Study of Self Compacting Concrete using Glycerin as Viscosity Modifying Agent & Fly Ash as Filler Material

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***Abstract*—Self Compacting Concrete is a concept introduced in late 1988 by Professor Ozawa with the sole intention of overcoming the problem of insufficient compaction by a workforce or non availability of the same. Thus to create uniformity in the quality as well as to ease the placement of the concrete the concept of SCC was introduced. SCC as its name suggests, is a concrete that can easily flow into reinforcements without the need of compaction due to its own weights. In recent year, SCC has gained wide use for placement in a congested reinforced concrete structure with difficult casting condition. For such applications the fresh concrete must possess high fluidity & good cohesion. However wide spread application of SCC has been restricted due to its high manufacturing cost; which is again due to the high cost of the superplasticizers, retarders & Viscosity Modifying Agents (VMA) used in manufacturing of SCC. The paper aims at developing SCC using glycerin as VMA and flyash as filler material, which would make it economical imparting comparatively more strength at the same time. The results of the experimental program are presented in the paper representing the strength of concrete at the end of 7days, 14 days & 28 days; which ranged from 28.7 Mpa to 38Mpa at the end of 28days. Various proportions of glycerin were tried and it was found that glycerin can replace both the superplasticizers and the retarders imparting comparatively more flowability and strength as compared to SCC with superplasticizers and retarders & has proved to be more economic at the same time. The test results for acceptance characteristics of SCC such as slump flow, V-funnel & L-box are also presented.**

***IndexTerms*— Compersive Strength , Fly Ash , Glycerin , Self-Compacting Concrete, VMA'S**

1. INTRODUCTION

Self-Compacting Concrete (SCC) was first researched by Professor Ozawa in 1988 at Japan with the intention of creating concrete of uniform quality by eliminating or controlling the ever rising issue of insufficient compaction by a workforce or sometimes non availability of the same. Professor Hagime Okamura was the first one who gave the concept of SCC in 1986.

SCC is a fluid mixture which is suitable for easy placement in case of congested reinforcements without applying vibration. The SCC in hardened state is homogeneous and dense and shows similar engineering properties like traditional concrete.

In recent year, SCC has gained wide use for placement in a congested reinforced concrete structure with difficult casting condition. For such applications the fresh concrete must possess high fluidity & good cohesion. However wide spread application of SCC has been restricted due to its high manufacturing cost; which is due to the high cost of the superplasticizers, retarders & VMA'S used in manufacturing SCC.

Table 1: History of SCC

Source: https://www.buildipedia.com

Year	Event	Place
March 1986	Proposal for developing self-compacting concrete by Okamura	Japan
August 1988	Completion of a prototype by Okamura	Japan
July 1989	An open experiment	University of Tokyo, Japan
May 1992	Presentation on SCC by Ozawa at ACI & CANMET international conference	Istanbul
September 1993	A text book on self-compacting HPC in Japanese	Japan
November 1994	ACI Workshop on High Performance Concrete sponsored by Prof. Paul Zia	Bangkok
January 1997	RILEM Committee found SCC	Bangkok

European Federation of National Associations Representing for Concrete (EFNARC) in the year 2002 published their Specification & Guidelines for Self Compacting Concrete, which provided significant information regarding the procedure of preparing SCC.

Self Compacting Concrete development should ensure a remarkable balance between stability and deformability. Compatibility of SCC is affected by characteristics of material, mix proportion, viscosity agents/super-plasticizers. Researchers mentioned some guidelines for mixture proportioning of SCC. Which suggests the following: -

- Reducing the ratio of volume of aggregate to cementitious material.
- Increasing the water cement ratio & paste volume.
- Carefully controlling total volume & the maximum coarse aggregate particle size &
- Using various admixtures which enhances viscosity.

According to above mentioned guidelines the process of preparing the mix becomes complex as well as costly at times. Specially adding super-plasticizers like retarders, PCE based chemicals add up to the overall cost of SCC.
If some locally available or regularly used viscous material is used as a super-plasticizer then it might be able to replace the costly super-plasticizers. In recent year, SCC has gained wide use for placement in a congested reinforced concrete structure with difficult casting condition. For such applications the fresh concrete must possess high fluidity & good cohesion. However wide spread application of SCC has been restricted due to its high manufacturing cost; which is again due to the high cost of the superplasticizers, retarders & VMA'S used in manufacturing of SCC.

2. Mix Design Principles

The viscosity and flow-ability of the paste can be attained/modified initially by proportioning water (including additives) to powder ratio and cement content and then after by adding super plasticizers & Viscosity Modifying Agent.

The paste acts as a medium for transport of aggregates, and so the volume of the paste should be greater than the volume of voids in aggregates.

In order to control rise in temperature & strength, as well as thermal shrinkage cracking, filler material (like fly ash, mineral filler, silica fume, etc.) must be added in order to keep the cement content at an acceptable level.

Self Compacting Concrete should have:

- Low coarse aggregate content
- Increased paste content
- Low water powder ratio
- Increased super plasticizer dosage
- Viscosity modifying agents

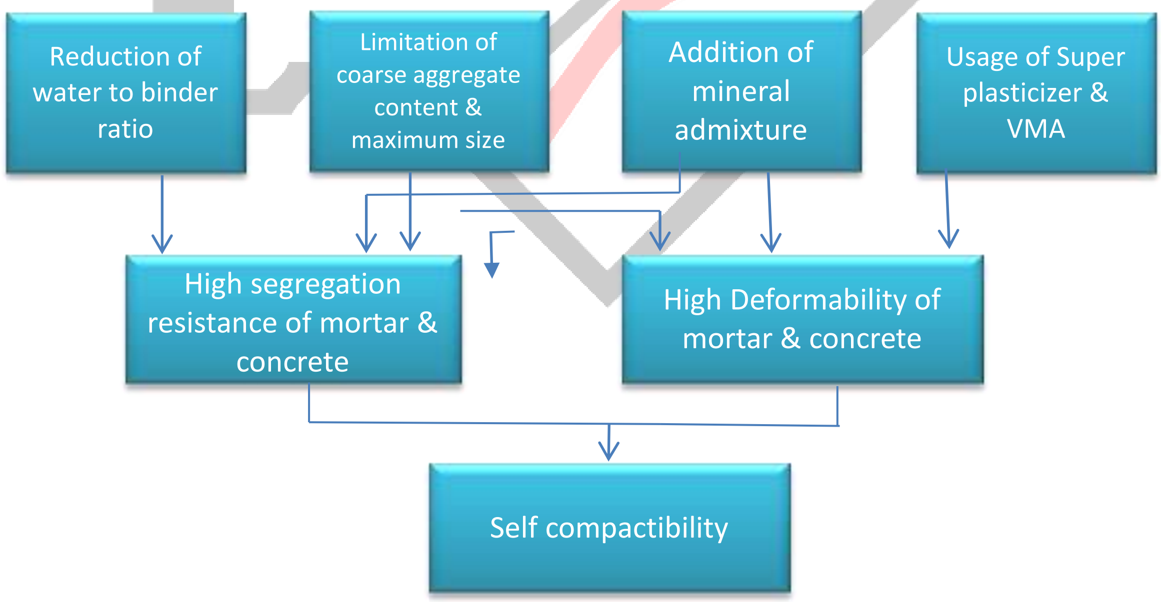

Fig.1 Mix designs principal elements

3. Methodology

Properties of various materials used for SCC are checked in the laboratory and found as following.

Table: 2 Properties of Cement

Properties	Results Achieved
Setting Time: Initial Final	 30 minutes 600 minutes
Compressive Strength(Mpa): 1 Days 7 Days 28 Days	 27 37 53
Air Contain of water (%) by volume	10%
Fineness (Specific Surface)	342 m^2/kg

Table:3 Properties of Aggregate

Properties	Coarse aggregate 10mm	Zone 2 Sand
Bulk Specific Gravity (Oven Dry Basis)	2.50	2.54
Apparent Specific Gravity	2.70	2.71
Unit Weight(kg/m^3)	1542	1591
Absorption (%)	1.50	1.1

Table:4 Properties of Fly-Ash

Physical Properties	Test Result
Color	Grey(blackish)
Specific Gravity	2.13
Average Strength after 28 days of mixing	4.90Mpa

3.1 Laboratory Tests:

According to guidelines of EFNARC,2002 following test has been done in the laboratory to carry the mix design of SCC.

3.1.1 Slump-Flow Test

The Slump flow test is carried out in order to measure horizontal flow of concrete when there is no obstruction to the flow. It gives a good assessment of filling ability. Slump cone is of 300mm height, 100mm upper diameter and 200mm bottom diameter. The diameter of spread should lie between 450mm to700mm.

Procedure:

1. To carry out the test about 6 liter of concrete is needed, sampled normally.
2. The base plate and inside of slump cone is to be moistened.
3. The base plate is to be placed on level stable ground and the slump cone is placed centrally on the base plate; it has to be hold down firmly.
4. Now the cone is filled with the scoop. Do not tamp, the concrete level is simply to be struck off with the top of the cone using the trowel.
5. Any surplus concrete is to be removed from and around the base of the cone.
6. The cone is to be raised vertically and concrete is allowed to flow out freely.
7. Simultaneously, start the stopwatch and note down the time taken for the concrete to reach the 500mm spread circle. (This is known as T50 time).
8. The final diameter of the concrete in two perpendicular directions is to be measured.(Fig.1 & 2)
9. The average of the two measured diameters is calculated. (This is the slump flow in mm).
10. Any border of mortar or cement paste without coarse aggregate at the edge of the pool of concrete is to be noted down.

If the value of flow is high the workability of concrete will be high.

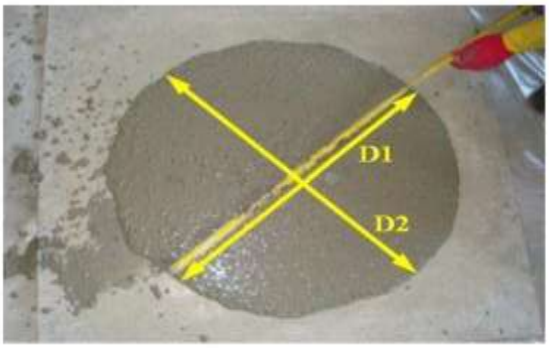

Fig.1: Measurement of diameter **Fig.2 Photograph of laboratory testing**

Source: wwww.buildpedia.com

3.2 L-Box Test

L-box test is used for measuring the passing ability of the SCC i.e. its ability to flow through obstructions without blocking or segregation.

Procedure:

1. To carry out the test, about 14 liter of concrete is needed, sampled normally.
2.The apparatus should be set at a level on firm ground, ensuring that the sliding gate can be opened freely and then close sliding gate.
3. The inside surfaces of the apparatus should be moistened.Any surplus water is to be removed.
4. The vertical section of the apparatus is filled with the concrete sample and left to stand for 1 minute.
5. Then the sliding gate is lifted and the concrete is allowed to flow out into the horizontal section.
7. Simultaneously, the stopwatch is to be started and the time taken for the concrete to reach the 200 and 400 mm marks are recorded.
8. As and when the concrete stops flowing, the distances "H1 (depth at vertical end)" and "H2 (depth at horizontal end)" are measured.
9. Now the blocking ratio H2/H1 is calculated. Passing ability ratio (PL) is given as the ratio of depth at the end of horizontal by depth at the end of vertical=H2/H1.

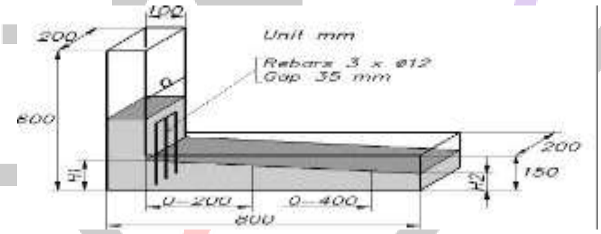

Fig.3 L-Box test (Ref.5)

3.3 V-Funnel Test

The V-funnel test is used for determining the filling ability of SCC and viscosity of SCC.

Procedure:

1. To carry out the test about 12 liter of concrete is needed, sampled normally.
2. V-funnel should be set on firm ground.
3. The inside surfaces of the funnel is moistened.
4. The trap door should be opened; so as to allow any surplus water to drain.
5. Then close the trap door and place a bucket underneath.
6. The apparatus is filled completely with concrete without applying any compaction or tamping, having done that simply strike off the concrete level with the top with the trowel.
7. After filling the trap door within 10 Sec, allow the concrete to flow out under gravity.(Fig.3)
8. Start the stopwatch as soon as the trap door is opened, and time is recorded for the discharge to complete (the flow time). It is considered when the light is seen from above through the funnel.

Fig.4 Laboratory testing of SCC using V-funnel test

4. LAB ORATORY PERFORMANCE RESULT

Table:5 Mix Proportion

Trials	T1	T2	T3	T4	T5	T6
Cement (Kg/m^3)	408	432	396	420	444	450
Fly ash (Kg/m^3)	192	168	204	180	156	150
Water (Kg/m^3)	210	210	210	210	210	210
Coarse aggregate (Kg/m^3)	802	802	802	802	802	802
Sand (Kg/m^3)	802	802	802	802	802	802
Super plasticizer(Liters/m^3)	0.90	1.5	-	-	-	-
Retarder(Liters/m^3)	3.00	-	4	-	-	-
Glycerin(Liters/m^3)	-	-	-	3.15	4.2	5.25

Table:6 Results Obtained

Trials	T1	T2	T3	T4	T5	T6
Initial Slump Flow(mm)	589	542	600	650	695	730
Slump Flow at end of 30 mins(mm)	500	450	530	600	620	676.7
L-Box Blocking ratio (H2/H1)^d	0.2	0.3	0.4	0.1	0.2	0.1
V-Funnel T_f(Sec)	6	5	4	5	5	4
7-Days Strength (Mpa)	15	17	14	16	18	20
14-Days Strength (Mpa)	26.5	28.5	22.5	25	28	30
28-Days Strength (Mpa)	30	33.5	28.70	32	34	38

5. COST ANALYSIS

A comparative cost analysis was carried out showing the cost of the traditional concrete with the cost of the standard SCC mix to SCC mix using only Glycerin. The analysis does also include the manpower as well as the equipment cost. It also includes their comparative compressive strengths at various levels.

In the table:

SCC MIX 1: demonstrates the standard SCC mix using super plasticizer and retarder.

SCC MIX 2: represents the SCC mix with only glycerin as an admixture without using super plasticizer or retarder.

Table: 7 Cost Analysis (For 1cum of mix)

	Ordinary Concrete(Rs)	SCC MIX 1 (Rs.)	SCC MIX 2 (Rs.)
Cement	2340	2340	2340
Aggregate 20mm	665	0	0
Aggregate 10mm	220	722	722
Sand	548	518	518
Fly Ash	450	450	330
Chemical Admixture	200	792	0
Super plasticizer	0	100	0
Glycerin	0	0	800
Initial Cost	**4423**	**4922**	**4710**
Manpower Cost	1300	650	650
Equipment Cost	1900	1500	1500
Total Cost	**7623 Rs**	**7072 Rs**	**6860 Rs**
Compressive Strength(Mpa)	**30**	**33.5**	**38**

CONCLUSIONS

- By increasing the amount of glycerin from 1.5% to 2.5% of water, the mix yielded comparatively more strength as well as the flowability of the concrete.
- By varying the content of fly ash, it was observed that upto an extent, it added to the strength and contributed to the concrete being more economical.
- Trial-4 shows that notable amount of flow as well as strength can be obtained by replacing fly ash by 30% of cement; although maximum amount of flow and strength is obtained at 25% of replacement as replicated by Trial-6.
- The cost analysis shows that SCC produced by using only glycerin as admixture yields more strength and flowability at a comparatively low cost.

FUTURE SCOPE OF STUDY

- Durability test should be carried out on SCC containing glycerin as VMA.
- The further effect on SCC by increasing the amount of glycerin more than 2.5% of water can be checked.
- Silica Fume may be added as filler material as a partial or complete replacement of fly ash.

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