Design Mix - Self Compacting Concrete

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***Abstract* – Self compacting concrete(SCC) is a mixture obtained by mixing cement, water and aggregate such that the mixture has enough flow ability. SCC is a more often used in heavily reinforced structures where normal concrete stuck between the reinforcements. The main characteristics which allow SCC to show greater efficiency in heavily reinforced concrete are its flow ability, and deformability. To achieve sufficient flow ability and the desired compressive strength it is essential to determine the design mix. The properties of materials used in SCC plays an influential role in determining the flow properties of SCC. Hence it is essential to find the right quantities of materials mixed such that the SCC compacts without providing any vibration due to its own weight.**

***Keywords:* Self compacting concrete (SCC), Mix Design, Workability.**

I INTRODUCTION

Self-compacting concrete is concrete which has very high flow ability and can compact on its own under self-weight, this reduces the effort produced due to vibration. It's suitability is more in the structures which are heavily reinforced. The viscosity and low yield value makes it possible to have a greater flow ability. Self compacting concrete is so designed such that the homogeneity is maintained during various phases before setting of SCC which allows it to give better strength and durability. SCC's development should strike a remarkably good balance between deformability and stability. Guidelines set by researchers for mixture proportioning of SCC includes i) reducing the volume ratio of aggregate to cementitious material [1-2]; (ii) increasing the paste volume and water-cement ratio (w/c) [1]; (iii) carefully controlling the maximum coarse aggregate particle size and total volume[1]; and (iv) using various viscosity enhancing admixtures (VEA) [1]. SCC is produced using S.P. (Super Plasticiser) which on one hand reduces the water demand and on the other provides high flow ability with ease. SCC being a material with high flow ability, considerable care has to be taken to avoid segregation. For segregation to be minimum, it is necessary to alter the composition of coarse and fine aggregate such that fines are more. Mix composition and characteristics of materials used plays an important role in governing the self – compacting ability of SCC hence it becomes an important aspect to develop a highly reliable procedure to obtain mix composition of SCC. Okamura and Ozawa have contributed in this field and proposed a mix proportioning system for SCC [3]. To obtain suitable self-compacting property it is advised to fix the aggregate composition and vary the w/p ratio and S.P. quantity. The w/p ratio for best mix-design is determined by trial and hit using various mixes and opt the best. The major drawback as far with SCC is that we are yet not able to identify a best procedure to compute mix composition. With this paper we are describing a procedure to obtain mix proportion keeping in mind the self-compacting ability, strength and durability.

II MATERIALS

Cement: OPC43 is used, which is readily available in the region. Cement of higher grade is used to obtain better cementious properties.
Fly-Ash: The Fly-Ash used is obtained from Badarpur thermal power plant. The physical properties are mentioned in Table 1 and chemical properties are accounted in Table 2.
Aggregates: The coarse aggregate sizes used varied from 20mm – 10mm. It was so done to make sure the concrete has enough flow ability. The aggregates used were checked so that the water absorbed by the aggregates is not more than 0.75% by weight. Proper inspection were carried out to identify presence of any material that may hinder properties of concrete like organic materials, dirt etc.
Water: The water used, had a pH in range 7-8.

Super Plasticizer: The super plasticizer used is SS-PLAST-PC-100. SS-PLAST -PC-100 is new generation super plasticizer for long retention. It is formulated with synthetic polymers with High Molecular weight poly carboxylate and organic polymers. SS-PLAST-PC-100 conforms to IS: 9103-1999, IS: 2645-1975 and ASTM C-494 type F & G.

Table 1: Fly-Ash Properties (Physical)

Sn.	Physical Properties	Value
1	**Color**	Greyish
2	**Specific Gravity**	2.23
3	**Compressive Strength at 28 Days**	5.10 MPa

Table 2: Fly-Ash Properties (Chemical)

Sn.	Particulars	Percentage by weight
1	**Loss on Burning**	4.18
2	**Silica**	58.55
3	**Iron Oxide**	3.45
4	**Alumina**	28.20
5	**Calcium Oxide**	2.23
6	**Magnesium Oxide**	0.32
7	**Total sulphur**	0.09
8	**Insoluble residue**	Nil
9	**Alkalies : a) Na_2O**	0.58
	b) K_2O	1.26

III METHODOLOGY

SCC is the concrete obtained when cement, aggregate, water and admixtures are added in right proportion such that the concrete have enough flow ability to consolidate under its own weight without providing any kind of vibration to compact it.

Following parameters are used to evaluate the mix design:

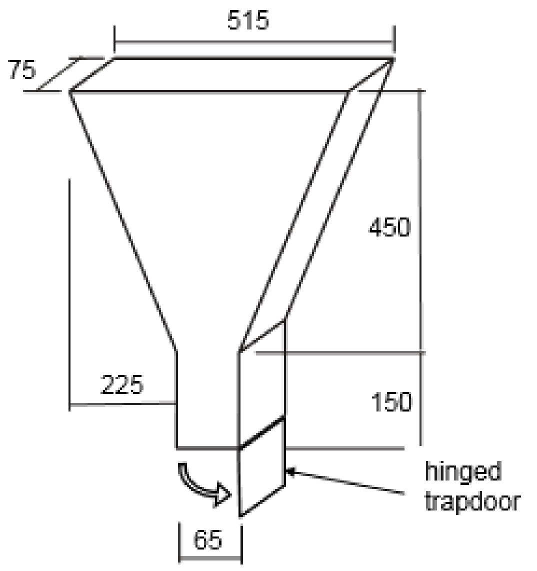
Test: Slump flow:

As per the EFNARC guidelines the slump test is performed. The slump test is a test performed to determine the flow capacity of the SCC so produced. The procedures to be followed while performing slump test are described in detail in EN 12350-2.

Figure 1: Slump Flow Test Apparatus

Test: V- Funnel:

V- Funnel test measures the flow rate and viscosity of concrete by holding SCC in V- Funnel apparatus and then allowing it to pass through the bottom. The time it takes to empty the apparatus completely is noted and is used to compare various design mix. The range of time and procedure are all mentioned in EN 12350-1.



All Dimensions are in mm.

Figure 2: Apparatus for V- Funnel Test

Test: L- Box:

The L- Box test is a method of testing the passing ability of concrete through tight reinforced structures. The test is performed in compliance with EN 12350-1.

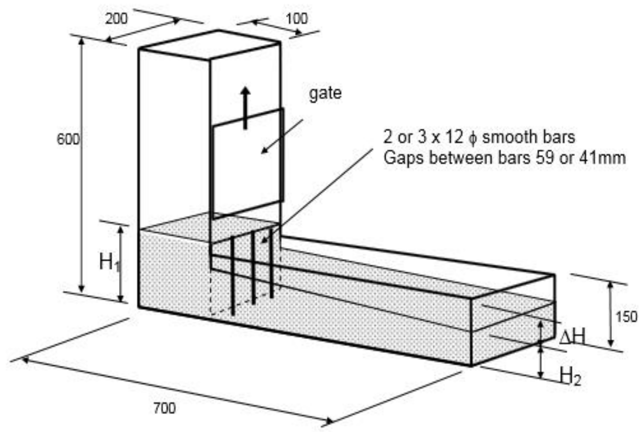


Figure 3: L- Box Test Apparatus

IV MIX DESIGN

Mix design is the process of choosing the optimum quantities of different constituents of concrete to attain a specific minimum compressive strength and durability in a most economic composition.

Design consideration for M25 Mix Design as per BIS.

- Characteristic compressive strength 28-days : 25Mpa
- Aggregate size (Max.) : 12.5mm
- Compaction Factor : 0.9
- Quality control : Good
- Exposure : Severe

Test Results

Cement:

Specific Gravity: 3.01

Compressive strength (7 Day): 37 MPa as per IS269-1989.

Aggregates:

Specific Gravity: 2.65

Water absorption: 0.5% by weight

Fineness Modulus: Coarse: 6.15

: Fine: 2.72

Steps Followed

1. Target mean strength calculation

$f_{ck*} = f_{ck} + ks$

fck* = 25 + 1.65*6.0 = 34.9 N/mm^2

Where,

fck* = mean target strength in MPa

k= Probability factor for 5% tolerance.

s= Standard deviation for degree of control.

2. The w/c ratio for the mean target strength of 34.9 MPa is 0.5.

3. Find water and sand quantity for 12.5 mm max aggregate size and the sand in compliance to ZONE -II.

Water quantity per m^3 of concrete = 186 kg/m$^{3.}$

Sand quantity as % of net aggregate quantity = 65%

Compaction Factor = 0.9

Next is application of corrections

Table 3: Corrections

Change in Condition	Water	Sand
W/C (.22)	0	-4.4%
C.F.	+3%	0
Rounded	-15Kg	-7%
Zone II	0	0

As the above corrections
Water Content = 208 + (0.03*208) -15 = 199.24 MPa
As per correction the sand content as percentage of total aggregates = 65- 11.4 = 53.6%

4. Determine the content of water and cement.

5. Determination of coarse and fine aggregate contents.

Assuming 3% air entrapment.
V= [W/SW+C/SC+ fa/ (P*SFA)]*0.001;
V= [W/SW+C/SC+ Ca/ ((1-p)*SCA)]*0.001;
F.A. =788.77kg/m^3.
C.A.=773.06kg/m^3.
Hence the mix proportion becomes:

Table 4: Normal Concrete design Proportions

Cement	Sand	Coarse Aggregate	Water
524.31 Kg	788.77Kg	773.06 Kg	199.24 Kg
1	1.5	1.47	0.38

Converting to SCC proportions

The normal design mix is converted to SCC proportions and then the fresh properties of concrete are considered and we arrive at a final mix design.
Cement = 524.31 kg
Fine aggregate (F.A.) = 788.77 kg
Coarse aggregate (C.A.) = 773.06 kg
Total aggregate (T.A) = 788.77+773.06 = 1561.83 kg.
Taking F.A. : C.A. as 3:2

Table 5: Final SCC Mix Proportions.

Cement	Sand	Coarse aggregate	Water
524.31 Kg	937.09 Kg	624.73 Kg	199.24 Kg
1	1.78	1.19	0.38

The different trial mixes are made considering different ratios.

V RESULTS AND DISCUSSIONS

Table 6: Design Proportions for SCC

Sn.	**Design Mix**	**Cement (Kg/m^3)**	**Fly-Ash (Kg/m^3)**	**Fine Aggregate (Kg/m^3)**	**Coarse Aggregate (Kg/m^3)**	**H_2O (Kg/m^3)**	**Super P. %**	**W/p Ratio**
1	TRS1	500	145	753	776	188	-	0.93
2	TRS2	500	145	753	776	188	0.75	0.93
3	TRS3	500	145	753	776	188	3.50	0.93
4	TRS4	525	149	790	696	233	1.15	1.07
5	TRS5	525	149	790	696	262	1.15	1.10

6	TRS6	525	149	790	696	263	1.15	1.19
7	TRS7	525	149	790	696	239	1.15	1.05
8	TRS8	525	149	790	696	260	1.15	1.19
9	TRS9	525	149	790	696	242	1.15	1.10
10	SC1	495	125	967	551	247	1.15	1.22
11	SC2	495	125	967	551	246	1.15	1.23
12	SC3	495	125	967	551	244	1.15	1.11
13	SC4	495	125	967	551	233	1.15	1.17
14	SC5	495	125	967	551	243	1.15	1.17

The values shown in Table 6 are the mix proportions that were determined using the above discussed method. The trial mixes from TRS 1 to TRS 9 are the trial mixes which stand on some properties of SCC whereas SC1 – SC5 are the trial mixes which represent all properties of SCC. Different properties are shown in Table 7.

Table 7: Compressive strength and Workability for SCC

Sn.	Design Mix	Slump flow (mm)	T50cm (second)	V- Funnel (second)	L – Box Blocking Ratio	7 Day (MPa)	28 Day (Mpa)
1	TRS1	-	-	-	-	-	-
2	TRS2	-	-	-	-	-	-
3	TRS3	-	-	-	-	-	-
4	TRS4	-	-	-	-	9.1	23.12
5	TRS5	590	15.0	46	-	11.1	21.34
6	TRS6	-	-	-	-	12.1	22.43
7	TRS7	-	11.0	-	-	19.39	34.2
8	TRS8	400	-	-	-	17.42	
9	TRS9	670	5	39	-	17.2	
10	SC1	696.7	3	12	0.1	16.3	24.98
11	SC2	697.6	3.7	11	0.3	16.13	26.76
12	SC3	713.43	2	10	0.5	16.45	27.57
13	SC4	670	4.5	8	0.9	15.78	31.87
14	SC5	680	4.5	9	0.8	13.24	26.65

VI CONCLUSIONS

1. SCC can be obtained by modifying the fine aggregate and coarse aggregate quantities such that fine aggregate is nearly 50% – 60% of total aggregate.
2. SCC can also be obtained without addition of VMA (Viscosity Modifying Agent).
3. Considerable reduction has to be applied to water content when adding Super Plasticiser.
4. The size of coarse aggregate controls the test results of L-Box test and hence it signifies that greater the size of aggregate less is the flow ability throught the heavily reinforced structures.

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