SELF-COMPACTING CONCRETE

Self-compacting concrete has been described as "the most revolutionary development in concrete construction for several decades". Originally developed in Japan to offset a growing shortage of skilled labour, it has proved to be beneficial from the following points.

- Faster construction
- Reduction in site manpower
- Better surface finish
- Easier placing
- Improved durability
- Greater freedom in design
- Thinner concrete sections
- Reduced noise level
- Safer working environment

Material for SCC

Cement : Ordinary Portland Cement, 43 or 53 grade can be used.

Aggregates : The maximum size of aggregate is generally limited to 20 mm. Aggregate of size 10 to 12mm is desirable for structures having congested reinforcement. Wherever pos- sible size of aggregate higher than 20mm could aslo be used. Well graded cubical or rounded aggregates are desirable. Aggregates should be of uniform quality with respect to shape and grading.

Fine aggregates can be natural or manufactured. The grading must be uniform through- out 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 con- tribute to the powder content.

Mixing Water: Water quality must be established on the same line as that for using rein- forced concrete or prestressed concrete.

Chemical Admixtures: Superplaseizers are an essential component of SCC to provide necessary workability. The new generation superplasticizers termed poly-carboxylated ethers (PCE) is particularly useful for SCC.

Other types may be incorporated as necessary, such as Viscosity Modifying Agents (VMA) for stability, air entraining agents (AEA) to improve freeze-thaw resistance, and retarders for Control of Setting.

Mineral Admixtures:

Fly ash: Fly ash in appropriate quantity may be added to improve the quality and durability of SCC.

Ground Granulated Blast Furnace Slag (GGBFS) : GGBFS which is both cementitious and pozzolanic material may be added to improve rheological properties.

Silica Fume: Silica fume may be added to improve the mechanical properties of SCC.

Stone Powder: Finely crushed lime stone, dolomite or granite may be added to increase the powder content. The fraction should be less than 125 micron.

Fibres : Fibres may be used to enhance the properties of SCC in the same way as for normal concrete. The approximate compositions of traditional concrete and SCC are shown below.

The SCC mixes are designed and tested to meet the demands of the projects. It is re- ported that SCC for mass concrete was designed for pumping and depositing at a fairly high rate in the construction of the anchorages of the Akashi-Kaikyo batching plant and pumped through a pipe line to the location of anchorages 200 m away. The SCC was dropped from a height of 5 m without segregation. For mass concrete, the maximum size of coarse aggregate was as large as 50 mm. The SCC construction reduced the construction time for the anchor- ages from 2.5 years to 2 years. The coarse aggregate size for reinforced concrete generally varies from 10 mm to 20 mm.

Examples of SCC Mixes

There are three ways in which SCC can be made (*i*) Powder Type

(ii) VMA Type

(iii) Combined type

In powder type SCC is made by increasing the powder content. In VMA type it is made by using viscosity modifying admixture. In combined type it is made by increasing powder content and using VMA. The above three methods are made depending upon the structural conditions, constructional conditions, available material and restrictions in concrete produc tion plant etc. The following table gives an idea about the three methods and a feel for how SCC mixes differ from normal concrete mixes and from each other mixes.

Requirements for self-compacting concrete

The main characteristics of SCC are the properties in the fresh state. The mix design is focussed on the ability to flow under its own weight without vibration, the ability to flow through heavily congested reinforcement under its own weight, and the ability to retain homogeneity without segregation. The workability of SCC is higher than “very high” degree of workability mentioned in 15 456 : 2000.

A concrete mix can only be classified as self-complicating if it has the following characteristics.

- Filling ability
- Passing ability
- Segregation resistance

Several 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 to include in national or international organisations. However, the Table 12.17 gives the list of test methods for workability properties of SCC based on EFNARC specification and guidelines.

Table 12.17. List of test methods for workability properties of SCC

Srl No.	*Method*	*Property*
1.	Slump flow by Abrams cone.	Filling ability
2.	$T_{50\ cm}$ Slump flow	Filling ability
3.	J-ring	Passing ability
4.	V-funnel	Filling ability
5.	V-funnel at T_5 minutes	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	Filling ability

Table 12.18. The workability properties of SCC and alternative test methods.

Property	Test Methods Lab mix. design	Field quality control	Modification of test according to max. size agg.
Filling ability	slump flow T_{50} cm slump flow V-funnel orimet Orimet	slump flow $T_{50\ cm}$ slump flow V-funnel Orimet	None None Max. 16 mm
Passsing ability	L-box, U-box Fill-box	J-ring	Different openings in L-box and J-ring

Segregation resistance	GTM test V-funnel at T_5 min.	G.T. test V-funnel at T_5 minutes	None

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, even a single test method carried out by trained and experienced technician may be sufficient.

Workability Requirement for the fresh SCC

The following requirements are to be fulfilled at the time of placing. Any changes in workability during transport and other delay should be taken into account in production.

Table 12.19. The typical acceptance criteria for SCC 12.18.

Srl values No.	*Method*	*Unit*	*Typical ranges of Minimum*	*Maximum*
1.	Slump flow by Abrams cone.	mm	650	800
2.	$T_{50\ cm}$ Slump flow	sec	2	5
3.	J-ring	mm	0	10
4.	V-funnel	sec	8	12
5.	V-funnel at T_5 minutes	sec	0	+3
6.	L-box	(h_2/h_1)	0.8	1.0
7.	U-box	$(h_2 - h_1)$mm	0	30
8.	Fill-box	%	90	100
9.	GTM Screen Stability Test	%	0	15
10.	Orimet	sec	0	5

Initial Mix composition

In the design of mix, the relative proportions of the key components may be considered by volume rather than by mass. Indicative proportions of materials are shown below for self compactability.

- Water/powder ratio by volume is to be 0.80 to 1.00
- Total power content to be 160 to 240 litres (400-600 kg) per m^3
- The sand content may be more than 38% of the mortar volume
- Coarse aggregate content should normally be 28 to 35% by volume of the mix
- Water/cement ratio is selected based on strength. In any case water content

should not exceed 200 litres/m^3.

One must bear in mind that there is going to be some variation in raw material quality and variation in moisture content in aggregates.

After laboratory trials, the mix should be tested at full scale at the concrete plant or site. In the event of not getting satisfactory performance, the mix should be readjusted in respect of type and quantity of filler material, proportions of F.A. or C.A., dosage of superplasticizer and VMA. Try also alternative type of superplaticizer which may be more compatible.

Mix Design

Procedure : The following sequence is followed

- Determine the desired air content
- Determine the coarse aggregate volume
- Determine the sand content
- Design the paste composition
- Determine the optimum water to powder ratio and superplasticizer dosage in mortar
- Finally the concrete properties are assessed by standard tests.

Air Content: Generally air content may be assumed to be 2%. In case of freeze-thaw conditions in cold weather concreting higher per cent of air content may be specified.

Determination of Coarse Aggregate Volume : Coarse aggregate volume is defined by bulk density. Generally coarse aggregate (D > 4.75) should be between 50% and 60%. Optimum coarse aggregate content depends on the following parameters.

- The lower the maximum aggregate size, the higher the proportion.
- The rounded aggregate can be used at higher percentage than crushed aggregates.

Determination of Sand Content: Sand, in the context of mix design procedure is defined as all particles bigger than 125 micron and smaller than 4.75 mm. Sand content is defined by bulk density. The optimum volume content of sand in the mortar varies between 40-50% depending on paste properties.

Determination of Optimum Volumetric Water/powder ratio and Superplasticizer

Dosage in mortar :

Tests with flow cone and V-Funnel for mortar are performed at varying water/powder ratios in the range of (0.8 to 0.9) $\square_p$ and dosages of superplasticizer. The superplasticizer is used to balance the rheology of the paste. The volume content of sand in the mortar remains the same as determined above.

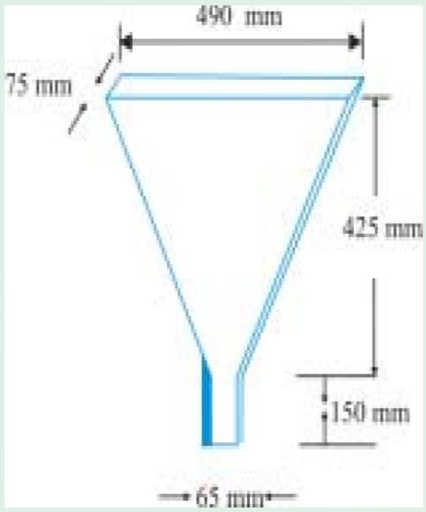
The target values are slump flow of 24 to 26 cm and V-funnel time of 7 to 11 seconds.

At target slump flow, where V-funnel time is lower than 7 secs, then decrease the water/ powder ratio. For largest slump flow and V-funnel time in excess of 11 seconds water/powder ratio should be increased.

V- Funnel test and V-Funnel test at T_5 min.

This test was developed in Japan. The equipment consists of a V-shaped funnel shown in Fig. 12.26. The V- Funnel test is used to determine the filling ability (flowability) of the concrete with a maximum size of aggregate 20 mm size. The funnel is filled with about 12 litre of concrete. Find the time taken for it to flow down.

After this the funnel can be filled with concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.



Equipment

- V-funnel
- Bucket 12 litres
- Trowel
- Scoop
- Stopwatch

Procedure : About 12 litre of concrete is needed for the test. Set the V-funnel on firm ground. Moisten inside of the funnel. Keep the trap door open to re- move any surplus water. Close the trap door and place a bucket underneath. Fill the applaratus completely with concrete – No compaction or tamping is done. Strike off the concrete level.

Observing the time of emptying of concrete from V- funnel

Open within 10 seconds the trap door and record the time taken for the concrete to flow down. Record the time for empltying. This can be judged when the light is seen when viewed from top. The whole test is to be per- formed within 5 min.

Procedure for flow time at T5 mm :

Do not clean or moisten the inside surface of the funnel. Close the trap door and refill the V-funnel immediately after measuring the flow time. Place the bucket underneath.

Fill the apparatus completely with concrete without tamping or tapping. Strike off the concrete level with the top by trowel. Open the trap door after 5 minutes after the second fill of the funnel and allow the concrete to flow. Calculate the time taken for complete discharge. It is called the flow time at T5 min. For V test the flow time should be between 8 and 12 secfonds. for V-funnel flow time at T5 min. + 3 seconds is allowed.