Influence of Copper Slag in Concrete as Partial Replacement for Fine Aggregate

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Abstract— Concrete is the widely used construction material. In which fine aggregate is one of the important constituents. An experimental investigation was conducted to study the effect of using copper slag as a fine aggregate on the properties of concrete. Various concrete mixtures were prepared for M20 and M40 grade with different proportions of copperslag ranging from 0% (for the control mixture), 20%, 40%, 60%, 80%, and 100% as fine aggregate replacement. Hardened concrete tests such as compressive strength, split tensile strength for M20 and M40 grade concrete is tested and the mechanical properties of the conventional concrete is compared with copperslag concrete. The M20 and M40grade results are compared and variation in strength properties between the grades is to be examined and it is recommended up to a 40% replacement of for fine aggregate obtain a concrete with good strength and also grade wise same strength only obtained.

Key words: Cement, Compressive Strength, Copperslag, Split Tensile Strength

I. INTRODUCTION

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. At the same time the scarcity of aggregates are also greatly increased nowadays. In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. But nowadays it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregate.

A. Copper Slag

Copper slag is a by-product material produced from the process of manufacturing copper. It is a byproduct obtained during the matte smelting and refining of copper. World copper production is currently about 14.98 million tones and it is estimated that for every tonne of copper produced, about 2.2tonnes of copper slag is generated as a waste. Around 24.6 million tons of Copper slag is generated from the world copper industry. Copper slag used in this work 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 utilize only about 15% to 20% and the remaining dumped as a waste material and this causes environmental pollution. Copperslag is used as an abrasive in shot blasting to prepare steel surfaces for painting. The widespread use of lead and other heavy metals in protective paints increases heavy metals in used slag, which is classified as a solid or hazardous waste.

B. Copperslag as Construction Material

The use of copperslag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copperslag is produced and also several researchers have investigated the possible use of copperslag as fine and coarse aggregates in concrete and its effects on the different mechanical and long term properties of mortar and concrete. Copperslag 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.

C. Uses of Copper Slag

1) Copper slag has also gained popularity in the building industry for use as a fill material for various places.
2) Copper slag is widely used as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness (6-7 Mohs), high density (2.8- 3.8 g/cm3).
3) Copper slag have been widely used for roofing granules, cutting tools, abrasive, road base construction, rail road ballast and cement industries.

II. SCOPE AND OBJECTIVE

A. Scope of the Investigation

1) To determine the behavior of concrete using Copper slag as fine aggregate.
2) To meet the scarcity of Natural fine aggregate in future, the copper slag can be alternatively used.
3) Vast quantities of copper slag are produced from manufacturing of copper.In our project we are using the copper slag by replacing natural fine aggregate at different percentage like (0%, 20%, 40%, 60%, 80%, and 100%).

B. Objective of the Investigation

1) The use of copper slag in the concrete as a replacement for fine aggregate, reduces the costs of disposal, lowers the cost of the concrete and also helps in protecting the environment.
2) In this project M20 and M40 grade concrete are prepare with different ratios of copperslag instead of fine aggregate and also finding the optimum percentage of copper slag used in concrete.

III. MATERIAL PROPERTIES AND TESTING

A. Cement

Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. In the present work 53 grade was used for casting for various concrete mixes.

B. Aggregate

1) Fine Aggregate

Fine aggregate are material used for the experimental works was conformed to grading zone II. 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.

2) 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. 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.

C. Water

Water is an important ingredient of concrete, it participates in the chemical reaction with cement. It helps to form the strength, the quantity and quality of water is required to be looked into very carefully.

D. Copper Slag

Copper slag is an abrasive blasting grit made of granulated slag from metal smelting process.

E. Physical Properties of Material

1) Properties of Cement

Properties	Test value	Standard value
Specific gravity	3.15	3.15
Normal consistency	33%	30%
Initial setting	45 minutes	30 minutes
Fineness	5%	<10%

Table 1: Physical Properties of Cement

2) Properties of Fine Aggregate

Sl. No.	Characteristics	Test Value	Standard value
1	Type	Natural sand	Natural sand
2	Specific gravity	2.70	2.3
3	Fineness modulus	2.705	2.6-2.9

Table 2: Physical Properties of Fine Aggregate

3) Properties of Coarse Aggregate

Sl.	Characteristics	Test Value	Standard Value
1	Type	Crushed	Crushed
2	Specific gravity	2.74	2.5 – 2.8
3	Maximum size	20mm	20mm
4	Fineness modulus	3.33	2.9 – 3.5

Table 3: Physical Properties of Coarse Aggregate

4) Properties of Copper Slag

S. No	Characteristics	Test Value
1	Type	Air cooled
2	Specific gravity	3.0
3	Maximum size	2.36 mm
4	Fineness modulus	3.08

Table 4: Physical Properties of Copper Slag

F. Chemical Properties of Materials

Elements	% of Cement	% of sand	% of copper slag
O	49.74	58.12	51.37
Ca	13.09	-	20.31
Si	5.40	26.75	7.65
Fe	4.94	2.74	4.15
Al	2.07	12.40	9.26
C	24.76	-	5.88

Table 5: Chemical Properties of Materials

IV. EXPERIMENTAL INVESTIGATION

A. Preparation of Test Specimen

The most common tests on hardened concrete is the compressive strength, Flexure strength and split tensile test because of the intrinsic importance of the strength of concrete in construction. Here the mix ratio of M20 grade and W/C ratio of 0.50. Fifty four cubes and cylinders are prepared with different percentage of copper slag as replacement of fine aggregate.

B. Testing of Specimen

1) Cube Compression Test

The cubes of size 150x150x150mm are placed in the machine such that load is applied on the opposite side of the cubes as casted. Align carefully and load is applied, till the specimen breaks.

Compressive Strength= Failure load / Area of cube

2) Split Tensile Test

The test is carried out by placing cylinder specimen of dimension 150mm diameter and 300mm length, horizontally between the loading surface of compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. The failure load of tensile strength of cylinder is calculated by using the formula

Tensile strength= 2P / 3.14 DL

C. Concreting

The test specimens were casted in six different mix proportions of M20 grade with 0.50 water cement ratio and M40 grade by weight with water cement ratios of 0.40. The materials were mixed in hand mixer.

Fig. 1: Mixing of Concrete

D. Casting

The mould was placed in position on an even surface. All the interior faces and sides were coated with mud oil to prevent the sticking of concrete to the mould. Concrete was poured into the mould using trowels. Hand compaction was done. The concrete was compacted in three layers.

Fig. 2: Casting of Concrete Cube

E. Compaction

Hand operated compaction was done for all the cubes used in the test. The damping mild steel rods having point ends were used to poke the concrete.

F. Curing

The mould is replaced after 2 hours. The test specimens were cured for different duration 7, 14 days.

Fig. 3: Specimens after curing

V. MIX DESIGN

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The main objective is to stipulate the minimum strength and durability.

A. M20 Concrete Mix Design

Water	Cement	FA	CA
191.61	383kg	567kg	1252kg
0.5	1	1.48	3.26

Table 6: Mix Proportion for M20 Grade

B. M40 Concrete Mix Design

Water	Cement	FA	CA
197	493 kg	664 kg	1100 kg
0.4	1	1.34	2.23

Table 7: Mix Proportion for M40 Grade

VI. TEST RESULTS AND DISCUSSION

A. Tests for Compression Strength

S. No	Cube	M20		M40	
		7 Day	14 Day	7 Day	14 Day
		Mpa			
1	CC	16.7	20.1	35.8	39.2
2	CS20	22.3	27.2	41.1	43.3
3	CS40	26.1	31.5	43.4	49.5
4	CS60	21.7	22.9	38.7	42.1
5	CS80	17.8	18.4	29.1	38.3
6	CS100	17.8	18.4	27.7	32.8

Table 8: Compression Strength of M20 and M40 Grade

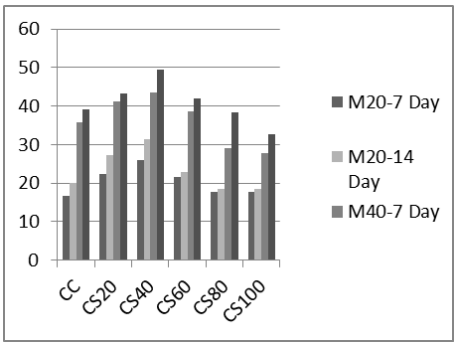

Fig. 4: Bar chart for compressive strength

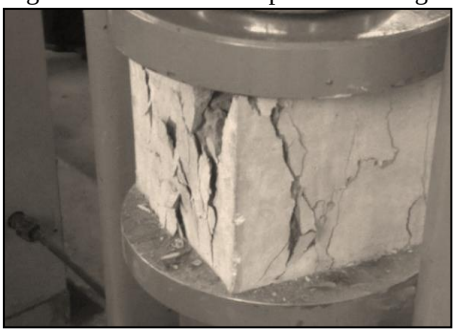

Fig. 5: Failure of Cube

B. Tests for Split Tensile Strength

Sl.	Cylinder	M20		M40	
		7 Day	14 Day	7 Day	14 Day
		Mpa		Mpa	
1	CC	1.3	2.5	2.1	2.8
2	CS20	1.4	2.7	2.3	3.1
3	CS40	1.8	2.9	2.7	3.4
4	CS60	1.5	2.5	2.1	3.1
5	CS80	1.5	2.5	2.0	3.1
6	CS100	1.5	1.9	2.0	2.6

Table 9: Tensile Strength of M20 and M40 Grade

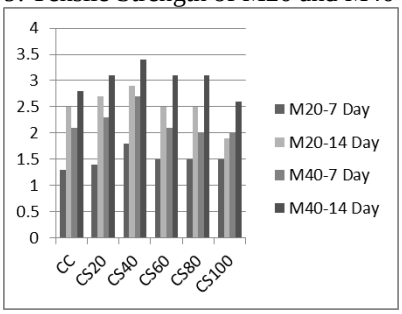

Fig. 6: Bar chart for Tensile strength

Fig. 7: Failure of Cylinder

C. Tests for Flexural Strength

S. No	Beam	M20		M40	
		7 Day	14 Day	7 Day	14 Day

		Mpa			
1	CC	3.9	5.5	5.83	6.67
2	CS20	6.1	6.1	6.83	7.17
3	CS40	6.7	7.6	7.33	7.33
4	CS60	5.9	6.1	6.17	6.33
5	CS80	4.0	5.1	5.17	5.67
6	CS100	3.7	4.1	4.33	5.17

Table 10: Flexural Strength of M20 and M40 Grade

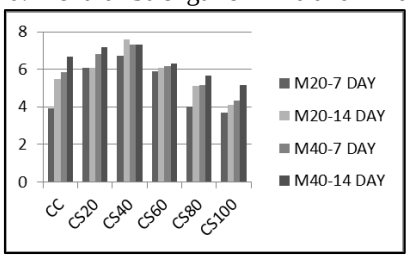

Fig. 8: Bar chart for Flexural strength

Fig. 9: Failure of Beam

D. Results And Discussion

- Better results are obtained in 40% replacement of fine aggregate with copper slag only.
- From 0-40% replacement the strength has been increased and from 40-60 % the strength has been decreased.
- From the results obtained the strength of copper slag concrete provides more strength than the conventional concrete casted.

VII. Conclusion

1) The test results show clearly that copper slag as a fine aggregate replacement has beneficial effects of the mechanical properties of high strengthening concrete. Of all the mixtures considered, concrete with 0%, 20%, 40%, 60%, 80%, 100% of copper slag (CS40) was found to be superior to other mixtures as well as conventional concrete operating conditions.
2) The copperslag used concrete give more strength than normal concrete, compressive strength has been increased about 56% than conventional concrete at S40 mixture for 14 days curing.
3) Split tensile strength has been increased about 18% than conventional concrete and the felxural strength is increased about 10 % than conventional concerete at S40 mixture for 14 days curing.
4) Better results are obtained in 40% replacement of fine aggregate with copperslag only after that the strength has been decreased gradually up to 100%. It is believed that the copperslag concrete will be the benefit of construction industry in the presents.
5) As the compressive, tensile and flexural strength of the copperslag concrete is higher than the conventional concrete, it can be used for load bearing structures and in foundations.
6) As copperslag is a waste material from the sterllite industry it can be constructively used for concreting. This can decrease the copperslag waste, pollution problem and increase the strength of concrete.

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