READY MIXED CONCRETE MANUFACTURERS' ASSOCIATION – (RMCMA)

RMCMA

(Bulletin No. 11)

Self-Compacting Concrete (SCC)

PRESIDENT'S MESSAGE

Dear Esteemed Members and Industry Colleagues,

It is with great pleasure and pride that I present to you our latest technical bulletin on Self-Compacting Concrete (SCC). As the President of the Ready Mix Concrete Manufacturers Association - India, I am delighted to introduce this comprehensive resource that promises to be an invaluable asset for our industry.

Self-Compacting Concrete has revolutionized the construction sector, offering enhanced workability, improved structural integrity, and increased efficiency in placement. This bulletin is a testament to our commitment to staying at the forefront of technological advancements and best practices in concrete manufacturing.

Within these pages, you will find a wealth of information meticulously compiled to address the various aspects of SCC. From mix proportioning guidelines aligned with EFNARC and IS 456 standards to detailed explanations of quality validation tests, this bulletin covers it all. We have also included insights on the diverse materials that can be incorporated into SCC and the necessary adjustments in mix design when working with special additives such as fibres.

Our aim is to equip you with the knowledge and tools needed to excel in the production and application of Self-Compacting Concrete. This bulletin not only serves as a technical guide but also as a platform for fostering innovation and excellence within our industry.

I would like to extend my heartfelt gratitude to the technical committee and all contributors who have dedicated their time and expertise to create this comprehensive resource. Your efforts will undoubtedly elevate the standards of concrete manufacturing across India.

As we continue to embrace new technologies and methodologies, let us use this bulletin as a stepping stone towards greater achievements in concrete innovation. I encourage all members to thoroughly study this document, implement its recommendations, and share their experiences to further enrich our collective knowledge

Together, we can build a stronger, more sustainable future for the Indian construction industry.

Wishing you all the best in your endeavours.

Er. Anil Banchhor
(President, RMCMA)

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1.0 Introduction:

The Self-compacting concrete (S.C.C) is the concrete that is able to flow and consolidate under its own weight, completely fills the formwork even in the presence of dense reinforcement, and maintains homogeneity and cohesiveness without any additional compaction.

In this Bulletin, the requirements and characteristics of S.C.C are discussed. They are based on the European Guidelines EFNARC and IS 10262. The EFNARC provides Specifications and detailed guidelines for S.C.C. while IS 10262 provides application areas, features and concrete mix proportioning approach. An worked-out example for concrete mix proportions for M30 grade concrete is illustrated by the Indian Standard. IRC: 112 also gives characteristics and tests for S.C.C. The Water Resources Department, Government of Maharashtra[4] provides a chapter in a Handbook covering materials, concrete mix proportioning approach, engineering properties, durability and construction site requirements, placement by pumping and finishing at sites from the supply of ready mixed concrete plant. Different test methods, typical concrete mix proportions and utilization of S.C.C in different projects of the country are also discussed in this Handbook.

The Bulletin also covers the materials and concrete mix proportions for high strength S.C.C, which are different from those specified by EFNARC and IS 10262. This has been verified by carrying out experiments in a laboratory on M90 grade concrete. Recommendations have been made for proper placement of S.C.C in structural elements.

The laboratory experiments were necessary to verify the required characteristics of S.C.C for the specific materials and concrete mix proportions, used in the R.C.C columns of a high-rise building. The concrete was transported by truck mixers, and pumped in the formwork of the R.C.C columns. After about one year, when the columns were loaded by the 13-storey building, cracks were observed in basement and ground floor columns. Some of the samples of concrete collected from the cracked columns had no aggregates, but only cementitious materials.

2.0 Specifications of Self-Compacting Concrete as given by EFNARC and IS 10262:

1. Water content of concrete 150-210 kg/m^3 of concrete,
2. Powder content (less than 0.125mm size): 400-600 kg/m^3 of concrete,
3. Fine aggregate content: 48-60% of total aggregate,

3.0 Mineral admixtures:

(i) Fly ash content: 25 to 50% as percentage of cementitious materials.

(ii) Ground granulated blast furnace slag (GGBFS): up to 50% of the cementitious materials.

(iii) Silica fume, as necessary for increasing the strength of concrete and abrasion resistance.

4.0 Chemical Admixtures:

The chemical admixtures used in S.C.C are generally high range superplasticizers with viscosity modifying agent (VMA) for stability and a retarder for controlling the setting time of concrete.

Admixtures that modify the cohesion of concrete without significantly altering its fluidity are called VMA. The VMA is a necessary ingredient of S.C.C for stability, homogeneity and to reduce the tendency to segregation of concrete. These admixtures are water-soluble polymers having high molecular weight. Such polymers form a network of large molecules covering throughout the mass of concrete. Their particles are in colloidal range. Some of them are polyacrylic amide-based, some are polysaccharide-based and some are cellulose-based. Generally, the VMA content in S.C.C is 1% to 2%, percentage by weight of the superplasticizer.

5.0 Fibers:

Fibers are sometimes used in S.C.C in the same way as for normal concrete. Steel fibers are used to enhance the flexural strength, toughness and abrasion resistance. The polymer fibers are used to reduce the segregation and plastic shrinkage. Use of fibers in S.C.C may reduce its flowability and passing ability. Trials are therefore needed to establish the optimum type, length and quantity to give all the required properties of fresh and hardened concrete. Fibers are generally avoided in highly congested reinforced sections due to above reasons, however where their use is considered essential, then it is recommended to first prepare a mock up for trials before making actual use at site.

6.0 Water-powder ratio:

The water-powder ratio in SCC is normally kept between 0.85 to 1.10 (by volume). However, it can be varied depending upon the quality of local materials, aggregate size, fineness modulus of sand and placing conditions. It is observed that for normal grade concrete, the above proportions of materials should be fulfilled as the S.C.C has to satisfy the following characteristics.

7.0 Characteristics of Self-Compacting Concrete

The main characteristics of S.C.C are:

(a) Filling ability, (b) Passing ability, (c) Segregation resistance, and (d) Viscosity.

EFNARC and IS 10262 provide guidelines covering test methods to satisfy the above-mentioned characteristics of S.C.C. IS 1199 (Part 6) describes the test methods for fresh S.C.C. They are explained below.

Test Methods for Self-Compacting Concrete

7.1.1 The Slump Flow Test

The apparatus consists of a steel base plate of area 900mmx900mm, the usual slump cone and a measuring tape. About 6-liter concrete is poured in the slump cone placed on the center of the base plate. After the cone is lifted, when the flow of concrete is stabilized on the base plate, the spread of concrete is measured in two places at right angles. The slump flow is the mean of the spread of concrete on the base plate. Retention of flow is checked generally after 1h, 2h and 3h.

7.1.2 The V-Funnel Test

A V-shaped funnel (Fig.1) with a hinged sliding gate is used. The top width of the funnel is 515mm and the bottom width is 65mm. About 12 litre concrete is poured through the funnel, and the flow time of concrete through the funnel is measured. Fig.4 shows the concrete being poured through the V-funnel. The viscosity of the S.C.C in terms of flow time is thus assessed.

7.1.3 The Sieve Segregation Resistance Test

About 10 litre concrete is screened through the 4.75 mm perforated plate sieve (with square aperture), and the quantity of concrete passing through the sieve is weighed. The percentage of concrete passed through the sieve indicates the sieve segregation resistance value.

7.1.4 The L-Box Test

The L-box (Fig.2) test is performed to assess the passing ability of the S.C.C to flow through the openings i.e the spaces between reinforcements in the formwork. After closing the gate between the vertical and the horizontal section, the concrete is poured to fill the hopper of the L-box. When the gate is opened, the concrete comes down the vertical section and flows to the horizontal section through the space between the 3 steel bars of 12mm dia. The passing ability is calculated from the ratio of the depth of concrete in the horizontal section to that in the vertical section.

8.0 Required Range of Test Values of SCC.

8.1 Filling Ability (Flowability):

This is comprising of 'slump flow' values for different structural elements to be constructed. For example, slump flow values of 550mm-650mm are suggested for lightly reinforced concrete structures e.g. housing slabs, and for small sections not having long horizontal flow e.g concrete piles and other deep foundations. For normal applications e.g walls and columns, slump flow of 660mm-750mm is suitable. For heavily reinforced structures, the slump flow values suggested are 760mm-850mm.

8.2 Passing Ability:

Passing ability of concrete is the ability to pass through the confined spaces and narrow openings, such as areas of congested reinforcements, without segregation or causing blocking.

L-box (with 3, 12mm dia. bars, 50mm apart) test is performed. The requirement is: ratio of depth of concrete in the horizontal section to the depth of concrete in the vertical section, it should be 0.8 to 1.0.

8.3 Segregation Resistance (Stability)

This test, screening through 4.75mm size sieve (square aperture) is performed to find the ability of fresh concrete to remain homogeneous in the fresh state. Segregation Resistance SRI: 15-20% materials passed and vertical flow distance of less than 5m, and confinement gap greater than 80mm.

Segregation Resistance SR2: Less than 15% material passed, and is applicable for vertical flow distance of more than 5m and a confinement gap of less than 80mm.

8.4 Viscosity

Viscosity of concrete is assessed by V-funnel test. V1: Flow time less than 8 seconds, i.e. flow of concrete through the funnel quickly, has the good filling ability even with congested reinforcements.

V2: Flow time to pass the V-funnel: 8-25 seconds. This class of concrete is helpful in limiting the formwork pressure and for improving segregation resistance and can be used where reinforcement is not congested.

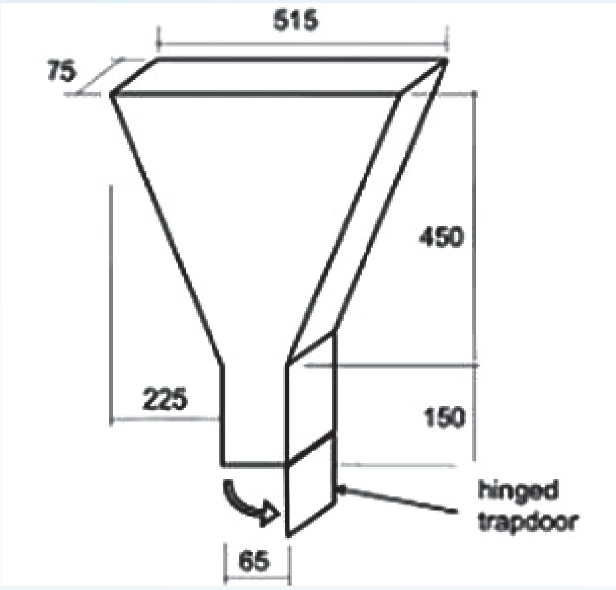

Figure 1 - V- funnel

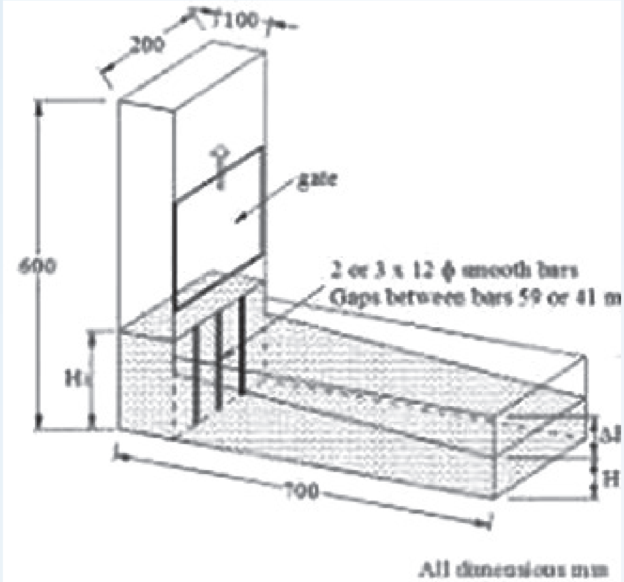

Figure 2 - L – Box

9.0 Concrete Mix Proportioning Approach for S.C.C

The concrete mix proportioning is generally based on the following approach:

(a) Determine the target average 28-day compressive strength for the nominal grade of concrete.

(b) Select the water-cementitious materials ratio from a suitable correlation.

(c) Select water content for high workability S.C.C. The suggested water content for 'standard' grade concrete is 150-210 kg/m^3 of concrete. Using a PCE – based superplasticizer, this water content can be optimized.

(d) The admixture content (including a VMA & a retarder) may be based on manufacturers' recommendations.

(e) Select fine aggregate content. This will be generally higher than 40%, percentage by weight of total aggregate. Various guidelines suggest on higher fine aggregate content for 'standard' grade concrete, i.e. 48% to 60%. For SCC, the maximum size of coarse aggregate is limited to 10 to 12.5mm.

(f) The mineral admixture content can be selected. For fly ash [(as per IS 3812 (Part1)], it can be 25% to 50% and GGBS (as per IS 16714) content can be up to 50% of the cementitious material content.

(g) Select powder content: This includes cement, mineral admixture including ultrafine materials and fine aggregate content passing 125micron sieve.

10.0 Case study of M 90 grade SCC and its Performance.

Materials used (kg per m^3 of concrete):

(a) OPC (53-grade): 480 kg.

(b) Fly ash (of fineness $411m^2/kg$): 130 kg (19.1% by weight of cementitious materials).

(c) Fine aggregate (grading Zone II, FM=2.77): 650 kg (38% of total aggregate).

(d) Silica fume: 70 kg (14.6% by weight of cement)

(e) Water: 137 kg (Water-binder ratio = 0.20)

(f) Water-powder ratio (by volume) = 0.52

(g) Coarse aggregate (12.5mm maximum size): 1040 kg.

(h) Superplasticizer with VMA and retarder: 8 kg (1.18% of cementitious materials).

(i) Polypropylene fibre : 2.52 kg.

11.0 Test Results on the Specified Characteristics

(a) Slump flow: 700mm (initially), 650mm (after 3h.) (Fig. 3)

(b) V-funnel flow time: 16 seconds

(c) Sieve segregation resistance value : 8.12%

No segregation of concrete was observed after thorough compaction (Fig. 5).

12.0 Discussion on the Concrete Mix Proportions used and on the Test Results.

The concrete mix proportions used for M90 grade S.C.C indicates lower fine aggregate content (38%). Usually, the recommendation is to use about 48% fine aggregate. The concrete mix tested indicated that the concrete looked under- sanded. The other recommendations are: higher water content (150- 210kg/m^3 of concrete), and water-powder ratio (by volume) of 0.85-1.10.

In the present case, mixing water content of 137 kg/m^3 of concrete is low as recommended value is 150-210 kg/m^3. The fly ash content of 19.1% of cementitious materials is justified as more fly ash (25-50%) recommended) is not suitable to achieve such high strength concrete. Usually, silica fume content of 5-10% (% by weight of cement) is recommended for concrete structures, for achieving high-strength and abrasion-resistant concrete. But silica fume of about 15% is also used to achieve such high strength concrete.

The test results on concrete mix were satisfactory. The desired slump flow of 650mm (after 3 hours) was achieved. This is because, the superplasticizer was very efficient with the required VMA and the retarder.

The V-funnel flow time of 16 seconds was satisfactory, as the limit set by IS 10262 is 8-25 seconds, for V2 class concrete, for improved segregation resistance. The Sieve segregation resistance value of 8.12% also indicates that the concrete is satisfactory for a flow distance more than 5m, as a value less than 15% is recommended.

Figure 3 - The Slump- flow(650mm) of Self-Compacting Concrete after 3 hours

Figure 4 - The Fresh Concrete is being Poured for V-Funnel Test

Figure 5 - The Self-Compacting Concrete after Thorough Compaction. No Segregation Observed.

13.0 Conclusions and Recommendations

The following conclusions are drawn.

The EFNARC/IS 10262 guidelines on self-compacting concrete are for 'Standard Concrete' i.e. up to M60 grade. For higher strengths of concrete (M65 to M100), the above guidelines are not applicable. This has been confirmed after carrying out experiments on M90 grade self-compacting concrete. The concrete mix proportions and the constituent materials are different than what are recommended by EFNARC/IS 10262 guidelines. Typically, for high-strength S.S.C, 53 grade OPC and silica fume are essential ingredients.

For high-strength concrete, the mixing water content may be required to be lower than 150 kg/m^3 of concrete, in order to adopt a low water-cementitious materials ratio of concrete. Similarly, with so much fine aggregate (48-60%) and with so much fly ash content (25-50%), it will be difficult to achieve such high-strength self-compacting concrete.

The experiments carried out with mixing water content of 137 kg/m^3, fine aggregate content of 38%, with fly ash content of 19%, and with silica fume content of 14.6%, the satisfactory characteristics of M90 S.C.C i.e. slump flow of 700mm (initially), 650mm (after 3 hours), V-funnel flow time of 16 seconds, and the segregation resistance value of 8.12% were achieved.

It is recommended that, the high-strength S.C.C is to be carefully transported from the batching plants to the construction sites, without causing any segregation and to be pumped in the formwork of R.C.C columns of buildings and in other structures carefully. In case of vertical structural elements, pumping from the bottom of the formwork is recommended for satisfactory placement and surface finish. A little external vibration may be necessary, but any internal vibration must be avoided to avoid segregation of concrete. Experience shows that to achieve required characteristics of SCC, especially for high strength concrete (M 65 and above), water content shall be in the range of 160 kg/m^3 and above. To achieve target strength the cementitious materials shall be accordingly chosen.

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ABOUT RMCMA

The Ready Mixed Concrete Manufacturer's Association (RMCMA), India is a non-profit industry organisation of leading Ready Mixed Concrete Producers from India, established in March 2002. The vision of RMCMA is to make Ready-Mixed Concrete the preferred building material of choice for construction as the best environment-friendly sustainable material. The RMCMA is committed to provide leadership to the Ready Mixed Concrete industry in India. It promotes the interests of the entire Ready Mixed Concrete industry in India, without sacrificing the interests of end users, designers, specifiers, owners and other stakeholders. RMCMA strongly supports the Quality Scheme for RMC Plants as spearheaded by Quality Council of India (QCI) and BIS. RMCMA through its efforts have already brought about 350 RMC plants throughout the country under certification scheme. RMCMA is endeavouring that all RMC plants in India shall be brought under the umbrella of 3rd party certification. RMCMA is focused on following activities.

1) Organising Training Programs for different officials working in RMC Industry. RMCMA is conducting on regular basis following training programs.
   a) Concrete Technologist of India (CTI) for QC and Technical support service staff of Cement and Concrete industries.
   b) RMC business overall view for Marketing and New QC staff.
   c) Safety, Hygiene and Environment Training Program in association with National Safety Council of India for safety in RMC operations.
2) Creating awareness about advantage of quality concrete in construction.
3) Certification of RMC Plants through QCI and BIS.
4) Participation at National and International level to promote RMC.
5) Participating in formulation and revision of Codes with BIS pertaining to concrete and RMC.
6) Safety, Health and Environment requirements at RMC Plants.
7) Dissemination of Knowledge amongst Civil Engineers and QC Professionals on Concrete Technology through publishing Bulletins and holding Round Table Conferences.
8) Participation in Seminars/ Conferences and Exhibitions for promotion of RMC.
9) Focusing on use of Special Concretes or niche applications.
10) Organizing lectures in engineering colleges to expose students on RMC Technology.

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