Parametric Study of Self Compaction Concrete with Subjected Acidic and Alkali Attack

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Abstract

This paper propose a new mix design method for Conventional concrete(CC) tends to present a problem with regard to adequate consolidation in thin sections or areas of congested reinforcement, which leads to a large volume of entrapped air voids and compromises the strength and durability of the concrete. Using self-compacting concrete (SCC) can eliminate the problem, since it was designed to consolidate under its own mass. Normal concrete was designed as IS method and self-compacting concrete was designed by a simple mix design proposed by Nan Su. SCC was developed in 1988's by Prof. Hagime Okaura in Japan. SCC was one of the latest concrete in across the world. This project deals with the comparison of two different type of high strength concretes(M50).Which is high strength of normal concrete and self-compacting concrete. An experimental and numerical study on mechanical properties, such as compressive strength, flexural strength and split tensile strength of self-compacting concrete (SCC) under the acidic and alkali attack and the corresponding properties of normal compacting concrete (NC) when subjected same. The age at loading of the concretes varied between 7 and 28 days

Key Words

Fine aggregate, coarse aggregate, cement , water, micro silica, super plasticizer glenium B233, Compressive strength, Split tensile strength, Flexural strength.

I. Introduction

Concrete is the most basic element for any kind of construction work. No matter what type of building structure it is, the concrete used should be sturdy and well compacted. The main reasons for compacting any type of concrete are:

- To ensure attaining maximum density by removal of any entrapped air.
- To ensure that the concrete used is in full contact with both the steel reinforcement and the form work.

Ensuring the above points not only provide additional strength to the structure but also good finish and appearance to the final product. The compacting of any conventional concrete is done through external force using mechanical device. Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures. There are many types of concrete available, created by varying the proportions of the main ingredients below. By varying the proportions of materials, or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.The mix design depends on the type of structure being built, how the concrete will be mixed and delivered, and how it will be placed to form this structure.Unlike the conventional concrete, self- compacting concrete doesn't require compacting using external force from mechanical equipment such as an immersion vibrator; instead SCC is designed in such as way that it gets compacted using its own weight and characteristics. Once applied, the self-compacting property enables the concrete to fully reinforce around the steel structures and completely fill the space within the framework. The self-compacting of concrete is achieved without losing any kind of strength, stability, or change in properties.Self-compacting concrete is a type of concrete, which is not a product of mixing substances having different properties but a combination of several mixes having the same flow characteristics.

Manufacturing of a Self -Compacting Concrete requires three main aspects to be full-filled.They are as follows:

- High amount of water reducing substance or super plasticizers is added for obtaining high flowing characteristics.
- A type of aggregate mixture is added to gain the desired compactness. Note that the aggregate content is of round shape and proportional in size in order to increase the locking tendency of the concrete.
- Alteration of fluid properties is done to ensure a cohesive mix which will keep the aggregate and paste together. These fluid properties can be achieved by adding a high quantity of fine content such as cement fly-ash or by adding viscosity modifying admixtures (VMA).

properties, at similar water/cementitious material ratio, properly proportioned, produced and placed SCC is generally denser and less variable than the equivalent conventional vibrated concrete, thereby resulting in improved strength and durability performance.

Comparison: Typical SCC vs Conventional Concrete Mix

Material, by volume	Conventional vibrated concrete (%)	SCC (%)
Admixtures	<0.01	0.01
Water	18	20
Coarse aggregate	46	28
Sand	24	34
Fines, including Portland cement	12	18

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Properties of Coarse Aggregate:

S. No	Properties	Coarse aggregates
1	Specific gravity	2.74
2	Loose bulk density	1365 kg/m3
3	Rodded bulk density	1610 kg/m3

Super Plasticizer Glenium B233 conforming to ASTM C494 Types F, EN934-2 T3.1/3.2, IS 9103: 1999 is used. GLENIUM B233 is an admixture of a new generation based on modified polycarboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required.

Cement

Ordinary Portland Cement of 53 Grade available in local market is used in the investigation. The cement used has been tested for various properties as per IS: 4031 – 1988 and found to be conforming to various specifications as per IS: 12269 – 1987. The test results on ordinary Portland cement are shown in Table

PROPERTIES OF FINE AGGREGATE:

S. No	Properties	Fine aggregates
1	Specific gravity	2.670
2	Loose bulk density	1450 kg/m3
3	Rodded bulk density	1713 kg/m3

Mix design for SCC:

This mix design was proposed by Nan-Su:

To produce SCC, the major work involves designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained. Initial trail mixes are obtained from Nan su mix design procedure and mixes are modified according to get fresh, hardened properties and hardened properties. Among them the bold ones satisfy the specifications and economical mixes. From the obtained mixes a simplified mix design was developed for PPC and SCC on the lines of Non-su method using Portland pozzolana cement and micro silica. The procedure is described in the following steps.

Step 1: Calculation of coarse aggregate and fine aggregate:

The packing factor (PE) of aggregate is defined as the ratio of mass aggregate of tightly packed state in SCC to that of loosely packed state. Clearly, PF affects the content of aggregates in SCC. A higher PF value would imply a grater amount of coarse aggregates used, thus, decreasing the content of binders in SCC consequently, its flowability, self-compacting ability and compressive strength will be reduced. On the other hand, a low PF value would mean increased dry shrinkage of concrete. As a result, more binders are required, thus, raising the cost of materials. In addition, excess binders used would also affect the workability and duration of SCC. Therefore, it is important to select the optimal PF value in the mix design method so as to meet the requirements for SCC properties, and at the same time taking economic feasibility into consideration. The content of fine and coarse aggregates can be calculated as follows

$Wg = PF*Wgl*(1-(s/a))$

$Ws= PF*wsl*(s/a)$

Where

Wg = content of coarse aggregates in SCC (kg/m3);

Ws = content of fine aggregates in SCC (kg/m3);

Wgl = unit volume mass of loosely piled saturated surface-dry Coarse aggregate in air (kg/m3);

Wsl = unit volume mass of loosely piled saturated surface-dry fine aggregates in air (kg/m3);

PF = packing factor;

(s/a) = volume ratio of fine aggregates to total aggregates, which ranges from 50% to 57%.

Step 2: Calculation of PPC content:

To secure good flowability and segregation resistance, the content of binders (power) should not be too low. However, too much cement used will increase and drying shrinkage of SCC. Generally, it was observed that SCC produce with PCC provides a compressive strength of 0.11 Mpa/kg cement. Therefore, the cement content to be used is:

$C= (fc/0.110)$

Where

C= Portland pozzolana cement (kg/m3);

fc = designed compressive strength (Mpa).

Also while arriving at cement content one should remember that the total powder content to be maintained in SCC is 400-600 kg/m3 as per EFFNARC specifications.

Step 3: Determining the Micro silica content:

The ultra fine particles of micro silica fill the gaps between cement grains refining the voids in the fresh concrete. These particles act like ball bearing which give more mobility to the concrete and make it much more cohesive. Because the micro silica particles are ultra fine, with a specific surface area of around 20,000 m2/kg and siO2 content around 90%, the reactivity is very high. The crystalline structure formed by this reaction is very fine and fills the void spaces within the matrix. This densifies the whole concrete structure, resulting in increased strength and significant in permeability.

So, based on propose and economy micro silica can be used up to 10% of the cement used as addition. But in this work the dosage of micro silica is restricted to 2-4% only.

Step 4: Determining the mixing water content:

Although factors such as content of fine and coarse aggregates, material proportions, and curing age can affect the compressive strength of SCC, the ratio of water to binders by weight (W/B) is the most prominent determinant of compressive strength. The smaller PF value, the more the paste volume in SCC will be. As a result, the compressive strength becomes higher. W/B ratio is studied from the fig and required water content to be used is:

$WW = (W/B) * (C+ Wms)$

Where C = Portland pozzolana cement content (kg/m3);

Wms=micro silica content (kg/m3);

WW = water content(kg/m3);

Step 5: Determining SP dosage:

Adding an adequate dosage of SP can improve the flowability, self-compacting ability and segregation resistance of fresh SCC for meeting the design requirements.

Optimum dosage of GLENIUM B233 should be determined with trail mixes. As a guide, a dosage range of 500ml to 500ml per 100kg of cementitious material is normally recommended. In this work dosage of SP is taken as 1.3% of amount of binders. Dosage of SP in kg/m3 is given by

WSP = 0.013 * (C + Wms)

Step 6: Adjustment of mixing water content needed in SCC. According to the moisture content of aggregates at the ready-mixed concrete plant or construction site, the actual amount of water used for mixing should be adjusted.

Step 7: trial mixes and tests on SCC properties
Trial mixes can be carried out using the contents of materials calculated as above. Then, quality control tests for SCC should be performed to ensure that the following requirements are met.

1. Results of slump flow, U-Box, L-flow and V-Funnel tests should comply with the specifications of the JAS.
2. The segregation phenomenon of materials should be satisfactory.
3. Water–binders ratio should satisfy the requirements of durability and strength.
4. Air content should meet the requirement of the mix design.

Step 8: Adjustment of mix proportion:
If results of the quality control tests mentioned above fail to meet the performance required of the fresh concrete, adjustments should be made until all properties of SCC satisfy the requirements specified in the design. For example, when the fresh SCC shows poor flow ability, the PF value is reduced to increase the binder volume and to improve the workability.

Mix Design of SCC for M 50:
Characteristic Strength = 50 Mpa
Maximum size of aggregates = 20mm
Specific gravity of coarse aggregates, Gg= 2.74
Specific gravity of fine aggregates, Gs= 2.67
Bulk density of loose coarse aggregates= 1385.50 kg/m^3
Bulk density of loose fine aggregates = 1450.19 kg/ m^3
Specific gravity of cement, Gc = 3.15
Volume of fine/course aggregate ratio(s/a) = 0.55
Determination of Coarse aggregate:
Assume P.F = 1.15
Amount of coarse aggregate, Wg = 1.15 x 1385.50x(1-0.55)
Wg =717.177 kg/ m^3
Determination Fine aggregate:
Amount of fine aggregate, Ws= P.F x Wsl (s/a)
= 1.15 x 1450.19 x 0.55
= 917.125kg/m^3

Determination of cement:
C = F′c/0.110
Given 0.11 Mpa= 20PSI
∴ C= 50/0.110
= 529.540 kg/m^3
Determination of micro silica content:
Assume 2% of micro silica in cement
Wms=0.02x529.54=10.59 kg/m^3
Determination of water:
For water to binder ratio for 58.25Mpa is = 0.34
∴ W/B = 0. 34
W=(W/B)x(C+Wms)
=0.34X(529.54+10.59)
=183.64kg/ m^3
Determination of SP dosage:
SP dosage = 1.3 % of (529.54+10.59)
= 7.02 kg/ m^3

1	:0.02 :	1.730:	1.354:	0.346	0.013

Adjustments:
After conducting no of trails we conclude that, the following SCC mix ratios are satisfying the required workability and flow ability conditions.
Water binder ratio = 0.340.

S. No	I.S. sieve designa-tion	Weight retained (grams)	Cumu-lative weight retained (grams)	Cumulative % of weight retained	Percentage passing By weight	Remarks
1	40 mm	0	0	0	100	Fine Ag-gregate conforming to Grading Zone II of IS: 383 – 1970
2	20 mm	0	0	0	100	
3	10 mm	0	0	0	100	
4	4.75 mm	0	0	0	100	
5	2.36 mm	20	20	2	98	
6	1.18 mm	80	100	10.0	90	
7	600 microns	344	444	44.4	55.6	
8	300 microns	329	773	77.3	22.7	

Conventional Concrete Mix Design:

DESIGN PARAMETERS (FOR M50)
(a) Maximum size of aggregate : 20 mm
(b) Degree of workability : 0 . 9 0 Comp., factor
(c) Degree of quality control : Good
(d) Type of Exposure : Mild
(e) Compressive Strength of cement : 53 N/mm^2 at 28 days
(f) Selection of W/C ratio : 0.40 for M50

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economical as possible.

Concrete mix design for M50 grade of concrete was done according to IS: 10262 – 2009 and the final proportion achieved are given in table – 5.4

A) Target strength for mix proportioning:
f'ck= f'ck+ks
From Table 1 standard deviation, *s* = 5 N/mm²
Therefore target strength = 50+1.65 x5 = 58.250 N/mm²

B) Selection of w/ c ratio:
From Table 5 of IS 456:2000, maximum water cement ratio = 0.4 (Mild exposure)
Based on experience adopt water cement ratio as 0.40
0.4 < 0.55, hence ok

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C) Selection of water content

From Table 2, maximum water content = 186 litres (for 25 mm –50 mm) slump range and for 20 mm aggregates

D) Calculation of cement content

Water cement ratio = 0.40
Cement content = 186/0.4
=465 kg/m3 >320 kg/m3(given)
From Table 5 of IS 456, minimum cement content for mild exposure condition = 300 kg/m3, Hence OK

E) Mix calculations

The mix calculations per unit volume of concrete shall be as follows

a) Volume of concrete = 1 m3
b) Volume of cement = mass of cement/specific gravity of cement x 1/1000
= [465/3.15] x [1/1000] = 0.147 m^3
c) Volume of water = [186/1] x [1/1000] = 0.186 m3
d) Volume of all in aggregates (e) = a – (b + c)
=1 – (0.147 + 0.186) = 0.666 m3
e) Volume and weight of coarse aggregates
Volume of coarse aggregate = 0.62+0.02 = 0.64 m3
Weight = Volume of all in aggregates x volume of coarse aggregate x specific gravity of CA x 1000
= 0.666x0.64 x2.74 x 1000 = 1170 kg
f) Volume and weight of fine aggregates
Volume = 0.667 x 0.36 = 0.240 m^3
Weight = Volume of all in aggregates x Volume of FA x specific gravity of FA x 1000
= 0.240 x 2.67 x 1000
= 641 kg

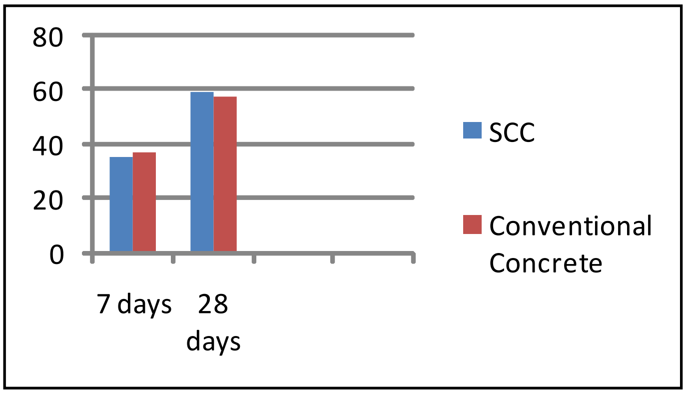
I)Mix proportions :
Cement = 465 kg/m^3
Water = 186 kg/m^3
Fine aggregate = 641 kg/m^3
Coarse aggregates = 1170 kg/m^3
Water cement ratio = 0.40.

COMPARISION OF RESULTS

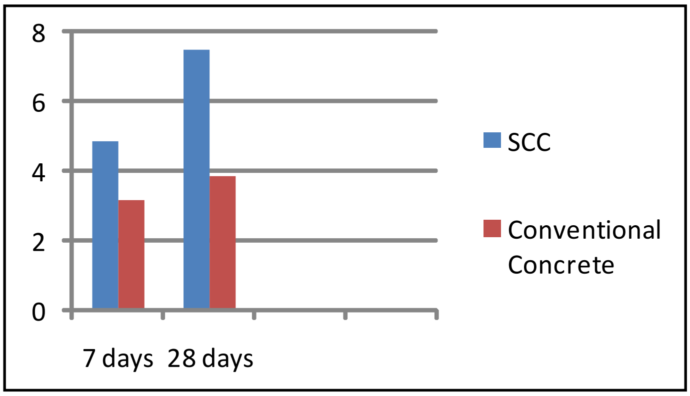
Strengths(in days)		SCC (N/mm²)	Conventional Concrete(N/mm²)
Compression Strength	7	43.50	39.87
	28	57.92	55.24
Flexural Strength	7	4.2	3.2
	28	7.6	3.9
Split Tensile Strength	7	3.12	2.9
	28	4.09	3.76

GRAPHS:

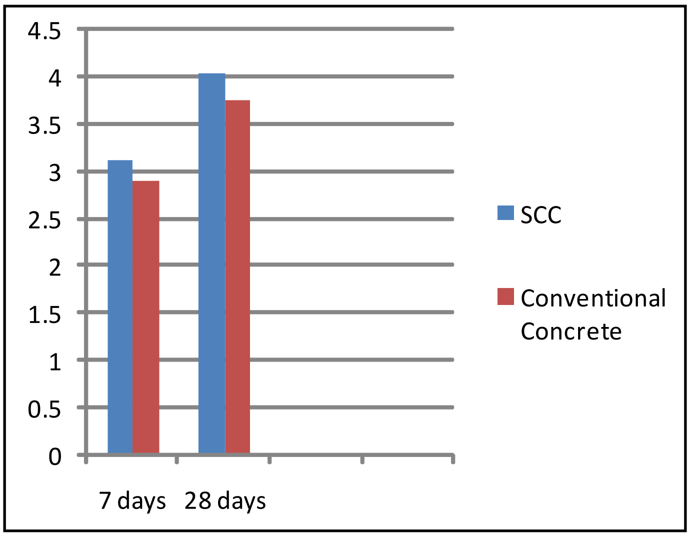
Comparison of Compression Strength: Strength (N/mm²)



Comparison of Flexural Strength: Strength (N/mm²)



Comparison of Split Tensile Strength: Strength (N/mm²)



Physical Properties of Ordinary Portland Cement 53 Grade

S. No	**Property**	**Test Results**
1	Normal consistency	30 %
2	Specific gravity	3.15
3	Setting time Initial setting time Final setting time	35 min 230 min
4	Fineness of cement (IS sieve no.9)	4.0 %

SIEVE ANALYSIS FOR COARSE AGGREGATE:

S. No	I.S. sieve designation	Weight retained (grams)	Cumulative weight retained (grams)	Cumulative % of weight retained	Percentage passing By weight	Remarks
1	40 mm	0	0	0	100	Coarse Aggregate conforming to Grading Zone II of IS: 383 – 1970
2	20 mm	0	0	0	100	
3	10 mm	9155	9155	91.55	8.45	
4	4.75 mm	750	9905	99.05	0.95	
5	2.36 mm	0	9975	99.05	0.95	
6	1.18 mm	0	9905	99.05	0.95	
7	600 microns	0	9905	99.05	0.95	
8	300 microns	0	9905	99.05	0.95	
9	150 microns	0	9905	99.05	0.95	

Total = 9905 grams 685.85

PHYSICAL PROPERTIES OF ORDINARY PORTLAND CEMENT 53 GRADE

S. No	Property	Test Results
1	Normal consistency	30 %
2	Specific gravity	3.15
3	Setting time Initial setting time Final setting time	 35 min 230 min
4	Fineness of cement (IS sieve no.9)	4.0 %
5	Compressive strength 1:3 sand mortar cubes At 7 days At 28 days	35 Mpa 53Mpa

Acceptance criteria for SCC:

S. No	Method	Unit	Typical Range of Values	
			Minimum	Maximum
1	Slump Flow Test	Mm	650	800
2	T_{50}cm Slump Flow	Sec	2	5
3	V-Funnel Test	Sec	6	12
4	V-Funnel at T_5minuts	Sec	6	15
5	L-Box Test	h_2/h_1	0.8	1.0

5	Compressive strength 1:3 sand mortar cubes At 7 days At 28 days	35 Mpa 53Mpa

Conclusions

1. After committing various trail tests, we have finally achieved M_{50} grade self-compacting concrete for 20mm size of coarse aggregates which could satisfy all the SCC characteristics such as flowability, passing ability and segregation resistance given by European standards. As there are no Indian standards, comparison could not be made.
2. From the observations it was found that nearly 2/3of the compressive strength is gained in 7 days curing which satisfies IS: 456-2000.
3. It was also observed that Split Tensile strength of SCC has attained the permissible values for 7 days and 28 days as per IS: 456-2000.
4. It was also observed that flexural strength of SCC has attained the permissible values for 7 days and 28 days as per IS: 456-2000.
5. With the help of workability and strength characters we got M50 grade mix proportion for 20mm size of coarse aggregate.
6. Finally we conclude that the strength of Self-Compacting Concrete is higher than the Conventional Concrete.

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