point flexural bending system is adopted for the tests. Specimens are tested in a loading frame of 2000 kN (200 t) capacity with an effective span of 1100 mm. Load cell of 200 kN capacity with a least count of 1 kN is used to measure the applied load. Fig. 3.18 shows the schematic diagram of test setup. The load is increased in stages till the failure of the specimen in the case of monotonic loading and at each stage of loading deflection at mid span is found out using a dial gauge.

Fig.1: Test set-up

IV. RESULTS AND DISCUSSIONS

A. *Test on fresh properties of different SCC mixes*

TABLE 5: TEST RESULTS FOR FRESH PROPERTIES

Sl.No.	Mix Designation	V-funnel (sec)	T50 (sec)	Slump (mm)	L-Box (h_2/h_1)	J-Ring (mm)
1	SCC 1	8.6	2	725	0.92	6.4
2	SCC 2	8.8	2.2	718	0.91	6.5
3	SCC 3	9.8	2.8	709	0.90	7.3
4	SCC 4	10.4	3.6	690	0.87	8.2
5	SCC 5	10	4.4	674	0.84	8.9
6	SCC 6	10.9	4.3	683	0.86	8.4
7	SCC 7	11.4	4.9	659	0.82	9.2

B. *Test on hardened properties of concrete*

TABLE 6: COMPRESSIVE STRENGTH FOR DIFFERENT MIXES

Sl.No.	Mix Designation	Compressive strength (N/mm^2)	
		7 days	28 days
1	SCC1	21	30.42
2	SCC2	24.40	33.84
3	SCC3	23.26	30.67
4	SCC4	27.94	36.12
5	SCC5	25.82	34.96
6	SCC6	28.32	37.24
7	SCC7	24.62	34.26

Compressive strength was maximum for mix containing 0.1% polypropylene fibre and 0.75% steel fibre.

TABLE 7: FLEXURAL AND SPLITTING TENSILE STRENGTH VALUES FOR DIFFERENT MIXES

Sl.No.	Mix Designation	Flexural strength (N/mm^2)	Splitting Tensile strength (N/mm^2)
1	SCC1	4.28	2.32
2	SCC2	5.16	2.56
3	SCC3	3.64	2.39
4	SCC4	6.42	2.97
5	SCC5	5.36	2.69
6	SCC6	6.98	2.97
7	SCC7	5.82	2.82

Flexural strength and splitting tensile strength were maximum for mix containing 0.1% polypropylene fibre and 0.75% steel fibre.

C. *Test on Beams*

1. *First crack load and ultimate load*

First crack load was determined from the load deflection plot corresponding to that point on the curve at which the curve deviated from linearity. The test results show that the fibre addition increased the first crack load and the ultimate load of beams. The first crack and the ultimate load increased with the increase of fibre addition and the maximum was obtained for mix containing 0.1% polypropylene fibre and 0.75% steel fibre. The test results are shown in below tables.

TABLE 8: TEST RESULTS FOR FIRST CRACK LOAD AND ULTIMATE LOAD FOR FLEXURAL BEAM SPECIMENS

Sl. No	Beam Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
1	SCCF1	11.9	46	9.68
2	SCCF2	12.76	47.97	10.30
3	SCCF3	13.10	48.12	10.37
4	SCCF4	15.38	50.73	10.49
5	SCCF5	19.34	58.20	12.62
6	SCCF6	16.10	54.00	10.96
7	SCCF7	21	61.48	13.28

TABLE 9: TEST RESULTS FOR FIRST CRACK LOAD AND ULTIMATE LOAD FOR SHEAR BEAM SPECIMENS

Sl. No	Beam Designation	First Crack Load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
1	SCCS1	8	38	4.63
2	SCCS2	9	40	4.98
3	SCCS3	10	34	5.48
4	SCCS4	12.72	41.38	6.34
5	SCCS5	15	46	6.48
6	SCCS6	14	42	6.41
7	SCCS7	16.82	48	6.52

2. *Load deflection behavior*

Mid span deflection was noted at every 2kN load increament. Deflection of all specimens was observed to increase considerably after the first crack was observed. Deformations corresponding to each increment of load for all specimens were noted.

3. *Crack pattern and failure mode*

The typical crack pattern of the flexural and shear beams are shown below.

Fig 2: Typical crack pattern of the flexural beam

Fig 3: Typical crack pattern of the Shear beam

4. *Energy absorption capacity*

The amount of energy the material can absorb before failure is called energy absorption capacity. The materials having high energy absorption capacity is preferred for earthquake resistant structures. The area under the curve gives the energy absorption capacity of concrete.

Due to inherent limitations of the testing machine, full load deflection curve could not be obtained. Therefore 80% of peak load is noted. Here, the deflection at which the test was stopped beyond the peak load is considered as ultimate deflection. The deflection at yield was arbitrarily obtained as follows. First the maximum load was determinedP_{max}, and a horizontal line parallel to the deflection axis was drawn through $P_{max.}$ A secant line was drawn from the origin through a point corresponding to 0.8 P_{max} on the load deflection curve; an arbitrary point was taken as the point where the secant line intersects the horizontal line passing by Pmax. The corresponding deflection was considered the yield deflectionand energy dissipated at yield was defined as the shaded area under the load deflection curve. For flexural members, structural ductility is defined as the ratio ultimate deflection and yield deflection of the tensile reinforcement.

TABLE 10: ENERGY ABSORPTION CAPACITY AND DUCTILITY INDEX FOR FLEXURAL BEAM SPECIMENS

Sl. No	Beam Designation	Energy absorption (kNm)	Ductility index
1	SCCF1	0.209	1.13
2	SCCF2	0.213	1.27
3	SCCF3	0.216	1.62
4	SCCF4	0.239	1.68
5	SCCF5	0.256	2.13
6	SCCF6	0.248	2.02
7	SCCF7	0.262	2.35

TABLE 11: ENERGY ABSORPTION CAPACITY FOR SHEAR BEAM SPECIMENS

Sl. No	Beam Designation	Energy absorption (kNm)
1	SCCS1	0.12
2	SCCS2	0.18
3	SCCS3	0.21
4	SCCS4	0.24
5	SCCS5	0.26
6	SCCS6	0.248
7	SCCS7	0.262

V. CONCLUSION

The major conclusions of my thesis work are presented below:

- Compressive strength, Flexural strength and splitting tensile strength were maximum for mix containing 0.1% polypropylene fibre and 0.75% steel fibre.
- The improvement of all the hardened properties of SCC beams demonstrated the hybrid effect of the combination of steel and polypropylene fibre.
- Maximum energy absorption capacity was obtained for SCC7.
- The fibre distributes the strain more evenly in concrete and improves the tensile strength, thereby causing the increase in first crack load and ultimate load.
- When fibres are added to concrete, crack propagation is arrested and this results in improving load carrying capacity and energy absorption capacity. So the toughness and ductility is improved with the addition of percentage of scrap steel fibre.
- Hybrid fibre mix shows better results than those mix having monofibre.

REFERENCES

[1] Ahmed Fathi Mohamed Salihet al.(2013) Comparison of the effects of different fibers on the properties of self-compacting concrete, *Research Journal of Applied Sciences, Engineering and Technology*,7,3332-3341.

[2] Anitha M. et al. (2012)Mechanical properties of scc with polypropylene fibres, *International Journal of Advanced Scientific Research and Technology*, 3, 375-388.

[3] Dr. Arivalagan S et al. (2013)An investigation on engineering properties of hybrid fibre (steel fibre and silica fume) reinforced self compacting composite concrete members, *World Journal of Engineering science*, 1,188-196.

[4] Habita M. F. et al.(2006)Hybrid fibre reinforced self-compacting concrete: hardened properties, *International Journal of Civil Engineerng*, 4, 77-85.

[5] Hakeem Esmoue et al.(2012) Influence of silica fume on the properties of self-compacting concretes,*3rd International Conference on Engineering Optimization.*

[6] Jagadeesh K and E. Ramesh Babu (2014) Flexural strength of self compacting concrete with silica fume and polypropylene fibres with and without reinforcement, *International Journal of Advanced Technology in Engineering and Science*, 2, 463 - 472.

[7] Karthik Poovaiah D et al.(2014) Durability and strength properties on high performance self compacting concrete with GGBS and silica fume, *International Journal of Engineering Research and Applications*,4, 12-19.

[8] Kazim Turk and Mehmet Karatas (2011)Abrasion resistance and mechanical properties of self-compacting concrete with different dosages of fly ash/silica fume,*Indian Journal of Engineering and Materials Sciences*, 18, 49-60.

[9] Slamet Widodo et al. (2012)Fresh and hardened properties of polypropylene fibre added self-consolidating concrete,*International Journal ofCivil and Structural Engineering,* 3, 85-93.

[10] Suchithra K. S.et al. (2014)Experimental investigation manufactured sand as apartial replacement material of fine aggregate in self-compacting concrete, *Indian Journal of Applied Research,* 4, 236-239.