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Study on Mix Design & Hardened Properties of Self-Compacting Concrete

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Abstract: Self-compacting concrete represents one of the most significant advances in concrete technology for decades. It is a high workable concrete and do not require any external vibration for consolidation. Inadequate homogeneity of the cast concrete due to poor compaction or segregation may drastically lower the performance of mature concrete. SCC ensures adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. The research work includes workability tests of SCC, their application in the development of mix design for SCC and finally exploring various properties in its hardened state.
Keywords: SCC, workability, superplasticizer, VMA, compatibility

I. INTRODUCTION

In 1980's durability of concrete structures and lack of skilled labors become an important issue in Japan, an adequate compaction by skilled labors was required to obtain durable concrete structures. This requirement led to the development of self-compacting concrete. In 1986 basic concept of SCC was given by Prof. Okamura of Tokyo University and its development was first reported in 1989. In 1996, several European countries formed the "Rational production and Improved Working Environment through using SCC" project in order to explore the significance of published achievements in SCC and develop applications to take advantage of the potentials of SCC. In India, use of SCC is still not much. Ultra Tech Concrete, a division of Ultra Tech Cement Ltd. is the first commercial supplier of SCC in India.

SCC is a high performance concrete which flows under its own weight without requiring vibrators to achieve consolidation by completely filling of formworks even when access is hindered by narrow gaps between reinforcing bars. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction of fresh concrete such as under water concreting, cast in-situ pile foundation, machine bases and columns or walls with congested reinforcement.

II. MECHANISM OF SCC

The requirements to be satisfied by SCC are filling ability (unrestricted flow in open), passing ability (concrete flow through congested reinforcement) and must be free from segregation and aggregate interlock. To obtain SCC, constituents of conventional concrete are either altered and there is significant change in proportion. There is no significant change in proportion of air, water and sand but the proportion of sand volume is increased with a corresponding decrease in proportion of aggregate in order to minimize the friction between solid particles of mixture so that desired deformability of concrete can be achieved. Cement is the main ingredient of paste, however increasing cement content to increase powder volume has undesirable effects. Therefore, other materials like fly ash, blast furnace slag, limestone, stone dust need to be added to increase powder volume. Another route available for modification of concrete properties is use of chemical admixtures which include superplasticizers and viscosity modifying agents. Superplasticizers help to increase deformability of concrete that is, cement or powder content increased without compromising on workability of mix. Viscosity modifying agents can be used to modify the viscosity of paste that is, water content can be increased without increasing chances to segregate.

Although there is no established mix design procedure yet for SCC, Okamura and Ozawa have employed the following method to achieve self compatibility of SCC:

A. Limited aggregate content (coarse aggregate 50% of concrete volume and sand 40% of mortar volume).
B. Low water-powder ratio (determined by conducting number of trials).
C. Use of higher dosage of superplasticizer.

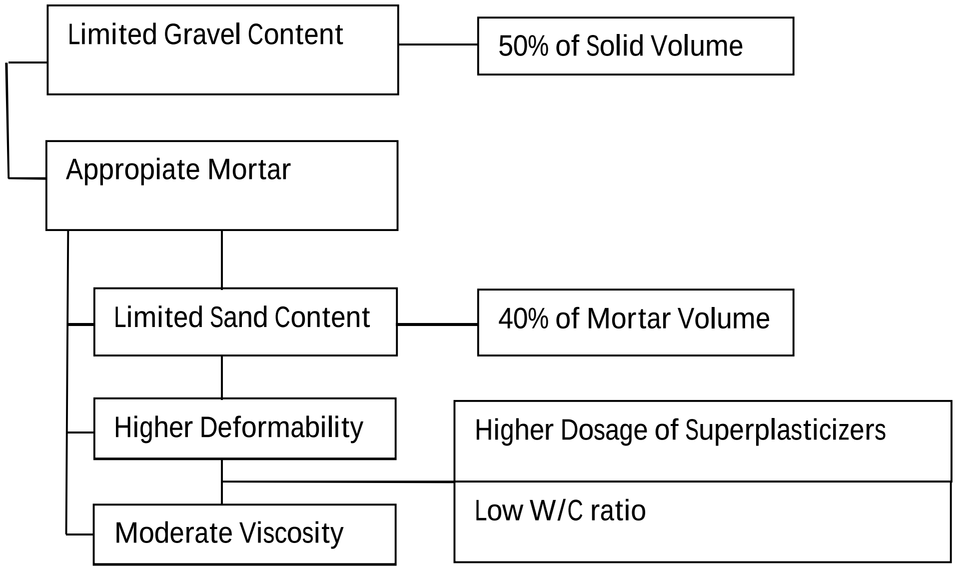

Fig. 1 Method of achieving Self compatibility (H.Okamura and M. Ouchi/ Journal Of Advanced Concrete Technology)

III. TESTS FOR SCC

A concrete can be described SCC, if the requirements for all the properties filling ability, passing ability and segregation resistance are satisfied. No single test can give idea of all three workability properties, so many different methods have been developed to characterize the properties of SCC.

The Slump flow test measures the filling ability of SCC and gives some indication of resistance to segregation. The test method is based on conventional slump test. The diameter of concrete circle is a measure of filling ability of concrete. T_{50cm} test is a corollary slump flow test where T_{50cm} is the measure of time taken in seconds from the instant the slump cone is lifted to the instant when flow reaches a diameter of50cm.

The flowability of SCC concrete can be tested by V-funnel test in which the funnel is filled with 12 liters of concrete and the time taken by concrete to flow through the apparatus is measured. Shorter flow time indicate greater flowability

The U-box test indicates the passing ability of SCC. The two legs of U are separated by gate which has simulating reinforcing bars. The difference in height of concrete in two legs of U gives indication of passing ability of concrete

Table below gives values for acceptance criteria for SCC.

S. no.	Method	Unit	Typical ranges of values	
			Minimum	Maximum
1	Slump flow	mm	650	800
2	T_{50cm} slump flow	Sec	2	5
3	V-Funnel	Sec	6	12
4	U-Box	mm	0	30

IV. MATERIALS USED

Cement: Portland cement of 43 grade was used.The physical properties of cement are mentioned.

Physical properties of cement

Physical properties	Results obtained	IS:8112-1949 SPECIFICATIONS
Fineness	8%	10%
Normal consistency	29%	-
Vicats initial setting time(minutes)	72	30 (min.)
Vicat final setting time(minutes)	220	600 (max)
Compressive strength 3-day(Mpa)	23	22 (min.)
Compressive strength 7-day(Mpa)	36	33 (min.)
Compressive strength 28-day(Mpa)	45	43 (min.)

Aggregate: The coarse aggregate used in this study were crushed stone. The maximum aggregate size was 20mm. The average value of specific gravity was 2.5. Grading of coarse aggregate is shown below:

Grading of coarse aggregate

Seive opening	Percentage passing
20mm	100
10mm	45
4.75mm	0

Locally available sand with maximum size of 4.75mm was used as fine aggregate. Both fine and coarse aggregate confirmed to IS: 383-1970[6]

A. Filler

Filler in this study is limestone.

B. Admixture

Sulphonated naphthalene formaldehyde under the trade name of “Structure 220” and carboxylic acrylic ester under the trade name of VISCO-crete I were used as superplasticizers.

A high performance cohesion agent named "Sika stabilizer 229" specially designed to ensure good consistency and stability in concrete was used as stabilizer. Admixtures confirmed to IS 9103: 1999.

V. EXPERIMENTAL PROCEDURE

A. Eight trial mixes were prepared by varying the limestone powder content, fine to coarse aggregate ratio and superplasticizer content

B. Two levels of limestone powder 100kg/m3 and 125kg/m3, two levels of fine to coarse aggregate ratio: 1 and 1.1 (by mass) and two levels of superplasticizer (sulphonated naphthalene formaldehyde):0 .8% and 1% by mass of powder were used for preparing and testing eight trial mixes.

C. For each trial mix constant water powder ratio of 0.42 (by mass) and constant amount of stabilizer (3kg/cum) were taken.

D. Tests such as Slump flow, V funnel and U box were carried out for each trial mix and the mix which showed highest strength properties was considered for further tests.

Weight of constituents in trial mixes

Trial mix	Mix variables			Quantities of min ingredients (kg/cum)					
	FA/CA ratio	Filler content kg/m3	SP %	Water kg/m3	Cement kg/m3	FA kg/m3	CA kg/m3	SP kg/m3	Stablizer kg/m3
1	1	100	0.8	190	350	845	845	3.6	3.00
2	1	100	1.0	190	350	845	845	4.5	3.00
3	1	125	0.8	199	350	820	820	3.8	3.00
4	1	125	1.0	198	350	820	820	4.7	3.00
5	1.1	100	0.8	190	350	890	808	3.5	3.00
6	1.1	100	1.0	189	350	890	808	4.5	3.00
7	1.1	125	0.8	198	350	860	780	3.8	3.00
8	1.1	125	1.0	197	350	860	780	4.7	3.00

Self-compatibility and Average compressive strength of trial mixes

Trial mix	Workability properties				Compressive strength	
	Slump flow (mm)	T_{50cm} slump flow (sec.)	V-funnel (sec)	U-box (mm)	7 day (Mpa)	28 day (Mpa)
1	650	4.5	10	19	16.58	23.88
2	690	3	6	25	17.79	27.79
3	720	2	8	29	16.95	22.36
4	710	2	8	28	17.91	27.41
5	680	3.5	8	36	16.20	22.86
6	**750**	**3**	**7**	**15**	**18.34**	**29.09**
7	730	3	7	26	17.60	27.33
8	730	3	7	6	17.94	27.50

Trial mix 6 was selected for further research on the basis of its high workability and compressive strength compared to other mixes. Further tests were conducted to evaluate compressive strength, split tensile strength and water absorption properties of self compacting concrete.

VI. TEST RESULTS FOR TRIAL MIX 6

Compressive Strength of SCC specimens

S. No.	Strength averaged of all three values (Mpa)		
	7 days	14 days	28 days
1	20.52	27.35	30.17
2	19.77	27.52	29.00
3	19.35	27.60	29.00
AVERAGE	19.88	27.49	29.39

Result of cube compressive strength (vibrated control casting)

S. No.	7 DAY		14 DAY		28 DAY	
	Load (KN)	Strength (Mpa)	Load (KN)	Strength (Mpa)	Load (KN)	Strength (Mpa)
1.	430	19.11	553	24.45	596	26.48
2.	428	19.02	560	24.88	570	25.33
3.	430	19.11	542	24.08	572	25.42
Average	429.33	19.08	551.67	24.47	579.33	25.74

Split tensile Strength of SCC specimens for SCC specimens

S. No.	Strength averaged of all three values (Mpa)		
	7 days	14 days	28 days
1	1.31	1.595	1.70
2	1.28	1.425	1.595
3	1.378	1.735	2.155
AVERAGE	1.322	1.585	1.816

Flexural strength of SCC specimens for SCC specimens

S. No.	Strength averaged of all three values(Mpa)		
	7 days	14 days	28 days
1	3.125	4.080	5.355
2	3.060	4.233	5.355
3	4.284	5.227	5.993
AVERAGE	3.489	4.513	5.567

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Water absorption of SCC specimens

Sample	Actual weight (g)	(W_1 g) Weight after drying	(W_2 g) Weight after 24 hrs of soaking	Absorption (%) =[W2-W1] x100 / W1
1	12437.00	12405.00	12739.00	3.34
2	12553.00	12521.00	12892.00	3.71
3	12499.00	12468.00	12800.00	3.32
AVERAGE				3.456

VII. CONCLUSIONS AND DISCUSSIONS

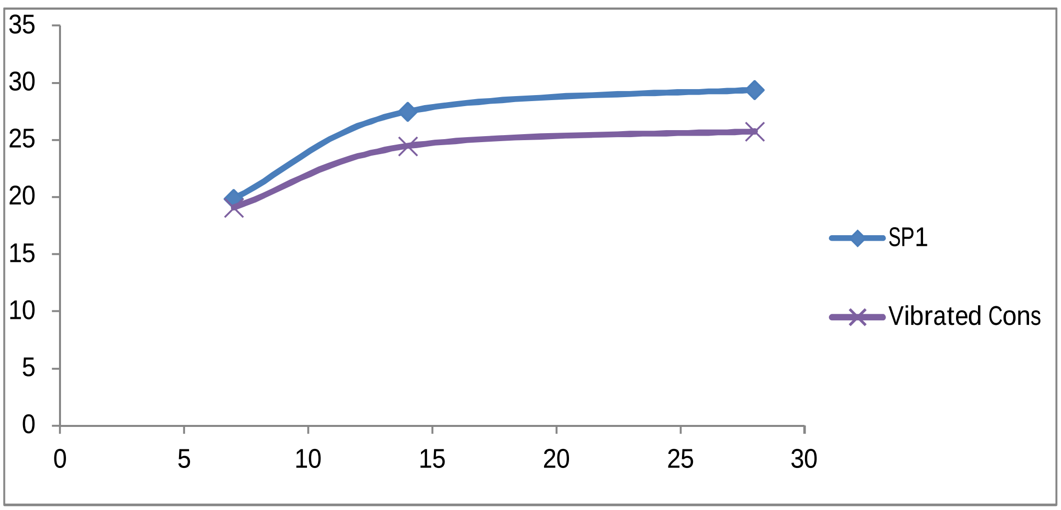
A. From eight trial mixes, a mix with FA/CA ratio of 1.1, a filler content of 100 kg/m3 and 1.00% superplasticizer, was found to meet the compatibility criteria and possessed maximum compressive strength.

B. The compressive strength of SCC specimens increased with the time of curing.

C. The SCC specimens displayed better performances with regard to water absorption. The water absorption of specimens exposed to normal laboratory conditions was 3.51% against 5% of conventional concrete.

D. Effect of different superplasticizers on strength is small and is of the order of 2-3 N/mm^2.

E. The graph below shows variation of compressive strength with no. of days, for SCC and vibrated control castings.



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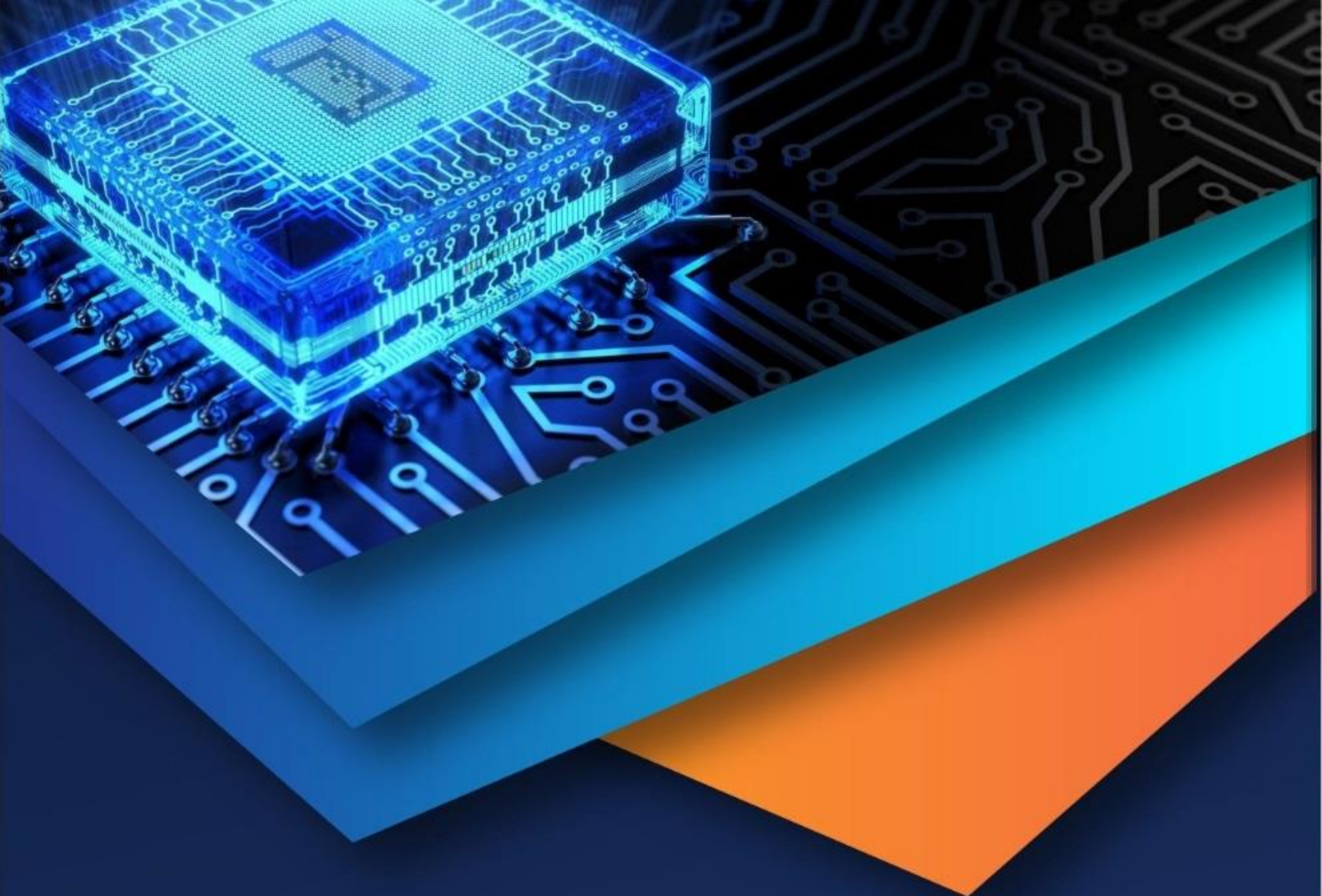

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