A STUDY ON PERFORMANCE OF CONCRETE BY REPLACING FINE AGGREGATE WITH VARIOUS INDUSTRIAL SLAGS

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ABSTRACT

Modification of concrete properties by the addition of appropriate materials is a popular field of concrete research. In this study we are focusing on the use of selected waste of steel industry (steel slag) as a partial replacement for fine aggregate in the production of concrete. In this research study, concretes were made with steel slag as substitution for raw fine aggregate. Fine aggregate was replaced by these wastes in different proportions (20%, 40%, & 60 %,) by weight of fine aggregate. The aim of this study is to investigate the compressive strength, split tensile strength and Material properties of concrete with steel chips as a partial replacement for fine aggregate. The experimental results indicates that, the concrete mixed with steel chips have better strength than conventional concrete, while in the case of concrete mixed with the scale of 40%, it attains the maximum strength.

Keyword- Fine Aggregates, Steel Slag, Compressive Strength, Split Tensile Strength.

I. INTRODUCTION

1.1 Background

Concrete – a composite material compound of the filler (coarse aggregate / fine aggregate) embedded with the binder (cement) that glues together to form hard matrix. Concrete is most economical and readily available construction material. Present statistics shows that the concrete consumption is over 10 billion tonnes a year, i.e., each person on earth consume more than 1.7 tonnes of concrete per year. Aggregates, besides cement and water, form one of the main constituent materials of concrete since it occupies nearly 55% - 80% of concrete volume [1]. It has identified that without proper alternative aggregates in the upcoming days, the concrete industries globally consume over 8-10 billion tonnes of natural aggregates annually. Such large consumption of natural aggregates will cause destruction of the environment. Recently natural sand is becoming a very costly material because of its demand in the construction industry due to this condition research began for cheap and easily available alternative material to natural sand [2]. Therefore there is an urgent need to find and supply alternative replacements for natural aggregates by innovative usage of possible industrial by-products. This may lead to sustainable concrete design and greener environment.

1.2 Latest trends

Latest trends and growth in concrete technologies are focusing on sustainable development by using industrial by-products as ecological raw materials in concrete. In this context, Central Road Research Institute (CRRI) published the usage of Copper Slag as replacement with sand at a level of 40% - 50% and 12th five year plan suggested usage of 75% Blast Furnace Slag.

The materials like –

- Fly ash, Fine ground slags, Silica fumes, Metakaolin, Sugar cane bagasse, Palm oil fuel ash, Rice husk ash, Saw dust ash, Glass powder, etc can be used as alternative materials for replacement of cement.
- Slags, Quarry dust, Manufactured sand, Municipal incineration waste ash, Bottom ash, Recycled sands from construction and demolished waste, Spent fire bricks, etc can be used as alternative materials for replacement or full substitution of sand (fine aggregate).
- Recycled concrete aggregates, Recycled brick aggregates, Basalt rock fragments, etc can be used as alternative materials for replacement or full substitution of gravel (coarse aggregate).

1.3 Objective and Scope

The objective of this research program is to identify the alternative sustainable materials which replace the natural river sand without morphing strength and durability aspects of concrete.

In this present study - copper slag, granulated blast furnace slag, silicomanganese slags are adopted as alternative materials.

This research program include an experimental phase to study and compare mechanical properties and durability of concrete by replacing natural sand with CS, GBFS and SiMn. A total number of 96 cubes and 96 cylinders are casted and tested to study the mechanical properties of concrete by replacing sand with CS, GBFS and SiMn. Attempt is made to study the durability of concrete by conducting carbonation test, replacing natural sand with CS, GBFS and SiMn.

II. REVIEW OF LITERATURE

2.1 General

The usage of industrial by-products especially industrial slags in making of concrete is an important innovation in concrete technology, this usage not only manages the industrials wastes but also improve concrete properties. Many researchers have investigated the possible use of slags as a concrete aggregate. For this investigation, some of the important existing literatures on behaviour of concrete replacing its fine aggregate with industrial slags are reviewed and presented briefly.

2.2 Literatures Reviewed

Khalifa S. Al-Jabri et al. 2009 [1] investigated the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability and studied the effect of superplasticizer addition on the properties of HSC made with copper slag. Two series of concrete mixtures were prepared with different proportions of copper slag. They reported that the water demand reduced by almost 22% at 100% copper slag replacement compared to the control mixture. Segregation and dryness of the concrete paste effected the strength and durability requirement. They concluded that use of copper slag as sand substitution improves HSC strength and durability characteristics at same workability while superplasticizer is very important ingredient in HSC made with copper slag in order to provide good workability and better consistency for the concrete matrix.

Akshay C. Sankh et al. 2014 [2] studied the non-availability or shortage of river sand will affect the construction industries and suggested to improve the compressive strength, split tensile strength and flexural strength of concrete with addition of copper slag as replacement to fine aggregate. The density of concrete will increases with replacement of copper slag percentage in concrete. There is increase in the flexural strength of the beam by 21% to 51% while replacement of copper slag. By partial replacement of sand by copper slag, the strength increase was observed up to 40% replacement. Copper slag replacement at higher level leads to segregation and bleeding due to less water absorption capacity of copper slag. They concluded that GGBS sand can be used as an alternative to natural sand from the point of view of strength and recommended to replace up to 75%.

Wei Wu et al. 2010 [3] investigated the mechanical properties of high strength concrete incorporating copper slag as fine aggregate. The workability and strength characteristics were assessed through a series of tests on six different mixing proportions at 20% incremental copper slag by weight replacement of sand from 0% to 100%. They concluded that the strength of the concrete with less than 40% copper slag replacement was higher than or equal to that of control mix. At 40% copper slag replacement the microscopic view was with limited differences from the control concrete. They suggested 40% copper slag as sand substitution can achieve a high strength concrete that is comparable or better than control mix, adoption of the copper slag as replacement level should consider with the desired compressive strength of concrete.

Khalifa S. Al-Jabri et al. 2009 [4] investigated the effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC). Eight concrete mixtures were prepared with different proportions of copper slag ranging from 0% to 100%, for these mixes workability, density, compressive strength, tensile strength, flexural strength and durability were evaluated. They reported that there was a slight increase in the HPC density; workability increased with increase in copper slag content. Further additions of copper slag as sand replacement caused reduction in the strength due to an increase of the free water content in the mix. They recommended that 40% weight of copper slag can be used as replacement of sand in order to obtain HPC with good strength and durability properties.

Khalifa S. Al-Jabri et al. 2011 [5] investigated the effect of copper slag as fine aggregate usage in cement mortar and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% to 100% as fine aggregate. They concluded that the workability, densities increased with different proportions of copper slag replacement; there was more than 70% increase in the strength of mortars with 50% copper slag substitution. Beyond 50% replacement the strength was reduced. They recommended that 40 – 50% of copper slag by weight can improve concrete strength and durability.

III. EXPERIMENTAL PROGRAMME

3.1 General

The experimental programme was planned to study the mechanical properties, durability of concrete by replacing sand with different types of slags. The slags used in this investigation are Copper Slag, Granulated Blast Furnace Slag and Silicomanganese Slag.

3.2 Constituents of concrete

To use slags as supplementary materials for sand, slag has to satisfy certain physical requirements and chemical compositions.

3.2.1 Cement

An OPC 53 grade of Maha Gold cement is used in this investigation. The quantity required for this research work is estimated and the entire quantity is purchased and stored properly in casting store yard. The following tests are conducted following IS codes respectively –

Fig. 1. Cement 53 grade used in the study

Table 1 - Properties of cement

S. No	Particulars of test	Test results	Requirement as per IS code
01	Standard consistency	31%	IS 4031 – 1988 (Part 4) Consistency of OPC should be 26% to 33%
02	Specific gravity	3.10	
03	Setting time		
	a. Initial setting time	98minutes	As per IS 12269:2013 30min, Minimum
	b. Final setting time	300minutes	As per IS 12269:2013 600min, Maximum

3.2.2 Fine aggregate

The fine aggregate used in this investigation is clean river sand, was purchased from a nearby crusher in Anantapuram, which are typically the same materials used in normal concrete mixtures and the following tests are carried out on sand as per IS 2386-1968 (Part 3)

Fig. 2. Sand used in the study

Table 2 - Properties of sand

S. No	Particulars of test	Test results
01	Specific gravity	2.53
02	Water absorption (%)	1.35
03	Bulk density (gm/cm^3)	1.63
04	Fineness modulus	3.15
05	Sieve analysis	Zone II

3.2.3 Coarse aggregate

In this present investigation, locally available crushed stone aggregate of size 20mm and down in Anantapuram are used and the various tests are carried out on coarse aggregate

Fig. 3. Gravel used in the study

Table 3 - Properties of gravel

S. No	Particulars of test	Test results
01	Specific gravity	2.63
02	Crushing value (%)	19.69
03	Impact Value (%)	23.2
04	Fineness modulus	7.24

3.2.4 Water

In this investigation, potable water was used.

3.3 Copper slag

Copper slag used in this project is from Hindustan Copper Limited,
Kolkata, supplied by India mart.

Fig. 4. Copper Slag used in the study

3.4 Granulated blast furnace slag

Granulated blast furnace slag used in this project is from Steel Plant, supplied by India Mart.

Fig. 5. Granulated blast furnace slag used in the study

3.5 Silicomanganese slag

In this project Silicomanganese Slag derived from Industrial slag from India mart.

Fig. 6. Silicomanganese slag used in the study

IV. MIX DESIGN AND EXPERIMENTAL PROGRAMME

4.1 General

All the methods used to design, prepare and test the concrete are as per their respective Indian Standard codes which are mentioned at appropriate places in this thesis. Various tests have been conducted on cement, fine aggregate, coarse aggregate to check their suitability in making concrete. The resulting concrete is proportioned for M35 mix as per nominal mix design. The natural sand in the concrete is replaced by CS, GBFS and SiMn in increasing percentages and the percentage replaced specimens were tested for compression and split tensile strengths. The variations of compressive strength, split tensile strength with respect to percentage of slags are discussed in the results section. The experimental setup and procedures for conducting various tests on concrete are discussed below:

4.2 Mixture Proportions

The mix proportion designed for this research work is 1: 1.66: 2.85 with water/cement ratio of 0.45. M35 grade of concrete is used. To study the effect of CS, GBFS and SiMn substitution as a replacement for fine aggregate on the mechanical properties and durability of concrete were prepared with different percentages of CS, GBFS and SiMn by weight, Fifteen concrete mixtures are prepared with different proportions – CS and GBFS are replaced from 0% – 100% by weight (20, 40, 50, 60, 80, and 100) and SiMn replaced at 20%, 40%, and 50% by weight. Each mixture contains six specimens for which three are tested at 7 days and rest three are tested at 28 days.

4.3 Mixing procedure

50 litres mixing drum is charged by cement, fine aggregate, coarse aggregate and water. The drum is loaded with about one-half of the coarse aggregate, then with the fine aggregate, then with the cement and finally with the remaining coarse aggregate on top and the water is added immediately before the rotation of the drum is started. The period of mixing is not less than 2 minutes after all the materials are in the drum and is continue till the resulting concrete is uniform in appearance. When using pan mixers, the concrete is heaped together before sampling.

Fig. 7. Pan mixer

4.4 Workability

Each batch of concrete was tested for slump immediately after mixing. Provided that care is taken to ensure that no water or other material is lost, the concrete used for the slump cone tests was remixed with the remainder of batch before making the test specimens. The period of re-mixing was as short as possible yet sufficient to produce a homogeneous mass.

4.5 Size of Test Specimens

Test specimens cubical in shape were 150 × 150 × 150 mm 3 (IS: 10086-1982). Cylindrical test specimens with a length equal to twice the diameter, 150 mm in diameter and 300 mm long (IS: 10086-1982).

4.6 Compacting by Vibration

Compacting by vibration, each layer is vibrated by means of a suitable vibrating table until the specified condition is attained.

4.7 Age at Test

Tests were done at 7 and 28 days. The ages were calculated from the time of the addition of water to the dry ingredients.

4.8 Number of Specimens

At least three specimens, preferably from different batches, were made for testing at each selected 7 and 28 days age.

4.9 Casting and testing for compressive strength of concrete

Compressive strength of 150 mm × 150 mm × 150 mm size concrete cubes is casted and tested in accordance with IS: 516-1959. All tests are conducted using 200 Tonnes compressive testing machine. Moulds of size 150mm × 150mm × 150mm are u sed. During casting these cubical moulds are properly cleaned and oiled along its inside faces. Concrete is then filled in moulds and then compacted using mechanical table vibrator. Concrete mixtures with different proportions of copper slag and granulated blast furnace slag ranging from 0 to 100%

and silicomanganese slag ranging from 0 to 50% are prepared and tested.

Fig . 8. Lubricated cubical moulds ready for cast

V. RESULTS AND DISCUSSIONS

5.1 General

Though there are many researches carried all over the globe to study the physical properties, chemical properties and behaviour of concrete for various replacement levels of slag in concrete as replacement to fine aggregate, this research is carried to generate specific experimental data on potential use of and comparison of properties among CS, GBFS and SiMn as fine aggregate in concrete in Indian conditions.

The research is carried out considering M35 mix design. The experimental programme was planned to investigate the performance of different slag as replacement to sand. The experimental work has been executed in following phases:

• Determining mechanical properties (compressive strength and split tensile strength) of concrete by replacing sand with slag at different replacement levels.

o Copper slag (20%, 40%, 50%, 60%, 80% and 100%)

o Granulated blast furnace slag (20%, 40%, 50%, 60%, 80% and 100%)

o Silicomanganese slag (20%, 40% and 50%)

• Effect of carbonation on concrete by replacing sand with different replacement levels of slag.

The details of test results are presented below.

5.2 Effect of copper slag substitution as fine aggregate on concrete properties

5.2.1 Workability

From Table 10, the workability of concrete increases significantly with the increase of copper slag content in concrete mixes. For the control mix the measured slump was 50 mm whereas with 100% replacement of copper slag, the measured slump was collapse. This considerable increase in the workability with the increase of copper slag quantity is accredited to the low water absorption characteristics of copper slag and its smooth, glassy surface compared with sand which caused surplus quantity of free water to remain after the absorption and hydration process have completed. This increase in the workability may have beneficial effect on concrete in the sense that concrete mixes with low water-to-cement ratios for the same amount of sand replaced, can be produced which may have good workability, greater strength and improve durability than the conventional.

5.3 Effect of granulated blast furnace slag substitution as fine aggregate on concrete properties

5.3.1 Workability

From Table 10, the workability of concrete decreases significantly with the increase of granulated blast furnace slag content in the concrete mixes. For the control mix the measured slump was 50 mm whereas for 20% to 100% replacement of granulated blast furnace slag the slump from 30mm to zero slump. This considerable decrease in the workability with the increase of granulated blast furnace slag quantity is attributed to the high water absorption characteristics of slag and its high surface area since finer than sand.

5.3.2 Density

From Table 11, the density of concrete with granulated blast furnace slag as replacement to sand decreased with the increase in the replacement percentage of slag varied from 2517.037 kg/m3 to 2362.962 kg/m3 at 28days. This decrease in the densities is due to low specific gravity of granulated blast furnace slag and the low bulk density of slag compared to sand.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Aggregate replacements have a significant effect on the performance of the fresh concrete mix and also the strength characteristics. One of the objectives of aggregate replacement is to produce sustainable concrete which need relatively low amount of natural resources and use the industrial by-products. These mixtures will be not only having less strength issues but also they are available at affordable price. The main objective of this investigation is to produce guidelines to proportion and optimize aggregate blends using slag as fine aggregate.

6.2 Conclusions

Based on the literature review, the results of the experimental work the following conclusions can be made.

6.2.1 Copper Slag

Fine aggregate when replaced with copper slag have impact on workability of fresh concrete, densities, compressive strength and split tensile strength –

- The smooth nature of copper slag affected slump value of fresh concrete, increased with the increase in copper slag percentage, the slump initially decreased at 20% (20mm) compared to control mix (50mm) and increased at 100% (Collapse).
- The densities of the concrete incorporating sand with the copper slag increased with increase in the replacement percentage due to the high specific gravity and slag density. The density was high at 100% replacement of copper slag when compared to the control concrete.
- This study was concerned mainly with the compressive strength characteristics of concrete. Concrete when replaced with the copper slag to sand the compressive strength increased from 20% to 60% and then decreased to the higher level replacements. Thus 60% replacement of copper slag is optimum to improve strength characteristics.
- The split tensile strength of the concrete increased with replacement of copper slag till 60%. To improve concrete split tensile strength the optimum replacement level is 60% with copper slag as fine aggregate.
- Concrete with the copper slag as sand replacement have no effect with CO2.

6.4 Recommendations for future work

- The concrete may achieve high strength if the slag is graded properly and replaced with sand.
- Slag can be used as partial replacement to cement and coarse aggregate, studies

must be extended incorporating concrete materials with slags.

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