Experimental Investigation of Self Compacting Concrete by using Copper Slag and Fly ash

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Abstract— The use of self-compacting concrete in concrete structures increasingly has become prevalent in recent years. In this regard, the use of admixtures in this type of concrete and determining the proportion of them will be important. The use of self-compacting concrete in concrete structures increasingly has become prevalent in recent years. In this regard, the use of admixtures in this type of concrete and determining the proportion of them will be important. 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. The concrete grade of M30 is used.

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

I. INTRODUCTION

Self-compacting concrete (SCC),which flows under its own weight and does not require any external vibration for compaction, has revolutionized concrete placement. Such concrete should have relatively low yield value to ensure high flowability, a moderate viscosity to resists segregation and bleeding and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability.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.

A. 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. There are many advantages of using SCC, especially when the material cost is minimized.

This includes:

Reducing the construction time and labor cost, Eliminating the need for vibration, Reducing the noise pollution, Improving the filling capacity of highly congested structural member, Facilitating construability and ensuring good structural performance.

Cement is the most costly and energy intensive component of concrete. Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable. At the same time the scarcity of aggregates are also greatly increased nowadays.

It is essential today, to reduce excessive consumption of the natural river sand and there by prevent sand mining. It is possible by utilization of industrial by-products as well as other waste materials in the production of normal concrete. They have been successfully used in the construction industry for partially or fully replacement for fine and coarse aggregates.

Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural resources. For many years, byproducts such as fly ash and copper slag were considered as waste materials.

They have been successfully used in the construction industry for partial or full replacement for fine and coarse aggregates (Akihiko Y, Takashi &AyanoToshiki, Kuramoto Osamu, Sakata). Some of the byproducts are also used as a Portland cement substitute (AlJabri K, Taha R)

B. 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.

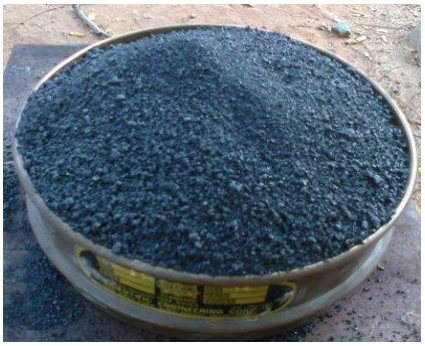


Fig. 1: Copper slag

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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) Ingredients Used:

- Cement: Ordinary Portland Cement 53 grade (OPC)
- Fine Aggregate: Natural River Sand
- Coarse aggregate: Maximum size of 10mm-12.5mm is used.
- Mineral admixtures: Fly Ash

2) 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.

3) Objective:

- To investigate the behaviour of self-compacting concrete beam with copper slag.
- To determine the optimum percentage of copper slag content (various mix proportions) for enhance the strength properties of concrete.Mix design for Self Compacting Concrete with water cement ratio of 0.40 is to be proposed.
- By varying the percentage of Fly ash is partially replacement for cement to improve strength and flow ability of concrete.
- Self-Compatibility is to be checked by various flow tests of U- tube, V- funnel, L- Box and Filling ability tests.
- To study the fresh and hardened properties of self-compacting concrete by adding varying mineral and chemical admixtures.
  - Workability
  - Compression strength
  - Split tensile strength
  - Flexural strength
- Strength study of cubes cylinders and impact specimen for 7, 14, and 28 days is to be studied
- Comparison of various experimental results.

II. PROPERTIES OF MATERIALS

A. 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

B. 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.

C. 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 coarse aggregate is suitable for concrete work. But where there is no restriction 40mm or large size may be permitted.

D. 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).

III. TEST ON MATERIALS

Testing Items	Test on values
Specific gravity	3.08
Fineness of Cement	5.3%
Standard consistency	34%
Initial setting time	29 minutes
Final setting time	10 hours

Table 1: Cement

Testing Items	Test on values
Specific gravity	2.85

Table 2: Fly Ash

Testing Items	Test on values
Specific gravity	2.69
Fineness modulus	3.43
Water absorption test	0.5%
Bulk Density test	1600 Kg/m^3

Table 3: Fine Aggregate

Testing Items	Test on values
Specific gravity	3.10

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Fineness modulus	3.80
Water absorption test	0.4%

Table 4: Copper Slag

Testing Items	**Test on values**
Specific gravity	2.77
Bulk Density test	1510 Kg/m^3
Water absorption test	1.2 %

Table 5: Coarse Aggregate:

IV. TEST ON FRESH CONCRETE

A. 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.

B. 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.

C. 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.

D. 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.



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. 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.

E. V-Funnel:



Fig. 3: V-Funnel tests

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.

Copper slag percentage	**Tested values(sec)**
Control concrete	12
10%	12
20%	10
30%	10
40%	10
50%	10
60%	08
70%	08
80%	08
90%	06
100%	06

Table 6: V-Funnel tests for various replacements of copper slag**;**

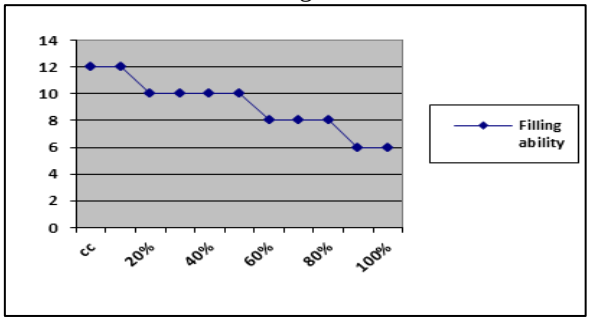


Fig. 4: V-Funnel tests for various replacements of copper slag

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F. U-Box Test:



Fig. 5: 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.

V. RESULTS AND DISCUSSION

Property measured	Test method	Test on values
Flow ability / Filling ability	Slump flow	710mm
	T_{500}	4-sec
	V – funnel	9-sec
Passing ability	U – box	H_2- H_1=17-15 =2 mm

Table 7: Fresh concrete tests

Copper slag percentage	Slump flow in mm
Control concrete	680
10%	720
20%	700
30%	700
40%	720
50%	750
60%	750
70%	785
80%	650
90%	680
100%	600

Table 8: Slump flow tests for various replacements of copper slag

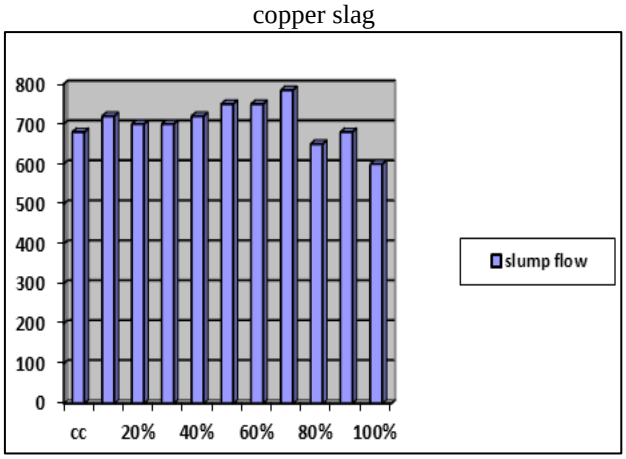




Fig. 6: Slump flow tests for various replacements of copper slag

A. Hardened Concrete Test:

Compressive strength the cube size of 150mm X 150mm X 150mm 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 25mm2. Determine the compressive strength of the concrete for each set of cubes after 7, 14 and 28 days of curing.



Fig. 7: Compressive Strength Tests

Replacement %	7 Days (N/mm^2)	14 Days (N/mm^2)	28 Days (N/mm^2)
conventional	21.00	28.00	31.55
10%	22.20	28.89	32.22
20%	24.20	29.77	32.88
30%	26.20	30.66	34.00
40%	27.40	28.44	34.66
50%	25.80	27.11	32.88
60%	24.40	26.00	32.22
70%	23.11	23.11	30.66
80%	21.77	21.77	30.00
90%	18.22	18.66	28.88
100%	16.88	16.89	28.44

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

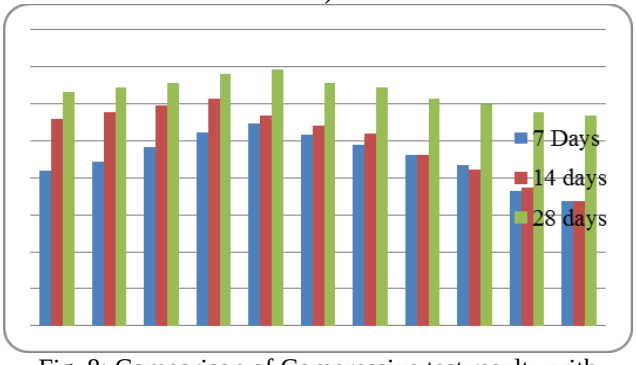


Fig. 8: Comparison of Compressive test result with various replacement (%)

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B. 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.



Fig. 9: spilt tensile strength Tests

Replacement %	**7 Days (N/mm^2)**	**14 Days (N/mm^2)**	**28 Days (N/mm^2)**
Conventional	1.41	2.12	2.68
10%	1.76	2.48	2.97
20%	2.05	2.75	3.18
30%	2.33	3.04	3.39
40%	2.68	3.12	3.74
50%	2.97	3.32	3.60
60%	2.82	3.18	3.25
70%	2.47	2.90	3.04
80%	2.19	2.61	2.75
90%	1.63	1.98	2.19
100%	1.34	1.69	1.90

Table 8: split tensile strength test results with various replacements (%)

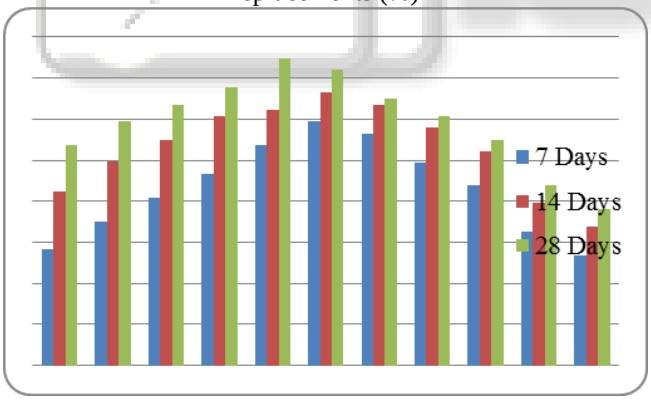


Fig. 10: Comparison of split tensile strength results

C. 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 ,14th and 28th days of curing.



Fig. 11: Flexural strength Tests

Replacement %	7 Days (N/mm^2)	14 Days (N/mm^2)	28 Days (N/mm^2)
Conventional	1.8	2.11	2.92
10%	2.15	2.21	3.11
20%	2.60	3	3.29
30%	2.77	3.22	3.37
40%	2.83	3.11	3.49
50%	2.30	2.77	3.32
60%	3.10	3.71	3.85
70%	2.85	3.28	3.40
80%	2.6	2.79	3.29
90%	2.4	2.65	3.06
100%	2.32	2.34	2.89

Table 9: Flexural strength test results with various replacement %

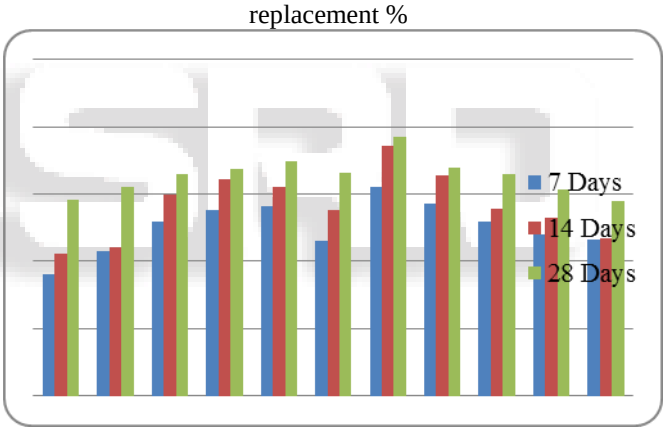


Fig. 12: Comparison of flexural strength test results on various replacement.

VI. Conclusion

In this work the use of copper slag as by-product in sterlite industries Ltd for continuous copper slag production was preliminarily studied to investigate the possibility of replacing the traditional aggregates to produce self-compacting concretes. A preliminary investigation of materials was carried out and the values are tabulated above. Mix design for M30 grade concrete was done by Nan-Su method for control specimen. Various mix proportions were arrived for self-compacting concrete and test for fresh concrete such as workability test and casting of specimens was carried out. Fresh properties and compressive strength of SCC containing copper slag as medium aggregate were experimentally investigated. The results encourage further investigations.

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

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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 by 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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