Journal of Civil & Environmental Engineering

Rakesh Kumar et al., J Civil Environ Eng 2015, 5:3
DOI: 10.4172/2165-784X.1000176

Review Article Open Access

Self-Compacted Concrete Mix Design and its Comparison with Conventional Concrete (M-40)

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Abstract

The self-compacted concrete is an innovative product in civil engineering field of India. The necessity of this product was felt by civil engineers to overcome in the issue of workmanship, in structural concreting of thickly/heavily re-in forced sections in execution of concreting. This product was first developed in Japan in 1997 and followed by Europe and U.S.A. Substantial research was carried out with regard to the properties of SCC Because of the well-controlled conditions; the introduction of SCC in the precast concrete industry was successful. With regard to the application in situ, the development is slower, because of the sensitivity of the product. In this paper the mechanical properties of SCC in comparison to conventional concrete are discussed. Examples of applications are shown, both for prefabricated concrete elements and in- situ structures. In this study the area has been covered is making the design mix of self-compacted concrete and it's performance – economic comparisons with prevailing conventional grade of concrete of M-40 grade .

Keywords: Self-compacting concrete; Super plasticizer; Mix design; Conventional concrete

Introduction

Self-compacting concrete (SCC) was first developed in Japan, in the early nineties of the previous century, under the stimulating leadership of Prof. Okamura. The main idea behind self-compacting concrete was, that such a concrete is robust and relatively insensitive to bad workmanship. In Western Europe the idea was picked up at the end of the last century. The main drive to develop self-compacting concrete's was the option to improve the labor conditions at the building site and in the factory (noise, dust, vibrations). During recent years self-compacting concrete developed to research item nr. 1. A large number of research projects were carried out, followed by recommendations for potential users. Especially for the precast concrete industry self-compacting concrete was a revolutionary step forward. Contrary to that, casting of SCC at the construction site was regarded with more reservation. The variable conditions at the construction site, the more complicated control of the mixture composition and disagreement with regard to the question how the properties should be measured at the site were retarding factors. In spite of a number of successful examples, some problems due to unsuitable use of SCC generated further skepticism. Hence, the major task now is to develop SCC mixtures, which are less sensitive to deviations in properties of the components and external conditions [1,2]. The main reasons behind the popularity of Self Compacted Concrete are listed below (Figure 1).

- Faster construction
- Reduction in Site manpower
- Better surface finish
- Easy placing
- Improved durability
- Greater freedom in design
- Thinner concrete sections
- Absence of vibration, reduced noise levels
- Safer working environment

Properties of self-compacting concrete

The remaining fresh and hardened properties are same as traditional concrete. It has been observed that performance wise SCC is more capable than conventional concrete because of its fluidity. This can reach all possible corners of form shutter, without giving any compaction efforts whereas in conventional concrete needs additional effort for its compaction [3,4].

Slump flow and T500 test: The slump-flow and T500 time is a test to assess the flow ability and the flow rate of self- compacting concrete in the absence of obstructions. It is based on the slump test to measure two parameters the flow speed and the flow time. The result is an indication of the filling ability of self-compacting concrete. The T500 time is also a measure of the speed of flow and hence the viscosity of the self-compacting concrete [5,6].

The first step is to prepare the cone and base plate then place the cleaned base in a stable leveled position, fill the cone without any agitation or Roding, and strike off surplus from the top of the cone. Allow the filled cone to stand for not more than 30s; during this time remove any spilled concrete from the base plate and ensure the base plate is damp all over but without any surplus water (Figure 2).

Lift the cone vertically in one movement without interfering with the flow of concrete. If the T500 time has been requested, start the stop watch immediately the cone ceases to be in contact with the base plate and record the time taken to the nearest 0.1 s for the concrete to reach the 500 mm circle at any point. Without disturbing the base plate or Concrete. Measure the largest diameter of the flow spread and record it as to the nearest 10 mm.

Then measure the diameter of the flow spread at right angles to the nearest 10 mm and record as to the nearest 10 mm. Check the concrete spread for segregation. The cement paste/mortar may segregate from the coarse aggregate to give a ring of paste/mortar extending several

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Received May 06, 2015; **Accepted** June 09, 2015; **Published** June 19, 2015

Citation: Rakesh Kumar D (2015) Self-Compacted Concrete Mix Design and its Comparison with Conventional Concrete (M-40). J Civil Environ Eng 5: 176. doi:10.4172/2165-784X.1000176

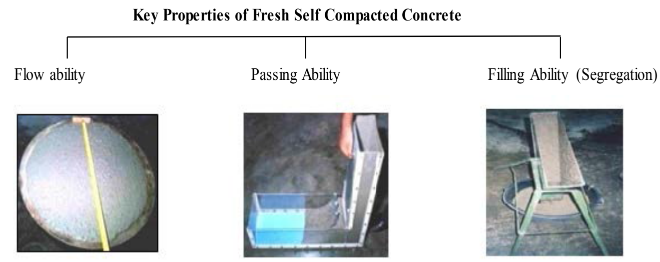

Figure 1: Properties of self compacted concrete.

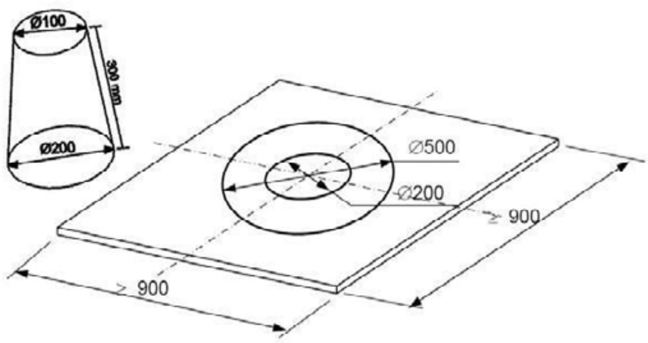

Figure 2: Slump flow and T500 test.

millimetres beyond the coarse aggregate. Segregated coarse aggregate may also be observed in the central area. Report that segregation has occurred and that the test was therefore unsatisfactory [7-11].

Then the slump-flow is the mean of dm and dr expressed to the nearest 10 mm, and the T500 time is reported to the nearest 0.1 s.

V-funnel test: The V-funnel test is used to assess the viscosity and filling ability of self-compacting concrete with a maximum size aggregate of 20 mm. A V shaped funnel is filled with fresh concrete and the time taken for the concrete to flow out of the funnel is measured and recorded as the V-funnel flow time [10-12].

V-funnel, made to the dimensions (tolerance ± 1 mm), fitted with a quick release, watertight gate at its base and supported so that the top of the funnel is horizontal. The V-funnel shall be made from metal; the surfaces shall be smooth, and not be readily attacked by cement paste or be liable to rusting. However container is needed to hold the test sample and having a volume larger than the volume of the funnel and not less than 12 L (Figure 3).

L-box test: The L-box test is used to assess the passing ability of self-compacting concrete to flow through tight openings including spaces between reinforcing bars and other obstructions without segregation or blocking. There are two variations; the two bar test and the three bar test. The three bar test simulates more congested reinforcement [13-15].

The main concept of this test is to allow a measured volume of fresh concrete to flow horizontally through the gaps between vertical, smooth reinforcing bars and the height of the concrete beyond the reinforcement is measured.

L-box, have the general arrangement and the dimensions (tolerance ± 1 mm) as shown in Figure 4. The L-box shall be of rigid construction with surfaces that are smooth, flat and not readily attacked by cement paste or be liable to (Table 1).

Tests applied on hardened concrete

The hardened self-compacted concrete properties are same i.e. Cube compressive strength, Flexural beam strength. In some cases the permeability tests also conducted in hardened cube cylinders (Figure 5).

The compressive strength σ comp (in MPa),of the specimen is calculated by dividing the maximum load carried by the cube specimen during the test by the cross sectional area of the specimen [16-19] (Tables 2 and 3).

$$\sigma comp = \frac{\text{Breaking Load}}{\text{Cube Cross Sectional Area}}$$

The compressive strength was determined at different ages 7 and 28 days.

The unit weight, the harden concrete density may be found out by this formula

Concrete Density=Weight of Cube/Volume of Cube

Presentation on Mix Design SCC

Stipulations for proportioning

a) Grade designation: M-40 (Flowable Concrete)

b) Type of cement: ULTRATECH OPC-53 Conforming to IS 12269

c) Maximum nominal size of aggregate: 20 mm

d) Minimum cement content: 320 kg/m^3

e) Maximum water-cement ratio: 0.40 (As per Morth Table 1700-3)

f) Workability**:** Flowable (after 60 min flow 650 mm) As per EFNARC

g) Exposure condition: Severe (For congested reinforced concrete)

h) Method of concrete placing: Pumping

i) Degree of supervision: Very good

j) Type of aggregate: Crushed angular aggregate

k) Characteristics flexural strength: 40 Mpa

l) Chemical admixture type: Superplasticizer Auramix-400 (PC20)

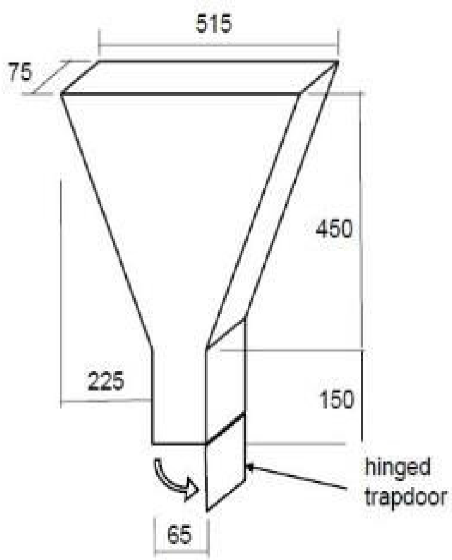

Figure 3: V-funnel test.

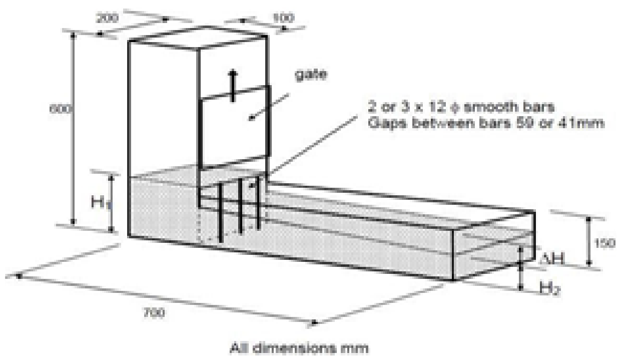

Figure 4: General assembly of L-box.

Method	Unit	Minimum Range	Maximum Range
Slump flow (Abram Cone)	mm	550	850
T500 mm Slump flow	S	2	9
V-funnel	S	6	12
L Box (h2/h1)	-	0.7	1.0

Table 1: SCC properties requirements as per EFNRC 2005. **Table 1:** SCC properties requirements as per EFNRC 2005.

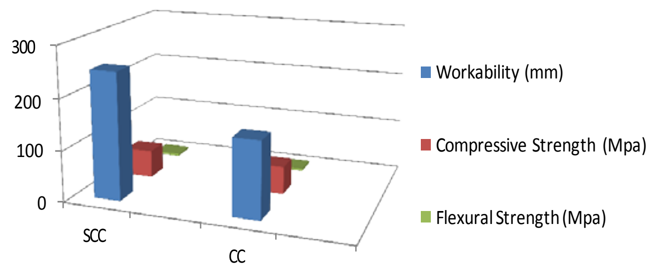

Figure 5: Bar chart of concretes properties (SCC &CC).

S.No.	Characteristics	Flow able Concrete	Traditional Concrete
1	Nominal size Aggregate	12.5 mm	20 mm
2	Workability	Excellent	Stiff
3	Compaction Efforts	Not Required	Required
4	Cost of Production	Same	Same
5	Workmanship	Fantastic	Good

Table 2: Performance comparisons (SCC Vs conventional concrete).

Test data for materials

a) Cement used: ULTRATECH OPC-53 conforming to IS 12269

b) Specific gravity of cement: 3.15

c) Chemical admixture: Super plasticizer conforming to IS 9103

d) Specific gravity

Coarse aggregate: 1) 20 mm-2.935

2) 10 mm - 2.924

Fine aggregate: 2.6

e) Water absorption

Coarse aggregate: 1) 20 mm-0.42% (Limit maximum 2%)

2) 10 mm-0.44% (Limit maximum 2%)

Fine aggregate: 1.32% (Limit maximum 2%)

f) Free surface moisture

Coarse aggregate: NIL

Fine aggregate: NIL

g) Sieve analysis

Coarse aggregate: NIL

Target mean strength for mix proportioning

Where

FCK=52 N/mm^2

FCK: Target avg. compressive strength at 28 days

(As per MORTH table 1700.5)

The standard deviation is considered as 52 Mpa which is maximum during the production of M 40 grade concrete and this is considered for fixing the Target compressive strength which is mentioned in MORTH Table 1700 – 5.

Calculation of cement content

Select Total cement content: 470 Kg

Cement Content: 470 (Approx.)

Selection of water cement ratio

Adopting W/C Ratio=0.39

0.39<0.4

Hence OK.

Selection of water content

470 × 0.39=183.3

Mix calculations

(a) Volume of concrete=m^3

(b) Volume of cement=(mass of cement/Sp. Gravity of cement) × (1/1000)

=(470.0/3.15) × (1/1000)

=0.149 m^3

(c) Volume of water=(mass of cement/Sp. Gravity of water) × (1/1000)

=(183.3/ 1) × (1/1000)

=183.3 m^3

(d) Volume of chemical admixture

Superplasticizer @ 0.60 percent by mass of cement=(mass of admixture/Sp. Gravity of admixture) × (1/1000)

0.6% =(2.82/ 1.1) × (1/1000)

=0.0026 m^3

(f) Mass of 20 mm (CA) =e × volume of 20 mm × specific gravity of coarse aggregate × 1000

=456.67 kg

(g) Mass of 10 mm (CA) =e × volume of 10 mm × specific gravity of coarse aggregate × 1000

=556.06 kg

ITEM DESCRIPTION	Unit	M40 Concrete Design- Pali Site			Proposed Self Compacting Concrete(M40)		
		Qty Per Cum	Rate	Amount	Qty Per Cum	Rate	Amount
Cement	Kg	440	4.700	2,068.0	343	4.700	1,612.1
Admixture	Kg	2.86	65.00	185.9	2.5	150	375.0
20 mm	Kg	638	0.258	164.6	332	0.258	85.7
10 mm	Kg	443	0.258	114.3	440	0.258	113.5
Sand	Kg	736	0.14	103.0	943	0.14	132.0
Water	Ltr	200	0.04	8.0	180	0.04	7.2
Total Cost per Cum				2,643.8			2,531.3
Add Wastage of Material			0.01	26.4		0.01	25.3
Total Cost of material per Cum incl wastage				**2,670.3**			2,556.6
Mixing Cost per Cum				239.7			239.7
Trasportation cost per Cum				329.7			329.7
Laying Cost per Cum				308.0			280.0
Curing Labour per Cum				51.0			51.0
Total Cost of Concrete including Transportation and Laying				**3,598.7**			**3,457.0**
Remarks		Admixture dosage-0.65%			Admixture dosage-0.5%		

Table 3: Cost benefit comparison of concrete vs. SCC.(Difference in rate per cum: Rs. 143)

Sl. No.	Materials	Weight of material in kg	Natural moisture	Water absorption	(+/-) Water	Corrected weight
1	Cement	470	0	-		470
2	20 mm	456.67	0	0.42	1.92	454.75
3	10 mm	556.06	0	0.44	2.45	553.61
4	Sand	829.83	0	1.32	10.95	818.88
5	Water	183.30		+	15.32	198.62
(c)Fine aggregate			=	818.88	kg/m³	
(d)Coarse aggregate			=	1008.36	kg/m³	
(e)Chemical admixture			=	2.82	kg/m³	
(f)Water - cement ratio			=	0.39		

Table 4: Mix proportion for trial number.

FLOW	INITIAL	60 Minutes
Required	**650**	**650**
Observed	**680**	**680**

Table 5: Showing the flow test.

(h) Mass of FA =e × volume of fine aggregate × specific gravity of fine aggregate × 1000

Mix proportion for trial number

(a) Cement=470.0 kg/m³

(b) Water=198.62 kg/m³

Table 4 shows the detailed picture of the mix proportion of the cement and water ratio.

Workability of trial mix

Table 5 shows the flow test for the workability of the trial mix.

Conclusion and Remarks

1. The Trial mix design complies with specification requirements of flow.
2. The proposed mix have flow value w.r.t to laboratory temperature and humidity conditions which may differ in mix produced from plant. To maintain the flow as per the placing requirement, slight modification in admixtures dosage may be required to be done
3. Compressive strength at 7 days and 28 days are found satisfactory.

Conclusion

1. In spite of its short history, self-compacting (or – consolidating) concrete has confirmed itself as a revolutionary step forward in concrete technology.
2. SCC is a relatively new form of concrete which is used for general applications. The main advantage that SCC has over standard concrete is its high compressive strength and self-compacting properties, include high flowability, workability, and passing ability.
3. The effect of using recycled aggregates on the fresh and hardened properties of SCC need to be investigated
4. It can be shown by cost analysis, that SCC in precast concrete plants can be more economically produced than conventional concretes, in spite of the slightly higher material price. Cost comparisons should always be made on the basis of integral costs.
5. The effect of fibers (Steel, Carbon, propylene and Glass) and polymers (Epoxy, SPR) addition on the mechanical properties of SCC need to be taken into consideration for further research
6. Another super plasticizer and silica fume trade markets to be used to study the fresh.

Acknowledgement

I would like to express my sincere Thanks to Mr Juned Ahamad– Assistant Professor (civil), Department of Civil Engineering, Faculty of Engineering –The Integral University, Lucknow, and Appreciations to Dr.Sabih Ahamad-Head of Department (civil), for their help and guidance in the preparation and development of the work. The constant encouragement, support and inspiration they offered were fundamental to complete the dissertation in time.

References

1. SCC (2005) The European Guidelines for Self Compacted Concrete – EFNARC Shikoku Island Concrete Research Association: Report by Self-Compacting Concrete Research Committee, Self- Compacting Concrete in Shikoku Island 2000 to 2002, 2002, UK.
2. Japan Society of Civil Engineers (1999) Concrete Library 93, High-fluidity Concrete Construction Guideline, Japan.
3. Precast, Prestressed Concrete Institute (2003) Interim Guidelines for the Use of Self- Consolidating Concrete in Precast, Prestressed Concrete Institute Member Plants, TR-6-03, Chicago, IL.
4. Okamura H, Maekawa K, Ozawa K (1993) High-Performance Concrete, Gihodo Publishing.
5. Nakajima Y, Nakazono A, Mori S (2002) High Strength Self-Compacting Colored Concrete for Ritto Bridge Substructure (New Meishin Expressway), Proceedings of the first fib Congress 137-146.
6. Taniguchi H, Tanaguchi K, Uechi H, Akizuki S (2002) Fabrication of Prestressed Concrete Composite Girders by Self-Compacting Concrete using Fly Ash, Technical Report of Sumitomo Construction Co., 120.
7. Billberg P, Osterberg T (2002) Self-Compacting Concrete, Technique of use. CBI report 2: 2002, Stockholm 2002 (in Swedish).
8. M.Collepardi (2003) Self compacting Concrete: What's new? Proceeding of the Seventh CANMET/ACI Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Berlin, Germany 1-16.
9. ACI 548.6R-96 (2003) Guide for the Use of Silica Fume in Concrete. ACI Manual of Concrete Practice part 2.
10. Arafa M, Shihada S, Karmout M (2010) Mechanical Properties of Ultra High Performance Concrete Produced in Gaza Strip, Asian J Mater Sci.
11. ASTM C109 (2004) Standard Test Method for Compressive Strength of cube Concrete Specimens, American Society for Testing and Materials Standard Practice C109, Philadelphia, Pennsylvania.
12. ASTM C127 (2004) Standard Test Method for Specific gravity and absorption of coarse aggregate, American Society for Testing and Materials Standard Practice C127, Philadelphia, Pennsylvania.
13. ASTM C150 (2004) Standard specification of Portland cement American Society for Testing and Materials Standard Practice C150, Philadelphia, Pennsylvania.
14. ASTM C128 (2004) Standard Test Method for Specific gravity and absorption of fine aggregate, American Society for Testing and Materials Standard Practice C128, Philadelphia, Pennsylvania.
15. ASTM C293 (1994) Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with center-Point Loading), American Society for Testing and Materials Standard Practice C293, Philadelphia, Pennsylvania.
16. IRC -SP -13 (2013) Design of Small Culverts and Small Bridges.
17. IS 456 (2000) Indian Standard plain and reinforced concrete - code of practice (Fourth Revision).
18. IS 9103:1999 – Indian Standard Concrete Admixtures.
19. IS 10262 (2009) Guidelines for concrete mix design proportioning.