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STUDIES ON EFFECT OF COPPER SLAG ON STEEL FIBER REINFORCED CONCRETE

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ABSTRACT: Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates are becoming popular in these days. Artificial aggregates generated from industrial wastes provide an alternative for the construction industry. The Rapid growth of technology and population in India, there is a huge demand for construction material mostly for natural sand, of late excessive consumption of sand caused ecological & economical imbalances. To overcome these effects large modifications are being carried out in construction industry, i.e. usage of by-products as a replacement of fine aggregate. In the present study to increase the mechanical properties of concrete steel fibres are added to the concrete mix. Experimental investigation was carried out to evaluate the mechanical properties of steel fibre reinforced concrete and conventional concrete by partial replacement of Fine Aggregate (F.A.) with copper slag for M30 grade concrete. Tests are conducted with 1% addition of hooked end steel fibres having aspect ratio 60 and replacement of F.A by 0%, 10%, 20%, 30%, 40%, 50%, 60%, copper slag with increase in 10% up to where optimum strength is obtained.

KEYWORDS: Copper Slag, Steel Fibres, Compressive Strength, Flexural Strength, Split tensile Strength.

I. INTRODUCTION

Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. The concrete has become so popular and indispensable because of its inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. Concrete is used to make pavements, architectural structures, foundations, and motor ways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles. Its great versatility and relative economy in filling wide range of needs has made it is very competitive building material. Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. This growth is jeopardized by the lack of natural resources that are available. The sustainable development for construction involves the use of non-conventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways for conserving the environment. Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete matrix. Therefore, utilization of aggregates from industrial wastes can be alternative to the natural and artificial aggregates. In the last few decades there has been rapid increase in the production of waste materials and by-products due to the exponential growth rate of population, development of industry and technology and the growth of consumerism. The basic strategies to decrease solid waste disposal problems have been focused at the reduction of waste production and recovery of usable materials from waste as raw materials as well as utilization of waste as raw materials whenever possible. The beneficial use of byproducts in concrete technology has been well known for many years and significant research has been published with regard to the use of materials such as coal fly ash, pulverized fuel ash, blast furnace slag and silica fume as partial replacements for Portland cement With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable by situations. Added to this is the necessity to combat the increasing cost and scarcity of cement and aggregates. Under these circumstances the use of admixtures and partial replacement of aggregate with other wastes are found to be an important alternative solution.

OBJECTIVE

The objective of the present work is to evaluate the mechanical properties of steel fibre reinforced concrete by partial replacement of Fine Aggregate (F.A.) with copper slag for for M30 grade concrete. Tests are conducted with 1% addition of hooked end steel fibres having aspect ratio 60 and partial replacement of F.A by copper slag with 0%, 10%, 20%, 30%, 40%, 50%, 60%, addition up to where optimum strength is obtained.

II. MATERIALS USED

CEMENT:

Cement is a well-known building material and has occupied an indispensable place in construction works. There is a variety of cements available in the market and each type is used under certain conditions due to its special properties. The cement commonly used is Portland cement, and the fine and coarse aggregates used are those that are usually obtainable, from nearby sand, gravel or rock deposits. In order to obtain a strong, durable and economical concrete mix, it is necessary to understand the characteristics and behavior of the ingredients. In this work Ordinary Portland cement (OPC) confirming to IS-12269 (53 Grade) having specific gravity of 3.14. The oter properties of cement were given in Table.1

Table 1. Physical properties of Cement

S.NO	PROPERTY	VALUES
1	Fineness of Cement	225 m^2/kg
2	Specific Gravity	3.1
3	Normal Consistency	33 %
4	Initial Setting time Final setting time	45 mins 6 hours
5	Compressive Strength 3 days 7 days 28 days	32 N/mm^2 46 N/mm^2 58 N/mm^2

AGGREGATES:
Aggregates are generally cheaper than cement and impart greater volume stability and durability to concrete. The aggregate is used primarily for the purpose of providing bulk to the concrete. To increase the density of the resulting mix, the aggregate is frequently used in two or more sizes. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. Aggregate was originally viewed as an inert, inexpensive material dispersed throughout the cement paste so as to produce a large volume of concrete. In fact, aggregate is not truly inert because it's physical, thermal and, sometimes, chemical properties influence the performance of concrete, for example, by improving its volume stability and durability over that of the cement paste. From the economic viewpoint, it is advantageous to use a mix with as much aggregate and as little cement as possible, but the cost benefit has to be balanced against the desired properties of concrete in its fresh and hardened state.
In this work sand conforming to Grading zone II of IS: 383 1970 having specific gravity of 2.6 and fineness modulus 2.47 was used as fine aggregate.
Crushed angular metal of 12 mm size having specific gravity of 2.78 and fineness modulus of 6.92 was used as coarse aggregate.

WATER:
Generally, cement requires about 3/10 of its weight of water for hydration. Hence the minimum water-cement ratio required is 0.35. But the concrete containing water in this proportion will be very harsh and difficult to place. Additional water is required to lubricate the mix, which makes the concrete workable. This additional water must be kept to the minimum, since too much water reduces the strength of concrete.
In this work Potable clean water was used.

COPPER SLAG:
Copper slag is a by-product of copper extraction by smelting. During smelting, certain impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed of as waste or utilized.
Specific gravity of the Copper Slag used was 2.99; Bulk Density 2.08 g/cc and moisture content 0.15% was used. Copper slag is a by-product obtained during the production of copper in copper industries. This copper slag sample is collected from Kanti Metal Stores, Sivalayam Market, Vijayawada, Sivalayam Street, Vijayawada. The copper slag used in this work is shown in Figure.1.

CRIMPED STEEL FIBRES:
In this work, Steel fibre of crimpled type, with density 7.3 gm/cc having aspect ratio 60 were used. The crimped steel fibres will enhance the resistance to cracking by arresting micro cracking.

Figure1. Copper Slag

Table 2. Chemical Composition of Copper Slag

S.NO	CHEMICAL COMPOSITION OF COPPER SLAG	% BY MASS
1.	Al2O3	3.01%
2.	Tio2	0.60%
3.	Fe2o3	55.00%
4.	SiO2	35.00%
5.	CaO	0.20%
6.	MgO	0.90%
7.	K2O	1.02%
8.	Na2O	0.95%
9.	CU	0.42%

III. METHODOLOGY

In this work performance of concrete with 1% crimped steel and different percentages of copper slag replacing fine aggregate is planned to be tested. To evaluate the strength characteristics in terms of compressive, split tensile and flexural strengths, a total of 6 mixes were tried with different percentages of Copper Slag (0, 10, 20, 30, 40, 50, & 60%). In all mixes the same type of aggregate i.e. crushed granite aggregate; river sand and the same proportion of fine aggregate to total aggregate are used. The relative proportions of cement, coarse aggregate, sand and water are obtained by IS - Code method. M30 is considered as the reference mix.

MIX PROPORTION:
For M30 1:1.5:3
Cement: 390 kg/m^3
Fine aggregate:582 kg/m^3
Coarse aggregate: 1298 kg/m^3
Water: 175.5 kg/$m^{3.}$

Workability test:
All the mixes were evaluated for workability in terms of Slump value.

Table 3. Overall result of slump of M30 concrete

MIX DESIGNATION	% OF COPPER BLAST & WITH 1% STEEL FIBERS	SLUMP (mm)
M0	0	53
M1	10	55
M2	20	57
M3	30	59
M4	40	61
M5	50	62
M6	60	65

CASTING OF SPECIMENS:
The cubes were cast in steel moulds of inner dimensions of 150 x 150 x 150mm, the cylinders were cast in steel moulds of inner dimensions as 150mm diameter and 300mm height and, the flexural beams were cast in steel moulds and timber moulds with inner dimensions of 100 x 100 x 500mm. For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers by tamping with a tamping rod and the vibration was effected by table vibrator after filling up moulds. The moulds were removed after twenty four hours and the specimens were kept immersed in clean water tank. After curing the specimens in water for a period of 28 days the specimens were taken out and allowed for drying under shade. Three cubes, three cylinders and three flexural beams were cast for each mix.

TESTING OF SPECIMENS:
The test program consists of conducting Compressive tests on Cubes, Split Tensile tests on Cylinders and Flexural strength on beams at 28 days. The prepared specimens including the material used for preparation of test specimen were tested with general procedures of concrete testing.

IV. RESULTS AND DISSUSSION

TEST RESULTS:
This section provides the results obtained from various tests conducted in this work. The different results obtained from Compressive Strength test, Split Tensile Strength tests and Flexural Strength test for M30 grade concrete cured for 28 days are presented in Tables 4,5 &6 below. The variations of these strength corresponding to the respective percentage of copper slag were shown in the form of graphs given in the Figures 2, 3&4 below.

COMPRESSIVE STRENGTH

The test results obtained from compressive strength test are given in the table below.

Table 4. Compressive strength of M30 concrete

PERCENTAGE COPPER SLAG WITH 1% STEEL FIBRE	COMPRESSIVE STRENGTH, MPa
	28 Days
0 %	44
10 %	47
20%	49
30%	50
40 %	50.4
50%	51
60 %	49.4

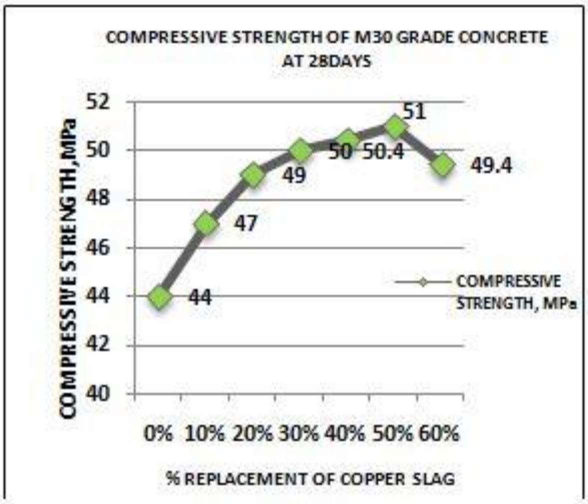

Figure 2. Variation of compressive strength with percentage of copper slag.

From the above Figure 2, it is observed that there is a increase in compressive strength with increase in copper slag up to 50% of copper slag with 1% steel fiber. Beyond 50%, increase in percentage of copper slag decreases the compressive strength. So 50% of copper slag is found to be optimum.

FLEXURAL STRENGTH
The test results obtained from flexural strength test are given in the table below.

Table 5. Flexural strength of M30 concrete

PERCENTAGE COPPER SLAG WITH 1% STEEL FIBRE	FLEXURAL STRENGTH, MPa
	28 DAYS
0 %	4.80
10 %	4.97
20%	5.07
30%	5.12
40 %	5.14
50%	5.17
60 %	5.09

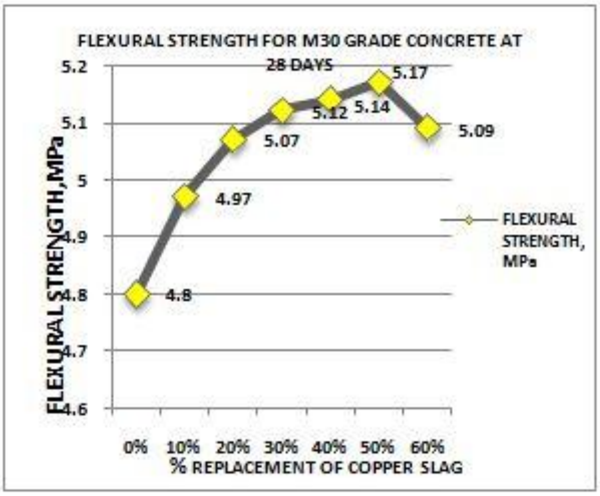

Figure 3. Variation of Flexural Strength with percentage of copper slag.

From the above Figure 3, it is observed that there is a increase in flexural strength with increase in copper slag up to 50% of copper slag with 1% steel fiber. Beyond 50%, increase in percentage of copper slag decreases the flexural strength. So 50% of copper slag is found to be optimum.

SPLIT TENSILE STRENGTH

The test results obtained from Split tensile strength test are given in the table below.

Table 6. Split Tensile strength of M30 concrete

PERCENTAGE COPPER SLAG WITH 1% STEEL FIBRE	SPLIT TENSILE STRENGTH, MPa
	28 DAYS
0 %	3.4
10 %	3.42
20%	3.85
30%	3.91
40 %	3.93
50%	4
60 %	3.88

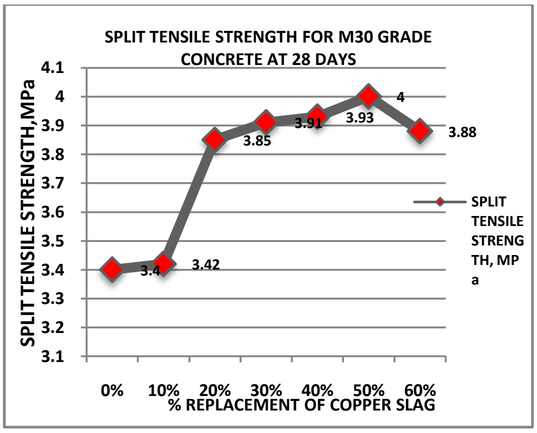

Figure 4. Variation of Split Tensile Strength with percentage of copper slag.

From the above Figure 4, it is observed that there is a increase in Split Tensile Strength with increase in copper slag up to 50% of copper slag with 1% steel fiber. Beyond 50%, increase in percentage of copper slag decreases the Split Tensile Strength. So 50% of copper slag is found to be optimum.

V. CONCLUSIONS

In this work experimental study was made to find out the optimum percentage of Copper Slag that can be added to Steel Fibre Reinforced concrete. Based on experimental observations, the following conclusions are drawn:

- As the percentage replacement of copper slag increases the workability increases.
- Compressive strength increases with increase in percentage of copper slag upto 50% and beyond 50% strength decreases at 28 days for M30 grade of concrete
- Flexural strength also increases with increase in percentage of copper slag upto 50% and beyond 50% strength drops down at 28 days for M30 grade of concrete.
- Split Tensile strength also increases with increase in percentage of copper slag upto 50% and beyond 50% strength drops down at 28 days for M30 grade of concrete
- Considering the strength criteria, replacement of fine aggregate with copper slag with is quite feasible. It can be concluded that the utilization of copper slag with steel fibre reinforced concrete is optimum at 50%.

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