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An Experimental study on self compacting concrete

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Abstract - Self compacting concrete is a flowable concrete mixture with excellent strength and durability properties.It can be able to flow under its own weight and it is able to compact itself without any additional vibration or compaction effort.It completely fills formwork and makes it suitable for filling even in the presence of congested reinforcement. The mix design and testing methods are different compared with ordinary concrete. But wide spread applications of Self Compacting Concrete have been restricted due to lack of standard mix design procedure. However getting high strength self compacting concrete is simple compared to medium and low strengths. In this paper an attempt has beenmade to develop self compacting concrete for some grades (M15, M20, M25 and M30) by using Ordinary Portland cement, fine aggregate, coarse aggregate, water, fly ash as a mineraladmixture and Master Glenium SKY 8630 as a combination of super plasticizer and viscosity modifying agent. Various trail mix proportions have been done to satisfy the workable properties of SCC.The fresh properties of self-compacting concrete such as slump flow test, slump flow T50cm test, L-Box test and sieve segregation resistance test were conducted and checked against EFNARC guidelines. Further, compressive strength at the age of 7 and 28 days is determined for SCC by adopting the trial and error approach mix proportioning.

Index Terms - self compacting concrete, strength, durability, proportion, compressive, aggregate, reinforcement

1. INTRODUCTION

As in need of sustainable infrastructure, Self Compacting Concrete (SCC) is gaining popularity worldwide due to ease in its placement without any need for compaction. It was first developed in 1988 by Okamura in Japan.The Guidelines and specifications for SCC were prepared by "The European Federation of Specialist Construction Chemicals and Concrete Systems" (EFNARC).It is environmental-friendly, as industrial wastes are used. Though the materials used for both conventional concrete and SCC are the same, with only change in the mix proportions and with addition of admixtures SCC need a higher paste volume compared to the conventional concrete. SCC is designed in such a way that it gets compacted by its own weight and characteristics.The 7 days compressive strength is decreased and 28 days compressive strength is increased. Permeability is decreased, easier placing, better surface finish than ordinary concrete. The cost for SCC is high due to addition of super plasticizers and adding of more cement content.But the main advantages of using SCC is it reduces construction time and also vibration cost. Therefore labor cost will be reduced. Cement content can be reduced by addition of fly ash to SCC. The bond strength is more compared to ordinary concrete. Self-Compacting Concrete should have lesser coarse aggregate contents and hence high cement content. Due to this it can increase the cost and temperature during hydration which leads to possible effect on other properties such as creep and shrinkage.

Requirements for SCC are

Filling Ability: It is the ability of SCC to flow into and fill completely all spaces in the formwork

Passing Ability: It is the ability of concrete to pass through narrow sections in form work and closely spaced reinforcement bars.

Resistance to segregation: It is the ability to maintain homogeneity completely during mixing, transportation and placing.

MATERIALS USED

Cement:

Ordinary Portland cement of 53 grade available in local market is used in the investigation. The cement used has been tested for various proportions as per IS 4031 – 1988 and found to be confirming to various specifications of IS 12269-1987.

Fly ash:

The fly ash used in this SCC is from Vijayawada thermal power station.It is a waste product, generated by the combustion of coal. Fly ash also reduces pollution whencompared with cement. Low heat of hydration is produced by adding mineral admixtures like fly ash.

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Fine aggregate:

Fine aggregate is reduced in SCC. The shape and gradation of aggregate plays a prominent role in generating self-compacting concrete. Locally available river sand conforming to zone II of IS 383:1970 is used.

Coarse aggregate:

In this SCC small sized and limited coarse aggregates should be used so as to reduce internal stresses causing blockage. The sizes of coarse aggregate used in this mix were 10mm, 12.5mm and 20mm.

Water:

Water used was fresh, colorless, and tasteless. Portable water free from organic compound is used in this experiment

Super plasticizer:

Super plasticizer is a chemical compound used in the present work to increase workability without any addition of water. Master Glenium sky8630 is used as a chemical admixture to increase the paste flow and to prevent segregation.The unique formulation of this admixture allows the concrete mix to achieve both self-compacting properties and concrete stability.

2. EXPERIMENTAL PROCEDURE

In this an attempt has been made to produce low and medium strengths of SCC by adopting trial and error approach of mix proportioning.With SCC it is particularly important that the mixer is in a good mechanical condition and that it can ensure full and uniform mixing of the solid materials.Experience has shown that the time necessary to achieve complete mixing of SCC may be longer than for normal concrete due to reduced frictional forces and to fully activate the admixture.

The experimental procedure includes the following steps:-

2.1 Material properties
2.2 Design of concrete mix
2.3 Mixing of concrete
2.4 Workability tests
2.5 Preparation of moulds
2.6 Hardened properties

2.1 Material properties

Table 1
Properties of Materials

Material	Bulk Density	Specific Gravity
Cement	1478.101	3.15
Fly Ash	1410.45	2.11
Coarse Aggregate(10mm)	1623.10	2.72
Coarse Aggregate(12.5mm)	1664.67	2.73
Fine Aggregate	1560.22	2.61

2.2 Design of concrete mix

As there is no specified mix design in this paper we followed IS 10262(2009) code book using EFNARC guide lines.

Assumed a constant w/c = 0.5 for all mixes.

Selection of water content

From table 2 of IS 10262(2009), maximum water content for 10mm aggregate = 208 liters

For 300mm slump = 208 +(30/100)×208

= 270 liters

Based on trails with super plasticizer, arrived water content = 270×0.8

= 216 liters

Calculation of cement content

Water-cement ratio = 0.5

Cement content = 216/0.50 = 432 kg/m3

Mix Calculations

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

Volume of concrete = 1 m3

$$\text{Volume of Cement} = \frac{Mass\ of\ cement}{Specific\ gravity\ of\ cement} \times \frac{1}{1000}$$

$$= \frac{432}{3.15} \times \frac{1}{1000}$$

$$= 0.137\ \text{m3}$$

$$\text{Volume of water} = \frac{Mass\ of\ water}{Specific\ gravity\ of\ water} \times \frac{1}{1000}$$

$$= \frac{216}{1} \times \frac{1}{1000}$$

$$= 0.216\ \text{m3}$$

Volume of all aggregates = 1- (0.1327+ 0.216)

= 0.647 m3

Mass of Fine aggregate = 0.647×0.55×2.61×1000

= 928 kg

Mass of Coarse aggregate = 0.647×0.45×2.72×1000

= 792 kg

Mix proportions for trail number 1

Cement = 432 kg/m3

Water = 216 kg/m3

Fine aggregate = 928 kg/m3

Coarse aggregate = 792 kg/m3

Cement:F.A: C.A

1 : 2.1: 1.8

Table 2
Mix Proportions

Mix	Proportions	Water %	Fly ash %	Aggregate size(mm)
1	1:2.1:1.8	0.5	0	10
2	1:2.1:1.8	0.5	10	10
3	1:2.1:1.8	0.5	20	10
4	1:2.1:1.8	0.5	30	10
5	1:2.3:2.0	0.5	0	12.5
6	1:2.3:2.0	0.5	10	12.5
7	1:2.3:2.0	0.5	20	12.5
8	1:2.3:2.0	0.5	30	12.5
09	1:2.7:2.3	0.5	0	20
10	1:2.7:2.3	0.5	10	20
11	1:2.7:2.3	0.5	20	20
12	1:2.7:2.3	0.5	30	20

Table 3
Concrete Proportions

Mix	Cement	Fly ash	Fine aggregate	Coarse aggregate	water
1	432	0	928	792	216
2	389	43	928	792	216
3	346	86	928	792	216
4	302	130	928	792	216
5	406	0	960	819	200
6	365	41	960	819	200
7	330	81	960	819	200
8	325	122	960	819	200
09	284	0	1012	863	186
10	326	36	1012	863	186
11	290	72	1012	863	186
12	253	109	1012	863	186

2.3 Mixing of concrete

The mixer should first be kept clean and in wet condition. The coarse and fine aggregates are put into the mixer and mixed for 1 minute. Next the cement and fly ash were added together with water and mixed for other 2 minutes. Finally super plasticizer was added. The total mixing should not exceed 15minutes from the time coarse and fine aggregates added to the mixer.

2.4 Workability Test Methods

Various test methods have been done to satisfy fresh properties of SCC. In the present work Slump flow, T_{50}cm slump flow, L-box and Sieve segregation tests were conducted.

- Slump flow test (filling ability)
- T_{50cm} Slump Flow (viscosity)
- L-box test (passing ability)

2.4.1 Slump flow and T_{50cm} test:-

The slump flow test is used to determine the filling ability of concrete without any obstructions. The apparatus required for this is mould, base plate, trowel, ruler and stopwatch. At first the base plate and the mould should be kept clean in a dry condition and the mould is placed at center of the base plate. Slump cone is filled with SCC up to its top. With the help of the trowel it is levelled and the left over residue on the base plate is cleaned immediately. The slump cone is raised upwards and allows the concrete flow freely. Simultaneously stop watch is started at the time of flow. The time taken by the concrete to reach the 50cm circle is the T50cm slump test and the average measured diameter on both sides is slump value. The T50cm value ranges from 2 to 6 secs and the slump value ranges from 600 to 800mm.

2.4.2 L-Box test:-

The L-box text is used to determine the passing ability of SCC which flow through tight openings between reinforcing bars without segregation and blocking. It is designed for under water concrete. The apparatus consists of rectangular shaped L-box separated by a gate reinforced with bars. Fresh concrete is poured into the vertical section and gate is released and concrete is allowed to go into the horizontal section. Height is measured from the end of the horizontal section (H2) and at the vertical section (H1) where the remaining concrete is left. Calculate H2/H1. The value ranges from 0.8 to 1.0.

Table 4

Workability tests results

Mix	Slump Flow(mm)	T50 cm(seconds)	L- Box
	600-800mm	2-6secs	0.8 - 1.0
1(0%)	664	2	0.82
2(10%)	672	2	0.84
3(20%)	680	3	0.87
4(30%)	698	4	0.9
5(0%)	650	3	0.83
6(10%)	650	3	0.84
7(20%)	655	5	0.84
8(30%)	662	4	0.87
09(0%)	610	4	0.89
10(10%)	616	4	0.90
11(20%)	620	5	0.94
12(30%)	620	6	0.98

2.5 Preparation of moulds

Cubes are used for this experimental procedure. They should be kept clean and oiled before poring fresh concrete into the mould. After finishing of workability tests, the fresh concrete is poured into the moulds which should be tested for strength. The concrete is kept in moulds for 24hours and then removed and placed in the curing tank. After certain curing period the moulds are removed from the tank and cleaned thoroughly and tested.

2.6 Hardened Properties of SCC

2.6.1 Compressive strength test

IS: 516 - 1959 covers tests for the determination of compressive strength of concrete. Test specimens cubical in shape shall be 15 × 15 × 15 cm. At least three specimens should be casted for testing. The cubes should be cured up to the specified date of testing and after the particular date the cubes are removed from the curing tank and tested immediately.In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom.

The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area and shall be expressed to the nearest N/mm^2.Average of three values shall be taken.

Table 5
Compressive strength test results

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3. CONCLUSIONS

- From the analysis it is concluded that partial replacement of ordinary Portland cement with fly ash does not affect the properties of fresh concrete to perform as Self Compacting Concrete.
- Use of fly ash adds to the cohesiveness of mix, workability, and ultimately durability.
- Use of fly ash addresses the issue of environmental and economical aspect and hence sustainability of concrete technology.
- Usage of fly ash by more than 40% reduces concrete strength and causes segregation.
- By this analysis it is known that self compacting concrete can be done for low and medium strengths also.
- By this experiment it is known that mixing of 10mm and 12.5mm aggregate is more flowable than 20mm size aggregate.
- The production of SCC is made possible by combining an innovative Viscosity Modifying Agent with a Superplasticizer. This combination of admixtures is capable of delivering a mix that is highly stable and robust.
- The VMA also enables the concrete producer to achieve self-compacting properties with lower fines and paste contents without the risk of excessive bleeding and tendency to segregate.

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Mix	7days compressive strength (N/mm^2)	28Days compressive strength (N/mm^2)	Comparable grade of concrete	Target mean strength f_{ck}= f_{ck}+1.65*S (N/mm^2)
1	36.31	42.65	M35	43.25
2	28.33	38.33	M30	38.25
3	16.11	30.11	M25	31.6
4	10.86	26.37	M20	26.6
5	46.66	51.01	M45	53.25
6	30.66	48.32	M40	48.25
7	20.34	42.43	M35	43.25
8	12.24	30.74	M25	31.6
09	48.24	58.23	M50	58.25
10	32.60	51.71	M45	53.25
11	25.44	47.32	M40	48.25
12	15.40	40.12	M35	43.25

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