PERFORMANCE OF SELF-COMPACTING CONCRETE USING HIGH VOLUME SAND AND FLY ASH

Priyanka[1], Rajesh Kumar[2], Anand Babu[1]

1. Bharat Institute of Technology, Sonepat India
2. Chandigarh College of Engineering & Technology (Diploma Wing), Chandigarh, India

ABSTRACT. Since the development of SCC, limited data is available on the use of high volume sand and fly ash in SCC as an alternate to coarse aggregate and cement respectively. Therefore in the present study conventional concrete of M30 grade is upgraded to SCC using high sand to total aggregate (S/A) ratio up to 0.56 with the help of 1.4% superplasticizer and 0.3% viscosity modifying agent (VMA) of total powder content. Effect of high S/A ratio up to 0.58 and cement replacement @ 0%, 15%, 25% and 35% with fly ash on the fresh and hardened properties of SCC were observed. It is found from the present study that SCC can be developed by the increased S/A ratio of 0.56 % with the help of superplasticizer and VMA without compromising on the strength properties. Use of fly ash has great impact on the reducing the cement content in SCC up to 25% replacement level effectively. Though it reduces strength at early ages but at the later ages of 56 days and more this effect is nullified thereby indicating great potential of using fly ash as replacement of cement in the development of SCC.

Keywords: Self-compacting Concrete, Fly ash, Superplasticizer, Viscosity Modifying Agent, Powder.

Priyanka is a PG Scholar in Civil Engineering department in Bharat Institute of Technology, Sonepat under the Deen Bandhu Chhotu Ram University of Science and Technology Murthal in Haryana, India. Her research interest is in self-compacting concrete and planning estimating and designing of Bridges.

Dr Rajesh Kumar is a Lecturer in Civil Engineering in Chandigarh College of Engineering & Technology (CCET-26), Chandigarh, India. His research interest are self-compacting concrete, behaviour of recycled concrete and composite material.

Er Anand Babu is a Assistant Professor in Civil Engineering in Bharat Institute of Technology, Sonepat under the Deen Bandhu Chhotu Ram University of Science and Technology Murthal in Haryana, India. His research interest area is composite material and high performance concrete.

INTRODUCTION

Self-compacting concrete (SCC) is one of the most revolutionary development in the recent years [12-14]. Modern application of self-compacting concrete (SCC) is focused on high performance, better and more reliable quality, dense and uniform surface texture, improved durability, high strength, and faster construction.

As per European Federation of National Associations Representing for Concrete (EFNARC) “SCC is an innovative concrete that does not require any vibration for placing and compaction [1-2]. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.” The major steps in the production of SCC are identifying an appropriate material, its proportioning and evaluating the properties of the concrete developed.

Therefore a lot of initial work and investigation have been done worldwide to develop self compacting concrete using different materials. However there is a lot of uncertainties concerning proportioning of mixes of self compacting concrete using different types of fillers. With all these uncertainties and to have better understanding regarding the use of self compacting concrete in India, there is a need to develop self compacting concrete using locally available materials for its adoption. Therefore the present work has been planned to study experimentally the strength property of self-compacting concrete with high volume of fine aggregate (Sand). Efforts have been made to develop self compacting concrete using fly ash as replacement of cement in different proportions and to quantify its most basic properties.

Supplementary cementious or inert material also known as fillers such as fly ash, stone dust, bottom ash etc can be used to increase the viscosity and reduce the cost of SCC and normal concrete.

The RILEM Technical Committee 174-SCC [15] notified in its State of the Art Report that fillers are one of the “interesting and challenging topics to study in order to further develop the technology, optimize the composition, enhance the production technique and improve the cost/benefits” of self-compacting concrete.

Powder contents required in SCC ranging from 380-600 kg/m^3 of concrete, which is much more than that of normal concrete. Due to its rheological requirements, filler additions (both reactive and inert) are commonly used in SCC to improve and maintain the workability, to regulate the cement contents and to reduce the heat of hydration. Mineral admixtures like fly ash can effectively replace part of this powder contents in addition to ground granulated blast furnace slag, silica fume, etc. the content of ultra fine materials in SCC is essentially higher.

It was observed by Miura et. al [11] that fly ash replacement up to 30% results in significant improvement of the rheological properties of flowing concretes the use of fly ash reduces the demand for the cement, fine fillers and sand, which are required in high quantities in SCC. Moreover, Kurita & Nomura [10] presented that the incorporation of fly ash improves rheological properties and reduces the cracking potential of concrete as it lowers the heat of hydration of cement

The influence of replacing cement partially with fly ash (0-80%) on the properties like compressive strength, workability, absorption, ultrasonic pulse velocity & shrinkage of SCC was investigated [9]. The results indicated that high volume fly ash replacing 40% of OPC resulted in strength of more than 65 N/mm² at 56-days. A linear relationship was observed to exist between the 56-day shrinkage and FA content. The correlation between strength and absorption indicated a sharp decrease in strength as absorption increased from 1 to 2% and strength reduced at a much slower rate.

GENERAL REQUIREMENTS OF SCC IN DECIDING MIX PROPORTIONS

In the design of SCC mix, the relative proportions of key ingredients may be considered by volume rather than by mass. A high content of fine materials and superplasticisers are necessary to achieve self-compacting properties. The mix should have sufficient flowability along with adequate stability. Okamura and Ozawa [12] have proposed a mix proportioning system in which coarse aggregate and fine aggregate contents are fixed and self-compatibility is to be achieved by adjusting the water/powder ratio and superplasticiser dosage. Indicative typical ranges of proportions and quantities in order to obtain self-compacting concrete are summarized below. Further modifications will be necessary to meet strength and other performance requirements.

- Volume of coarse aggregate is to be fixed between 28% to 35% of volume of mix.
- Water /powder ratio by volume is to be kept in the ranges of 0.80 to 1.10.
- Total powder content -160 to 240 liters (400-600kg) per m^3.
- Fine aggregate content should normally be 28% to 35% by volume of the mix.
- Water –cement ratio is selected based on strength requirements. Typically water content does not exceed 210 litre/m^3.
- The sand content balances the volume of the other constituents.

Generally, it is advisably to design conservately to ensure that the concrete is capable of maintaining its specified fresh properties despite anticipated variations in raw material quality. Some variation in aggregate moisture content should also be expected and allowed for at mix design stage. Normally, Superplasticiser and VMA admixture is a useful tool for compensating for fluctuations due to any variations of the sand grading, amount and moisture

RESEARCH SIGNIFICANCE

One of the significant limitations in the ready adoption of SCC in India is lack of availability of mixture proportioning methods. It is expected that the finding of the proposed research programme will help in understanding the performance of SCC with the use of high volume of fine aggregate and fly ash under different conditions and serve as a guide for use of SCC in construction industry.

EXPERIMENTAL PROGRAMME

In order to achieve the objective of the present study, an experimental program was planned to investigate the effect of fine aggregate to total aggregate (S/A) ratio, super plasticizer, VMA and fly ash variation on the fresh and hardened properties of SCC when part of cement replaced by fly ash in different percentage i.e. 0%,15%,25% and 35% respectively. The main parameters investigated were variation in SCC fresh properties (i.e. filling ability, passing ability and segregation resistance.) and SCC hardened properties (i.e. compressive strength, split tensile strength, and flexural strength at the age of 7, 28 and 56 days water curing).

MATERIAL USED

Cement

Ordinary Portland cement (43 Grade) conforming to IS 8112: 1989 was used. It's Chemical & physical properties are given in Table 1.

Table1 Physical Properties of Portland Cement

PHYSICAL PROPERTY	TEST RESULT	REQUIREMENT OF IS:8112-1989
Fineness(retained on 90-µm sieve)	7.5 %	10 %
Standard Consistency, %	29.5%	---
Initial Setting Time (minutes)	85	30 (min) as per IS:4031
Final Setting Time (minutes)	180	600 (max) as per IS:4031
Soundness (Le Chatelier test, mm)	2mm	10mm
Specific Gravity	3.12	---
Compressive Strength (MPa)		
3-days	26.72	23.0 (minimum)
7-days	35.17	33.0 (minimum)
28-days	52.0	43.0 (minimum)

Fly Ash

Fly ash obtained from Guru Hargobind Thermal Plant Ropar, Punjab was used. Fly ash is usually separated at the power plants & which qualify the fineness standard as per IS 3812: 2003 with retention of less than 34% on 45 micron sieve can be added as cementitious material in partial replacement of cement. The physical and chemical properties of fly ash are shown in the Table 2 and 3 respectively.

Aggregates

Locally available natural river sand with 4.75mm maximum size as fine aggregate and crushed stone aggregates of 10mm and 20mm maximum nominal sizes in 50:50 proportion were used as coarse aggregates in the study.

Superplasticizer and VMA

Polycarboxylate Ether (PCE) based superplasticiser which has been developed for the production of SCC, pumped concrete, high performance concrete obtained from "SIKA Chemicals Pvt. Ltd and admixtures that modify the cohesion of concrete without significantly altering its fluidity are called viscosity-modifying agents (VMA) were used in the study.. The properties of superplasticizer and VMA used are listed in the Table 5.

Table 2 Physical Properties of Fly Ash

PHYSICAL PROPERTIES	TEST RESULS	REQUIREMENT
Color	Grey (Blackish)	-
Specific Gravity	2.22	
Fineness-specific surface in cm^2/gm by Blaine's permeability method	3697	Min 3200
Particles retained on 45 micron IS Sieve (wet sieving) in percent	31%	Max 34%
Lime reactivity – Average compressive strength at 28 days in N/mm^2.	3.4% 82.5%	Not less than the 80% of the strength of corresponding plain cement mortar cubes
Soundness by autoclave test – Expansion of specimen in percent	0.23 %	Max 0.8

The properties of fly ash conform to IS: 3812-2003

Table 3 Chemical Properties of Fly Ash

CONSTITUENTS	PERCENT BY WEIGHT	REQUIREMENT	METHOD OF TEST
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3) in percent by mass.	74.88	Min 70	IS 1727
Silicon Dioxide (SiO_2) in percent by mass.	72.6	Min 35	IS 1727
Reactive silica in percent by mass.	41.48	Min 20	IS 1727
Magnesium Oxide (MgO) in percent by mass.	0.64	Min 5.0	IS 1727
Total Sulphur as sulphur trioxide (SO_3) in percent by mass.	0.31	Min 3.0	IS 1727
Available alkalis as sodium oxide (Na_2O) in percent by mass.	0.27	Min 1.5	IS 4032
Total Chlorides in percent by mass.	0.03	Max 0.05	IS 12423
Loss on ignition in percent by mass	1.61	Max 5.0	IS 1727

The properties of fly ash conform to IS 3812: 2003

Table 4 Physical Properties of Coarse and Fine Aggregates

CHARACTERISTICS	RESULTS OBTAINED	
	COARSE AGGREGATE PROPORTION 50:50 (10MM:20 MM)	FINE AGGREGATE
Grading Zone	---	Grading Zone III (IS: 383-1970)
Fineness Modulus	6.52	2.17
Specific Gravity	2.66	2.62
Water Absorption (%)	0.6%	0.8 %
Free surface moisture Content (%)	0.0%	0.0 %

Table 5 Properties of Superplasticizer and Viscosity Modifying Agent

CHARACTERISTICS	SUPERPLASTICIZER	VMA
Type	Modified Polycarboxylate	Polymer solution
Color	Light Yellowish	Colorless liquid
Specific gravity at 30°C	1.08 ± 0.01	-
Density	-	1.0 kg/Ltr

Water

Tap water as available in the laboratory which was fit for drinking was used for developing various trial mixes of concrete.

MIX DESIGN PROCEDURE USED TO DEVELOP SCC

The initial mix composition for M30 grade was arrived in accordance with IS 10262-1982 assuming compacting factor equal to 1. The new information given in IS456-2000 has also been incorporated. The normal mix proportioning so obtained are modified to SCC in following ways:

- In each phase, water content obtained was kept constant as obtained in conventional mix design of concrete and should not exceed 210 litres/m^3.
- Optimum dosage of superplasticizer is arrived through marsh cone test and mortar flow test.
- The dosage of VMA is fixed through trial mix to adjust the rheology of mix.
- In each phase all the mixes were tested to fulfil the requirements of SCC i.e. slump flow test, V-funnel test and L-box test.

- The coarse aggregate content is reduced by increasing the fine aggregate by absolute volume method.
- Even though the mix proportion have been arrived at, trial mixes are necessary to fine tune the dosage of the superplasticiser and VMA and also to identify and correct any problems in the rheological behaviour of SCC mix taking in to consideration the demands of the projects.

The trial mixes and SCC so achieved are shown in Table 6.

Table 6 Mix Proportions Trials for Achieving SCC

MIX	CEMENT Kg/m^3	F.A. Kg/m^3	C.A. 20:10mm 1:3	FLY ASH Kg/m^3	WATER Lt/m^3	S.P %	V.M.A %	S/A
TR1 (NC)	383.00	546.07	1233.15	-	210	-	-	0.30
TR2	383.00	890.00	890.00	-	210	-	-	0.50
TR3	383.00	925.60	854.40	-	210	-	-	0.52
TR4	383.00	961.20	818.80	-	210	-	-	0.54
TR5	383.00	996.80	783.20	-	210	-	-	0.56
TR6	383.00	996.80	783.20	-	210	1.0	-	0.56
TR7	383.00	996.80	783.20	-	210	1.1	-	0.56
TR8	383.00	996.80	783.20	-	210	1.2	-	0.56
TR9	383.00	996.80	783.20	-	210	1.3	-	0.56
TR10	383.00	996.80	783.20	-	210	1.4	-	0.56
TR11	383.00	996.80	783.20	-	210	1.4	0.1	0.56
TR12	383.00	996.80	783.20	-	210	1.4	0.2	0.56
SCC1	383.00	996.80	783.20	-	210	1.4	0.3	0.56
SCC2	325.55	996.80	783.20	54.45	210	1.4	0.3	0.56
SCC3	287.40	996.80	783.20	95.75	210	1.4	0.3	0.56
SCC4	248.40	996.80	783.20	134.05	210	1.4	0.3	0.56

Where,
NC= Normal Concrete
SCC1= 0.3% viscosity modifying agent
SCC2= 15% cement replaced by fly ash
SCC3= 25% cement replaced by fly ash
SCC4= 35% cement replaced by fly ash

Casting and Testing of Specimens

Standard cubical moulds of size 150 mm X 150 mm X 150 mm, cylindrical moulds of size 300 mm length X 150 mm diameter were cast and tested in compression and split tension after 7days, 28days and 56 days. The results so obtained are presented in Table 6.

RESULTS AND DISCUSSION

Investigation has been carried on the following consideration:

i) Analysing flow properties i.e. filling, passing and segregation resistance of SCC using different percentages of sand aggregate ratio, superplasticizer, VMA and fly ash.
ii) Study the effect of fly ash as a partial replacement of cement on compressive strength and split tensile strength of SCC.

Effect of High Volume of Sand and Fly Ash on the Flow Properties of SCC

Concrete in its fresh state was tested to determine the SCC properties within the specified criteria as per the EFNARC guidelines for SCC. Slump flow test for filling ability, V-funnel for filling and segregation resistance and L-Box test to determine passing ability were conducted on each mix which is altered after observation of previous mix behaviour.

Slump flow test

Slump value of trail TR1 is just 342mm which had sand aggregate ratio (S/A) 30% drastically increase to 453 mm for trail TR2 due to sudden change in S/A ratio i.e. 50%. Then slump value increase in nearly uniform fashion from 453mm, 504mm, 578mm and 637mm for trails TR2, TR3, TR4 and TR5 respectively.

For TR6, TR7, TR8,TR9 and TR10 in which superplasicizer dosages increased from 1%, 1.2%,1.2%, 1.3% and 1.4 % respectively, Slump value increased 712mm, 735mm, 758mm, 781mm and 802mm respectively. For the trail mix TR11, TR12, and SCC1 slump flow 763mm, 722mm, and 706mm respectively due to increased of dosages of VMA which make it more homogeneous and viscous. Slump flow which was increased for mix SCC2, SCC3 and SCC4 those are 720mm, 738mm and 752mm respectively.

Above observation and values of the test strongly indicated that the frequency of collision and contact between coarse aggregate particles can increase as the relative distance between the particles decreases and the internal stress can increases when percentage of coarse aggregate more than fine while concrete is deformed. More percentage of fine aggregate than coarse aggregate minimised the chances of collision and consumed less energy. Which results in more availability of energy required for flowing.

The increased in slump due to the dosages of superplasticizer shows that high viscous paste is required for flowing when concrete deformed. High deformability can be achieved only by the employment of a superplasticizer, keeping the water powder ratio to a very low value.

Dosing the VMA decreased the slump flow which cause due to the more viscous form of the concrete.VMA give more homogeneity but reduce the free flow of concrete.

The increased in slump flow value caused due to replacement of cement by fly ash which is lighter than in weight produces more lubricating effect on the ingredient of concrete and helps in achieving in free concrete with closer packing of particles. Fly ash also reduces the heat of hydration and loss of water during chemical reaction of cement which results in increased workability. Apart from this, fly ash also acts as dispersing agent for cement coated water particles. It released the water entrapped between various cement particles, hence making that water available for increasing workability of SCC mix.

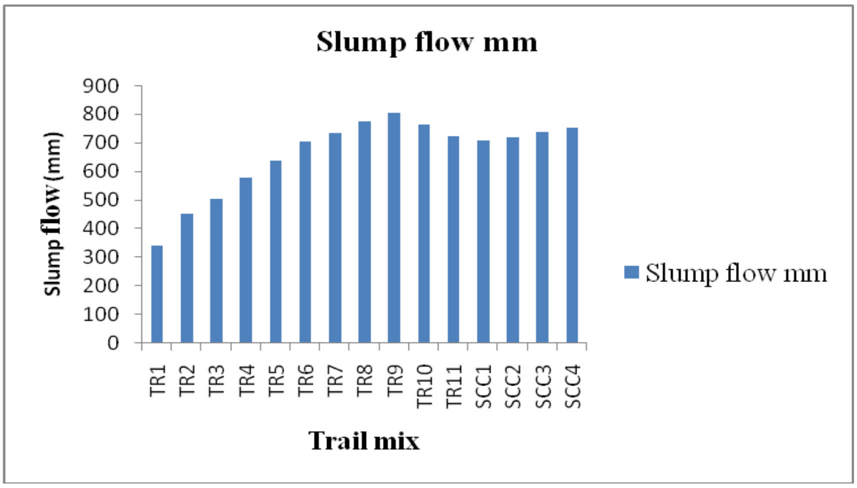

Figure 1 Variation of slump flow Vs different S/A, SP, VMA & fly ash

V-funnel test

The result values for trail mix TR1, TR2, TR3, TR4, TR5 and TR6 are show that they were unable to pass through fully. Some part of concrete could passes through V- funnel. Volume of concrete passes through were 15%, 58%, 65%, 73% and 86% for percentage of sand to aggregate(S/A) ratio of 30 %, 50%, 52%, 54% and 56%. Due to introduction of superplasticizer concrete mix TR6, TR7, TR8, TR9 and TR10 and recorded time of passing are 12.1 sec, 10.9sec, 9.6sec, 8.7sec and 7.8 sec respectively passes through V-funnel for 1%, 1.1%, 1.2%, 1.3%, and 1.4% of superplasticizer in respective mix.

Time of passing was less than the required minimum time as per the EFNARC specification for SCC and increases with increasing percentage of superplasticizer. Time of passing through for mix TR11, TR12 and SCC1 were 7.2sec, 7.9sec, and 8.2sec increased due to increase in percentage of VMA (i.e. o.1%, 0.2%, 0.3% and 0.4%). With percentage of cement replaced by fly ash shows 8.8 sec, 10.5 sec, and 13.2 sec respectively passing through V-funnel. Trail mix SCC1 to SCC3 fulfil the all the criteria for SCC according to EFNARC guidelines.

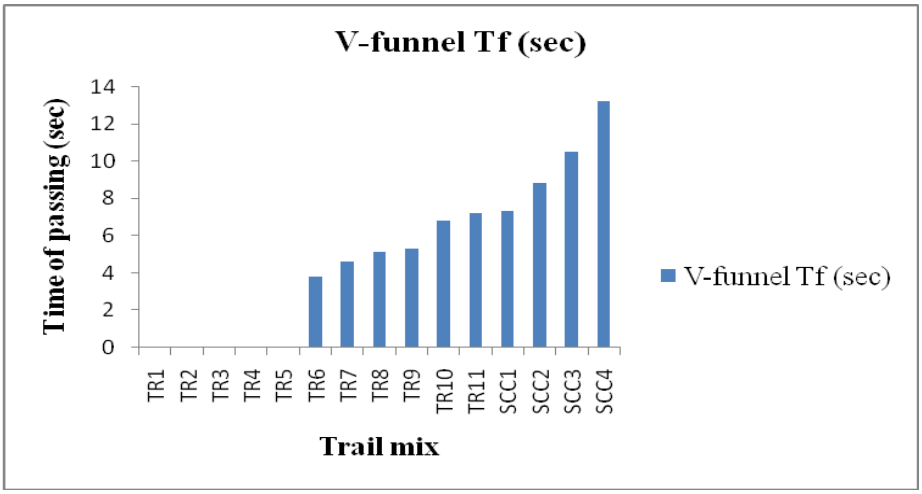

Figure 2 Variation of time of passing Vs different S/A, SP, VMA & fly ash

Above results shows clearly that sand to aggreagate (S/A) ratio improve the passing percentages of concrete, though it minimise the friction between the coarse aggregtes (internal stress). It also allow the concrete to flow some homogeneously. Superplasticizer make concrete to pass through that each successive dose of it minimize the time of passing 1.2sec, 1.3sec 0.9sec, 0.9secand 0.6sec for respectively mix.

It indicate the improvement in deformability of fresh SCC. VMA modify the viscosity of concrete and delay the concrete to pass by 0.6sec, 0.7sec and 0.3sec. VMA minimize the effect of variations in moisture content, fines in the sands or its grain size distribution, making the SCC more robust and less sensitive to small variations in the proportions and condition of other constituents.

V-funnel test at T_{5min}

Concrete mix TR1, TR2, TR3, TR4, TR5 and TR6 were unable to pass through V- funnel because of the segregation. Time interval (5min) between filling of apparatus and opening of bottom lid make coarse aggregate to settle and blockage was occurred. Superplasticizer dose 1.1% makes it to pass through in time 15.3 sec.

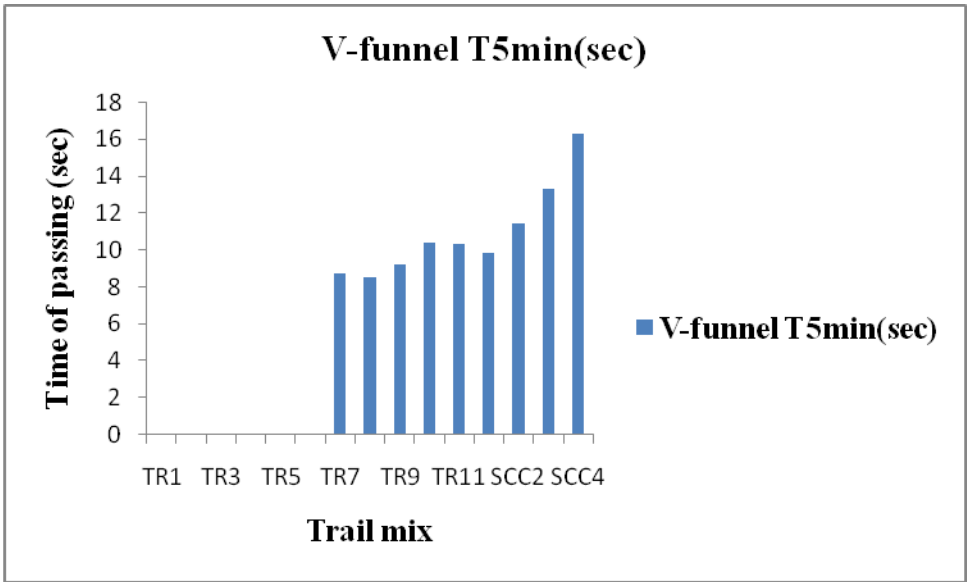

Figure 3 Variation of time of passing Vs different S/A, SP, VMA & fly ash

Dosages 1.2%, 1.3% and 1.4% achieved time of passing13.7sec, 12.6sec and 11.7sec. Adding of VMA which make concrete more viscous (homogeneous) and eliminate the blockage problem and gives time of passing 10.8sec, 11.0sec,and 10.7sec for trail TR11, TR12 and SCC1. The time difference between V-funnel and V_{5min}-funnel were 2.5 sec, 2.6 sec, 2.8 sec and 3.0 sec within the range for mix SCC1 to SCC 4 as per the EFNARC guidelines for SCC.

During this test we had observed that the variation in sand to aggregate (S/A) ratio does not affect the result directly because the time difference between the filling the funnel and opening the lid that is 5 minutes allow the coarse aggregate to concentrate at the narrow path which result in the blocking. But when superplasticizer dosage facilitate the concrete some uniformity up to some duration by this concrete able to pass through funnel even after 5min. VMA play very important role in this test it give complete rheology to the concrete due to this it can pass through and also in specified time as per the guidelines of EFNARC for SCC. Replacement of cement with fly ash make it delayed by averagely by 0.20 sec for each 25%. It happened because of more viscous form of the concrete

L-box test

Concrete mixes TR1 to TR7 were unable to reach up to the end of L-box not makes any significant (notable) result. While TR9, TR10, TR11, TR12 SCC1, SCC2, SCC3 and SCC4 reach and gives blocking ratio (i.e. H_2/H_1) of 0.53, 0.61, 0.70, 0.81, 0.85, 0.90 and 0.98 respectively. Mixes SCC1, SCC2, SCC3 and SCC4 gives value of blocking ratio within the range of self compacting concrete as per the EFNARC guidelines.

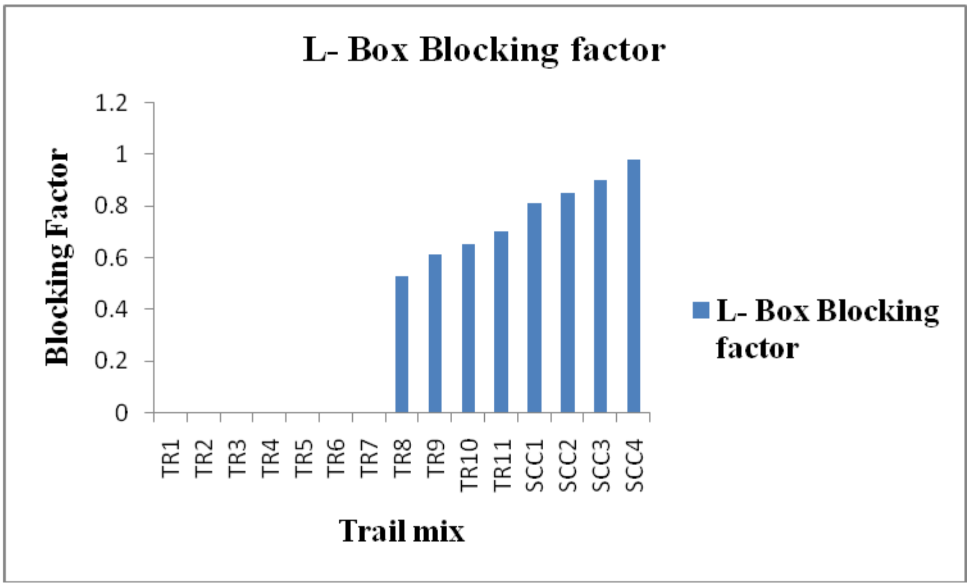

Figure 4 Variation of blocking factor Vs different S/A, SP, VMA & fly ash

It clear from above result that the frequency of collision and contact between coarse aggregate particles can increase as the relative distance between the particles decreases and the internal stress can increases when percentage of coarse aggregate more than fine while concrete is deform. More percentage of fine aggregate than coarse had minimised the chances of collision and consume less energy. Which results in more availability of energy required for flowing. Research has found that the energy required for flowing is consumed by the increased internal stress, resulting in blocking of aggregate particles. Limiting the coarse aggregate content, whose energy consumption is particularly intense, to a level lower than normal is effective in avoiding this kind of blockage. Use of superplasticizer gives the highly deformable concrete which makes it to give some good performance against the test.

Rheology measurements on concrete indicate that it is reasonable to approximate the concrete flow behaviour. The rate of increased of shear stress slow down with increasing shear strain rate is called shear thinning and opposite is true for shear thickening behaviour. On the other hand, pseudoplastic behaviour, exhibited by VMA which is water- soluble high molecular weight polysaccharides, means a drop in shear stress at high shear rates. Thixotropy defined as the property by certain gels of becoming fluid when stirred or shaken and returning to the semisolid state upon standing would also be equivalent to the pseudoplastic behaviour. In static condition, the heavier aggregate particle tends to settle, and this tendency can be controlled ensuring a minimum yield stress for the paste by the VMA which give good flow through congested reinforcement results in the good blocking ratio.

Effect of Fly Ash on the Compressive Strength of SCC

The result of compressive strength tests using fly ash in varying percentages (i.e.0%, 15%, 25%and 35%) as partial replacement of cement at moist curing ages of 7days, 28 days and 56 days are presented in Table 7 and are plotted in figure 5.

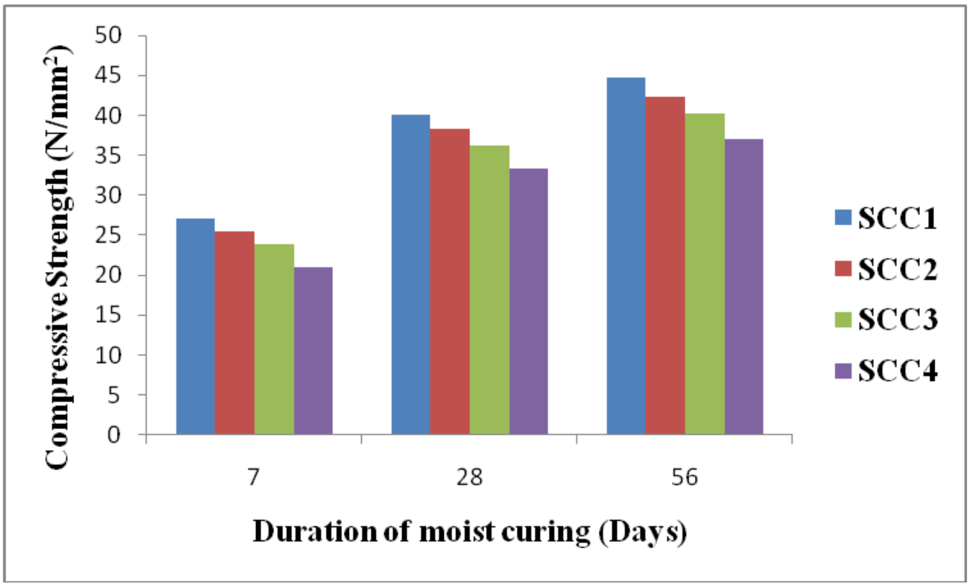

Figure 5 Variation of compressive strength with age

It is clear from the above tables and figure that the compressive strength of SCC mixes with fly ash at 7 days are substantially lower than that of control mix (SCC1). The compressive strength decreased with replacement of cement by fly ash content. The compressive strength at 28 days of SCC containing fly ash is also less than that of SCC without fly ash for all replacement levels.

The control mix achieved strength of 40.10 MPa at the age of 28 days while SCC containing fly ash with replacement levels of 15%, 25%, and 35% attained strength of 38.30 MPa, 36.18 MPa and 33.27 MPa respectively. Thus the fly ash SCC with 15%, 25%, and 35% replacement of cement gained 0.95, 0. 92 and 0.82 times strength in comparison to the control mix at the age of 28 days respectively. The corresponding values at the age of 56 days are 0.94, 0.90 and 0.82 times respectively.

The compressive strength of SCC with fly ash is lower at the initial ages due to the reason that reduction in quantity of cement paste and adhesion to the aggregate particles. As approximately 75% strength rendering primary mineralogical phases is developed at the ultimate hydration of OPC. The balance $Ca(OH)_2$, whose contribution of chemical reaction, because of the fact that sufficient cementious action of fly ash is not activated at the initial stages and thus the unreactive quantity of fly ash at this stage reflect insignificant effect.

Effect of Fly Ash on Split Tensile Strength

The result of split tensile strength test using fly ash in varying percentages (i.e. 0%, 15%, 25%, 35%) as partial replacement of cement the moist curing ages of 7, 28 and 56 days are presented in tables 7. The test result values are plotted in figure 6.

Table 7 Variation of strength for different replacement levels of cement by fly ash

MIX	% OF CEMENT REPLACEMENT BY FLY ASH	COMPRESSIVE STRENGTH (N /MM^2)			SPLIT TENSILE STRENGTH (N /MM^2)		
		7days	28days	56days	7days	28days	56days
SCC1	0	27.01	40.10	44.74	3.15	3.75	4.10
SCC2	15	25.51	38.30	42.30	2.56	3.28	4.05
SCC3	25	23.84	36.18	40.21	2.41	3.10	3.87
SCC4	35	21.02	33.27	37.01	2.20	3.00	3.68

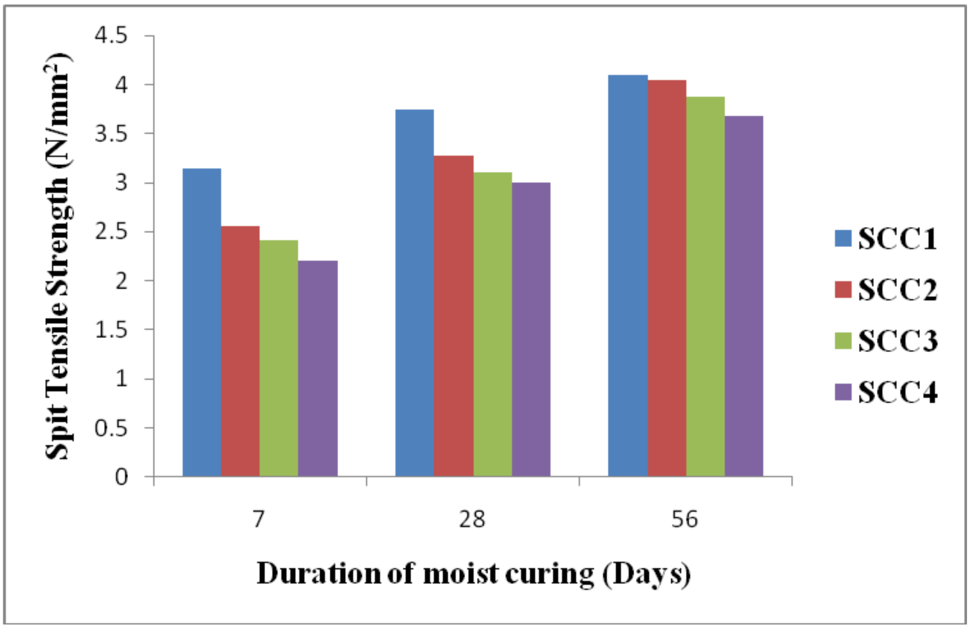

Figure 6 Variation of split tensile strength for different replacement levels of Cement by fly ash

Relationship Between Compressive Strength and Split Tensile Strength

The correlation between compressive strength and split tensile test result were obtained for various mixes of SCC as shown in figure7.

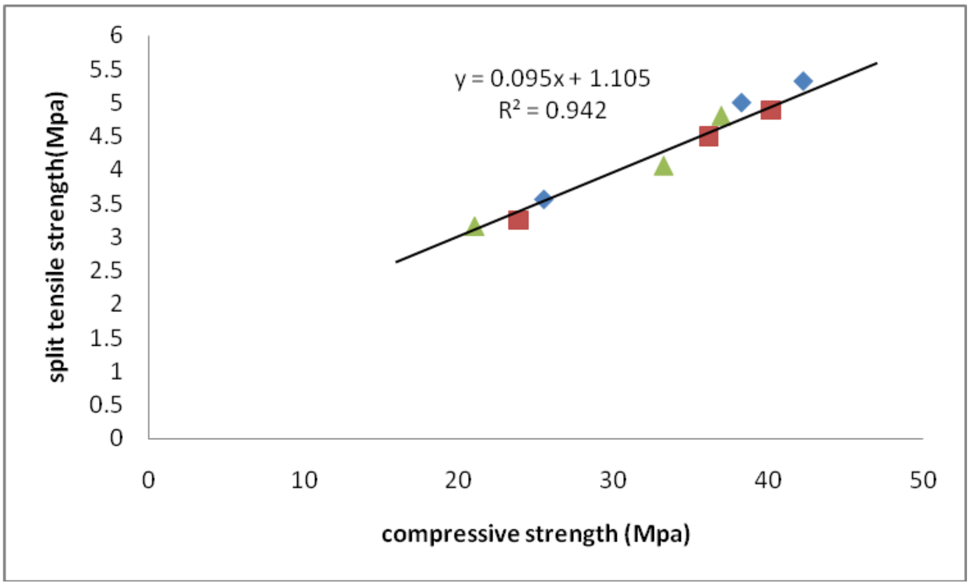

Figure 7 Regression Chart for Compressive Strength and Split Tensile Strength

For the SCC mix with fly ash, the following relation was obtained between compressive strength and split tensile strength y= 0.080x + 0.437. Value of Regression coefficient of the relationship is 0.942 which is near to 1 depicting has very good relationship between the two parameters.

CONCLUSIONS

From the present study it is concluded that the SCC can be developed by the increased S/A ratio of 0.56 % with the help of superplasticizer and VMA without compromising on the strength properties and increased percentage of sand favourable for the SCC properties (filling ability, passing ability and segregation ability).

Dosages of superplasticizer help significantly to improve filling ability. Addition of Velocity Modifying Agent (VMA), improve the rheology and segregation resistance of SCC.

Cement replacement by fly ash improved the fresh SCC properties. SCC with fly ash as replacement of cement reduces early age strength i.e. 7 days and 28 days, whereas at later ages of 56 days testing, it increased almost equal to the control mixes without fly ash.

Use of fly ash has great impact on the reducing the cement content in SCC up to 25% replacement level. Though it reduces strength at early ages but at the later ages of 56 days and more this effect is nullified thereby indicating great potential converting waste in to wealth by using fly ash as replacement of cement in the development of SCC.

REFERENCES

1. EFNARC (European Federation of national trade associations representing producers and applicators of specialist building products). Specification and guidelines for self-compacting concrete, February 2002, Hampshire, U.K.

2. EFNARC (European Project group: BIBM, CEMBUREAU, ERMCO, EFCA, EFNARC). The European Guidelines for Self Compacting Concrete, Specification , Production and Use (May 2005).
3. IS 383 : 1970, Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian standards, New Delhi, India.
4. IS 456:2000, Indian standard code of practice for plain and reinforced concrete (fourth revision), Bureau of Indian standards, New Delhi, India.
5. IS SP-23:1982, Handbook on Concrete Mixes, Based on Indian Standards. Bureau of Indian standards, New Delhi, India.
6. IS: 516-1959, Methods of Test for Strength of Concrete, Bureau of Indian Standards, New Delhi.
7. IS: 5816-1970 , Methods of testing for split tensile strength of concrete cylinders.
8. IS: 8112: 2013, Indian Standard on 43 Grade Ordinary Portland Cement-Specification, Bureau of Indian standards, New Delhi, India.
9. IS: 9103 -1999, Specification for admixtures for concrete. Bureau of Indian standards, New Delhi, India.
10. KHATIB J.M.. Performance of Self Compacting Concrete containing Fly Ash, Construction and Building Materials, 2008, 22, 1963-1971.
11. KURITA M & NOMURA T. Highly-flow able steel fiber reinforced concrete containing fly ash. ACI SP 178, 1998, 159-175.
12. MIURA N, TAKEDA N, CHIKAMATSU R AND SOGO S.(Application of super workable concrete to reinforced concrete structures with difficult construction conditions, ACI SP 140, 1993.163-186.
13. OKAMURA H. AND OZAWA K. Mix design for self-compacting concrete, Concrete Library of JSCE, 1995, 25, 107-120.
14. OKAMURA, H., Self compacting High performing concrete, ACI concrete International, July 1997.Vol. 19,No.7, pp. 50-54. ,
15. OKAMURA, H.,Self compacting High performing concrete, concrete library of JSCE, 1988, Vol.25, 107-120.
16. SKARENDHAL A. AND PETERSON O. (EDS) (2000). “State of Art Report of RILEM Technical Committee 174-SCC, Self Compacting Concrete”, RILEM Publications S.A.R.L., Cachan Cedex (France).