STUDIES ON THE EFFECT OF STEEL FIBRE IN NON- CONVENTIONAL SELF COMPACTING CONCRETE

Lemlem Mulat[1] Udhaya Kumar.T[2]

[1]*P.G Scholar,* Department of Civil Engineering

[2]*Assistant Professor,* Department of Civil Engineering

Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Chennai, India.

ABSTRACT

Self-compacting concrete (SCC) is concrete with enhanced fresh properties that allow pouring without external compaction. Its advantages also are extended to good segregation resistance, higher homogeneity, lower permeability, which among others, lead to a product with higher durability. In this study self-Compacting-Concrete containing steel fiber offer improvements on strength parameters of self-compacting concrete for M-30 grade of concrete. The main objective of this project is to investigate the effect of steel fiber on fresh and hardened properties of Non-conventional self-compacting concrete. The use of fibers extends its possibilities since fibers arrest cracks and retard their propagation. To improve the compressive strength, Split tensile strength, flexural strength properties of the concrete steel fiber of 1%, by volume of cement was used as additional material. The non-conventional concrete with 1% steel fiber gives highest compressive strength at 28 days and 8.7% higher in split tensile strength.

Keywords: *Compressive Strength, Demolished Aggregate, SCC, Split Tensile Strength, Steel Fiber.*

1. INTRODUCTION

Self-compacting, or "self-consolidating" concrete (SCC) was first developed in Japan in the early nineties. SCC is concrete with enhanced fresh properties that allow pouring without external compaction. Its advantages also are extended to good segregation resistance, higher homogeneity, lower permeability, which among others, lead to a product with higher durability SCC consists basically of the same constituents as a normally vibrated concrete. The use of fibers extends its possibilities since fibers arrest cracks and retard their propagation. Steel fibers used in self-compacting in a view of improving the mechanical properties of SCC so that it can be applied in beam column joints. There are several concepts for producing SCC. For all concepts, some kind of high-efficient water reducing and dispersing super plasticizer is used. Superplasticizers aim at increasing the dispersing effect and furthermore decreasing the friction between the particles. There has been an intense development of superplasticizers during the last decades making SCC feasible.

2. EXPERIMENTAL INVESTIGATION

Materials used for the study are Cement, coarse Aggregate, M-Sand, GGBS, Steel Fiber, Super Plasticizer and Water.

a. material used and properties

Cement

Portland Pozzolana cement grade 43confirming to IS: 12269-1987 was used for the study. The specific gravity is 2.85.

Coarse aggregate test

A demolished aggregate with assize of 12.5 mm was used with a specific gravity of 2.8 and water absorption of 2.59.

M- Sand

A manufacture sand confirming to the grading zone –II as per IS 383/1970 was used with a specific gravity of 2.68 and a water absorption of 0.9.

Steel Fibers

Straight Steel Fibers type with a diameter of 0.75 mm having a length 30mm and 1% addition was used for the experiment.

GROUND GRANULATED BLAST FURNACE SLAG (GGBS): with a Specific gravity of 2.9

Superplasticizer

Superplasticizer conplast SP450 is manufactured by **ASTRA chemicals c**onstructive solutions was used in the present work.

Water

Potable water free from salts is used was used during mixing and curing process.

Figure 1 Straight Steel Fiber

a. mix proportion

Table 1 non-conventional SCC mix proportion

Cement	M-Sand	Coarse aggregate	Water
524.31kg	**887.23kg**	**697.03kg**	**199.24lit**

Table 2 Conventional Mix(control) Design Proportion

Cement	M-Sand	Coarse Aggregate	Water
524.31kg/ m^3	774.57kg/ m^3	809.78kg /m^3	199.24 Lit/ m^3

GGBS = 20% of cement

Steel fiber = 1% of cement

Admixture = 1% of cement

3. Results and Discussion

3.1 Fresh Concrete

To characterize the flow and the deformability properties of SCC mixtures, the standardized slump-flow, U- Box, L- Box and V-funnel tests were performed. Fresh properties of the concrete mixtures are summarized below.

3.1.1 Slump Flow

The slump flow diameters of self-compacting steel fiber concretes mixture was 600 mm, which were determined as the average of four measured diameter of flowed concrete as shown in Fig. 4.1 were produced, in the study; however, the slump flow diameters of plain self-compacting concrete was 765 mm. According to EFNARC, the acceptable limit of diameters falls in the range of 650-800 mm. Test results indicated that the producing self-compacting concrete with addition of steel fiber and according to EFNARC (Table 4.1), can be categorized as SF1, which is appropriate for unreinforced or slightly reinforced concrete structures that are cast from the top with free displacement from the delivery point (e.g. housing slabs) , casting by a pump injection system (e.g. tunnel linings) , sections that are small enough to prevent long horizontal flow (e.g. piles and some deep foundations). It can be noticed that the addition of steel fibers decreased the slump-flow diameter fewer values were recorded when more fibers are added to the concrete.

Fig.2slump flow Source: EFNARC

Table3 slump flow class classes according to EFNARC

Class	Slump flow diameter (mm)
SF1	550–650
SF2	660–750
SF3	760–850

Table 4 Fresh concrete test Acceptance criteria for Self-compacting Concrete

S.no	Method	Unit	Typical range of values	
			minimum	Maximum
1	Slump flow	Mm	650	800
2	L box	h_2/h_1	0.8	1.0
3	V - funnel	Sec	0	12
4	U box	(H2-h1)mm	0	30

3.1.2 L-box

The L-box height ratio by means of H2/H1 ratio was determined to specify the passing ability of the produced SCC. The L-Box test to BS EN 12350-10 is used to evaluate the passing ability of self-compacting concrete to flow through tight obstructions without segregation or blocking. For perfect fluid behavior of self-compact concretes, L-box height ratio value is from 0.8 to 1.0 According to EFNARC (table 4.2) all mixtures satisfy the EFNARC limitation for the given L-box height ratio. The L-box height ratio value for the produced non-conventional SCC and conventional SCC was 0.93 and 0.925 respectively.

3.1.3 U – Box

The U Box test method was performed to measure the filing ability of self-compacting concrete. The U Box difference by a means of h_2-h_1 ratio was determined to specify the passing ability of the produced SCC mix. The U Box value was found to be 20 mm. according to EFNARC the limitation for the given u box test value ranges from 0 to 30mm.based on the reference EFNARC the produced mix satisfies the limited range. Street steel fiber with a length of 30-50 mm was found to be not recommended for passing ability characteristics but according to

(Yaseen Patel, 2017). In this study proves that a fiber length of 30mm had affected the passing characteristic of the mix.

3.1.4 V-funnel

The findings of the V-funnel time test results were in the range of 12.56 seconds for the non-conventional mix and 10.57 seconds for the conventional one. The V-funnel flow time of the produced mix value is higher than what is confirmed in the EFNARC, which is from 6 to 12 seconds. According to the EFNARC conformity criteria for SCC the produced mix can be categorized into class of VF2 (Viscosity classes expressed by V-Funnel time). Has no upper- class limit but with increasing flow time it is more likely to exhibit thixotropic effects, which may be helpful in limiting the formwork pressure or improving segregation resistance.

Table 5 Viscosity Conformity criteria for the properties of SCC

Property	**Criteria**
V-funnel class VF1	≤ 10s
V-funnel class VF2	≥ 7s, ≤ 27s
V-funnel specified as a target value	± 3s

3.2 HARDEN CONCRETE

3.2.1 COMPRESSIVE STRENGTH

The result of compression and splitting tensile test performed on both conventional concrete and SCC cube and a cylindrical specimen is presented below. Each reported result as presented the table was obtained as the average value of three tested specimens. The compressive strength was tested according to IS 516/1995. A cube specimen of 15cm diameter and 15cm height was made, and tested at 7 days, 14 day and 28 days as shown in figure 4. The results of compressive strength for both normal concrete and SCC for all the mixes fall within the acceptable allowance limit for the target compressive strength of 30 N/mm^2 for this study. The non-conventional SCC gets 29.2N/mm^2 compressive strength at 14 days and the concrete specimen does show little improvement after that which was not as expected. The reason behind this might be the full replacement of coarse aggregate by demolished one according to Panda et al (2017). The detailed 28 days result is presented below in figure 4.

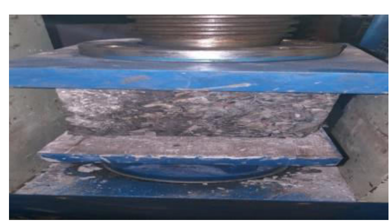

Fig 3 Cube testing

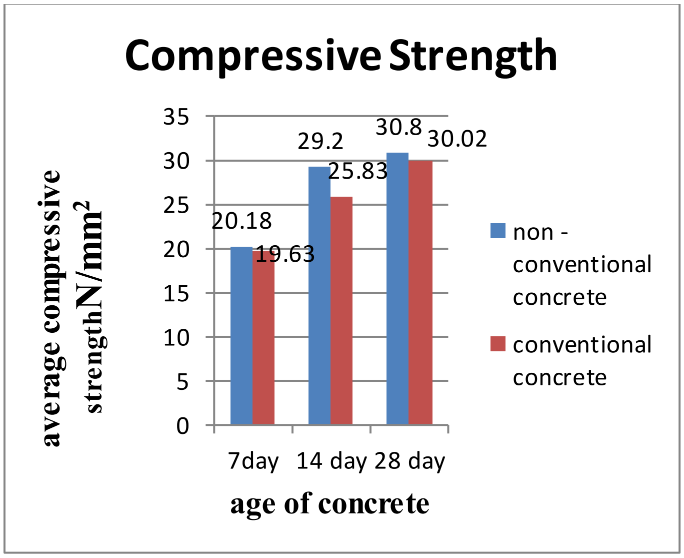

Fig 4 compressive strength

3.2.2 SPLITTING TENSILE STRENGTH

Three-cylinder specimens each of the mix were tested to determine the split tensile strength after 7day, 14day and 28 days using a Compression Testing Machine as shown in figure 4.5. The tests were conducted as per standard specifications. The test results are presented in fig 5

The split tensile strength of the SCC was found to be 8.7% higher than the normal/ conventional concrete. With this increased split, tensile strength means the produced mix is highly homogeneous than the conventional concrete. The increased tensile strength because of the addition of steel fiber was also described by (Yaseen Patel, 2017). Average splitting tensile strength result of the produced mix is shown in the fig. below.

Fig 3 cylinder testing

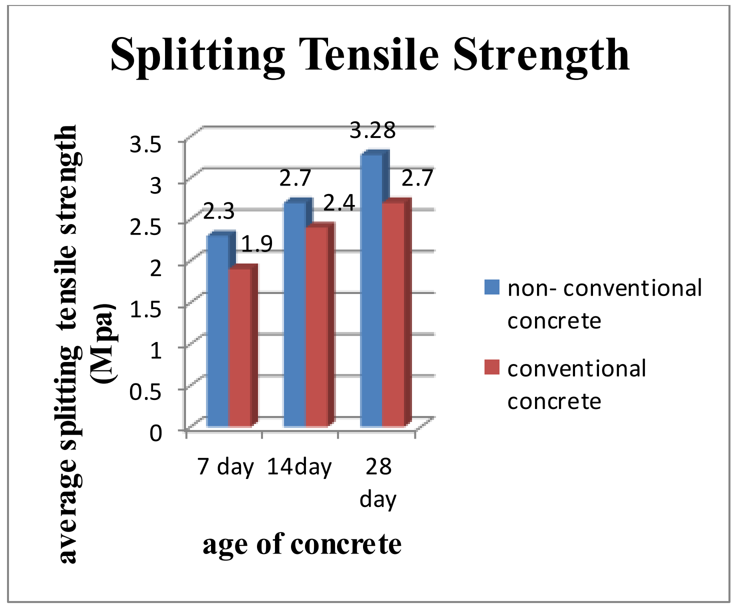

Fig.5 splitting tensile strength test result

3.2.2 Flexural Strength Tests

Prisms of size (100 x100x500mm) were cast and tested for determining Flexural Strength at 7, 14 and 28 days. The modulus of rapture of the produced SCC and control mx is 5 N/mm^2 and 4.5 N/mm^2 respectively. The increase in modulus of rupture of the SCC may be due to the addition of self-compacting concrete. The average modulus of rapture of the control mix and non-conventional mix is presented in fig6 below..

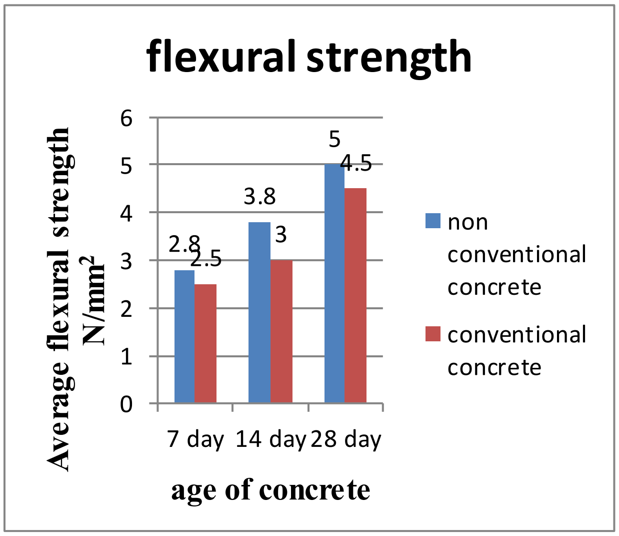

Fig6 Flexural Strength result

3.3 NONDESTRUCTIVE TEST

3.3.1 Rebound Hammer

In this project the Rebound Hammer test was conducted for a convenient and rapid indication of the compressive strength of the concrete, to assess the uniformity of the concrete, to assess the quality of the concrete based on the standard specifications, to relate one concrete element with other in terms of quality. The rebound hammer test was conducted on a prism beam and during the testing time, the length of the beam was dividing into 5 equal points with a distance of 10cm. the test was performed based on IS 13311-1 (1992): the average rebound hammer result becomes 34.5 N/mm^2 & 30.2 N/mm^2 for non-conventional and for the control mix respectively, which explain the quality of concrete is good according to the EFNARC acceptance criteria presented in table 6.

Table6 Quality of Concrete for different values of rebound number

Average Rebound Number	Quality of Concrete
>40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
< 20	Poor concrete
0	Delaminated

3.3.2 Ultrasonic Pulse Velocity (UPV)

The test was used to check the quality of concrete. In this test, the strength and quality of concrete were assessed by measuring the velocity of an ultrasonic pulse passing through a prism concrete specimen formation. In this project the Ultrasonic test was used to evaluate The homogeneity of a material, The presence of voids, cracks or other internal imperfections or defects, Changes in the concrete which may occur with time (i.e. due to the cement hydration) or damage from fire, frost or chemical attack, The strength or modulus of a material, The quality of the concrete in relation to specified standard requirements. The test was conducted in three different transmission methods such as direct, indirect and semi-direct. Ultrasonic pulse velocity detection was performed on a prism beam according to IS 13311-1 (1992): result becomes 4.9.based on the acceptance criteria presented in table 4.8 the concrete quality cane be categorised excellent quality grading. An ultrasonic instrument was used to transmit ultrasonic pulse waves to the prism specimen, and the signals were returned to the pulse wave receiver.

Table 7 Velocity criterion for concrete quality grading

S.No.	Pulse velocity by cross probing (km/sec)	Concrete quality grading
1	Above 4.5	Excellent
2	3.5 to4.5	Good
3	3.0to3.5	Medium
4	Below3.0	Doubtful

4. CONCLUSION AND RECOMMENDATION

CONCLUSION

The following conclusions are drawn from the experimental work on the effect of steel fiber on SCC.

1. The length of the steel fiber affects the flowability and passability property of the mix. To have a mix with an excellent flowability and passability characteristics, the length of the steel fiber should be less than 30mm.
2. The 7 and 28 days flexural strength of self-compacting concrete with street steel fibers is higher than the conventional concrete. The non-conventional concrete with steel fiber shows an improvement in deflection.
3. The split tensile strength of the SCC was found to 8.7% higher than the control/ conventional concrete.
4. Fully replacement of demolished aggregate affects the 28 day compressive strength of SCC with steel fiber. When the age of concrete increases it should get higher strength, but in this case because of the demolished aggregate the mix does not show much improvement as it was expected to get.

REFERENCES

1. Salem G. Nehmea, Roland Laszlob, Abdulkader El Mirc (2017). 'mechanical performance of steel fiber reinforced self-compacting concrete in panels', science direct, Vol.5, pp.57-70.

2. M.M. Kamal, M.A. Safan1, Z.A. Etman1 and M.A. Abd-elbaki (2015). 'Effect of steel fibers on properties of recycled self-compacting concrete in fresh and harden state. , science direct, Vol.6, pp11

3. Kshama Shukla1, Akansha Tiwari2 (2017). 'Self-compacting concrete mix design for

m 30', International Research Journal of Engineering and Technology (IRJET), Vol. 8, pp.4

4. Maralinga, K. Nagamani, Kannan, Mohammed Haneefa, and Bahurudeen (2016). 'Assessment of hardened characteristics of raw fly ash blended self-compacting concrete', Science Direct Vol.8, pp31.

5. EFNARC (European Federation of National Associations Representing for Concrete) (2002) 'Specification and Guidelines for Self-Compacting Concrete'. Vol.3, pp.9

6. Abdulkader El Mira, Salem Georges Nehmea (2015). 'Porosity of self-compacting concrete', science direct, Vol.5, pp.8-145

7. Arabi N.S. Alqadi, Kamal Nasharuddin Bin Mustapha, Sivakumar Naganathan, Qahir N.S. Al-Kadi (2013). 'Development of self-compacting concrete using contrast constant factorial design', Journal of King Saud University – Engineering Sciences, Vol.3, pp.105

8. B.H.V. Pai, M. NandyA. Krishnamoorthy P.K.Sarkar C. Pramukh Ganapathy. (2014). 'Experimental Study on Self-compacting Concrete Containing Industrial BY-Products', European Scientific Journal, Vol.4, pp.10

9. Bal, KC. Panda (2013). 'Properties of self-compacting concrete using recycled coarse aggregate', Procedia Engineering, Vol.5, pp.159

10. Mahmoud Abu Yaman, Metwally Abd Elaty, Mohamed Taman (2017). 'Predicting the ingredients of self-compacting', Alexandria Engineering Journal, Vol.11, pp.523

11. Subahn Ahmed and Arshan Umer (2016) 'studies the Characterization of Self-compacting Concrete,' science direct, Vol.10, pp.807-809.

12. Behnam Vakhshouri, Shami Nejadi(2017) 'Mix design of light-weight self-compacting concrete,' ELSEVIER, Vol. 5,pg10.

13. Ench a. g. (2017). Developing a Commercial Self-Compacting Concrete Without Thermo-mechanical modeling of a high-pressure turbine blad. science direct, Vol.2, pp.45-70

14. Malgorazata pajak, Tomasz Ponikiewski (2017). Experimental investigation on hybrid

steel fibers reinforced',science diret, Vol. 2,pp. 121 – 126

15.Batham Geeta, Bhadauria S. S., Akhtar Saleem (2013). 'A Review: Recent Innovations in SCC', International Journal of Scientific & Engineering Research, Vol. 10, pp.10

16. Bhattacharya, Rajdip Paul and Debashis (2015). 'Self-compacting Concrete: A REVIEW', International Journal of Development Research, Vol. 6, pp.3

17. Magorzata Pajka, (2016). 'Investigation On Flexural Properties of Hybrid Fiber Reinforced Self-Compacting Concrete,Science direct, Vol. 5,PP.6

18. Mutiu. Akinpelu, Samson. Odeyemi, Oladipupo. Olafusi, Fatimah and Z. Muhammed (2017) ,'Evaluation of splitting tensile and compressive strength relationship of self-compacting concrete', Journal of King Saud University – Engineering Sciences, Vol.4, pp.1-7

19. Tomasz ponikiewski,jacek golaszewski(2013) 'the rheological and mechanical properties of high performance self-compacting concrete with high calcium fly ash'. Science direct, Vol.4, pp.30-33

20 Diego Carro lopez, Belen Gonzalez Fonteboa, Fernando Martinez Abella, Iris Gonzalez Taboda,Jorge de Brito andFernando Verela Puga(2017) 'proportioning microstructure and fresh properties of self-compacting concrete with recycled sand' Science direct, Vol. 3,pp.13

21 Ofuyatan, Edeki(2018) 'Dataset on predictive compressive strength model for self-compacting concrete Data in Brief' ELSEVIER, Vol.2, pp.6

22 Paweł Niewiadomski, Damian Stefaniuk, and Jerzy Hoła (2017) 'investigate "Microstructural analysis of self-compacting concrete modified with the addition of nanoparticles'. Science Direct, Vol. 7,pp.8

23 Mahalingam, K. Nagamani, Kannan, Mohammed Haneefa, and Bahurudeen(2016) 'Assessment of hardened characteristics of raw fly ash blended self-compacting concrete'. Science Direct India 2016, Vol. 8, *pp.3.*

24 EFNARC (European Federation of National Associations Representing for Concrete (2002) 'Specification and Guidelines for Self-Compacting Concrete', Vol.4, pp.1-9.

25 Yaseen Patel , Nadeem Pasha, Dr S.K.Mohammed.Azam (2017) 'Effect of Different Types of Steel Fibers on Strength Parameters of Self-Compacting' International Journal of Innovative Research in Science Engineering and Technology, Vol. 4,pp.10

26 Arabi N.S. Alqadi , Kamal Nasharuddin Bin Mustapha , Sivakumar Naganathan , Qahir N.S. Al-Kadi(2013), 'Development of self-compacting concrete using contrast constant factorial design' Journal of King Saud University – Engineering Sciences, Vol. 2,pp.8

27 Metwally A.A. Abd Elaty, Mariam F. Ghazy (2017) 'Fluidity evaluation of fiber reinforced-self compacting concrete based on buoyancy law' HBRC Journal, Vol. 2, pp.11

28 Subahn Ahmed and Arshan Umer (2016) 'Characterization of Self-compacting Concrete' science direct, Vol.4, pp.17

29 Behnam Vakhshouri, Shami Nejadi(2017), 'Mix design of light-weight self-compacting concrete' *ELSEVIER,* Vol. 5,*pp.10*

30 Paratibha Aggarwal , Rafat Siddique and Yogesh Aggarwal(2014) 'Self-Compacting Concrete - Procedure for Mix Design' Leonardo Electronic Journal of Practices and Technologies, Vol. 3,pp.11

31 N. Nalanth, P. Vincent Venkatesan, andM. S. Ravikuma**.** **(**2014**), '**Evaluation of the Fresh and Hardened Properties of Steel Fibre Reinforced Self-Compacting Concrete Using Recycled Aggregates as a Replacement Material', Hindawi Publishing Corporation, Vol.4, pp.7