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Appraisal of strength of self compacted concrete with variable size of steel fibre

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ABSTRACT

The development of self-compacting concrete (SCC) was a significant step towards effectiveness at building sites, realistically producing prefabricated concrete rudiments, improved working conditions and better quality and emergence of concrete structures. By addition of fibres to SCC, bar reinforcement can be replaced and the performance of concrete structures improved. Self-compacting fibre reinforced concrete (SCFRC) combines the benefits of SCC in the fresh state and an enhanced performance of fibre reinforced concrete in the hardened state. With the special characteristics of SCFRC new fields of application can be explored. The objective of the study is to determine and do the comparative study of the properties of concrete containing no fibres and concrete with fibres, as well as the comparison on the effects of different type and aspect ratio of fibres to the self compacted concrete. This investigation was carried out using several tests, which included workability tests of SCC, compressive test, indirect tensile test and flexural test.

Introduction

Self compacting concrete (SCC) is a concrete which flows to a virtually uniform level under the influence of gravity without segregation, during which it de-aerates and completely fills the formwork and the spaces between the reinforcement. It is used to facilitate and ensure proper filling and good structural performance of restricted areas and heavily reinforced structural members. SCC was developed in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions. SCC can also provide a better working environment by eliminating the vibration noise. There are many advantages of using SCC, especially when the material cost is minimized. These include reducing the construction time and labor cost, eliminating the need for vibration, reducing the noise pollution, improving the filling capacity of highly congested structural members.

Such concrete requires a high slump that can easily be achieved by super plasticizer addition to a concrete mixture. Also to enhance stability, a viscosity-modifying admixture is incorporated. However chemical admixtures are expensive, and their use may increase the materials cost. Savings in labour cost might offset the increased cost, but the use of mineral admixtures such as fly ash could increase the slump of the concrete mixture without increasing its cost.

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is only approximately one tenth of its compressive strength. As a result for these characteristics, concrete member could not support such loads and stresses that usually take place, majority on concrete beams and slabs. Historically, concrete member reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. Furthermore, steel reinforcement adopted to overcome high potentially tensile stresses and shear stresses at critical location in concrete member. The additional of steel reinforcement significantly increase the strength of concrete, but to produce concrete with homogenous tensile properties, the development of micro cracks is a must to suppress. The introduction of fibres was brought in as a solution to develop concrete in view of enhancing its flexural and tensile strength, which are a new form of binder that could combine Portland cement in the bonding with cement matrices. Fibres are most generally discontinuous, randomly distributed throughout the cements matrices. The term of 'Fibre reinforced self compacted concrete' (FRSCC) is made up with cement, various sizes of aggregates, which incorporate with discrete, discontinuous fibre.

The objective of this study is to assess the effects of fly ash replacement on the fresh and hardened properties of SCCs incorporating steel fibers. Even though, the suitability of using such a fly ash needs much detailed investigations, this study covers some fresh and hardened properties of mixtures. In addition to the fly ash; steel fibers were used at different aspect ratio (80,50) with 2.5% volume fraction in making the concrete. Total mass of cementations materials is 498.3 kg/m3, in which 30% of cement is replaced by the fly ash and the water powder ratio, was constant at 0.408. Grade of concrete used was M30.The commercially available chemical admixtures used in this study included a viscosity modifying admixture (VMA) and a polycarboxylic based superplasticizer (SP).

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

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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. Mixture proportion

Cement : Fly Ash: Sand : Coarse Aggregate : Water
1 : 0.3 :1.814: 1.48 : 0.408

H. Testing on Fresh Concrete

Test conducted for verifying the flow characteristics of fresh concrete are

1. Slump flow
2. V-Funnel
3. L Box
4. U Box.
5. J Ring

Deformability and viscosity of fresh concrete is evaluated through the measurement of slump flow time and diameter, J-Ring test, L-Box ratio test, U-Box test and V-funnel flow time. The slump flow is used to assess the horizontal free flow (deformability) of SCC in the absence of obstructions. The procedure for the slump flow test and the commonly used slump test are almost identical. In the slump test, the change in height between the cone and the spread concrete is measured, whereas in the slump flow test the diameter of the spread is determined as the slump flow diameter (D). According to Specification and Guidelines for SCC prepared by EFNARC (European Federation of National Trade Associations), a slump flow diameter ranging from 650 to 800 mm can be accepted for SCC. In the slump flow test concrete's ability to flow and its segregation resistance can also be measured. To measure these properties, the time it takes for the concrete to reach a 50-cm spread circle and any segregation border between the aggregates and mortar around the edge of spread are recorded. EFNARC suggests a slump flow time (t50cm) of 2-5s for a satisfactory SCC. In addition to the slump flow test, J-Ring test, L-Box test, U-Box test and V-funnel test, is also performed to assess the flow ability, passing ability and stability of the SCC. The L-box ratio was in the range of 0.80-1.0, the J-ring test values were in the range of 0-10mm. The V-funnel is filled completely with concrete and the bottom outlet is opened, allowing the concrete to flow. The V-funnel flow time is the elapsed time in seconds between the opening of the bottom outlet and the time when the light becomes visible from the bottom, when observed from the top. Good flowable and stable concrete would consume short time to flow out. According to EFNARC, time ranging from 6 to 12 sec is considered adequate for a SCC.

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 II: 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 III: 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 IV: 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 V: L-Box Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	L Box Test		
			T20 Time (Sec)	T40 Time (Sec)	H2/H1 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 VI: U Box Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	U Box Test		
			H1 (mm)	H2 (mm)	H2-H1 (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 VII: J Ring Test

Sr. No.	Type of Steel Fibre	Aspect Ratio	J Ring Test		
			H1 (mm)	H2 (mm)	H1-H2 (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 Self Compacted Concrete:

Table VII: Compression Test of Cubes of SCC at the End of 28 Days

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

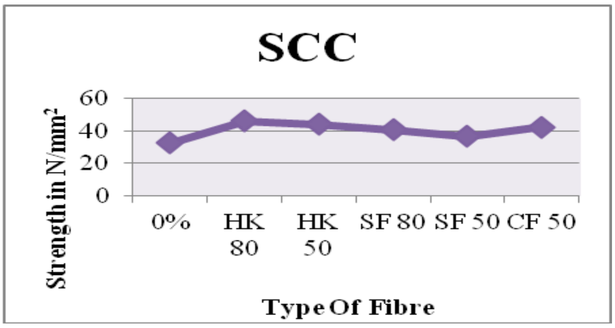

Fig.(a): Graph of Compressive Strength at the End of 28 days

From fig. (a), the strength of HK 80 is higher than all types of fibre. For SCC, maximum percentage increase in the strength 29.34% .For the same aspect ratio and different types of fibre, HK 80 gives highest strength and SF 80 giving lowest strength.

Table VIII: Split Tensile Strength on Cylinder of SCC 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

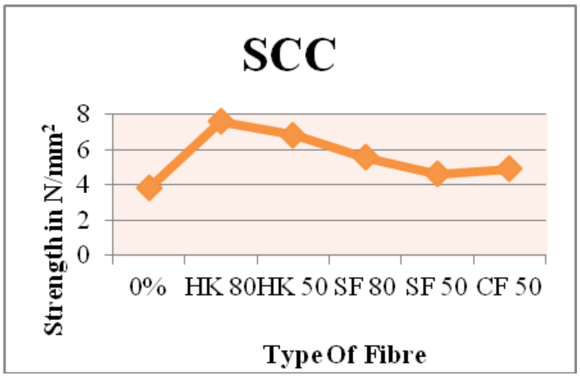

Fig. (b): Graph of Split Tensile Strength at the End of 28 Days

From fig. (b), for 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 maximum percentage increase in the strength is 49.67%. 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.

Table IX: Flexural Strength on Beam of SCC at the End of 28 Days

Sr. No.	Type of Steel Fibre	Avg. Flexural Strength, $0.7\sqrt{fck}$ (N/mm^2)
1.	0	4.98
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

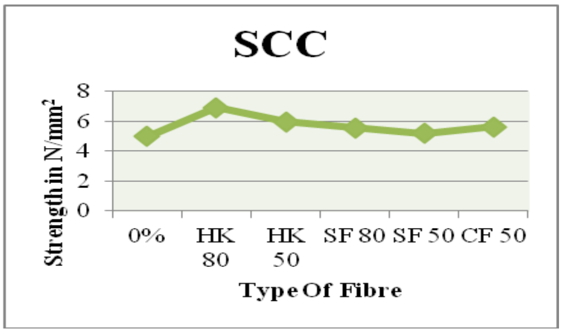

Fig. (c): Graph of Flexural Strength at the End of 28 Days

It can be observed from fig. (c), for 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. For SCC, maximum percentage increase in the strength is 28.03%.

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 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.The SCC developed split tensile strengths ranging from3.82 to7.59 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. 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. 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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