

# Experimental Investigation Of Self Compacting Concrete With Copper Slag

Edwin Fernando\*, Vandana C.J\*\*, Indu.G.Nair\*\*\*

\*(Assistant Professor, Department Of Civil Engineering, Akshaya College of Engineering & Technology, Kinathukadavu, Coimbatore-46  
Email: civiledwin@gmail.com)

\*\* (PG Student, Department Of Civil Engineering, Akshaya College of Engineering & Technology, Kinathukadavu, Coimbatore-46  
Email: vandanaajayaram123@gmail.com)

\*\*\* (PG Student, Department Of Civil Engineering, Akshaya College of Engineering & Technology, Kinathukadavu, Coimbatore-46  
Email: indugnair17@gmail.com)

## ABSTRACT

The concrete technology has made tremendous strides in past decade. Concrete is now no longer a material consisting of cement, aggregates, water and admixtures but it is an engineered material with several new constituents. The concrete today can take care of any specific requirements under most of different exposure conditions. The concrete today is tailor made for specific applications and it contains several different materials like PFA, GGBSF, Micro silica, Metakaolin, Colloidal Silica and several other Binder, Filler and Pozzolanic materials. The development of specifying the concretes as per its performance requirements rather than the constituents and ingredients in concrete has opened innumerable opportunities for producer and user of concrete to design concrete as per specific requirements.

In that way self compacting concrete has been developed in Japan in 1990's. In this project literature review of SCC has been done and the mix design has been arrived as per EFNARC Specifications. For the developed mix design, the self compactability has been checked. At first the normal concrete is prepared and then further steps 5% - 25% of sand is partially replaced as copper slag, self compact ability test such as slump flow, V- funnel and J-ring tests have conducted and their results are reported. Also compressive, Split- Tensile strength and have been conducted and the results are compared.

To know the optimum dosage of super plasticizer for each mix combination of cement, Fly ash, SF and Marsh cone test has been conducted and their results are reported.

## I. INTRODUCTION

### 1.1. General

The concrete technology has made tremendous strides in past decade. Concrete is now no longer a material consisting of cement, aggregates, water and admixtures but it is an engineered material with several new constituents. The concrete today can take care of any specific requirements under most of different exposure conditions. The concrete today is tailor made for specific applications and it contains several different materials like PFA, GGBSF, Micro silica, Metakaolin, Colloidal Silica and several other Binder, Filler and Pozzolanic materials. The development of specifying the concretes as per its performance requirements rather than the constituents and ingredients in concrete has opened innumerable opportunities for producer and user of concrete to design concrete as per specific requirements. Self Compacting Concretes were designed initially in Japan around 1988 and since then several research

papers have been published and compositions are tried out in different developed countries especially in Western Europe, Canada, Sweden and Netherlands.

### 1.2. Definition

Self Compacting Concrete (SCC) as the name signifies should be able to compact itself without any additional vibrations or compaction. Self Compacting concrete should compact itself by its self weight and under gravity.

### 1.3. Applications of SCC

- SCC can be used in pre-cast industry or for concrete placed on site
- In complicated steel reinforcement area
- Construction element in high rise buildings
- Pre-cast Industry Filigree Construction Elements
- Natural draught cooling tower tank bund areas
- Marine structures

## **II. OBJETIVE AND SCOPE**

### **2.1. Objectives of investigation**

- To find the optimum dosage of Super plasticizer to achieve the self computability.
- By varying the percentage of Fly ash, Silica fume and Metakaolin that is partially replace for cement to improve strength and durability of concrete.
- The object of present investigation is to study the Compressive strength, Tensile strength and impact strength of Self Compacting Concrete by adding varying mineral and chemical admixtures.

### **2.2. Scope of investigation**

The scope of present investigation can be summarized as follows

- Mix design for Self Compacting Concrete with water cement ratio of 0.40 is to be proposed.
- self Compactability is to be checked by various flow tests of U- tube , V- funnel , L- Box and Fillability tests.
- Marsh cone test is to be conducted for finding the optimum dosage of Super Plasticizer
- Finding strength and flow ability by Cement replacement by varying the mineral admixture like fly ash, silica fume and Metakaolin
- Strength study of cubes cylinders and impact specimen for 7, 14, and 28 days is to be studied.

## **III. LITERATURE REVIEW**

### **3.1. Literature review**

**Self-Compacting Concrete - Procedure for Mix Design Paratibha AGGARWAL, Rafat SIDDIQUE, Yogesh AGGARWAL, Surinder M GUPTA**

At the water/powder ratio of 1.180 to 1.215, slump flow test, V-funnel test and L-box test results were found to be satisfactory, i.e. passing ability; filling ability and segregation resistance are well within the limits.

SCC could be developed without using VMA as was done in this study.

The SCC1 to SCC5 mixes can be easily used as medium strength SCC mixes, which are useful for most of the constructions; the proportions for SCC3 mix satisfying all the properties of Self-Compacting Concrete can be easily used for the development of medium strength self-compacting and for further study.

**Self-Compacting Concrete (SCC) Time Development of the Material Properties and the Bond Behaviour, Frank Dehn, Klaus Holschemacher, Dirk Weiße**

In this investigation, the time development of the bond behaviour between the reinforcing bars and self-compacting concrete was tested under monotonic

loading. Depending on the mix design and the modified test specimens it was found out, that the bond behaviour in SCC is better than the correlated bond stresses according to the bond law. Therefore, different ranges of steel stresses and loadings shall be provided in order to obtain creep displacement factors for self-compacting concrete. To compare the results found for the dynamic loading, tests with normally vibrated concrete, with vibrated concrete which has a large amount of sand, as well as with SCC are planned.

**G.Menendez et al (2006) studied** the mechanical performance and durability of concrete made with either lime stone or granulated blast furnace slag, very little is known about the effect of the combined action of these two additions on concrete properties. The evaluates the early stage properties and mechanical strength of binary and ternary cement concrete containing up to 18 % lime stone and 20% granulated blast furnace slag. The result show that the use of ternary cements has no substantial effect on concrete setting time and also reduce bleeding and isoresponse contours can be used to define a large number of lime stone –slag combinations yielding a given strength .

**Dr.R.Malathy et al (2006) Studied** A mix design for SCC has been developed EFNARC specifications. The mix design of SCC for different grades, M20 to M60 was developed and their flow properties and strength properties were studied. The flow properties such as Passing ability, filling ability, viscosity and segregation resistance and compaction factor. The charts have been developed for obtaining quantity of cement, fly ash and coarse aggregate required for different grades of SCC.

## **IV. EXPERIMENTAL INVESTIGATION**

### **4.1. Introduction**

For making SCC, it is essential to select proper ingredients, evaluation of their properties and know how about the interaction of different materials for optimum usage. The ingredients used for concrete for the project were the same as that used conventional cement concrete- cement, coarse and fine aggregate, and water except mineral admixtures and chemical admixtures which is generally not used in conventional concrete.

Effective production of SCC is achieved by carefully selecting, controlling and proportioning of all ingredients. In order to achieve Self compacting concrete, optimum proportion must be selected considering the characteristics of cementitious materials, aggregate quality, paste proportions, aggregate paste interaction, admixture type, and dosage and mixing.

### **4.2. Portland cement**

Selection of type of cement mainly depends on the specific requirements of concrete. It determines the strength and properties of fresh and hardened concrete. Some important factors which place a vital role in selection of type of cement paste are

- Compressive strength at various stages
- Attainment of appropriate rheological characteristics

Variation in chemical composition and physical properties of cement affects the concrete compressive strength more than variation in any other single material. The use of 43 grade OPC is prepared as it was seen from the past records of cements available in market. Among the chemical constituents of cement the most important are  $C_3A$ ,  $C_3S$  and  $C_2S$ .

#### PROPERTIES OF CEMENT

The properties of cement are

Initial setting time	: 35 min
Final setting time	: 180 min
Standard consistency	: 32%

#### Compressive strength

72 ± 1 Hrs (3 days)	: 330 Kgf/ Sq cm
168± 2 Hrs (7 days)	: 400 Kgf /Sq cm
672 ± 4 Hrs (28 days)	: 550 Kgf/ Sq cm

#### 4.3. Fine aggregate (fa)

Among various characteristics, the most important on for SCC is its grading. Fine aggregate used for SCC should be properly graded to give the minimum voids ratio and shall be free from deleterious materials like clay, silt content and chloride contamination.

River sand is normally preferred over crushed sand since in the former; particle shape is fully water worn by attrition which helps in reduction of water content of mix and also lesser resistance to pumping. SCC contains high quantity of cement and fine particles in the form of micro silica and hence use of coarser sand is preferable. Properties such as voids ratio, gradation, specific surface and bulk density have to be assessed to design a dense SCC mix with optimum cement content and reduced mixing water

The fine aggregate use for this entire experimental Programme was locally available sand.

#### 4.4. Coarse aggregate (ca)

Fineness modulus of coarse aggregate = 6.4

The coarse aggregate is the strongest and least porous component of concrete. Some important properties of coarse aggregate like crushing strength, durability modulus of elasticity, gradation, shape and surface texture characteristics, percentage of deleterious particles and flakiness and elongation indices need special consideration while selecting the aggregate for SCC.

Coarse aggregate used for this entire experimental programme was broken gravel.

#### 4.5. Water

Water is an important ingredient of concrete as it actively participates in the chemical reactions with cement. The strength of cement concrete comes mainly from the binding action of the hydrates cement gel. The requirements of water should be reduced to that required for chemical reaction of unhydrated cement as the excess water would end up only formation of undesirable voids, in the hardened cement paste in concrete.

#### 4.6. Super plasticizer

Super Plasticizer is a chemical admixture used in concrete to give workability to SCC. Since water a cement ratio is reduced.

#### Use in concrete

Super Plasticizer is a low cost water reducer which can be used to get one or a combination of benefits.

#### Advantages:

- Increased workability
- Easier placing compaction and finishing
- Increased strength and durability
- Lower cement content for specified strength and workability
- Higher cohesion – reduces risk of segregation and bleeding
- Lower water requirement for given workability

The super plasticizer used here is FLOCRETE N

The properties of FLOCRETE N used for this experimental investigation;

Color	- Brown
Specific gravity	- 1.19 @ 27° C
Chloride content	- Nil as per IS 456 & BS 5075 part-I
Air entrainment	- Less than 1% additional air is entrained

#### Fly ash

For this project the fly ash from METTUR THERMAL POWER PLANT was collected from various hopper. The characteristics of fly ash are

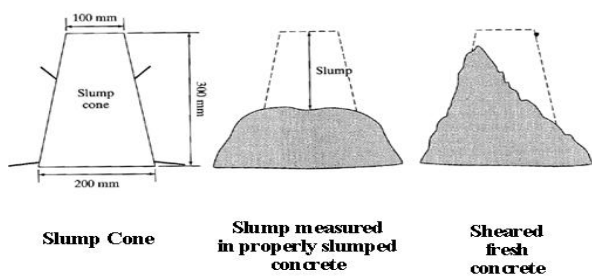
#### Physical properties

Specific gravity	- 2.00
Surface area	-2000 m <sup>2</sup> / Kg
Color	-light gray

#### Chemical properties

Moisture	- 1.76%
Ash	- 98.14%
SiO <sub>2</sub>	- 60.00%
CaO	- 6.00%
MgO	- 9.00%

NaO	- 8.50%	End Position [°2Th.]	79.9764
Properties of Metakaolin		Step Size [°2Th.]	0.0170
Physical properties		Scan Step Time [s]	25.1981
Average particle size, $\mu$ m	- 1.5	Scan Type	Continuous
Residue 325 Mesh (% max)	- 0.5	PSD Mode	Scanning
B.E.T Surface Area $m^2/gm$	- 15	PSD Length [°2Th.]	2.12
Pozzolana Reactivity	- 1050	Offset [°2Th.]	0.0000
Mg Ca(OH) <sub>2</sub> / gm		Divergence Slit Type	Fixed
Specific Gravity	- 2.5	Divergence Slit Size [°]	0.4785
Bulk Density (gm/lit)	- 300 +/- 30	Specimen Length [mm]	10.00
Brightness	- 80+/-2	Measurement Temperature [°C]	25.00
Physical foam	-off-white powder	Anode Material	Cu
Chemical composition		K-Alpha1 [Å]	1.54060
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	- 96.88%	K-Alpha2 [Å]	1.54443
CaO	- 0.39%	K-Beta [Å]	1.39225
MgO	- 0.08%	K-A2 / K-A1 Ratio	0.50000
TiO <sub>2</sub>	- 1.35%	Generator Settings	30 mA, 40 kV
Na <sub>2</sub> O	- 0.56%	DiffractionmeterType	0000000083008
K <sub>2</sub> O	- 0.06%	Diffractionmeter Number	0
Li <sub>2</sub> O	- Nil	Goniometer Radius [mm]	240.00
L.O.I	- 0.68%	Dist. Focus-Diverg. Slit [mm]	91.00
Properties of Micro Silica		Incident Beam Monochromator	No
Chemical composition		Spinning	No
SiO <sub>2</sub> (silicon dioxide,amorphous)- min	85.0%	A. Main Graphics, Analyze View: (Bookmark 2)	
H <sub>2</sub> O (moisture)	- max 1.0%	B. Peak List: (Bookmark 3)	
C (carbon)	- max 2.5%	C. Pattern List: (Bookmark 4)	
LOI (loss of ignition)	- max4.0%	D. Document History: (Bookmark 5)	
Physical properties		More items... (Bookmark 6)	
Bulk density D (kg/m <sup>3</sup> )	- 600-700 (when packed)	More items... (Bookmark 7)	
Bulk density U (kg/m <sup>3</sup> )	- 200-350 (when pack)	More items... (Bookmark 8)	
XRD Measurement		More items... (Bookmark 9)	
This is the simple example template containing only headers for each report item and the bookmarks. The invisible bookmarks are indicated by text between brackets.		More items... (Bookmark 10)	
Modify it according to your own needs and standards.		More items... (Bookmark 11)	
Measurement Conditions: (Bookmark 1)		More items... (Bookmark 12)	
Dataset Name	Deepak_7	More items... (Bookmark 13)	
File name	C:\X'Pert	More items... (Bookmark 14)	
Data\Deepak_7.xrdml		More items... (Bookmark 15)	
Sample Identification	carbon sludge	<b>V. EXPERIMENTAL PROGRAMME</b>	
Measurement Date / Time	11/26/2012	5.1 SLUMP FLOW TEST	
3:23:02 PM		The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. This test method is based on the test method for determining the slump. Dia of concrete circle is a measure for filling ability of the concrete. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and give good assessment of filling ability.	
Operator	Central		
Electrochem			
Raw Data Origin	XRD		
measurement (*.XRDML)			
Scan Axis	Gonio		
Start Position [°2Th.]	10.0044		



The test is performed by first completely filling in the left chamber with concrete. While the sliding door between the two chambers is closed. The door is then opened and the concrete flows past the re bars into the right chamber. SCC for use in highly congested areas should flow to about the same height in the two chambers. The criterion adopted, in this study, was that if the filling height was more than 70% of the maximum height possible, the concrete was considered self compacting. The selection of this percentage is arbitrary and a higher value might be considered more conservative. In the U-flow device used, the maximum height is 285.5 mm, half of 571 mm, the total height. Therefore, a concrete with a filling height of more than 200 mm is considered as SCC.

#### 5.2 V-Flow test

It consists of a funnel with a rectangular cross section. The top dimensions are 490 mm by 75 mm and the bottom opening is 70 mm by 75 mm. The total height is 572 mm with a 150 mm long straight section. The concrete is poured into the funnel with a gate blocking the bottom opening. When the funnel is completely filled, the bottom gate is opened and the time for the concrete to flow out of the funnel is measured. The time is called V-flow time. This time should be less than 6 seconds.

#### 5.3 L-Flow test

It consists of a L shaped tubular configuration with a vertical leg of dimension 400 mm x 200 mm x 80 mm and a horizontal leg of cross section 160 x 200 mm. The two legs are separated by a sliding vertical gate. Concrete is filled in the vertical leg and when the gate is opened, it flows into the horizontal part. Sensors are attached to the horizontal part at distance of 50 and 100 mm is recorded. The average speed of flow of concrete to travel 50 mm is referred to as L – flow velocity and is considered to be a measure of plastic viscosity.

#### 5.4 Compression test

The compression test is carried out on specimens cubical in shape.

The cube specimen of the size 15 cm x 15 cm x 15 cm, since the largest nominal size of aggregate does not exceed 20 mm.

Testing machine

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens shall be fitted with a ball seating in the form of a portion of a sphere, the center for which coincide with the central point of the face of the platen. The other compression platen shall be plain rigid block. The movable portion for the spherically seated compression platen shall be held on the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted small angles in a direction.

#### Experimental Investigation

Two series of test carried out to determine the compressive strength of concrete. In each series, both concrete with admixtures and plain concrete without admixtures are used.

The specimens were cast using water cement ratio 0.30 for self compacting concrete. For SCC different admixtures such as fly ash, silica fume and Metakaolin and chemical admixtures such as FLOWCRETE N with 1% of the weight of cement are also used.

#### Running the test

The cube is kept in the compression testing machine and adjusted until the top steel bearing platen touches the surfaces of cube. The load is applied until the ultimate crack appears on the specimen fails and crushing load is observed.

#### 5.5 Cylinder split tensile strength test

The cylinder specimen is of size 150 mm x 300 mm, if the largest nominal size of the aggregate does not exceed 12.5 mm.

#### Description

This is an indirect method of finding tensile strength of concrete. This is also sometimes referred as, “**BRAZILLIAN TEST**”. This test was developed in Brazil in 1943 as about the same time this was also independently developed in Japan. Some other indirect methods are also available i.e. Ring tension test, double punch test etc.

#### Test procedure

The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of cylinder, along the vertical diameter. When the load is applied generator, an element on the vertical diameter of the cylinder is subjected to

$$\text{Split tensile stress} = \frac{2P}{\pi LD}$$

Where,

P is the compressive load on the cylinder  
L is the length of cylinder

D is its diameter.

The advantages of this method is that the same type of specimen and the testing machine as are used for the compression test can be employed for this test. That is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than other tension tests. Strength determined in the splitting test believed to be closer to the true tensile strength of concrete, than the modulus of rupture. Split tension gives about 5 to 12% higher than the direct tensile strength.

#### 5.6 Impact strength test

##### Impact Strength Test

Drop weight method of impact test recommended by ACI committee 544.2R-89 (29,49,56). The size of the specimen recommended by the above committee is 150 mm in diameter and 64 mm in height. The equipment consists of a standard manually operated 10lb compaction hammer with an 18 inch drop (ASTM D 1557- 70), A 64 mm diameter hardened steel ball: and a flat base plate with positioning bracket. In addition to the above equipment a mould to cast 150 mm diameter and 64 mm thick concrete specimens is needed. Thickness of the specimens is recorded to the nearest millimeter at its center and at the ends of a diameter prior to the test. The specimen is placed on the base plate with the finished face up and positioned within four legs of the impact testing equipment. The bracket with the cylindrical sleeve is fixed in place and the hardened steel ball is placed on the top of the specimen within the bracket.

The drop hammer is then placed with its base upon the steel ball and held vertically. The hammer is dropped repeatedly, and the number of blows required for the first visible crack to form at the top surface of the specimen and for ultimate failure is to be recorded. The first crack was based on visual observation. While washing the surface of the test specimen facilitated the identification this crack. Ultimate failure is defined in terms of the number of blows required to open the cracks in the specimen sufficiently to enable fractured pieces to touch three of the four positioning legs on the base plate. The stages of ultimate failure are clearly recognized by the fractured specimen butting against the legs of the base plate.

## VI. CONCLUSION

The following conclusion has been drawn based on the experimental work.

- i. A sequential method of adjusting the mix proportions by replacing part of the coarse aggregate with the fly ash has been shown to be suitable for obtaining SCC.
- ii. In this study Viscosity Modifying Agents may not be strictly necessary for the material used

to obtain SCC. But VMA showed marginal improvement in the properties of passing ability of the mixes.

- iii. Use of fly ash resulted in increase of 28 days compressive strength of concrete.
- iv. It is found that the economical SCC with satisfactory properties with 28 days strength of 28 MPA can be obtained by using 40% Fly ash. This self compacting concrete can replace a normal concrete with significantly reduced cost.
- v. Some of the limits suggested in literature for the powder ratio can be relaxed to obtain self compacting concrete.
- vi. It is possible to produce SCC with allow water content of  $165\text{kg/m}^3$  and a power content of  $450\text{ kg/m}^3$ . For this a polycarboxylic ether based super plasticizer and fly ash may be employed.
- vii. Cement content could be as low as  $225\text{ kg/m}^3$ .
- viii. The slump flow value, 'V' funnel and the L-Box test can be used to qualitatively characterize the SCC mixtures as acceptable or unacceptable.
- ix. The mixtures of SCC containing 40 percent fly ash in the total power content showed adequate strength development at 28 days with a cement content of  $225\text{ kg/m}^3$  developed 38.07Mpa at 28 days.
- x. It is crucial to complete testing the fresh properties within a short time period after mixing, in order to get a true measure of the performance in various testes.

## VII. FURTHER INVESTIGATION

- i. Development of mixture design guidelines table.
- ii. A shift to normal powder content in SCC from the existing high powder mixture.
- iii. Better understanding of the problem of autogenous and plastic shrinkage in SCC.
- iv. Development of site quality control parameters such as in "all in one" acceptance tests.

Current studies in SCC, being conducted in many countries with relevance to the immediate needs can be divided into.

- i. Use of rheometers, to obtain data about flow behavior of cement paste and concrete.
- ii. Mixture proportioning methods for SCC
- iii. Characterization of SCC using laboratory test
- iv. Durability and hardened properties of SCC and their comparison with normal concrete

- v. Construction issues related to SCC.

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