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EXPERIMENTAL INVESTIGATION ON RC BEAM USING SELF-COMPACTING CONCRETE WITH COPPER SLAG

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Abstract— **This paper examines the possibility of using copper slag as partial replacement of sand and super plasticizer is used in self compacting concrete, in order to overcome problems associated with cast-in-place concrete. Self compacting concrete does not require skilled labours. The percentage of copper slag to be added is 10%, 20%, 30% of total weight of sand. According to ACI: 211.4R code of practice, control specimen is casted for M40. Finally the workability and strength characteristics of concrete have been compared with conventional concrete.**

***Index Terms*— Copper slag, super plasticizer, self compacting concrete, cast-in-place concrete.**

I. INTRODUCTION

SCC was highly workable concrete that can flow under its own weight through restricted sections without segregation and bleeding. Such concrete should have a relatively low yield value to ensure high flow ability, a moderate viscosity to resist segregation and bleeding and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. The successful development of SCC must ensure a good balance between deformability and stability. Researchers have set some guidelines for mixture proportioning of SCC which include (i) reducing the volume ratio of aggregate to cementitious material (ii) increasing the paste volume and water-cement ratio (iii) carefully controlling the maximum coarse aggregate particle size and total volume and (iv) using various viscosity enhancing admixtures. For SCC, it is generally necessary to use super plasticizers in order to obtain workability and. Adding a large volume of powdered material or viscosity modifying admixture can eliminate segregation. The mineral admixture copper slag is added to obtain high performance.

A. Definition

Self-compacting concrete, also referred to as self-consolidating concrete can flow and consolidate under its own self weight and de-aerated almost completely while flowing in the formwork. It is cohesive enough to fill the spaces of almost any size and shape without segregation or bleeding. This makes self-compacting concrete particularly useful wherever placing such as in heavily reinforced concrete members or in complicated formworks. Self-compacting concrete can save labour, eliminate consolidation noise and lead to innovative construction methods. It has been used in Japan for the construction of bridge girders, towers and piers, LNG tanks, culverts and building structures. Precast concrete plants are using self-compacting concrete in manufacturing, where it eliminates the need for vibrating machines and their associated noise.

B. Advantages of using SCC

The following advantages can be achieved by using self compacting concrete

- Reduces skilled manpower requirement
- The structures built with SCC shall be highly durable
- Faster construction
- Better surface finish
- Easier placing
- Improved durability
- Greater freedom in design
- Reduced noise level
- Safer working environment
- Doesn't require electrical or mechanical vibration for compaction

C. Materials used in SCC

The following materials are required for the preparation of self compacting concrete

- Cement- Ordinary Portland Cement - 53 Grade
- Fine Aggregates
- Coarse Aggregates- 20mm
- Mineral Admixtures - Copper slag
- Chemical Admixtures - Super Plasticizers

II. LITERATURE REVIEW

Deepak Gowda. B et al (2014), Many countries are witnessing a rapid growth in construction industry which involves use of natural resources for the development of infrastructure. This growth poses a threat to natural resources that are available. Copper slag is considered as waste material and can be used as replacement of fine aggregates. M30 grade of concrete mix with water-cement ratio of 0.45 is used to determine the various mechanical properties. This research work mainly consist of two parts, In the first part, substitution of natural sand partially by copper slag in concrete is done with replacement of 0%, 35%, 40% and 45%. The optimum value obtained for 40% replacement of copper slag. The 28 days average compression strength was observed to increase by about 0.45% - 23.6%, split tensile strength by 16.61% - 34.98% and flexural strength of concrete by 27.78% - 38.89% when compared with control mix. In the second part, the flexural behavior of reinforced concrete beams with optimum copper slag content is studied. The reinforcement is varied from 0.62% - 0.89% in the flexure zone and the parameters

like deflection, surface strain, cracking load, ultimate load and crack width of reinforced concrete beams was experimentally noted and compared with theoretical values as per code IS: 456-2000.

Edwin Fernando et al (2014), 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**.**

E. Sureshkumar et al (2013), this paper examines the possibility of using copper slag as partial replacement of sand and Nano Silica as partial replacement of cement and super plasticizer and Viscosity Modifying Agent are used in self compacting concrete, in order to overcome problems associated with cast-in-place concrete. Self compacting concrete does not require skilled labours. The percentage of copper slag to be added is 10%, 20%, 30% of total weight of sand. The percentage of Nano Silica to be added is 2%, 4%, 6%, and 8% of total weight of cement. According to ACI: 211.4R code of practice, control specimen is casted for M40. Finally the workability and strength characteristics of concrete have been compared with conventional concrete.

Suresh T et al (2013),The Present study for the proposed method of strengthening the pre cracked RC beams using Copper slag added ferrocement composites which were directly glued into the cracked exposed surfaces of the beam by epoxy adhesives. There are six beams of size 1600 mm length, 125 mm width and 200 mm depth were casted and tested under two point loading. All beams were tested to ascertain the load deflection behavior under maximum ultimate load. and under 60% of ultimate load . Out of 6 beams, one beam is kept as perfect beam and the remaining beams are cracked under overloading by applying 60% of ultimate load. Then the cracked beams were strengthened by copper slag added ferrocement composites with five different total volume fractions of 2.30% , 2.85%., 2.95 % ,4.10% and 4.70 %.on all the bottom and two sides of the beams. The Load - Deflection behavior for control specimen is compared with the tested strengthened Copper slag added Ferro cement composite laminated beams. And the test results shows that the load carrying capacity of the strengthened beam with a total volume fraction of 4.70 increases 72% over the ultimate load carrying capacity of the control beam.

Arivalagan.Set al (2013), this paper examines scarcity of fine aggregate for the preparation of mortar, and concrete, partial replacement of copper slag with sand have been attempted. The effects of replacing fine aggregates by copper slag on the compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams are evaluated in this study. Copper slag is obtained as waste product from the sterlite industries. Investigations were carried out to explore the possibility of using copper slag as a replacement of sand in concrete mixtures. The test results of concrete were obtained by adding copper slag to sand in various percentages ranging from 0%, 20%, 40%, 60%, 80% and 100%. All specimens were cured for 28days before compression test, splitting tensile test and flexural strength. The highest compressive strength obtained was 35.11MPa (for 40% replacement) and the corresponding strength for control mix was 30MPa. This results showed the effect of copper slag on RCC concrete elements has a considerable amount of increase in the compressive, split tensile, flexural strength characteristics and energy absorption characteristics.

Ajin Alex Vincent et al (2013),Textile waste water has become one of the greatest source of water pollution. Various chemical methods have been used earlier to control and prevent this problem but have been unsuccessful due to various reasons. One of the major reasons being, economic insufficiency. Therefore, the shift to biological methods, like, the use of decolorizing bacteria to treat such waste water from textile industries, that proved to be cost-effective and economical. Research, over the past years have proven that naturally occurring bacteria from soil and other microorganisms have the potential and characteristics to decolorize such waste water. This study is to decolorize industrial effluent using isolated microbes from soil, in order to devoid this waste water of its toxicity. It was found that some bacteria's could decolorize the dye water very efficiently within a short period.

Menendez.Get 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 iso response 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.

Ozawa et al (1989),this paper examines mainly by large construction companies. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Investigations for establishing a rational mix design Method and self-compact ability testing methods have been carried out from the viewpoint of making it a standard concrete. Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river sand. The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand of natural river sand is quite high in developed countries owning to infrastructural growth. The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of construction industry in many parts of the country. Recently, Tamilnadu government has imposed restrictions on sand removal from the river beds due to unsafe impacts threatening many parts of the state. On the other hand, the copper slag was generated by the industry has accumulated over years. Only insignificant quantities have been utilized and the rest has been dumped unscrupulously resulting in environment problem. In the present work, it is aimed at developing a new building material from the copper slag, an industrial waste as a replacement material of fine aggregate in concrete. By doing so, the objective of reduction of cost of construction can be met and it will help to overcome the problem associated with its disposal including the environmental problems of the region.

III. Mix Design & Specimen Details

The concrete mixes for the present study comprises of a Portland cement concrete and 4 diverse concrete mixes with constant water-cement ratio. Grade 20 concrete is aimed for the design.

A. Definition of Mix Design

Mix design is done as per IS10262-2009 and it is given below
Grade of concrete = M40
Type of cement = opc (53 grade)
Characteristic strength required = 40N/mm^2
Size of aggregate = 20mm
Shape of coarse aggregate = Angular
Degree of exposure = moderate
Sand confirming to = zone III
Specific gravity of coarse aggregate =2.51
Specific gravity of fine aggregate = 2.085

B. Mix Design

Finally the ratio of concrete is obtained

Grade	Cement : FA : CA	w/c ratio
M40	1 : 1.65:2.92	0.40

Volume of beam mould= 150×200×1500
=0.045m^3
Therefore quantity of concrete required for one batch is
Weight of cement =18.19kg
Weight of fine aggregate= 28.57kg
Weight of coarse aggregate= 52.59kg

C. Specimen Details

The concrete mixes for the present study comprises of a Portland cement concrete with constant water-cement ratio. Grade 40 concrete is aimed for the design.

D. Beam Specification

The experimental work consisted of a total of three rectangular beams under reinforced concrete. All beams were of the same size 150 mm x 200 mm x 1500 mm, 2 -12 mm diameter bars were used for flexural reinforcement at the bottom of each beam, 2-12 mm at the top of each beam and 8 mm diameter stirrups spaced 150 mm center-to- center for shear reinforcement and this were designed as per IS 456 -2000. The casting of beams was made as per IS code specification using M40 grade concrete with 20 mm maximum size of coarse aggregate, locally available sand and 53 grade ordinary Portland cement.

IV. Material Modeling

A. Cement

Cement is a binder, a substance that sets and hardens and can bind other materials together. The word cement can be traced back to the roman term opus cementicium used to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The cement is used in project is OPC 53 grade cement. OPC 53 grade cement is a higher strength concrete. As per BIS requirements the minimum 28 days compressive strength of 53 Grade OPC should not less than 53Mpa. For certain specialized works such as pre stressed concrete and certain items of precast concrete requires high strength concrete. 53 Grade OPC produces higher grade concrete at very economical cement content. In concrete mix design for concrete M-40 a saving of 8 to 10% of cement may be achieved with the use of 53 Grade OPC.

B. Fine Aggregate

It is the aggregate most of which passes 4.75mm sieve and contains only so much coarser as is permitted by specification. According to source fine aggregate may be described as,
1) Natural Sand: It is the aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.
2) Crushed Stone Aggregate: it is the fine aggregate produced by crushing hard stone.
3) Crushed Gravel Sand: It is the fine aggregate produced by crushing natural gravel. According to size the fine aggregate may be described as coarse sand medium and fine sand. IS specifications classify the fine aggregate into four types according to its grading as fine aggregate of grading zone I to zone IV . The four grading zones become progressively finer from grading zone I to zone IV. 90% to 100% of the fine aggregate passes 4.75mm sieve and 0 to 15% passes 150 micron is sieve depending upon its grading zone. In this project we use fine aggregate from grading zone III as per IS 383(1970).

C. Coarse Aggregate

According to the size coarse aggregate is described as graded aggregate of its normal size i.e. 40mm, 20mm, 16mm and 12.5mm etc. for example a graded aggregate of nominal

size 20mm means aggregate most which passes 20mm IS sieve. A coarse aggregate which has the size of particles mainly belonging to a single sieve size is known as single size aggregate. Foe e.g. 20mm single size sieve aggregate mean an aggregate most of which passes 20mm is sieve and its major portion is retained on 10mm IS sieve. In this project 20mm size aggregate and it shapes were angular are used.

D. Copper Slag

Copper slag blasting media/grit - is manufactured of the granulated slag of copper refineries, and used for blast-cleaning of metal surface. In different industries it is called different names - abrasive powder, grit, copper slag grit, mineral grit, grinding grains, etc. - but its main use is still for surface blast-cleaning. Internationally the described media is manufactured in compliance with ISO 11126-3. Blasting the grit at the surface is the most advanced approach for metal surface cleaning before paint spraying. The blasting media manufactured from copper slag brings less harm to people and environment than sand. The product meets the most rigid health and ecological standards.

Specific Gravity of copper Slag = 3.63

Mineral admixture used (copper slag)

E. Super Plasticizers

It is an admixture of a new generation based on modified poly carboxylic ether. The product has been primarily developed for the use in the concrete industry where the highest durability and performance is required. It is free of chloride & low alkali. It is compatible with all types of cement.

V. 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,

2P Split tensile stress = ---------- □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 the test is getting 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 close 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.

VI. Conclusion

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

- A sequential method of adjusting the mix proportions by replacing part of the fine aggregate with the

copper slag has been shown to be suitable for obtaining SCC.

- In this study Super plasticizer may not be strictly necessary for the material used to obtain SCC. But it showed marginal improvement in the properties of passing ability of the mixes.
- Use of copper slag resulted in increase of 28 days compressive strength of concrete.
- It is found that the economical SCC with satisfactory properties with 28 days strength of 28 MPA can be obtained by using 25% copper slag. This self compacting concrete can replace a normal concrete with significantly reduced cost.
- Some of the limits suggested in literature for the powder ratio can be relaxed to obtain self compacting concrete.
- It is possible to produce SCC with allow water content of 165kg/m3 and a power content of 450 kg/m3. For this a poly carboxylic ether based super plasticizer and copper slag may be employed.
- Cement content could be as low as 225 kg/m3 .
- The slump flow value, „V" funnel and the L-Box test can be used to qualitatively characterize the SCC mixtures as acceptable or unacceptable.
- The mixtures of SCC containing 25 percent fly copper slag in the total power content showed adequate strength development at 28 days with a cement content of 225 kg/m3 developed 38.07Mpa at 28 days.
- 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.

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