SELF COMPACTING CONCRETE USING INDUSTRIAL BY-PRODUCT

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ABSTRACT

Concrete is a mixing of binding material, aggregates and finally water. Concrete is normally use in the frame structure, but there is some limitation like self-compaction, surface finishes, maintains strength at congested area. Due to this limitation we are trying to make self-compacting concrete. SCC is considered a concrete that can be placed and compacted under its own weight without any vibration effort, assuring complete filling of formwork even when access is hindered by narrow gaps between reinforcement bars. Self-compacting concrete has ability involves not only high deformability of cement paste, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. In recent yea rs, self-compacting concrete (SCC) has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, the fresh concrete must possess high fluidity and good cohesiveness.

Keyword :- *Self Compacting Concrete, Ground Granulated Blast-Furnace Slag, Fresh Concrete Test, Compression Test.*

1. INTRODUCTION

Present days, self-compacting concrete can be classified as an advanced construction material. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction. An important improvement of health and safety is also achieved through elimination of handling of vibrators and a substantial reduction of environmental noise loading on and around a site. The compositio n of SCC mixes includes substantial proportions of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures, which are currently waste products with no practical applications.

Cement-based materials are the most abundant of all man-made materials and are among the most important construction materials, and it is most likely that they will continue to have the same importance in the future. However, these construction and engineering materials must meet new and high er demands. When facing issues of productivity, economy, quality and environment, they have to compete with other construction materials such as plastic, steel and wood. One direction in this evolution is towards self-compacting concrete (SCC), a modified product that, without additional compaction energy, flows and consolidates under the influence of its own weight. The use of SCC offers a more industrialised production. Not only will it reduce the unhealthy tasks for workers, it can also reduce the technical costs of in situ cast concrete constructions, due to improved casting cycle, quality, durability, surface finish and reliability of concrete structures and eliminating some of the potential for human error. However, SCC is a sensitive mix, strongly dependent on the composition and the characteristics of its constituents.

Self-compacting concrete is considered a concrete that can be placed and compacted under its own weight without any vibration effort, assuring complete filling of formworks ev en when access is hindered by narrow gaps between reinforcement bars. Concrete that must not be vibrated is a challenge to the building industry. In order to achieve such behaviour, the fresh concrete must show both high fluidity and good cohesiveness at the same time.

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. SCC was developed first in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions. As the durability of concrete structures became an important issue in Japan, an adequate compaction by skilled labours was required to obtain durable concrete structures. This requirement led to the development of SCC and its development was first reported in 1989. SCC can be described as a high performance material which flows under its own weight without requiring vibrators to achieve consolidation by complete filling of formworks even when access is hindered by narrow gaps between reinforcement bars. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete, such as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flow ability of SCC makes it possible to fill the formwork without vibration. Since its inception, it has been widely used in large construction in Japan. Recently, this concrete has gained wide use in many countries for different applications and structural configurations. It can also be regarded as "the most revolutionary development in concrete construction for several decades". Originally developed to offset a growing shortage of skilled labour, it is now taken up with enthusiasm across European countries for both site and precast concrete work.

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-pozz, etc. with some superplasticizer is mixed. Since super-pozz is a new emerging admixture and is a highly reactive alumina silicate pozzolanic material, its fineness and spherical particle shape improves the workability of SCC. Thus, it can be used as a suitable admixture in SCC.

Three basic characteristics that are required to obtain SCC are high deformability, restrained flow ability and a high resistance to segregation. High deformability is related to the capacity of the concrete to deform and spread freely in order to fill all the space in the formwork. It is usually a function of the form, size, and quantity of the aggregates, and the friction between the solid particles, which can be reduced by adding a high range water- reducing admixture (HRWR) to the mixture. Restrained flow ability represents how easily the concrete can flow around obstacles, such as reinforcement, and is related to the member geometry and the shape of the formwork. Segregation is usually related to the cohesiveness of the fresh concrete, which can be enhanced by adding a viscosity-modifying admixture (VMA) along with a HRWR, by reducing the free-water content, by increasing the volume of paste, or by some combination of these constituents. Two general types of SCC can be obtained: (1) one with a small reduction in the coarse aggregates, containing a VMA, and (2) one with a significant reduction in the coarse aggregates without any VMA.

To produce SCC, the major work involves designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained. In practice, SCC in its fresh state shows high fluidity, self-compacting ability and segregation resistance, all of which contribute to reducing the risk of honey combing of concrete. With these good properties, the SCC produced can greatly improve the reliability and durability of the reinforced concrete structures. In addition, SCC shows good performance in compression and can fulfil other construction needs because its production has taken into consideration the requirements in the structural design.

2. MATERIALS

SCC is something different than the conventional concrete or modification of conventional concrete it has similar ingredients such as Aggregate binder, however there blending is changed so as to get the advantages of self-compactness.

2.1 Cement

Ordinary Portland cement, 43 or 53 grades can be used. Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. Basic composition of cement is shown in Table 1.

Table -1 Composition Limits for Portland Cement

Ingredient	% Content
CaO (Lime)	60-67
SiO_2 (Silica)	17-25
Al_2O_3 (Alumina)	3-8
Fe_2O_3 (Iron Oxide)	0.5-6
MgO (Magnesia)	0.1-4
Alkalies	0.4-1.3
Sulphur	1-3

Table -2 Test Results of Portland Cement

Sr. No.	Test Description	Test Results	Required as per IS:12267-1987
1	Normal consistency	28%	---
2	Initial setting time	35 min	30 min
3	Compressive strength • 7 days • 14 days • 28 days	 29 N/mm^2 41 N/mm^2 55 N/mm^2	 27 N/mm^2 37 N/mm^2 53 N/mm^2
4	Specific gravity	3.01	---

2.2 Fine Aggregate

Fine aggregates can be natural or manufactured. The grading must be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes. Particles smaller than 0.125 mm i.e. 125 micron size are considered as FINES which contribute to the powder content.

The sand used for the experimental programme was locally procured and conformed to Indian Standard Specifications IS:383-1970. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust.

Table -3 Test Results of Aggregates

Sr. No.	Test Description	Fine Aggregates	Coarse Aggregates
1	Water Absorption (%)	1.47	1.47
2	Specific Gravity	2.78	2.78
3	Impact Value (%)	---	19
4	Crushing Value (%)	---	17

Table -4 Sieve Analyses of Aggregates

Fine Aggregates		Coarse Aggregates	
Sieve Size (mm)	% of passing	Sieve Size (mm)	% of passing
10.0	100.00	20.0	100.00
4.75	98.97	12.5	96.32
2.36	89.25	10.0	48.96
1.18	62.35	6.3	16.23
600	32.54	4.75	8.21
300	13.28	2.36	0.20
150	5.23	as per IS:383-1970	
75	0.15		
Zone	I		

2.3 Coarse Aggregate

The maximum size of aggregate is generally limited to 20 mm. Aggregate of size 10 to 20 is desirable for structures having congested reinforcement. Wherever possible size of aggregate higher than 20mm could also be used. Well graded cubical or rounded aggregate are desirable. Aggregate should be having uniform quality with respect to shape and grading.

The material which is retained on IS sieve no. 4.75 is termed as a coarse aggregate. The crushed stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 10 mm was used in our work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition.

2.4 Water

Water quality must be established on the same line as that for using reinforced concrete or prestressed concrete. This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete , should be clean and free from harmful impurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete. Ordinary potable water of normally pH 7 is used for mixing and curing the concrete specimen.

2.5 Admixtures

An admixture is a material other than water, aggregates and cement and is added to the batch immediately before or during its mixing. Admixtures are used to improve or give special properties to concrete. The use of admixture should offer an improvement not economically attainable by adjusting the proportions of cement and aggregates and should not adversely affect any properties of the concrete.

- **Superplasticizer** (high-range water-reducers) are low molecular-weight, water-soluble polymers designed to achieve high amounts of water reduction (12-30%) in concrete mixtures in order to attain a desired slump (Gagne et al., 2000). BASF MasterGlenium SKY 8784 based on second generation polycarboxylic etherpolymers is used as super-plasticizer.

- **Viscosity Modifying Agent** are high molecular-weight, water-soluble polymers used to raise the viscosity of water. Such compounds increase the cohesiveness of fresh concrete, reducing its tendency to segregate and bleed (Ferraris, 1999). BASF GLENIUM STREAM 2 is used as Viscosity Modifying Agent.

2.6 GGBS (Ground Granulated Blast-Furnace Slag)

GGBS is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water.

Table -5 Composition of Portland Cement & GGBS

Chemical Constituent	Portland Cement	GGBS
CaO	65%	40%
SiO_2	20%	35%
Al_2O_3	5%	10%
MgO	2%	8%

Table -6 Physical Results of GGBS

Colour	Off-white powder
Bulk density (loose)	1.0-1.1 tonne/m^3
Bulk density (vibrated)	1.2-1.3 tonne/m^3
Relative density	2.85-2.95
Surface area	400-600 m^2/kg Blaine

3. MIXTURE PROPORTION

The proportions of the concrete mixtures are summarized in Table 7. For all the mixtures, the coarse and fine aggregates were weighed in a room dry condition and then the materials are stacked on a water tight platform. The materials are thoroughly mixed in their dry conditions before water is added. The prepared mix of water & admixture was immediately used for testing the workability of fresh mix.

Table -7 Concrete Mix Design of M45 for 1 m^3

Design	Cement kg	GGBS kg	GGBS %	Water kg	F.A kg	C.A kg	Super Plasticizer kg	VMA kg
SCC	550	00	0	175	885	800	4.35	0.54
S - 9	500	50	9	175	885	800	4.35	0.54
S - 14	475	75	14	175	885	800	4.35	0.54
S - 18	450	100	18	175	885	800	4.35	0.54
S - 23	425	125	23	175	885	800	4.35	0.54
S - 27	400	150	27	175	885	800	4.35	0.54
S - 32	375	175	32	175	885	800	4.35	0.54

4. TEST PROCEDURE

4.1 Properties of Fresh Concrete

The slump flow, air content, bleeding, and setting time of fresh concrete were determined following as per European standards.

The viscosity of SCC mixtures was evaluated through the slump flow test. The slump flow represents the mean diameter of the mass of concrete after release of a standard slump cone; the diameter is measured in two perpendicular directions. According to European guidelines, a slump flow ranging from 650 to 800 mm is considered as the slump required for a concrete to be self-compacted. At more than 800 mm the concrete might segregate, and at less than 650 mm the concrete is considered to have insufficient flow to pass through highly congested reinforcement. During this test, time is also measured which was taken to reach 500 mm diameter, which should be within 2 to 5 seconds for a concrete to be self-compacted.

The stability of SCC mixtures was evaluated through the V-Funnel test, the flow time was determined using a simple procedure: the funnel is completely filled with fresh concrete, and the flow time is that between opening the orifice and the complete emptying of the funnel. According to European guidelines, a funnel test flow time from 6 to 12 second is recommended for a concrete to qualify for an SCC.

After this test, V-Funnel at T5 minutes has to be performed for segregation resistivity. In this test, concrete which was used again filled in V-Funnel after 5 minutes, and the flow time is measured that between opening the orifice and the complete emptying of the funnel. According to European guidelines, a funnel tes t flow time should be less than 3 more second than previous one for a concrete to qualify for an SCC.

The passing ability of SCC mixtures was evaluated through the U-Box test. In this test, U-Box's one compartment is completely filled with fresh concrete, and the gate between two compartments is opened and let concrete flow from gate to another compartment. After that height difference measured which should be 0 to 30 mm for a concrete to qualify for an SCC.

The passing ability of SCC mixtures was evaluated through the L-Box test. In this test, L-Box's vertical compartment is completely filled with fresh concrete, and the gate is opened and let concrete flow from gate to horizontal compartment and height measured. And ratio of height of L-Box should be 0.8 to 1.0 for a concrete to qualify for an SCC.

The passing ability of SCC mixtures was evaluated through the J-Ring test. In this test, J-Ring is placed on slump flow board and slump cone is filled with fresh concrete, after that the cone is released and heig ht difference is measured which should be within 0 to 10 mm for a concrete to qualify for an SCC.

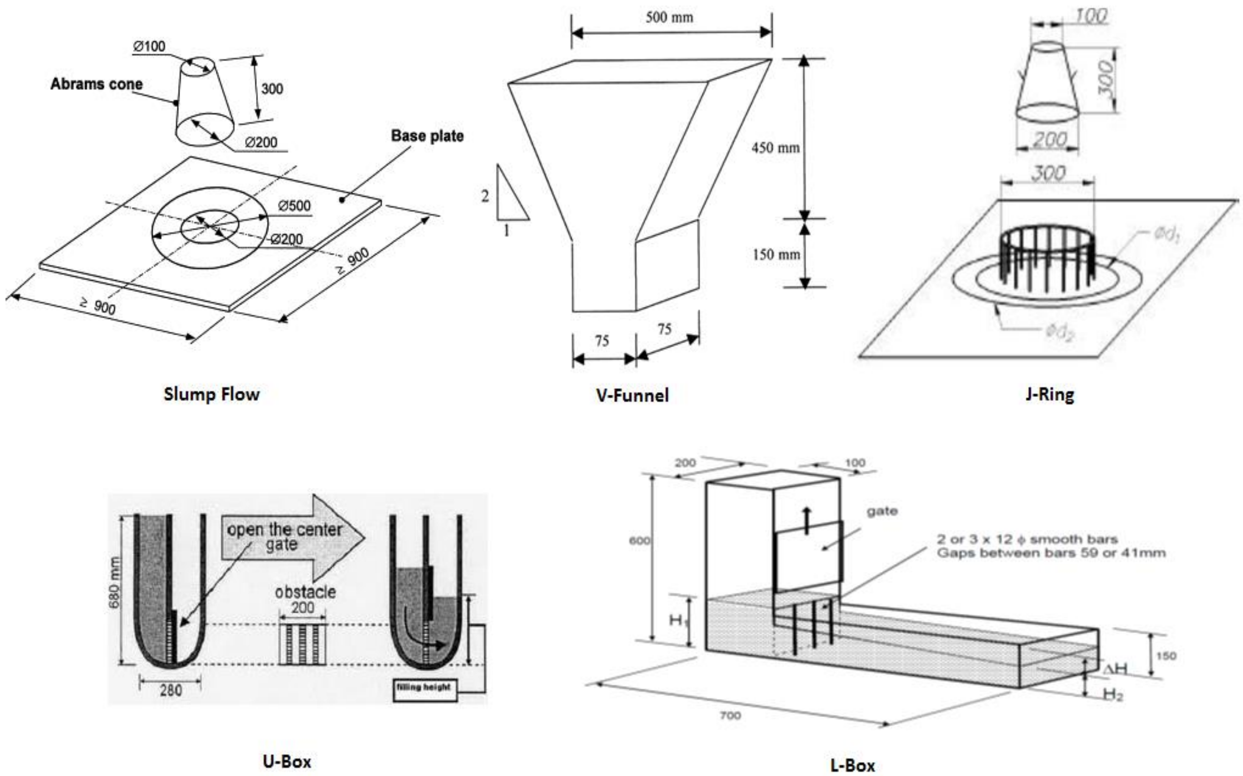

Fig -1 General Arrangement of Apparatus

Table -8 Suggested Value of Acceptance for Different Test Methods of SCC

Sr. No.	Methods	Unit	Typical Range of Values	
			Minimum	Maximum
1	Slump Flow	mm	650	800
2	Slump Flow T50 Time	Sec	2	5
3	V-Funnel	Sec	6	12
4	U-Box	mm	0	30
5	L-Box	----	0.8	1.0
6	J-Ring	mm	0	10
7	V-Funnel T5 Minutes	Sec	6	15

4.2 Mechanical Properties

For each mixture, the compressive strength was determined on three cubes at 3, 7, 14 and 28 days on 150x150x150 mm specimen.

5. TEST RESULTS

5.1 Fresh Concrete Properties

Table-9 gives the fresh concrete test results of effect of addition of GGBS in various percentages on the properties of self-compacting concrete containing an admixtures combination of (SP+VMA).

Table -9 Fresh Concrete Properties Test Results

Design	Flow Ability Test			Passing Ability Test			Segregation Test
	Slump Test		V-Funnel	U-Box	L-Box	J-Ring	V-Funnel at T5
	Slump Flow (mm)	Slump Flow T_{50} (sec)	Flow Time (sec)	H_1-H_2	H_2/H_1	Height Difference (mm)	Flow Time (sec)
SSC	640	6.35	17	18.5	0.63	14.21	21
S 9	710	3.13	8.84	13	0.81	9.3	9.96
S 14	660	5	9.81	3	0.7	10	13
S 18	655	6	10	0	0.82	10.2	13.15
S 23	660	5.10	8	2.5	0.87	9.9	11.40
S 27	665	3.91	11	0	0.83	9.8	13.8
S 32	680	2.23	13.24	3	0.76	9.0	4

5.2 Mechanical Properties

Table-10 gives the compression test results of effect of addition of GGBS in various percentages on the properties of self-compacting concrete containing an admixtures combination of (SP+VMA).

Table -10 Compression Test Results

Design	Compressive Strength (MPa)			
	3 days	7 days	14 days	28 days
SCC	29.94	33.16	39.73	49.74
S 9	24.53	32.94	38.82	53.25
S 14	22.14	32.71	39.55	43.55
S 18	18.16	22.8	27.19	40.25
S 23	17.32	22.21	30.05	37.83
S 28	17.92	24	28.09	32.09
S 32	17.8	23.48	28.72	31.17

The influence of GGBS on compressive strength of self-compacting concrete is given in Table 8 and Chart 1. The percentage of GGBS was 9%, 14%, 18%, 23%, 27% and 32% and the water- cement ratios ranged from 0.32.The test results indicated that, 9% percent by mass replacement of GGBS for cement gives the highest strength for short and long terms and when GGBS is replaced by 14%, 18%, 23, 27% and 32% the strength decreases.

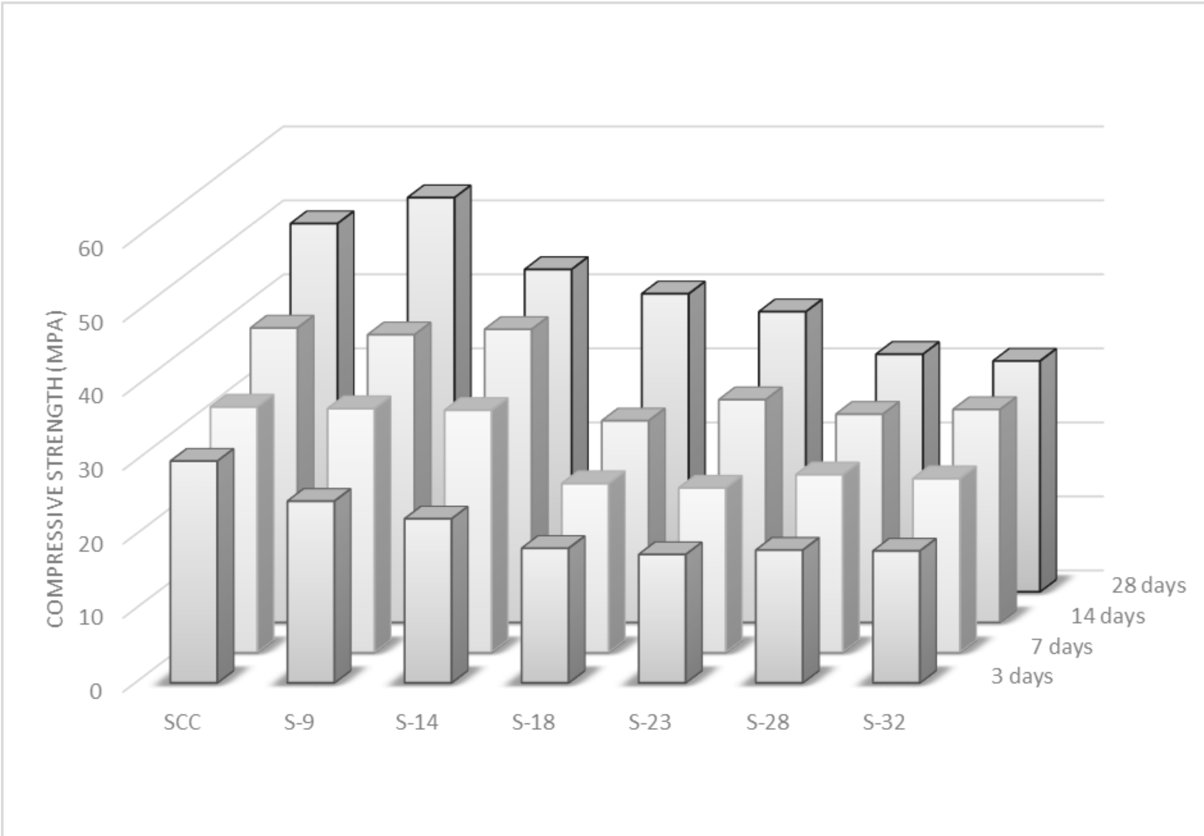

Chart -1 Compression Test Results

6. CONCLUSION

To increase the stability of fresh concrete (cohesiveness) using increased amount of fine materials in the mixes. To development of self-compacting concrete with reduced segregation potential. The systematic experimental approach showed that partial replacement of coarse and fine aggregate with finer materials could produce self-compacting concrete with low segregation potential as assessed by the V-Funnel test. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC. If we add the mineral admixture replacement for we can have a better workable concrete. It has been verified, by using the slump flow, T50 cm slump flow J-ring test, L-box test and U-tube tests, that self-compacting concrete (SCC) achieved consistency and self-compatibility under its own weight, without any external vibration or compaction. SCC with mineral admixture exhibited satisfactory results in workability, because of small particle size and more surface area.

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