SELF-COMPACTING CONCRETE - AN ADVANCED MATERIAL IN CONSTRUCTION TECHNIQUES

Mr. Ankit Srivastava[1], Mr. Naveen Singh[2], Mr. Chetan kumar[3], Mrs. Vidyotama Pandit[4], Er. Trimurti Narayan Panday[5], Er. Amit Choudhary[6]

[1]PG Scholar, Department of Civil Engineering,Bhagwant University , Ajmer Rajasthan., India
[2]PG Scholar, Department of Civil Engineering,Bhagwant University , Ajmer Rajasthan., India
[3]PG Scholar, Department of Civil Engineering,Bhagwant University , Ajmer Rajasthan., India
[4]PG Scholar, Department of Civil Engineering,Bhagwant University , Ajmer Rajasthan., India
[5]Assistant Professor, Department of Civil Engineering,Bhagwant University , Ajmer Rajasthan., India
[6]Assistant Professor, Department of Civil Engineering,Bhagwant University , Ajmer Rajasthan., India

ABSTRACT

Concrete is a widely-used construction component. its widespread use and specifications like durability, quality, compactness and optimization has led researchers to enhance its quality more and turn it into a more revolutionary material which will save time, material and will be eco-friendly, which is nowadays very important. Self-compacting concrete or high strength self-consolidating concrete (S.C.C) is a very fluid concrete and a homogenous mixture that solves most of the problems related to ordinary concrete. Besides, S.C.C gets compacted under its own weight and there is no need for an internal vibrator for the body of the mould. This specification helps the execution of construction components under high compression of reinforcement. high-strength self-consolidating concrete containing high-volumes of fly ash. In this study, Portland cement was replaced by Class C fly ash in the range of 35 to 55 % by the mass of cement. The results of fresh and hardened properties of concrete show that the use of high-volumes of class C fly ash in Self-Consolidating concrete drastically reduces the requirements for superplasticizer (HRWRA) and viscosity modifying agent (VMA) compared with the normal dosage for such admixtures in self-consolidating concrete.

Keywords- *self-compacting concrete, class C fly ash, workability, compression test.*

1. INTRODUCTION

Self-compacting concrete has been described as “the most revolutionary development in concrete construction for several decades.” originally developed to offset a growing shortage of skilled labours, Self-compacting concrete was proposed in 1988 for the first time to access stable concrete structure. Then, different studies were carried out to offer a reasonable mix design and suitable methods to control self-compaction test and introduce the unique characteristics of S.C.C to promote the use of this concrete like ordinary concrete.

Primary studies about S.C.C were carried out by Ozawa (1988) and Okamura (1993) in Tokyo University. There is no formal definition of S.C.C, but there is a theory saying that S.C.C is a concrete that:

(1) Has good fluidity which causes self-compaction and does not need external energy
(2) Remains consistent during and after concreting and easily moves within reinforcements.

It should be mentioned that the characteristics of fresh and hardened concrete depend mainly on its mix design. Having access to different sources to introduce S.C.C and different test methods of S.C.C, it has proved beneficially economical because of several factors, including:

- Faster construction
- Reduction in site man power
- Better surface finishing
- Easier placing
- Improved durability

- Greater freedom in design
- Thinner concrete sections
- Reduced noise levels (absence of vibration)
- Safer working environment

2. MATERIALS AND METHODS EMPOLYED

I) MATERIALS

The components of S.C.C are normally fine materials which constitute to the self-compaction. However, the materials used in S.C.C are:

a) CEMENT

The cement used was ordinary Portland cement. General suitability for cement conforming to EN 197-1

b) AGGREGATES

Aggregates shall confirm, to EN 12620 the maximum size of aggregates depends upon the application and is usually limited to 20 mm. particles smaller than 0.125 mm contribute to powder content the moisture content should be closely monitored and must be considered in order to produce SCC of constant quality.

c) WATER

The water used is portable water and should be free from any types of impurities

d) ADMIXTURES

Superplasticizers are an essential component of SCC to provide the necessary workability. other types maybe incorporated as necessary, such as viscosity modifying agents for stability, air entertaining admixtures to improve freeze – thaw resistance, retarders for control of setting etc.

e) **ADDITIONS** (including mineral fillers and pigments) General suitability as type I

- Filler aggregates
- Pigments

General suitability as type II

- Fly ash
- Silica fume
- Ground granulated blast furnaces slag

Due to several rheological requirements of SCC. both inert and reactive additions are commonly used to improve and maintain workability. Type II additions can significantly improve the long-term performance of concrete.

Typical additions are:

Stone powder: Finely crushed limestone, dolomite or granite may be used to increase the amount of powder: the fraction less than 0.125 mm will be of most benefit. Note: dolomite may present a durability risk due to alkali-carbonate reaction.

Fly Ash. Fly ash is a fine inorganic material with pozzolanic properties, which can be added to SCC to improve its properties. However, the dimensional stability may be affected and should be checked.

Silica Fume. Silica fume gives very good improvement of the rheological as well as the mechanical and chemical properties. Improves also the durability of the concrete.

Ground (Granulated) Blast Furnace Slag. GGBS is a fine granular mostly latent hydraulic binding material, which can also be added to SCC to improve the rheological properties.

Ground Glass Filler. This filler is usually obtained by finely grinding recycled glass. The particle size should be less than 0,1 mm and the specific surface area should be 2500 cm2/g. Larger particle sizes may cause Alkali-Silica reaction.

Pigments. The suitability of pigments used in SCC is established in EN 12878.

f) FIBERS

Fibres may be used to enhance the properties of SCC in the same way as for normal concrete. Steel fibres are used normally to enhance the mechanical characteristics of the concrete such as flexural strength and toughness. Polymer fibres may be used to reduce segregation and plastic shrinkage, or to increase the fire resistance. Ease of mixing and the placing processes proposed, shall be demonstrated by site trials to the approval of the engineer.

II) TEST METHODS

Many different test methods have been developed in attempts to characterise the properties of SCC. So far, no single method or combination of methods has achieved universal approval and most of them have their adherents. Similarly, no single method has been found which characterises all the relevant workability aspects so each mix design should be tested by more than one test method for the different workability parameters.

1. Slump-Flow Test

Slump-flow testing is the simplest and most commonly adopted test method for evaluating the flowability quality of self-consolidating concrete. An ordinary Abram's slump cone is filled with concrete without any tamping. The cone is lifted and the diameter of the concrete after the flow has stopped is measured. The mean diameter in two perpendicular directions of the concrete spread is taken as the value of slump-flow. Self-consolidating concrete is characterized by a slump-flow of 660 to 720 mm (26 to 28 inches). Measurement of slump-flow indicates the flowability of self-consolidating concrete and determines the consistency and cohesiveness of the concrete. The slump-flow test measures the capability of concrete to deform under its own weight against the friction on the surface of the base plate with no other external resistance present. According to Nagataki and Fujiwara, a slump-flow ranging from 500 to 700 mm (20 to 28 inches) is considered as a proper slump required for a concrete to qualify for self-consolidating concrete. At more than 700 mm, the concrete might segregate and at less than 500 mm the concrete is considered to have insufficient flow to pass through congested reinforcement. According to Bartos the slump-flow test can give an indication of filling ability and susceptibility to segregation of the self-consolidating concrete. The passing ability of concrete is not indicated by this test. Flowing time from the initial diameter of 200 mm to 500 mm, designated as T50, is sometimes used for a secondary indication of flow. A time of 3 to 7 seconds is acceptable for general applications and 2 to 5 seconds for housing applications. However, this test is not sensitive enough to distinguish between self-consolidating concrete mixtures and super-plasticized concrete.

2. U-Flow Test

The U-flow test examines the behaviour of the concrete in a simulated field condition. It is one of the most widely adopted test method for characterization of self-consolidating concrete. This test simulates the flow of concrete through a volume containing reinforcing steel. This test is considered more appropriate for characterizing self-compact ability of concrete. In this test, the degree of compact ability can be indicated by the height that the concrete reaches after flowing through an obstacle. This test is performed by first completely filling the left chamber of the U-flow device, while the sliding doors between chambers are closed. The door is then opened and the concrete flows past the rebar's into the right chamber. Self-consolidating concrete for use in highly congested areas should flow to about the same height in the two chambers. If the filling height is at least 70% of the maximum height possible, then the concrete is considered self-consolidating. The selection of this percentage is arbitrary and a higher value might be considered for more highly reinforced sections. In the U-flow device, the maximum filling height is 300 mm, a little more than half of the height (571 mm) of the U-flow apparatus. Therefore, a concrete with a final height of more than 200 mm is considered self-consolidating concrete. This test measures filling, passing, and segregation properties of self-consolidating concrete.

3. V-Flow Test

Another type of test, which is frequently adopted, is the V-flow test. It consists of a funnel with a rectangular cross section. The top dimension is 495 mm by 75 mm and the bottom opening is 75 mm by 75 mm. The total height is 572 mm with a 150 mm long straight section. The concrete is poured into the funnel with a gate blocking the bottom opening. When the funnel is completely filled, the bottom gate is opened and the time for the concrete to flow out the funnel is noted. This is called the V-flow time. A flow time of less than 6 seconds is recommended for a concrete to qualify as a self-consolidating concrete.

4. L-Box Test

The L-box test method uses a test apparatus consisting of a vertical section and a horizontal section. Reinforcing bars are placed at the intersection of the two areas of the apparatus. The vertical part of the box is filled with 12.7 litters (approximately 30 kg) of concrete and left to rest for one minute to allow any segregation and bleeding to occur. The gap between the reinforcing bars is generally kept at 35 and 55 mm for 10 and 20 mm maximum-size coarse aggregates, respectively. The time taken by the concrete to flow distances of 200 mm (T-20) and 400 mm (T-40) in the horizontal section of the apparatus, after the opening of the gate from the vertical section, is measured. The heights of concrete at both ends of the apparatus (H1 and H2) are also measured to determine L-box results. This test gives an indication of the filling, passing, and segregation-resisting ability of the concrete.

5. Ring Test

The J-ring test is another type of method for the study of the blocking behaviour of self-consolidating concrete. The apparatus consists of re-bars surrounding the Abram's cone in a slump-flow test. The spacing between the re-bars is generally kept three times of the maximum size of the coarse aggregate for normal reinforcement consideration. The concrete flows between the re-bars after the cone is lifted and thus the blocking behaviour/passing-ability of SCC can be detected.

III) STRUCTURAL PERFORMANCE OF SCC

The mechanical properties of self-consolidating concrete are like regular concrete with similar W/Cm. The homogeneity of self-consolidating concrete can be seen through micrograph analysis. Campion and Jost reported no difference in composition and in strength of the cores drilled from wall elements (of actual structure) at different heights. They further reported only minor differences between durability factors such as chloride diffusion and freezing-and-thawing resistance of self-consolidating concrete and regular plasticized concrete. Shrinkage measurement studies also revealed equal value or slightly higher shrinkage values for self-consolidating concrete. Zhu et al. studied the uniformity of in-situ properties of self-consolidating concrete mixtures, in structural columns and beams, and compared the results of core compression tests, pull-out test results, and rebound hammer for near surface properties to those of properly compacted conventional concrete. Based on the analysis, they noticed no significant differences in uniformity of in-situ properties between the two concretes. A comparative study by Pautre et al. on the structural behaviour of highly-reinforced columns, cast with SCC having compressive strength in the range of 60 MPa and 80 MPa, as well as columns cast with properly compacted controlled concrete of similar strength exhibited similar ductility but yielded slightly lower strength (5% less). However, it was reported that SCC showed greater homogeneity of distribution of in-place compressive strength than conventionally vibration compacted concrete. Several other studies related to durability aspects such as chloride permeability, deflection, rupture behaviour, freezing-and-thawing resistance, and chloride diffusivity, and other properties of self- consolidating concrete reported either comparable or better results compared with the conventional concrete.

Table 1: List of test methods for workability properties of SCC

S. No.	Method	Property
1	Slump-flow by Abrams cone	Filling ability
2	T50 cm slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel at T5minutes	Segregation resistance
6	L-box	Passing ability
7	U-box	Passing ability
8	Fill-box	Passing ability
9	GTM screen stability test	Segregation resistance
10	Orimet	Passing ability

For the initial mix design of SCC all three workability parameters need to be assessed to ensure that all aspects are fulfilled. A full-scale test should be used to verify the self-compacting characteristics of the chosen design for an application.

For site quality control, two test methods are generally sufficient to monitor production quality. Typical combinations are Slump-flow and V-funnel or Slump-flow and J-ring. With consistent raw material quality, a single test method operated by a trained and experienced technician may be sufficient.

Table 2: **Workability properties of SCC and alternative test methods.**

Property	Test Methods		Modification of test according to max. aggregate size
	Lab (mix design)	Field (QC)	
Filling ability	1 Slump flow 2 T50cmslumpflow 4 V-funnel 10 Orimet	2 Slump flow 2 T50cmslumpflow 4 V-funnel 10 Orimet	none max 20 mm
Passing ability	6 L-box 7 U-box 8 Fill-box	3 J-ring	Different openings in L -box, U-box and J-ring
Segregation resistance	9 GTM test 5 V-funnel at T5minutes	10 GTM test 5 V-funnel at T5minutes	None

IV) Workability criteria for the fresh SCC

These requirements are to be fulfilled at the time of placing. Likely changes in workability during transport should be considered in production.

Typical acceptance criteria for Self-Compacting Concrete with a maximum aggregate size up to 20 mm are shown in Table 3.

Table 3: Acceptance criteria for Self-Compacting Concrete.

S.No.	Method	Unit	Typical range of values	
			Minimum	Maximum
1	slump flow by Abrams cone	mm	650	800
2	T50cm slump flow	sec	2	5
3	J-ring	mm	0	10
4	V-funnel	sec	6	12
5	Time increase, V-funnel at T5minutes	sec	0	3
6	L-box	(h2/h1)	0,8	1,0

7	U-box	(h2-h1) mm	0	30

These typical requirements shown against each test method are based on current knowledge and practice. However future developments may lead to different requirements being adopted. Values outside these ranges may be acceptable if the producer can demonstrate satisfactory performance in the specific conditions, eg, large spaces between reinforcement, layer thickness less than 500 mm, short distance of flow from point of discharge, very few obstructions to pass in the formwork, very simple design of formwork, etc.

Special care should always be taken to ensure no segregation of the mix is likely as, at present, there is not a simple and reliable test that gives information about segregation resistance of SCC in all practical situations.

3. PRODUCTION AND PLACING

(1) General

The production of self-compacting concrete needs to be carried out in plants where the equipment, operation and materials are suitably controlled. Production should therefore be carried out at ISO 9000 accredited plants or plants with a quality systems that conforms to ISO 9000 or similar. It is recommended that production staff involved in the production of self-compacting concrete have been trained and have experience in self-compacting concrete.

(2) Production: -

Storage of constituent materials

If possible, aggregates should be covered to minimise the fluctuation of surface moisture content. It is also necessary to have good storage capacity for aggregates and additions (if used). Storage of concrete admixtures can be done in the same way as for normal concrete. The supplier's recommendations should be followed.

Mixing

There is no requirement for any specific mixer type. Forced action mixers, including paddle mixers, free fall mixers, including truck mixers, and other types can all be used. The mixing time necessary should be determined by practical trials. Generally, mixing times need to be longer than for conventional mixes. Time of addition of admixture is important, and procedures should be agreed with the supplier after plant trials. If the consistence has to be adjusted after initial mixing, then it should generally be done with the admixtures. If the requirements of EN 206 for the water/cement ratio can be maintained, then the water content can be varied to make the necessary modification.

(3) Production Control

Aggregates

During production of SCC, tests of aggregate grading and moisture content should be carried out more frequently than usual, since SCC is more sensitive than normal concrete to variations.

Mixing process

At the start of a contract and in the absence of previous experience with the mix design, additional resources may be needed for supervision of all aspects of initial production of SCC. Since the quality of freshly mixed concrete may fluctuate at the beginning of production, it is recommended that workability tests should be conducted by the producer on every load, until consistent and compliant results are obtained. Subsequently, every delivered batch should be visually checked before transportation to site, and routine testing is carried out. More frequent adjustment of mix proportions, particularly water content, may need to be made, depending on the results from monitoring aggregate moisture content.

(4) Delivery and transportation

Depending on the size of the concrete structure to be produced in SCC, production capacity, journey time and placing capability need to be balanced. Unexpected production stops can result in consistence variations that adversely affect the result. SCC should be designed so that workability is maintained to meet the requirements of the contract. Placing is faster, especially if a pump is used, but it is still essential to make sure that delivery and placing can be completed within the workability-retention (self-compactability) time of the concrete.

4. Placing

General

Before placing SCC, it should be confirmed that reinforcement and formwork are arranged as planned. The formwork must be in good condition but no special measures are necessary to prevent grout loss. Contractors may wish to consider possible advantages of pumping from the bottom of formwork. If concrete is placed by skip, attention should be paid to the closure of the gate. For forms, more than 3 m in depth, the full hydrostatic head should be taken into consideration. This may require modification of the formwork design and/or the SCC.

Placing distance

Though it is easier to place SCC than ordinary concrete, the following rules are advised to minimise the risk of segregation:

- limit the vertical free fall distance to 5 m
- limit the permissible distance of horizontal flow from point of discharge to10 m.

Note: this advice is conservative, and it may be that in favourable circumstances a contractor can demonstrate that the suggested limits can be extended.

Cold joints: - Although SCC bonds well with previously placed concrete, the likelihood of damage resulting from a cold joint cannot be mitigated by vibration, as with normal concrete.

Surface finishing: - Surfaces of SCC should be roughly levelled to the specified dimensions, and the finishing should then be applied at an appropriate time before the concrete stiffens. Difficulty may be encountered with the conventional process of final surface hardening of horizontal areas of concrete by repeated steel trowelling. Alternative procedures, or different tools may be required.

Curing: - SCC tends to dry faster than conventional concrete because there is little or no bleed water at the surface. Initial curing should therefore be commenced as soon as practicable after placing to minimise the risk of shrinkage cracking.

5. QUALITY CONTROL

Production control: - All SCC shall be subject to production control under the responsibility of the producer.

Site acceptance

In the case of SCC, it is particularly important that receiving control be standardised. Producer and purchaser should therefore agree a procedure for acceptance/compliance at the start of a contract. This should include a procedure for action to be taken in the event of non-compliance. Beside the normal check of delivery ticket, a visual check of the concrete should be made. The purchaser should ensure that all site acceptance testing is carried out by competent, trained personnel, in a suitable environment – this includes an area protected against the weather, suitably maintained and calibrated equipment, and level, stable ground for performing the test.

6. RESUTS AND CONCLUSIONS

The final composition that was established for a competitive self-compacting concrete are shown in table 4.

Table 4

Composition		Self-Compacting Concrete
Cement CEM I 42,5 R, [kg/m3] 477.2		477.2
Silica fume, [kg/m3] 53.5		53.2
Fly ash, [kg/m3] 53.5		53.2
Fine aggregate, [kg/m3]	0/4 mm river	987.3
Coarse aggregate, [kg/m3]	4/8 mm crushed	526.5
Superplastifiant, [kg/m3]	GLENIUM	7.2
	ACE 30	(1.5% from cement)
Water, [kg/m3]		198.8
Water Content		0.416
Total, [kg]		2,304

Fresh concrete characteristics are presented in Table 5.

Table 5

Characteristic			Self-Compacting Concrete
Volumetric mass, [kg/m3]			2304
Workability	Limits		680
	Slump, [mm]	600…800	
	L-box, h1/h2	0.8...1	8.3/9 = 0.92
	V-funnel, [sec.]	6…12	12

The samples were strike after 48 h and kept in water for 7 days. Then, until test have been done, the samples were placed on a grill over a water tank. The obtained hardened concrete properties (Table 6) for self-compacting concrete prove that it can be referred to, as SCC in the concrete resistance class C50/60.

Table 6

Characteristic	Self-Compacting Concrete
Volumetric mass, [kg/m3]	2,305 2,317/2,311
Compression strength on cubes, [N/mm2]	63.11 64.89/64.00
Compression strength on prisms, [N/mm2]	52

Bending tensile strength, [N/mm2]	8.3
Modulus of elasticity, [KN/mm2]	47.5

CONCLUSIONS: -

An overview of the development, properties, and advantages and disadvantages of using self-consolidating concrete has been outlined. Further, based on limited experimental study on the development of high-strength self-consolidating concrete incorporating high-volumes of Class C fly ash, the following conclusions can be drawn:

1. Use of high-volumes of Class C fly ash in the manufacturing of self-consolidating concrete significantly reduces the amount of superplasticizer and viscosity modifying agent compared with the normal dosage for such admixtures in SCC.

2. High-strength self-consolidating concrete for strength of about 9,000 psi at 28 days' age can be manufactured by replacing 35% of cement by Class C fly ash.

3. High-strength self-consolidating concrete for strength in the range of 7,000 to 9,000 psi at 28 days' age can be manufactured by replacing up to 55% of cement by Class C fly ash.

REFERENCES

[1] Ouchi-Kochi M., Hibino-Nagaoka M., Development, Applications and Investigations of Self-Compacting Concrete. Japan, 2000.

[2] Kordts S., Grube H., Controlling the Workability Properties of Self-Compacting Concrete Used as Ready-Mixed Concrete. Düsseldorf, Germany, 2006.

[3] Rooney, M., Bartos, P.M.J., 'Development of the settlement column segregation test for fresh self-compacting concrete (SCC)', to appear in the second international symposium on SCC, Tokyo, Japan (2001).

[4] Henderson N A, Baldwin N J R, McKibbins L D, Winsor D S, & Shanghavi HB, "Concrete technology for foundation applications", CIRIA Report C569: 2002

[5] Ozawa, K., Sakata, N., Okamura, H., "Evaluation of Self-Compactibility of Fresh Concrete Using, the Funnel Test", Concrete Library of JSCE, (25) (June 1995) 59-75.

[6] Petersson, Ö., Billberg, P., Van, B.K., 'A model for self-compacting Concrete', Proceedings of International RILEM Conference on 'Production Methods and Workability of Concrete', edited by P.J.M. Bartos, et al. (Chapman & Hall/E & FN Spon) (Paisley, 1996) 483-490.

[7] EFNARC;Specification and Guidelines for SELF-COMPACTING CONCRETE;february2002.