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Experimental Investigation of Flexural Behavior of Self Compacting Concrete Using Copper Slage

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Abstract

In recent years, self-compacting concrete (SCC) has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. In this experimental study M50 grade of concrete is adopted. The cement and fine aggregate is partially and fully replaced with fly ash and copper slag and it's compared with controlled specimens. Replacement of copper slag by weight of fine Aggregates in various percentages such as 10%, 20%, 30%, 40% up to 100% does not have any adverse effect on strength. Fly Ash of about 0.4% is replaced by weight of cement and strength properties of concrete is compared. The compressive strength and Flexural strength test, split tensile strength of hardened concrete with various replacements is to be investigated. This replacement would prove to have some environment benefits and would be an economical or a cost effective technique in concreting for the future. Environmental aspects move the research towards recycling industrial by-products, as Fly ash

Key Words: Self-compacting concrete, SCC Mix design, Flow ability, Workability, Testing methods, Copper slag, Fly Ash, and Compressive strength, split tensile strength, Flexural strength.

1. Introduction

Self-compacting concrete (SCC), a new kind of high performance concrete (HPC) with excellent deformability and segregation resistance, was first developed in Japan in1986. It is a special kind of concrete that can flow through and fill the gaps of reinforcement and corners of molds without any need for vibration and compaction during the placing process.

The application of concrete without vibration in construction is not new. For examples, placement of seal concrete underwater is done by the use of a tremie without vibration, mass concrete has been placed without vibration. These seal, mass and shaft concretes are generally of lower strength, less than 34.5 MPa and difficult to attain consistent quality. Modern application of self-compacting concrete (SCC) is focused on high performance better and more reliability, dense and uniform surface texture, improved durability, high strength and faster construction.

The performance required for concrete structures is more complicated and diversified. The concrete is required to have properties like high fluidity, self compactability, high strength, high durability, better serviceability and long service life of concrete structures. In order to address these requirements Self Compacting concrete (SCC) was developed.

It is relatively new product that sees the addition of High Range Water Reducing Admixture (HRWA) and Viscosity modifying admixture to the concrete mix to significantly increase the ease and rate of flow. By its very nature, SCC does not require vibration. It achieves compaction into every part of the mould or formwork simply by means of its own weight without any segregation of the coarse aggregate.

1.1 Self-Compacting Concrete

Self-compacting concrete (SCC) is defined as the concrete which can be placed and compacted into every corner of formwork, purely by means of its self-weight, by eliminating the need of either external energy input from vibrators or any type of compacting effort.

The intention behind developing this concrete was the concerns regarding the homogeneity and compaction of cast-in-place concrete with in intricate, of paste (i.e. highly reinforced structures and improvement of overall durability, quality of concrete due to lack of skilled labors.

This concrete is highly flow able and cohesive and enough to handle without segregation. It is also referred as Self levelling concrete, Super workable concrete, Self-consolidating concrete, High flow able concrete and Non-vibrating concrete.

1.2 Requirements of Self-Compacting Concrete

Increase of water-to-cementitious material increases the flow ability of cement paste at the cost of decrease in its viscosity and deformability the primary requirements of SCC. The SCC is flow able as well as deformable without segregation. Therefore in order to maintain deformability along with flow ability in paste, Super plasticizer is must in concrete. With Super plasticizers, the paste can be made more flow able with little decrease in viscosity. An optimum combination of W/C ratio and super plasticizers for achieving the self-compactibility can be derived for fixed aggregate content concrete.

1.3 Role of Mineral Admixtures in Self- Compacting Concrete

High flow ability requirement of SCC allows the use of mineral admixtures in its manufacturing, use of mineral admixtures results in reduction in the cost of concrete. The incorporation of one or more mineral admixtures/powdery materials having different morphology and grain size distribution can improve particle-packing density and reduce inter-particle friction and viscosity. Hence it improves deformability, Self-compactibility and stability of SCC.

1.4 Development of Self-Compacting Concrete

SCC mix should meet these key properties:

- Ability to flow into and completely fill intricate and complex form under its own weight.
- Ability to pass through and bond to congested reinforcement under its own weight.
- High resistance to aggregate segregation.

The SCC mixes are designed and tested to meet the demands of the projects. For examples, the mix for mass concrete is designed for pumping and depositing at a fairly high rate. SCC was mixed at a batch plant at the job site and pumping through a piping system to the location of the anchorage 200m away. The SCC was dropped from a height of as much as 5m without aggregate segregation. For mass concrete, the maximum size for coarse aggregates may be as large as 50mm. The SCC construction reduced the construction time for the anchorage from 2.5 years to 2 years. Similarly SCC mixed can be designed and placed successfully for concrete members with normal and congested reinforcement. The coarse aggregate size for reinforced concrete generally varies from 10mm to 20mm.

1.5 Merits of Self-Compacting Concrete

- Industrialized production of concrete.
- Promote the development of a more concrete production.
- Reduction in the construction time by accelerating the construction process.
- Improve working environment at a construction site by reducing noise pollution.
- Easily placed in thin walled on element with limited access.
- Ease of placement results in cost saving through reduced equipments and labor requirement.
- Increases the bond strength between the aggregates and reinforcement bars.

1.6 Applications of Self-Compacting Concrete

- SCC can be used in precast industries.
- In complicated reinforcement positions.
- Construction element in high rise buildings.
- Natural drought cooling tower tank bund areas.
- Marine structures. Reduced form work and equipment cost.
- Less man power.
- Improved durability and good structural performance.

1.7 Copper Slag

The use of industrial wastes in cement concrete is an economical and eco-friendly material. Copper slag is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. The copper slag was brought from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India. SIL is producing copper slag during the manufacture of copper metal. Currently, about 2600 tons of copper slag is produced per day and a total accumulation of around 1.5 million tons. This slag is currently being used for many purposes ranging from land-filling to grit blasting. These applications used only about 15% to 20% and the remaining dumped as a waste material and this causes environmental pollution.

Fig 1: Copper Slag

Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools. Since copper slag is glassy and granular in nature and has a similar particle size range to sand, indicating that it could be used as a replacement for the sand present in the cementitious mixes (CaijunShi, Christian Meyer, Ali Behnood).

1.8 Ingredients Used

- **Cement:** Ordinary Portland Cement 40 grade (OPC)
- **Fine Aggregate:** Natural River Sand

- **Coarse aggregate:** Maximum size of 10mm-12.5 mm is Used
- **Mineral admixtures:** Fly Ash

1.9 Developing SCC Mixes

SCC mixes must meet three key properties:

- Ability to flow into and completely fill intricate and complex forms under its own weight.
- Ability to pass through and bond to congested reinforcement under its own weight.
- High resistance to aggregate segregation.

1.10 Objective and Scope of Study

The objective of the present investigation in self-compacting concrete is to study its characteristics in fresh and hardened state.

In this project it is proposed to study:-

- Mix proportions for Self-Compacting Concrete and to obtain the optimum percentage of fly ash and Copper slag to be replaced in SCC.
- Study the workability characteristics of self-compacting concrete with partial replacement of cement by fly ash and copper slag using
    - Slump-flow test.
    - V-funnel test.
    - V-funnel at T- 5 minutes
    - L-box test.
- To study and compare the properties of hardened concrete and Self compacted concrete (SCC) using
    - Cube compressive strength
    - Split Tensile strength
    - Flexural strength.

1.11 Scope

The main scopes of this investigation are

- To varying the percentage replacement of cement by fly ash and copper slag from 0 to 100%
- The replacement of the cement by fly ash and copper slag in concrete applications would lead to considerable environmental benefits like dumping, exploiting natural resources and would be economical

2. Properties of Materials

2.1 Cement

Cement is a binding material. The history of cementing material is as old as the history of engineering construction. Ordinary Portland cement is far the most important type of cement. The OPC classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988.If 28 day strength is not less than 33N/mm^2 it is called 33 grade cement, if the strength is not less than 43N/mm^2, it is called 43 grade cement, and the strength is not less than 53N/mm^2, it is called 53 grade cement. But the actual strength obtained by these cements at the factory is much higher than the BIS specification. The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. The basic constitutive elements are lime, silica, alumina, iron and gypsum, magnesia and alkalis

2.2 Fine Aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm Gauge Usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as a fine aggregate. The sand used for the experimental works was locally procured and conformed to grading zone II. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS 383-1970. The fine aggregate was first sieved through 4.75mm sieve to remove any particle greater than 4.75 mm sieve and then was washed to remove the dust.

According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV.

2.3 Coarse Aggregate

The materials which are retained on 4.75mm sieve are called coarse aggregate. The broken stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used in the present work. According to IS 383:1970, coarse aggregate maximum 20mm is suitable for concrete work. But where there is no restriction 40mm or large size may be permitted.

2.4 Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory. In the present investigation, tap water was used for both mixing and curing purposes. A graph within a graph is an “inset,” not an “insert.” The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).

3. Test on Materials

Table :1 Cement

Testing Items	Test on values
Specific gravity	3.12
Fineness of Cement	5.1%
Standard consistency	32%
Initial setting time	30 minutes
Final setting time	11 hours

Table :2 Fly Ash

Testing Items	Test on values
Specific gravity	2.65

Table :3 Fine Aggregate

Testing Items	Test on values
Specific gravity	2.66
Fineness modulus	3.83
Water absorption test	0.5%
Bulk Density test	1560 Kg/m^3

Table : 4 Copper Slag

Testing Items	Test on values
Specific gravity	3.05
Fineness modulus	3.87
Water absorption test	0.3%

Table : 5 Coarse Aggregate

Testing Items	Test on values
Specific gravity	2.73
Bulk Density test	1450 Kg/m^3
Water absorption test	

4. Test on Fresh Concrete

4.1 Properties of Concrete

The properties of concrete is two types, they are fresh and hardened concrete properties. The performance of concrete properties are mainly depends upon the mix design, shape and strength of aggregates. Water-cement ratio is main factor of fresh concrete properties. It may affect the durability of concrete. The strength and life time of the structure is mainly depending on properties of concrete only.

4.2 Fresh Concrete Properties

The fresh concrete property is depending up on properties like cement, grading of aggregate and water. The slump test, compaction factor test are used to find the workability of the concrete. The required quantity of water is calculated and added to the concrete to find the workability of concrete. The test was carried out according to IS 6461 (Part 7)-1973 - define the workability as that property of freshly mixed concrete.

4.3 Slump Flow

Slump flow and T_{500} time is a test to assess the flow ability and the flow rate of SCC in the absence of obstructions.it is based on the slump test described in EN 1253-2. The result is an indication of the filling ability of SCC, and the T_{500} time is a measure of the speed of flow and hence viscosity. The fresh concrete is poured into a cone to when the concrete has flowed to a diameter of 500mm is measured; this is the T_{500} time. The largest diameter of the slow spread of the concrete and the diameter of the spread at right angles to it are then measured and the mean is the slump flow.

4.4 L-box Test

L-box test is asses the passing ability of SCC to flow through tight openings including spaces between reinforcing bars and other obstructions without segregation or blocking. L-box has arrangement and the dimensions as shown in Fig.

Fig 2: L-Box test

Test procedure is to support the L-box on a level horizontal base and close the gate between the vertical and horizontal sections. Pour the concrete from the container into the filling hopper of the box and allow to stand for (60±10)s. when movement has ceased, measure the vertical distance, at the end of the horizontal section of the box at three positions equally spaced across the width of the box. By difference with the height of the horizontal section of the box, these three measurements are used to calculate the depth of concrete immediately behind the gate as H1 mm. the passing ability is calculated from the following equations : PA = H2/H1.

4.5 V-Funnel

V-funnel test is used to assess the viscosity and filling ability of SCC, Procedure is to clean the funnel and bottom gate, then dampen all the inside surface including the gate, close the gate and pour the sample of concrete into the funnel, without any agitation or Roding, then strike off the top with the straight edges so that the concrete with the top of the funnel. Place the container under the funnel in order to retain the concrete to be passed. After a delay of (10±2) s from filling the funnel, open the gate and measure the time t_v, to 0.1s, from opening the gate to when is possible to vertically through funnel into the container below for the first time. t_v is the v-funnel flow time.

4.6 U-Box Test

U-Box test apparatus consists of vessel that is divided by a middle wall into two compartments. Especially fluidity of SCC is measured by using this test. It range is in between (h2 – h1) = 0 and 30mm.

Fig: 4 U-Box Test

5. Results and Discussion

Table: 6 Fresh concrete test

Property measured	**Test method**	**Test on values**
Flow ability / Filling ability	Slump flow	680mm
	T_{500}	3-sec
	V – funnel	10-sec
Passing ability	U – box	H_2- H_1=15-15 =0 mm

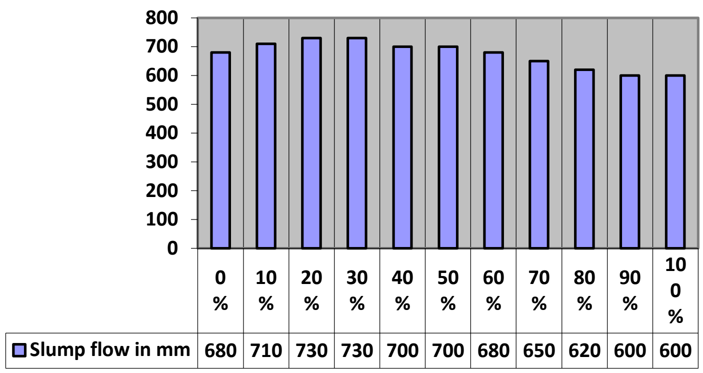

Figure: 5 Slump flow tests for various replacements of copper slag

5.2 Hardened Concrete Test

Compressive Strength

The cube size of 150mmX150mmX150mm as per the IS 10086-1982.moulds were cleaned thoroughly using a waste cloth and then properly oiled in the surfaces. Concrete is filled in to mould and then compacted using a standard tamping rod of 60 cm length having a cross sectional area of 25mm^2.the control and various replacement percentages of sand and cement with copper slag and fly ash concrete cube specimens are casted and demoulded after 24 hours from the casting. Determine the compressive strength of the concrete for each sets of cubes after 7, 14 and 28 days of curing.

Table :7 Compressive test result with various replacement (%)

Replacement %	7 Days (N/mm^2)	14 Days(N/mm^2)
conventional	23.11	30.22
10%	20.88	28.10
20%	22.22	30.22
30%	23.34	31.11
40%	18.55	30.66
50%	15.23	26.44
60%	14.22	22.33
70%	12.44	20.44
80%	11.11	19.33
90%	09.33	15.55
100%	08.22	14.22

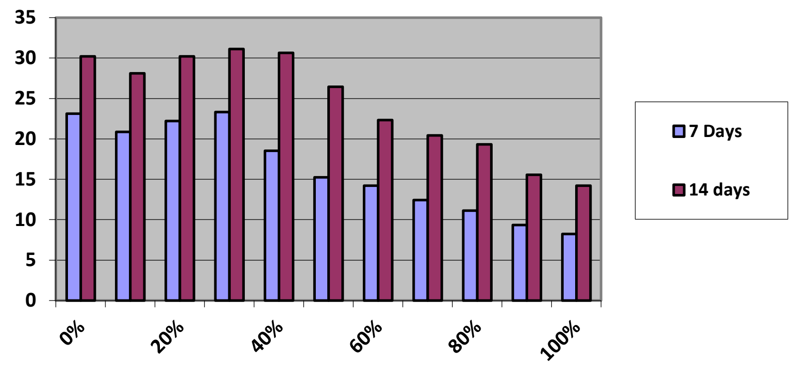

Fig: 6 Comparison of Compressive test result with various replacement (%)

Spilt 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. 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.

Table: 8 Split tensile strength test results with various replacement %

Replacement %	7 Days (N/mm^2)	14 Days(N/mm^2)
Conventional	1.37	1.87
10%	1.78	2.36
20%	1.89	2.61
30%	2.33	3.28

40%	**2.58**	**3.76**
50%	**2.18**	**2.62**
60%	**2.13**	**2.56**
70%	**1.92**	**2.33**
80%	**1.78**	**2.12**
90%	**1.32**	**1.65**
100%	**1.15**	**1.34**

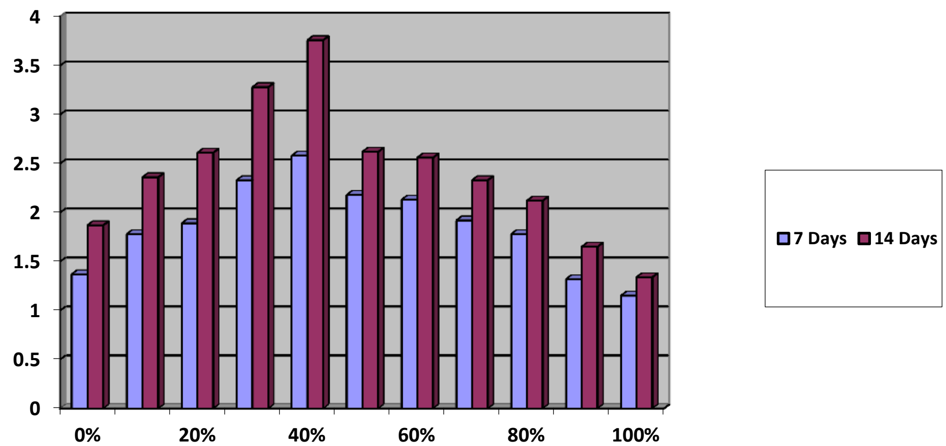

Fig:7 Comparison of split tensile strength results

Flexural Strength Test

The size of beam specimen is 500X100X100mm. The beam specimens were cast and tested with and without copper slag for normal conditions IS10086-1982.Moulds were cleaned thoroughly using waste cloth and then properly oiled the inner surfaces. Concrete is filled in to mould and then compacted using a standard tamping rod of 60cm length having a cross sectional area of 25mm^2. The specimens were immersed into water for curing up to 7 , 14 and 28days. Determine the flexural strength of concrete for each set of rectangle after 7th ,14thand 28th days of curing.

Table: 9 Flexural strength test results with various replacement %

Replacement %	7 Days (N/mm^2)	14 Days(N/mm^2)
Conventional	1.75	1.98
10%	1.97	2.12
20%	2.57	2.98
30%	2.65	3.12
40%	2.76	3.04
50%	2.18	2.62
60%	3.00	3.65
70%	2.80	3.13
80%	2.45	2.64
90%	2.27	2.45
100%	2.18	2.23

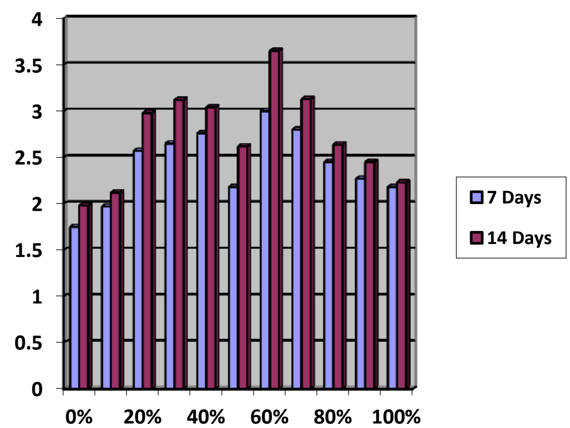

Fig:8 Comparison of flexural strength test results on various replacement.

6. Conclusion

- It shows that the water consumed by the copper slag during mixing is very less when compared with river sand.

- The blend of copper slag and river sand with slag upto 30% can be used as fine aggregate in pavement quality concrete as well as in dry clean concrete.
- Use of copper slag and fly ash in construction is possible to work and it is very cheap and gives good result.
- This study points out the beneficial aspects of using copper slag as a best replacement material of fine aggregate.
- The 30% replacement of sand with copper slag and 40% replacement of weight of cement with fly ash significantly increase the compressive strength of concrete mixtures.
- Results obtained from this study indicate the tremendous potential of copper slag as a mineral admixture.

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