Comparison of Self Compacted Concrete with Normal Concrete by Using Different Type of Steel Fibres

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Abstract

Self-compacting concrete (SCC) offers several economic and technical benefits; the use of steel fibres extends its possibilities. Therefore, a research work was performed to compare the mechanical properties of SCC and NCC with and without fibres with different aspect ratio. In this study aspect ratio and types of steel fibres are the variables and volume fraction of fibres is kept constant. A comparison is made between NCC and SCC; in SCC, a marginal improvement in all properties is observed. Results indicate that with optimum volume fraction i.e. 2.5%, concrete with HK 80 type steel fibres giving better performance in terms of strength compare to all other type of fibres and both type of concrete.

1. Introduction

Concrete is being used over 150 years. It is mixed, placed into form and then compacted. It is essential to compact the concrete so that it should completely cover the reinforcement and fill all the space in the form for meeting strength and durability requirement. The air entrained in concrete during mixing has to be completely expelled out for getting uniform dense mass. If compaction is not complete, it will lead to loss in strength and also affect performance of the structure. The compaction becomes difficult when percentage of reinforcement is high which does not allow insertion of vibrator at some places. Also the vibration increases noise level in and around construction site. Self-compacting concrete was therefore developed to overcome the problems mentioned above.

Self compacting concrete is defined as a concrete which is capable of self consolidating without any external efforts like vibration, floating, poking etc. The mix is therefore required to have ability of passing, ability of filling and ability of being stable. Concrete is heterogeneous material and the ingredients having various specific gravity values and hence it is difficult to keep them in cohesive form. This is especially true when the consistency is too high. The material having higher specific gravity would like to settle down which makes the mix no more a concrete and it becomes system of sediment layers of concrete ingredients. To overcome this, one can add more amounts of fines and use super-plasticizers. Superplasticisers reduce water demand and at the same time increase fluidity. However, there is chance of bleeding and mix may become sticky. To overcome this problem viscosity-modifying agent (VMA) is required to be added. VMA is a pseudo plastic agent, which thickens the water and keeps the mixture under suspension, providing segregation resistance. The principle of sedimentation velocity is inversely proportional to the viscosity of the floating medium is applied in the system. The VMA offers high shear resistance to the ingredients at rest and less shear resistance at movement and this property keeps the coarser particles under suspension in self-compacting concrete.

The SCC as any other type of concrete has a significantly lower tensile and shear strength in comparison to the compression strength and therefore, it needs to be reinforced. Fibre reinforced concrete is an alternative to traditional stirrups reinforcement leading to lowered labour costs. To be able to access mechanical properties of the fibre reinforced concrete, knowledge of final spread and directions of fibres is necessary.

Fly ash has high pozzolanic reactivity and low price as compared to silica fume and fly ash as it is a manufactured product. It reduces free drying shrinkage and restrains the shrinkage cracking width. It also helps in enhancing the compressive strength and durability of concrete.

The objective of this study is to compare the mechanical properties like compressive strength, split tensile strength and flexural strength of self compacted concrete (SCC) with normal compacted concrete with and without different types of fibre having different aspect ratio in addition to the 30% fly ash by the weight of cement.

2. Methodology

The present research work is experimental and requires preliminary investigations in a methodological manner.

A. Cement

The cement used in this experimental work is “Ultratech 53 grade Ordinary Portland Cement”. All properties of cement are tested by referring IS 12269 - 1987 Specification for 53 Grade Ordinary Portland cement. The specific gravity of the cement was 3.15. The initial and final setting times were found as 74minutes and 385 minutes respectively. Standard consistency of cement was 30%.

B. Fine aggregate

Locally available Pravra river sand passed through 4.75mm IS sieve was used. The specific gravity 2.75 and fineness modulus of 2.806 were used as fine aggregate. The loose and compacted bulk density values of sand are 1600 and 1688 kg/m3 respectively, the water absorption of 1.1%.

C. Coarse aggregate

Crushed granite aggregate available from local sources has been used. The coarse aggregates with a maximum size of 12mm having the specific gravity value of 2.70 and fineness modulus of 6.013 were used as coarse aggregate. The loose and compacted bulk density values of coarse aggregates are 1437 and 1526 kg/m3 respectively, the water absorption of 0.4%.

D. Fly ash

Fly Ash (FLA) is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nasik. It is available in 30Kg bags, colour of which is light gray under the product name "Pozzocrete 60". There are no standard performance tests and procedures specified for assessing the suitability of MAs to FAC. The Fly ash produced by the company satisfies all the requirements of the IS 3812: 1981, BS 3892: Part I: 1997.

E. Chemical admixtures

A polycarboxylic type superplasticizer (SP) was used in all concrete mixtures. In addition to the SP, a viscosity modifying admixture (VMA) was also used. The properties of both admixtures, as provided by their manufacturers, are shown in Table I.

Table I: Properties of chemical admixture

Chemical admixture	Dosage	Main component
SP	1%	Polycarboxylic ether
VMA	0.5%	Aqueous dispersion of microscopic silica

F. Fibres

The main variables used in the study are three different types of steel fibres i.e. hook ended steel fibre (HK), crimped type steel fibre(CR), straight type steel fibre(SF) with two values of aspect ratios (80 and 50). 2.5 % constant dosages of fibres are used by weight of cement.

G. Mix Design for M-30 Grade Conventional Concrete

Cement: Fly Ash: Sand : C. A. : Water
1 : 0.3 : 1.06 : 2.00 : 0.38

H. Mix Design for M-30 Grade Self Compacting Concrete

Cement: Fly Ash: Sand : C.A. : Water
1 : 0.3 : 1.814 : 1.48 : 0.408

I. Testing on Fresh Concrete:

Test conducted for verifying the flow characteristics of fresh concrete are
Slump flow
V-Funnel
L Box
J Ring

Table II: Requirements of Workability Tests

Sr. No.	Method	Unit	Typical Ranges of Values	
			Min.	Max.
01.	Slump flow by Abrams cone	mm	650	800
02.	T50 cm Slump flow	sec	2	5
03.	J-ring	mm	0	10
04.	V-funnel	sec	8	12
05.	V-funnel at T5 minutes	sec	0	+3
06.	L-box	H_2/H_1	0.8	1.0

The Table II show requirements of workability tests are to be fulfilled at the time of placing of concrete.

3. RESULT AND DISCUSSIONS

To satisfy flow requirement of SCC very first step is to determine the optimum dose of superplastisizer.

A. Trials for Optimum Dose of Superplastisizer

Table III: Trials for Optimum Dose of Superplastisizer

Dose of Superplastisizer	Slump Cone Test		V Funnel Test
	Horizontal Slump (mm)	T50 - Time (Sec.)	Flow Time (Sec.)
1%	715	2.5	8.2
2%	790	2.1	7.8
3%	815	1.9	7.3
4%	860	1.7	6.9
5%	890	1.2	6.6

As per guidelines of EFNARC, for slump flow by Abrams cone typical range of value is 650 to 800 mm, for T50 cm slump flow, range is 2 to 5 Sec and for v-funnel, range is 8 to 12 Sec. Hence from above observation the dose of superplastisizer is taken as 1% of volume of cement which satisfies the requirement of flow for SCC.

B. Fresh Concrete Test Results of Self Compacting Concrete

Table IV: Slump Cone Test by Abrams Cone

Sr. No.	Type of Steel Fibre	Aspect Ratio	Slump Flow by Abrams Cone (mm)	
			Horizontal Slump (mm)	T50 - Time (Sec.)
1.	0	0	715	2.89
2.	HK 80/60	80	660	4.90
3.	HK 50/30	50	690	4.30
4.	SF 80/130	80	670	5.00
5.	SF 50/80	50	700	4.70
6.	CR 50/30	50	705	4.10

Table V: V-Funnel Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	V-Funnel Test	
			Flow Time (Sec.)	Flow time at T5minutes (Sec.)
1.	0	0	7.2	9.02
2.	HK 80/60	80	12.2	15.56
3.	HK 50/30	50	10.3	12.34
4.	SF 80/130	80	12.59	16.21
5.	SF 50/80	50	11.23	13.39
6.	CR 50/30	50	8.1	10.5

Table VI: L-Box Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	L Box Test		
			T20 Time (Sec)	T40 Time (Sec)	H_2/H_1 Ratio
1.	0	0	0.9	3.1	0.948
2.	HK 80/60	80	2.05	4.6	0.821
3.	HK 50/30	50	1.37	3.47	0.890
4.	SF 80/130	80	1.89	3.92	0.858
5.	SF 50/80	50	1.4	3.72	0.890
6.	CR 50/30	50	1.1	3.26	0.898

Table VII: U Box Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	U Box Test		
			H_1 (mm)	H_2 (mm)	H_2-H_1 (mm)
1.	0	0	310	300	10
2.	HK 80/60	80	490	463	27
3.	HK 50/30	50	335	322	13
4.	SF 80/130	80	520	490	30
5.	SF 50/80	50	342	316	26
6.	CR 50/30	50	325	313	12

Table VIII: J Ring Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	J Ring Test		
			H_1 (mm)	H_2 (mm)	H_1-H_2 (mm)
1.	0	0	10	8	2
2.	HK 80/60	80	13	6	7
3.	HK 50/30	50	10	7	3
4.	SF 80/130	80	12	6	6
5.	SF 50/80	50	11	7	4
6.	CR 50/30	50	10	6	4

From the results of above tests carried out for the flow of fibre concrete, it shows that the SF 80/130 (aspect ratio=80) not satisfying the requirement of V-funnel test. Also all types of mixes are not satisfying the requirement of V-funnel test at T5 min.

C. Hardened Concrete Test Results for Normal Concrete and Self Compacted Concrete:

a. Test Results for Compression Strength

Table IX: Compression Test of Cubes of Normal Concrete

Sr. No.	Type of Steel Fibre	Avg. Compressive Strength (N/ mm^2)		
		3days	7days	28days
1.	0	17.07	23.53	32.20
2.	HK 80/60	22.00	28.47	44.96
3.	HK 50/30	19.50	24.13	43.64
4.	SF 80/130	19.13	26.44	40.60
5.	SF 50/80	17.10	23.00	35.51
6.	CR 50/30	17.25	24.15	41.80

Table X: Compression Test of Cubes of Self Compacted Concrete

Sr. No.	Type of Steel Fibre	Avg. Compressive Strength (N/ mm^2)		
		3days	7days	28days
1.	0	17.98	23.99	32.50
2.	HK 80/60	22.60	29.70	46.00
3.	HK 50/30	19.55	24.66	43.96
4.	SF 80/130	19.91	27.02	40.60
5.	SF 50/80	17.62	23.11	36.62
6.	CR 50/30	17.68	24.57	42.20

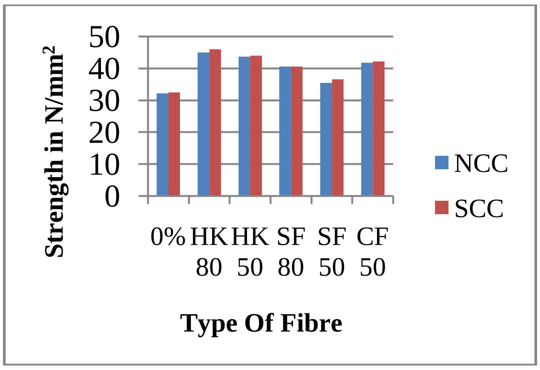

Fig. (a): Comparative Chart of Compressive Strength at the End of 28 days

From fig. (a), the strength of HK 80 is higher than all types of fibre. The compressive strength of all type of fibre mixes is higher than the strength of plain concrete mix. For SCC, maximum percentage increase in the strength 29.34% and for NCC, maximum percentage increase in the strength 28.38%. For the same aspect ratio and different types of fibre, HK 80 gives highest strength and SF 80 giving lowest strength. In all cases, the strength of SCC is slightly higher than NCC.

b. Test Results for Split Tensile Strength

Table XI: Split Tensile Strength on Cylinder of Normal Concrete at the End of 28 Days

Sr. No.	Type of Steel Fibre	Avg. Split Tensile Strength, $0.4\sqrt{fck}$ (N/ mm^2)
1.	0	3.45
2.	HK 80/60	7.09
3.	HK 50/30	6.00
4.	SF 80/130	5.10
5.	SF 50/80	4.03
6.	CR 50/30	4.45

Table XI : Split Tensile Strength on Cylinder of Self Compacted Concrete at the End of 28 Days

Sr. No.	Type of Steel Fibre	Avg. Split Tensile Strength, $0.4\sqrt{fck}$ (N/ mm^2)
1.	0	3.82
2.	HK 80/60	7.59
3.	HK 50/30	6.85
4.	SF 80/130	5.58
5.	SF 50/80	4.63
6.	CR 50/30	4.93

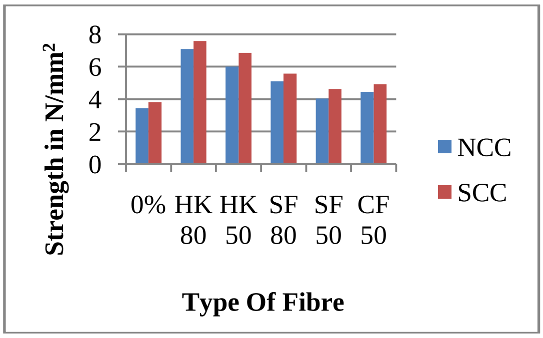

Fig. (b): Comparative Chart of Split Tensile Strength at the End of 28 Days

From Fig. (b), for both NCC and SCC, the results are obvious that the tensile strength of fibre concrete is higher than the concrete without fibre. In this case also HK 80 fibre giving higher strength as compare to the strength of concrete mix with other type of fibres. For SCC and NCC, maximum percentage increase in the strength is 49.67% and 51.33% respectively. While comparing the aspect ratio of same type of fibres; it shows that greater the aspect ratio higher will be the strength. For the same aspect ratio and different types of fibres HK 50 gives highest strength than CF 50 and SF 50. Also NCC has low tensile strength than SCC for all types of fibre.

c. Test Results for Flexural Strength

Table XII: Flexural Strength on Beam of Normal Concrete at the End of 28 Days

Sr. No.	Type of Steel Fibre	Avg. Flexural Strength, $0.7\sqrt{fck}$ (N/ mm^2)
1.	0	4.93
2.	HK 80/60	6.23
3.	HK 50/30	5.73
4.	SF 80/130	5.20
5.	SF 50/80	4.96
6.	CR 50/30	5.00

Table XIII: Flexural Strength on Beam of Self Compacted Concrete at the End of 28 Days

Sr. No.	Type of Steel Fibre	Avg. Flexural Strength, $0.7\sqrt{fck}$ (N/ mm2)
1.	0	4.98
2.	HK 80/60	6.92
3.	HK 50/30	5.97
4.	SF 80/130	5.58
5.	SF 50/80	5.18
6.	CR 50/30	5.63

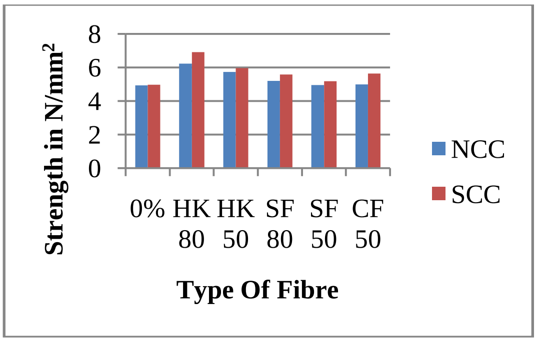

Fig. (c): Comparative Graph of Flexural Strength at the End of 28 Days

It can be observed from fig. (c), for NCC and SCC, flexural strength of plain mix is having lower strength than the concrete with fibre. The flexural strength of concrete HK 80 is having highest strength as compare to all other types of fibre. Flexural strength of SF for both aspect ratios is low as compare to other two types of fibre. Flexural strength is reduced in the same type of fibre when aspect ratio is lowered. For same aspect ratio and different types of fibre HK 80 gives higher strength. Also flexural strength of SCC is little higher than NCC for all types of fibre. For SCC and NCC, maximum percentage increase in the strength is 28.03% and 20.86% respectively.

4. CONCLUSION

The present investigation has shown that it is possible to design a steel fibre reinforced self-compacting concrete incorporating fly ash. The SFRSCCs have a slump flow in the range of 660-715 mm, a flow time ranging from 2.89 to 5 sec, V-funnel flow in the ranging from 7.2 to 12.59 sec and 9.02 to 16.21 sec at T5minutes, a L-Box ratio ranging from 0.821 to 0.948, U-Box test value ranging from 10 to 30 mm and a J-Ring test value ranging from 2 to 7 mm. It was observed that it is possible to achieve self compaction with different types of steel fibre with different aspect ratio.

Although results obtained from all of the mixes satisfy the lower and upper limits suggested by EFNARC (The European Federation of Specialist Construction Chemicals and Concrete Systems), all mixes had good flow ability and possessed self-compaction characteristics.

The SCC developed compressive strengths ranging from 17.98 to 22.60 Mpa at the end of 3 days, from 23.99 to 29.70 Mpa at the end of 7 days and from 32.50 to 46.00 Mpa, at the end of 28 days and NCC developed compressive strengths ranging from 17.07 to 22.00 Mpa at the end of 3 days, from 23.53 to 28.47 Mpa at the end of 7 days and from 32.20 to 44.96 Mpa, at the end of 28 days.

The SCC developed split tensile strengths ranging from3.82 to7.59 Mpa at the end of 28 days and the NCC developed split tensile strengths ranging from3.45 to7.09 Mpa at the end of 28 days.

The SCC developed flexural strengths ranging from 4.98 to 6.92 Mpa at the end of 28 days and the NCC developed flexural strengths ranging from 4.93 to 6.23 Mpa at the end of 28 days.

Also it is observed that for same aspect ratio the hook ended fibre showing pronounce improvement in all properties of concrete as compare crimped & straight fibre. There is decrease in the strength with decrease in aspect ratio of same fibre type. The straight fibres having less strength as compared with hook end and crimped fibres because of their shape. Due to the shape, it is obvious that the hook end and crimped fibre having good bond and anchorage in the matrix resulting in more strength.

In all above cases, the strength of SCC is higher than NCC because of addition of superplastisizer in SCC to maintain flow ability gives proper compaction of concrete which enhance all properties of SCC. Also the addition of fly ash in SCC improves microstructure of concrete that also helpful to enhance all mechanical properties with the durability of concrete. Use of fly ash reduces the consumption of cement due to which CO2 emulsion in manufacturing process is also reduced. By adding fly ash the disposal problem is neglected which reduces air pollution and land pollution.

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