SCC – AN ALTERNATIVE CONCRETE FOR REHABILITATION OF STRUCTURES

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ABSTRACT
With advancing technologies in the construction industry, it is a very much correct time to address for advancement in the materials also. Many newer materials as an alternative to conventional practices are introduced, and many of it is also accepted for usage. Different constituents having different properties, however, when composed together the resultant is an entirely unique one as concrete. Since around the period of 1900, the cement was invented, and later the use of concrete became widespread. After about a century, among various uses of concrete, a concept of self-compacting concrete is emerging since past a few years. The nations of Japan and USA has standardised the practice of SCC whereas India is yet lacking behind for the publication of a standard for manufacturing and practising with it. Current research work is an attempt to check for application of the SCC as an alternative concrete in the structural rehabilitation work. Mix design for M_{55} Grade was carried out after understanding properties of constituting materials along with admixtures. Tests were performed for fresh concrete and hardened concrete. It was found that replacement of cement content up to 25% shows legitimate results for the use of SCC in place of conventional concrete. However, it costs about INR 150/- higher. Apart from cost, the SCC saves time and efforts as resources and do not need any repairing post-casting. The compressive strength results show at par with that of desired designed values.
Keywords: Concrete, Innovation concrete, SCC, Self-compaction, Structural rehabilitation,

1. INTRODUCTION

Concrete's widely usage made this subject prime for continuous research and development for the betterment of construction for engineers. Over the years many research conducted and development has made which resulted in different types of concrete like Pervious concrete, Polymer concrete, Microbial concrete, Nano concrete.

The growth in using concrete has started since past many years, but still, there is a lot of scope for the research and development in concrete. Mostly used conventional concrete has some difficulties in placing and compaction. Which directed the way to study in a range of Self Compacting Concrete (SCC).

The SCC is an innovative concrete that does not require vibration for full compaction of concrete at the time of placing. Concrete that is able to consolidate under its own weight and have a high degree of fluidity is known as Self Compacting Concrete (SCC). It is understood that fluid nature of this concrete allows it for placing in severe conditions and most useful for sections having congested reinforcement.

A major advantage of this method is that SCC technology offers the opportunity to minimise or eliminate concrete placement problems in severe conditions. Construction and placing become faster & easier. It removes the need for vibration and reduces the noise pollution. It's widely acceptance overt the world made India work on this subject for word class structures.

This research work consists of different stages of SCC making, salient features of SCC, Selection of raw material to meet the desired requirement and to produce concrete in the way of environmentally friendly, overall economic, safe structure.

2. TESTING OF MATERIALS

Selection of raw material is crucial in the composition of SCC as compared conventional concrete. Raw material should be consistent with its properties. If raw material changes its properties, it may improve the properties and performance of SCC with massive changes. There is test requirement given for raw material like cement, aggregates, water and so on in various IS codes.

The test run in the current research is carried out as per the provisions of relevant IS codes. All necessary precautions were taken, and procedures were followed as recommended by these codes. Following were the results obtained after the testing of coarse and fine aggregates.

Table 1 Aggregates used for specimen concrete

№	Type of test	Sieve size	20 mm	10 mm	Sand
1	Gradation (% passing through IS sieve)	40 mm	100	-	-
		20 mm	92.6	-	-
		12.5 mm	-	100	-
		10 mm	5.4	87.5	100
		4.75 mm	0.3	4.9	94.5
		2.36 mm	-	0.6	87.6
		1.18 mm	-	-	74.6
		600 microns	-	-	44.8
		300 microns	-	-	12.7
		150 microns	-	-	1.3
2	Fineness modulus		-	-	2.85
3	Impact value test (%)		9.87	11.2	-
4	Crushing value test (%)		13.4	15.3	-
5	Flakiness Index (%)		11.9	13.8	-
6	Elongation Index (%)		12.7	14.6	-
7	Specific Gravity		2.83	2.83	2.66
8	Water Absorption (%)		1.1	1.1	1.25
9	Silt Content (%)		-	-	2.8

As per above test reports, the aggregates are confirming the requirements of IS codes and shall be used as constituents of SCC. It is anticipated that these constituents should not be creating any properties up on composition that may generate harmful effects for the SCC.

Testing of Cement

For casting of the self-compacting concrete, the binding material of cement used was of make 'UltraTech OPC 53 Grade' without any additional pozzolana materials like fly-ash or so. Below table illustrates the results obtained by performing various tests on the cement samples.

Table 2 Cement testing details

№	Type of tests	Test Results obtained		
1	Fineness of Cement (%)	4		
2	Standard Consistency	28.5		
3	Initial setting time (Minutes)	92		
4	Final setting time (Minutes)	157		
5	Compressive strength			
5a	3 days (in kN/mm^2)	29.65	28.99	28.31
5b	7 days (in kN/mm^2)	38.45	40.26	39.61
5c	28 days (in kN/mm^2)	57.98	62.42	59.82

Testing of Water

Water is very critical for concrete, and it should be confirming to IS 456 requirements. The water to be used for the composition of the SCC was tested and the results were obtained as shown in the table below.

Table 3 Water testing results

№	Type of test	Test Results
1	pH value	7.60
2	Organic compound (Mg/l)	Not detected
3	Inorganic compound (in ppm)	486.40
4	Sulphate as SO_4 (in ppm)	41.56
5	Chlorides as Cl (in ppm)	38.99
5a	Suspended matter (in ppm)	20.60

Testing of Mineral Admixture

Fly ash is used as binder/cementitious material for SCC. Fly ash is the waste generated from combustion of coal in power generation plants. Fly ash is very cheap and material which can improve the so many properties of Concrete.

Testing of Chemical Admixture

It is specially designed, or any establish product can be used from the manufacturer. Its main aim is to reduce water content and maintain good cohesive concrete without segregation and bleeding.

Now once the material is selected and SCC mix design started.

3. DESIGN OF SELF COMPACTING CONCRETE (LAB-TRIAL MIX)

The design strength of the self-compacting concrete was performed assuming the grade to be of M_{55}. Four different compositions were prepared and designed. These designs were with the replacement of cement for 20%, 25%, 30% and 35% with fly-ash obtained from the Wanakbori thermal power plant. Aggregates were of Basalt and obtained from Chikhli based stone crushing site. Sand used was obtained from River Narmada. The content of the Admixture – 1 (Chryso fluid Optima 100, Manufacturer: SWC Limited, India) and Admixture – 2 (Chryso fluid Premia K640, Manufacturer: SWC Limited, India) was kept uniform for all the mixes. Only the cement content was replaced by the fly-ash to obtain a control blend. The design mix was obtained for a concrete of 600 kg and applied for weight corrections for water absorption, and moisture correction and converted to the desired weight for laboratory trials. The following table shows the important design parameters set for each composition of M_{55} grade concrete with variation in replacement of fly ash contents.

Table 4 Laboratory trial weight for concrete design mixes

20% cement replacement by fly-ash	**30% cement replacement by fly-ash**
OP Cement – 14.400 kg Fly-ash – 3.600 kg Water – 5.711 kg Admixture 1 –0.126 kg Admixture 2 –0.005 kg 20 mm aggregates – 6.656 kg 10 mm aggregates – 19.948 kg R. Sand – 23.827 kg Total weight of materials – 74.268 kg	OP Cement – 12.600 kg Fly-ash – 5.400 kg Water – 5.701 kg Admixture 1 –0.126 kg Admixture 2 –0.005 kg 20 mm aggregates – 6.569 kg 10 mm aggregates – 19.687 kg R. Sand – 23.515 kg Total weight of materials – 73.598 kg
25% cement replacement by fly-ash	**35% cement replacement by fly-ash**
OP Cement – 13.500 kg Fly-ash – 4.500 kg Water – 5.706 kg Admixture 1 –0.126 kg Admixture 2 –0.005 kg 20 mm aggregates – 6.613 kg 10 mm aggregates – 19.818 kg R. Sand – 23.671 kg Total weight of materials – 73.933 kg	OP Cement – 11.700 kg Fly-ash – 6.300 kg Water – 5.696 kg Admixture 1 –0.126 kg Admixture 2 –0.005 kg 20 mm aggregates – 6.525 kg 10 mm aggregates – 19.556 kg R. Sand – 23.359 kg Total weight of materials – 73.262 kg

4. COMPARISON OF SCC WITH CONVENTIONAL CONCRETE

An exercise was performed for obtaining the cost of SCC and compare the same with conventional concrete through rate analysis. It was identified that the SCC is costlier than the conventional concrete. It may be a reason for users in India are not acquainted of SCC and may hesitate to choose the SCC concept in the RCC structures. Rate of SCC – Rate of Conventional concrete = INR 3898.22 – INR 3742.17 = INR 156.05 Per Cu.mt. is the difference on the higher side of cost of the SCC.

Table 5 Rate analysis of SCC

№	**Material**	**Weight/Cu.mt.**	**The rate of Material/ Cu.mt.**	**Amount (INR)**
1	Cement	450	4.50	2,025.00
2	Fly ash	150	2.10	315.00
3	Water	165	0.01	1.65
4	Admixture 1- Chryso fluid optima 100	4.19	115.00	481.85
5	Admixture 2- Chryso fluid premia K640	0.77	122.00	93.94
6	20 mm	226	0.58	131.08
7	10 mm	677	0.48	321.58
8	Sand	815	0.65	528.12
Totals		**2487.96**	**245.31**	**3,898.22**

Table 6 Rate analysis of Conventional concrete

№	Name of Material	Weight/Cu.mt.	The rate of Material/Cu.mt.	Amount (INR)
1	Cement	440	4.50	1,980.00
2	Fly ash	120	2.10	252.00
3	Water	165	0.01	1.65
4	Admixture 1- Chyso fluid optima 100	4.19	115.00	481.85
5	20 mm	563	0.58	326.54
6	10 mm	460.35	0.48	218.67
7	Sand	743	0.65	481.46
Totals		**2495.54**	**123.31**	**3,742.17**

There are several other points stands valid for consideration against the overall cost. SCC consume 1/3 of time as compared to conventional concrete, mean very fast production and time-saving. 5 times more manpower, 5 times more cost of men power. Not a single vibrator required for SCC, so now wear and tear to segment moulds and reduces accessory cost like vibrators. Energy saving as compared to conventional concrete. As per quality perspective, there is no doubt in choosing SCC concrete because SCC gives smooth concrete finished as shown in Figure below. Almost Nil on repairing work is required for spending as the finished product is good.

Figure 1 Concrete segment surface finish with conventional concrete

5. EXPERIMENTS AND RESULTS

The tests were performed for fresh as well as hardened concrete. It was identified about the self-compacting concrete to have three identical properties – filling ability, passing ability and higher resistance towards segregation of constituent materials. These properties assign a value to the concrete for deforming excellently and pass through the reinforcement without blocking. To measure these properties the tests conducted on the fresh concrete that consists of Flow ability test, V-funnel test, and L-Box test. To measure the flow ability of fresh concrete, Flow-cone and table were used. V-funnel test was used to measure the consistency of the concrete. The time was measured for concrete to pass through the apparatus. The L-box test performed the ability of compaction of the fresh concrete. The height of concrete was measured at both ends of the L-box. The tests were performed for three-times for each of fresh concrete sample, and the average results were obtained.

Figure 2 Flow-cone and table test

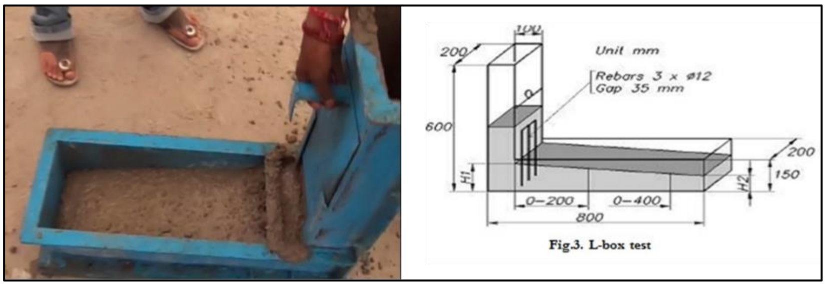

Figure 3 L-box test

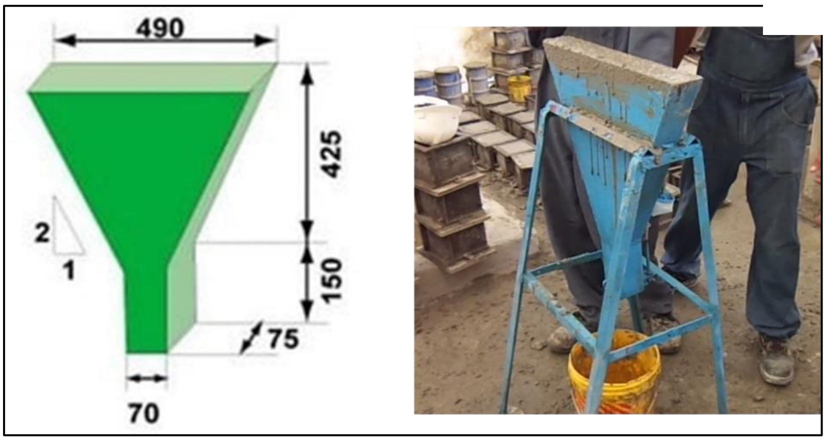

Figure 4 V-funnel test

Table 7 Results of tests on fresh concrete

№	Test	20% Fly-ash mix	25% Fly-ash mix	30% Fly-ash mix	35% Fly-ash mix	Remarks
1	Slump flow test	632	648	671	646	Values in 'mm' – required >600 mm
2	V-funnel test	14.2	9.6	15	19.8	Values in 'sec' – required 8 to 12 sec
3	L-box test	0.94	0.92	0.87	0.84	Values in 'ratio' – required ratio of 0.9 to 1.0

The cubes for measuring compressive strength of laboratory trial mixes were cast and tested. The cubes were prepared and opened from moulds after 24 hours. These cubes were set in a water tank for in-house curing. The compressive strength of these cubes (three samples for each trial mix) were tested on a compression testing machine after seven-days and twenty-eight-day curing period. The table below shows the average test results for three samples of each mix.

Table 8 Results of compressive strength test on SCC

№	% age fly-ash	Average Compressive strength (in kN/mm^2)	
		7 days	28 days
1	20	50.17	68.61
2	25	48.57	67.35
3	30	44.70	60.81
4	35	40.77	59.21

The comparison of test results is shown in above figures for various tests performed on fresh and hardened concrete. The flow test shows consistent improvement for increasing the fly-ash contents (Figure 5). The consistency of the concrete also mostly increases with the increase in the fly-as content (Figure 6). It is a result of finer particles of the fly-ash that allows for more flexibility to the material. However, as the fly-ash content increases, the L-box test show reducing ratio for two sides of the box. It means that ability of self-compaction of concrete is reduced (Figure 7). Also, the compressive strength of concrete shows declining trend with increasing percentage of replacement of cement with fly ash. However, during the current exercise, all mixes could obtain the minimum strength required for the design mix of M_{55}. However, a higher percentage of fly-ash could obtain marginally higher value than the design value of compressive strength.

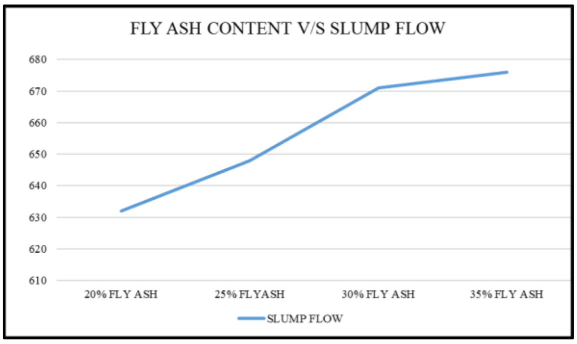

Figure 5 Flow test results

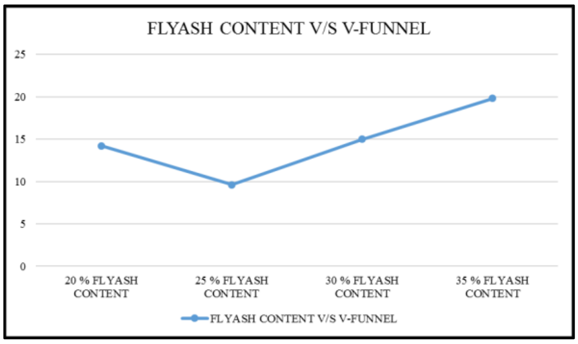

Figure 6 Funnel test results

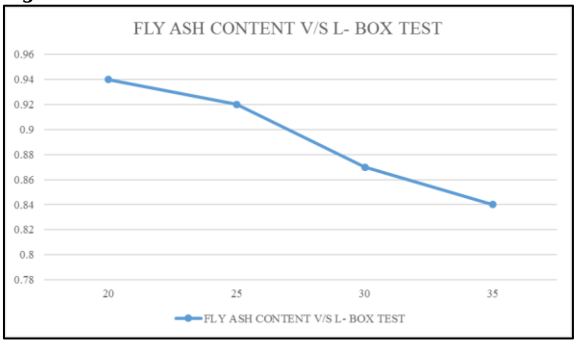

Figure 7 L-box test results

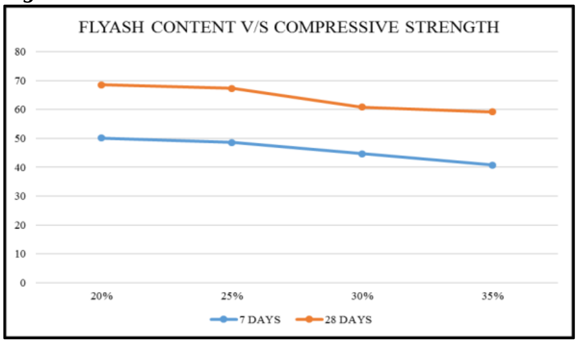

Figure 8 Compressive strength test results

6. CONCLUDING REMARKS AND DISCUSSION

SCC is already introduced by many countries and completed many projects successfully. India's numbers of private and public-sector based organisations have also introduced the application of SCC for many projects and, completed these projects. Nowadays, several developments in SCC are subject to research and possess a great scope in future. SCC standardisation is a need of the hour for Indian standards to promote practising for assured quality. The cost of SCC in comparison with conventional concrete is higher. However, it can result in durable concrete for tougher formwork sections and difficult sites for operations. The cost reduction is also a matter of investigation for further optimisation. It seems that the awareness regarding the application of SCC is missing among small-scale construction practitioners, engineers and government organisations at large in India.

Based on the current study discussed in earlier sections, some concluding remarks are drawn. The self-compaction properties of concrete are obtained using a superplasticiser with minor adjustments done for the coarse aggregates and the content of fly-ash. However, additional properties are achieved compared to normal concrete without affecting primary and required characteristics recommended by the IS codes. The flow characteristic increases with increase in fly-ash content. By using fly-ash in optimum content, the ability to flow and physical properties can be increased with abnormal expectation. Such ideally is a requirement for a difficult site of structural rehabilitation. The constituent properties play a crucial role for the obtained properties of the hardened concrete, however, in a case of improper contents and poor quality of fly ash can ruin the overall quality of concrete drastically. Fly ash is one of easily and abundantly available raw-material for crafting the SCC, and hence use of SCC will promote utilisation of industrial waste that in turn can contribute to saving the environment. The SCC with fly-as content can lead to a sustainable concrete structure construction practices at large as well as structural rehabilitation. Based on current research results, it is suggested that a mix design with 25% of fly-ash replacement of cement content seems to be ideal for an M_{55} grade of concrete concerning fresh concrete and hardened concrete.

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ACKNOWLEDGEMENT
Without the strength imparted by the almighty, the current work could not be possible. The authors are thankful to Dr. P. H. Tandel, Chariman (2016-2018), IEI-SGLC and Dr. Vaishali B. Mungurwadi, Principal, SCET for motivating for research attempts. The authors are also grateful to Er. Mukund B. Master, Hon. Secretary, IEI-SGLC and Dr. Pratima A. Patel, Head, FCE, SCET for their support. Also, the authors acknowledge the support of L&T for extending support to the researchers. Authors extends a special credit to Shri S. J. Desai, IEI-GSC for boosting enthusiasm.

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