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Study on Self Compacting Concrete as Partial Replacement for Fine Aggregate with Coarse Aggregate

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Abstract - *Self-compacting concrete is a new type of concrete which can be placed in every corner of framework under its weight without any segregation. Self-compacting concrete gives a fast rate of concrete placement with rapid construction times and ease of flow around congested reinforcement. The use of the waste materials has been increased for making concrete due to various environmental and economic considerations. Recycled concrete is one of the waste materials that have been used in concrete. Due to increasing air pollution the important issue of repelling the pollutants in which construction industry plays a key role so that recycled concrete has been suggested to decrease the construction pollutants and which not only allows for a more efficient life cycle of natural resources but also contributes to environmental protection leading to sustainable environment. The research is an experimental study of the effect of partial replacement of fine aggregate by coarse aggregate in self compacting concrete. This research is an attempt to provide very useful information for the practical use of aggregate in advance concrete production. The fine aggregate has replaced with coarse aggregate in percentages of 9%, 12%, 15% and 18%. From the study it was concluded that the optimum replacement of aggregates by course aggregate with fine aggregate 18% for coarse aggregate for self-compacting concrete. Self-compacting concrete development must ensure a good balance between deformability and stability. Also, compatibility is affected by the characteristics of materials and the mix proportions; it becomes necessary to evolve a procedure for mix design of SCC. The paper presents an experimental procedure for the design of self-compacting concrete mixes. The test results for acceptance characteristics of self-compacting concrete such as slump flow; J-ring, V-funnel and L-Box are presented. Further, compressive strength at the ages of 7 and 28 days was also determined and results are included here.*

Key Words: Self-compacting Concrete; Fly Ash; Mix Design; Fresh Properties; Hardened Concrete Properties; Compressive Strength.

1. INTRODUCTION

Self-compacting concrete (SCC) represents one of the most significant advances in concrete technology for decades. Inadequate homogeneity of the cast concrete due to poor compaction or segregation may drastically lower the performance of mature concrete in-situ. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas.

Self-compacting concrete can be produced using standard cements and additives. It consists mainly of cement, coarse and fine aggregates, and filler, such as fly ash, water, super plasticizer and stabilizer. The composition of SCC is similar to that of normal concrete but to attain self-Flow ability, admixtures such as fly ash, glass filler, limestone powder, silica fume, Super-pozzoluna, etc. with some super plasticizer is mixed. Fineness and spherical particle shape improves the workability of SCC.

The research is an experimental study of the effect of partial replacement of fine aggregate by coarse aggregate in self-compacting concrete. This research is an attempt to provide very useful information for the practical use of aggregate in advance concrete production. The fine aggregate has replaced with coarse aggregate in percentages of 9%, 12%, 15% and 18%. From the study it was concluded that the optimum replacement of aggregates by course aggregate with fine aggregate 18% for coarse aggregate for self-compacting concrete. Self-compacting concrete development must ensure a good balance between deformability and stability. Also, compatibility is affected by the characteristics of materials and the mix proportions; it becomes necessary to evolve a procedure for mix design of SCC. The paper presents an experimental procedure for the design of self-compacting concrete mixes. The test results for acceptance characteristics of self-compacting concrete such as slump flow; J-ring, V-funnel and L-Box are presented. Further, the strength characteristics in terms of compressive strength for the 7 days and 28 days are also presented.

2 Material Used

2.1 Cement

Ordinary Portland cement (Grade 53) was used. Its physical properties are as given in table1.

Table-2.1 Physical Properties of Ordinary Portland cement.

PROPERTY	VALUE	IS CODE IS : 8112 – 1989
Specific Gravity	3.15	3.10-3.15
Consistency	28%	30-35
Initial setting time	35min	30min minimum
Final setting time	178min	600min maximum
Compressive strength at 7 days N/mm^2	38.49 N/mm^2	43 N/mm^2
Compressive strength at 28 days N/mm^2	52.31 N/mm^2	53 N/mm^2

2.2 Fly ash

Class C Fly ash obtained from "JSW Thermal Power Station, Rajasthan, India. The physical and chemical properties of fly ash are given in the Table 2 and Table 3, respectively.

Table -2.2 Physical Properties of fly ash

Sr.no	Physical Properties	Test Result
1	Colour	Grey
2	Specific Gravity	2.13

Table 2.3 Chemical Properties of fly ash "CLASS C"

Sr. No	Constituents	Weight % by
1	Loss on ignition	4.17
2	Silica (SiO_2)	69.40
3	Iron Oxide (Fe_2O_3)	3.44
4	Alumina (Al_2O_3)	28.20
5	Calcium Oxide (CaO)	2.23
6	Magnesium Oxide (MgO)	1.45
7	Total Sulphur (SO_3)	0.165
8	Insoluble residue	-
9	Sodium Oxide (Na_2O)	0.58
ALKALIES	Potassium Oxide (K_2O)	1.26

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

2.3 Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 4 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 4 was used as coarse aggregate. Both fine aggregate and coarse aggregate conformed to Indian Standard Specifications IS: 383-1970 [6]. Table 4 gives the physical properties of the coarse and fine aggregates.

Table 2.4 Physical Properties of Coarse and Fine Aggregate

Physical tests	Coarse aggregate	Fine aggregate
Specific gravity	2.67	2.66
Fineness modulus	6.86	2.32
Bulk density (kg/m3)	1540	1780

3 Parameters of test

Self- Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. Many different methods have been developed to characterize the properties of SCC. No single method has been found until date, which characterizes all the relevant workability aspects, and hence, each mix has been tested by more than one test method for the different workability parameters. Table 5 gives the

Recommended values for different tests given by different researchers for mix to be characterized as SCC mix.

Table 3.1. Recommended Limits for Different Properties

Sr. No.	Property	Range
1.	Slump Flow Diameter	500-700 mm [7]
2.	T50cm	2-5 sec [7]
3.	V-funnel	6-12 sec [8]
4.	L-Box H2/H1	≥ 0.8 [9]

4. Experimental Procedure

The procedure adopted in the study is as follows

1. Using Japanese method of mix design, initial mix design was carried out at coarse aggregate content of 50 percent by volume of concrete and fine aggregate content of 40 percent by volume of mortar in concrete, the water/powder ratio was kept at 0.82. These Trial mixes were designed with super plasticizer content of 4.5 ltr for mixes SSC 1 to SSC 5.

2. To proceed towards achieving SCC, the coarse aggregate content was reduced up to 18% by volume of concrete and thereby kept constant. Fine aggregate content was kept increase up to 18% by volume of mortar in concrete and super plasticizer content at 4.5ltr percent i.e. Cement and fly ash. The water-cement ratio was constant 0.40 for SSC 1 to SCC 5.

3. Coarse aggregate content was further reduced and fine aggregate content was increased, until a slump flow of 500-

700 mm is achieved by slump flow test. For each trial, tests are carried out in order that the mix satisfies slump flow test, V-funnel test and L-box passing ability test.

Table 4.1 Proportion of material per CUM of concrete:

Sr.	Material	Quantity	Ratio
1	Cement	425 kg	1
2	Fine aggregate	788 kg	1.99
3	Course aggregate	870 kg	2.05
4	Fly ash	150 kg	0.35
5	Water	180 kg	0.40
6	Admixture	4.5 ltr	0.01

Table 4.2. Mix Proportions

Sr. No.	Mix	Cement (Kg/m3)	Fly ash (Kg/m3)	Increase FA %age	F.A (Kg/m3)	Decrease CA in %age	C.A (Kg/m3)	Water (Kg/m3)	S.P. (%)	W/P ratio
1	SCC1	425	0	0	788	0	870	180	4.5	0.82
2	SCC2	425	150	9	859	9	799	180	4.5	0.82
3	SCC3	425	150	12	882	12	776	180	4.5	0.82
4	SCC4	425	150	15	906	18	752	180	4.5	0.82
5	SCC5	425	150	18	930	15	728	180	4.5	0.82

By reducing contents of coarse aggregate up to 18% and increasing fine aggregate contents up to 18% required results in all the tests i.e., slump flow, V-funnel and L-Box were obtained.

SCC1 to SCC5 are the SCC mixes that satisfy all the properties of SCC mixes and determination of optimum water-powder ratio was carried out for these mixes. Mix proportions for various mixes are given in Table 5.2.

4.1 SLUMP FLOW TEST AND T50cm TEST

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

Fig:-1. Slump flow test

Table 4.3. Slump Flow Test result

Mix	Slump flow (mm)	Typical range of value in mm
SCC1	706	600 to 800
SCC2	688	
SCC3	680	
SCC4	669	
SCC5	654	

4.2 V-Funnel test

About 12 liter of concrete is needed to perform the test, sampled normally. Set the V-funnel on firm ground. Moisten the inside surfaces of the funnel. Keep the trap door open to allow any surplus water to drain. Close the trap door and place a bucket underneath. Fill the apparatus completely with concrete without compacting or tamping, simply strike off the concrete level with the top with the trowel. Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity. Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time). This is taken to be when light is seen from above through the funnel. The whole test has to be performed within 5 minutes.

Fig:-2 V-funnel TEST

Table 4.4. V-funnel Test result

MIX	V-funnel (sec)	Typical range
SCC1	8.0	6 to 12
SCC2	8.5	
SCC3	9.6	
SCC4	10.3	
SCC5	11.5	

4.3 L BOX TEST METHOD

About 14 liter of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surfaces of the apparatus, remove any surplus water Fill the vertical section of the apparatus with the concrete sample. Leave it to stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200 and 400mm marks. When the concrete stops flowing, the distances "H1" and "H2" are measured. Calculate H2/H1, the blocking ratio. The whole test has to be performed within 5 minutes.

Interpretation of result If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1 = 1. Therefore the nearer this test value, the 'blocking ratio', is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8. T20 and T40 times can give some indication of ease off low, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcing bars can be detected visually.

Fig:-3 L-box TEST

Table 4.5 L- box test result

Mix	H1 (mm)	H2 (mm)	H2/H1
SCC1	126	121	0.96
SCC2	130	123	0.94
SCC3	132	121	0.91
SCC4	134	118	0.88
SCC5	137	116	0.84

4.4 COMPRESSIVE STRENGTH TEST

150 mm × 150 mm × 150 mm concrete cubes are cast. Specimens with ordinary Portland cement (OPC) and OPC replaced with and fly ash. The specimens are removing from the mould and subjected to water curing for up to 90 days. After curing, the specimens are tested for compressive strength using a calibrated compression testing machine of 2,000 KN capacities.

Fig:-4 COMPRESSIVE STRENGTH TEST

The experimental investigations show that for 7th day compressive strength:

Table 4.6 7th day compressive strength

S.No.	Mix	Average Compressive Strength of 7th days (N/mm2)
1	SCC1	24.44
2	SCC2	26.52
3	SCC3	26.96
4	SCC4	23.33
5	SCC5	22.07

The experimental investigations show that for 28 day compressive strength:

Table 4.7 28th day compressive strength

S.No.	Mix	Average Compressive Strength of 28th days (N/mm2)
1	SCC1	38.67
2	SCC2	41.11
3	SCC3	43.41
4	SCC4	39.56
5	SCC5	34.52

5. Results and Discussion

Table 4.3 presents the results of workability tests, conducted to achieve self-compacting concrete. The trials were started at 31 percent volume of total concrete as content of coarse aggregates and 30 percent by volume of total concrete as contents of fine aggregates and variation in w/p ratio and super plasticizer was carried out to achieve SCC mixes. In case of further trials, the coarse aggregate content and fine aggregate content were varied with further variation in water/cement ratio. Similarly, different trials were carried out until mix characterizing all the properties of SCC was obtained. SCC1 to SCC5 were mixes with cement content of 425 kg/m3 and fly ash content as 150 kg/m3 .The coarse aggregate and fine aggregate contents were kept as 870 kg/m3 and 788 kg/m3, which amounted to 61 % of total concrete and w/p ratio of 0.82. The super plasticizer content was constant 4.5ltr. The consistency and workability of SCC1 to SCC5 satisfied slump flow property but SCC3 was the only mix to have T50 cm as 3 sec, thus satisfying both slump flow and time property. In addition, all the mixes SCC1 to SCC5 have the V-funnel time Tf between 8-11.5 sec and V-funnel time T 5min within the range of Tf +3. The L-Box blocking ratio H2/H1 could be satisfied for SCC1 and SCC5.

The experimental investigations show that for 7th day compressive strength:

Table 5.1 7th day compressive strength in %age

S.No.	Mix	Average Compressive Strength of 7th days (N/mm2)	Increase in Average Compressive Strength (%)
1	SCC1	24.44	0
2	SCC2	26.52	8.51
3	SCC3	26.96	10.31
4	SCC4	23.33	-4.54
5	SCC5	22.07	-9.69

The experimental investigations show that for 7 day compressive strength:

- The partial increased of fine aggregate by 9 % and reduced 9 % of coarse aggregate, increases the compressive strength by 8.51%.
- The partial increased of fine aggregate by 12 % and reduced12 % of coarse aggregate, increases the compressive strength by 10.31%.
- The partial increased of fine aggregate by 15 % and reduced 15 % of coarse aggregate, decreases the compressive strength by 4.54 %.
- The partial increased of fine aggregate by 18 % and reduced 18 % of coarse aggregate, decreases the compressive strength by 9.69 %.

The experimental investigations show that for 28 day compressive strength:

Table 5.2 28th day compressive strength in %age

S.No.	Mix	Average Compressive Strength of 28th days (N/mm2)	Increase in Average Compressive Strength (%)
1	SCC1	38.67	0.00
2	SCC2	41.11	6.30
3	SCC3	43.41	12.25
4	SCC4	39.56	-2.30
5	SCC5	34.52	-10.73

- The partial increased of fine aggregate by 9 % and reduced 9 % of coarse aggregate, increases the compressive strength by 6.30 %.

- The partial increased of fine aggregate by 12 % and reduced 12 % of coarse aggregate, increases the compressive strength by 12.25 %.
- The partial increased of fine aggregate by 15 % and reduced 15 % of coarse aggregate, decreases the compressive strength by 2.30 %.
- The partial increased of fine aggregate by 18 % and reduced 18 % of coarse aggregate, decreases the compressive strength by 10.73 %.

5.1 SLUMP FLOW TEST

Table 5.3 Slump flow result

Mix	Slump flow (mm)	Typical range of value in mm
SCC1	706	0
SCC2	690	-2.26
SCC3	680	-3.68
SCC4	675	-4.39
SCC5	654	-7.36

- The partial increased of fine aggregate by 9 % and reduced 9 % of coarse aggregate, decreases slump flow value by 2.26 %.
- The partial increased of fine aggregate by 12 % and reduced 12 % of coarse aggregate, decreases slump flow value by 3.68 %.
- The partial increased of fine aggregate by 15 % and reduced 15 % of coarse aggregate, decreases slump flow value by 4.39 %.
- The partial increased of fine aggregate by 18 % and reduced 18 % of coarse aggregate, decreases slump flow value by 7.36 %.

Hence the relative flow area reduced with increase in Fine aggregate content, which is an indicator of a decrease in deformability of the mix.

5.2 V-FUNNEL TEST

Table 5.3 V-FUNNEL TEST result

Mix	Slump flow (mm)	Typical range of value in mm
SCC1	706	0
SCC2	690	-2.26
SCC3	680	-3.68
SCC4	675	-4.39
SCC5	654	-7.36

- The partial increased of fine aggregate by 9 % and reduced 9 % of coarse aggregate, increases V- funnel value by 6.25 %.
- The partial increased of fine aggregate by 12 % and reduced 12 % of coarse aggregate, increases V- funnel value by 18.82 %.
- The partial increased of fine aggregate by 15 % and reduced 15 % of coarse aggregate, increases V- funnel value by 23.95 %.
- The partial increased of fine aggregate by 18 % and reduced 18 % of coarse aggregate, increases V- funnel value by 33.98 %.

This increase in the V-funnel time indicates decreased values of relative flow time and thereby higher resistance to flow.

5.2 L-BOX TEST

Table 5.4 L-BOX TEST result

Mix	H1 (mm)	H2 (mm)	H2/H1	Decrease in %age
SCC1	126	121	0.96	0
SCC2	130	123	0.94	-2.08
SCC3	132	121	0.91	-5.32
SCC4	134	118	0.88	-8.79
SCC5	137	116	0.84	-13.64

- The partial increased of fine aggregate by 9 % and reduced 9 % of coarse aggregate, decreases L-box value by 2.08 %.
- The partial increased of fine aggregate by 12 % and reduced 12 % of coarse aggregate, increases decreases L-box value by 5.32%.
- The partial increased of fine aggregate by 15 % and reduced 15 % of coarse aggregate, decreases L-box value by8.79 %.
- The partial increased of fine aggregate by 18 % and reduced 18 % of coarse aggregate, decreases L-box value by 13.64 %.

The L-Box value was also observed to follow a decreasing trend by 2.08 %, 5.32 %, 8.79 % and 13.64 % for partial increased of fine aggregate by 9 %, 12% 15%, and 18% and reduced coarse aggregate by 9 %, 12% 15%, and 18% respectively. This indicates a decrease in the relative flow of the mix.

1. At the water/powder ratio of 0.82, slump flow test, V-funnel test and L-box test results were found to be satisfactory, i.e. passing ability, filling ability and segregation resistance are well within the limits.
2. SCC could be developed without using VMA as was done in this study.
3. The SCC1 to SCC5 mixes can be easily used as medium strength SCC mixes, which are useful for most of the constructions; the proportions for SCC3 mix satisfying all the properties of Self-Compacting Concrete can be easily used for the development of medium strength self-compacting and for further study.
4. By using the OPC 53 grade, normal strength of 38.6 MPa to 43.41 MPa at 28-days was obtained, keeping the cement content around 425 kg/m3 and fly ash 150 kg/m3.

   As SCC technology is now being adopted in many countries throughout the world, in absence of suitable standardized test methods it is necessary to examine the existing test methods and identify or, when necessary to develop test methods suitable for acceptance as International Standards. Such test methods have to be capable of a rapid and reliable assessment of key properties of fresh SCC on a construction site. At the same time, testing equipment should be reliable, easily portable and inexpensive. A single operator should carry out the test procedure and the test results have to be interpreted with a minimum of training. In addition, the results have to be defined and specify different SCC mixes. One primary application of these test methods would be in verification of compliance on sites and in concrete production plants, if self-compacting concrete is to be manufactured in large quantities.

CHAPTER 6:- REFRENCES

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