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Study on Utilization of Copper Slag in Sustainable Construction of Rigid pavement

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Abstract: Copper slag is an industrial by-product generated during extraction and refining of copper metal from copper ore. The fine aggregates were replaced partially by copper slag in two grades of concrete i.e. M25 and M30 by 0%, 10%, 20%, 30% and 40% copper slag, by weight. The compressive strength and flexural strength tests were conducted on the cement mixes and results were analyzed. The principal objective of this research is to assess the possibility of using copper slag in the construction of rigid pavements.
Keywords: Concrete, copper slag, Compressive strength,flexural strength M25 and M30.

I. INTRODUCTION

In India, various schemes are going on for large road infrastructure projects. These road projects are required large quantities of road aggregates. Highway engineers have the greatest challenge to meet the demand of good quality aggregates for the undergoing and new road projects. The utilization of industrial by-products and solid waste as alternative aggregates is one of the alternative solutions in the direction of sustainable construction. Hence researchers and engineers have to pay their attention for utilization of industrial by- products and waste materials in construction. It has several benefits such as reduction in the cost of disposal, reduced landfill requirement, minimum depletion of natural resources caused by excavation of natural materials, preservation of energy requirement to produce natural aggregates and many more. Use of copper slag in concrete mix has been harnessed by various researchers and they gave way to use this concrete in rural roads, low traffic street in municipal areas, cross drainage works, drainage lines, deck floors for low volume traffic culverts, medians, and precast interlocking tiles etc. This study explores the possibility of partially replacing fine aggregate by copper slag in the concrete. Copper slag is generated during extraction and refining of copper metal from its ore or concentrate. Presently in India only 10 to 20% of its production is being utilized in various purposes such as in the manufacture of cement, in the manufacture of ready mix concrete, as abrasive material in shot blasting and as embankment material in the construction of roads . The remaining part is dumped unattended in the landfills. If stockpiling is continued then it might be a threat to the future generation. Therefore in the present study, fine aggregates are replaced by copper slag in different proportions in the concrete.

A. Objectives

The prime objective of the research is to study the possible application of copper slag in cement concrete for utilization in various components of low volume road construction. In more detail; the objectives of this dissertation are as follows :

1) To study the characterization of copper slag in order to contribute to a better knowledge of its properties.
2) To investigate the potential use of copper slag as fine aggregate in cement concrete by partial replacement of sand.

II. MATERIALS USED

Material are used for cement concrete are cement, fine aggregate coarse aggregate and copper slag.

1) *Cement:* A cement is a binder, a substance that sets and hardens and can bind other materials together **.**

The cement used in this experimental work is OPC43.

Table -1: Properties of cement

Sl.No.	Property	IS Recommendation
01.	Specific Gravity	3.15
02.	Initial SettingTime	115 minute
03.	Final SettingTime	225 minute

2) *Sand:* It is a naturally granular material composed of the crushed form of rock and and minerals .defined by size its finer than coarse aggregate and coarser than clay and silt prticles.
3) *Copper Slag (CS):* Copper slag is generated during extraction and refining of copper metal from its concentrate. Copper slag can be classified in two types differentiated by the types of cooling process. If the slag is cooled in air than it is called air cooled copper slag and if cooled into water it is granulated copper slag. Air-cooled copper slag has a dull black color and a glassy appearance. Granulated copper slag is more vesicular and porous and therefore has lower specific gravity and higher absorption than air-cooled cooper slag. In general, the specific gravity of copper slag will vary with its iron content. The unit weight of copper slag is somewhat higher than that of conventional aggregate. The absorption of the material is typically very low compared to river sand. Due to the attractive quality of copper slag with respect to mechanical and chemical characteristics it is extensively used in cement or as a replacement for aggregates. At present there are very limited data for, and research that has been carried out on the application of copper slag in road pavements. Copper slag has many interesting properties such as excellent unassailability characteristics, good scratch resistance and good consistency for using as aggregates in road construction (Gorai et al 2003).The slag particles are having high friction angle due to sharp angular shape, which gives good interlocking property between aggregates.
4) *Coarse Aggregate:* Aggregates are the most mined materials throughout the world. Aggregates are the component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material.

Table -2: Properties of FA, CA, CS

S.No	Properties	FA	CA	CS
01.	Specific Gravity	2.62	2.66	3.52
02.	Water absorption (%)	1.10	0.80	0.33

5) *Water:* Water is an important ingredient of concrete as it actively participates in the chemical reaction with the cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to become very important.

III. METHODOLGY

In the present study, two grades of concrete mixes i.e. M-25 and M-30 were selected which are most commonly used in the rigid pavements. The materials such as copper slag, coarse aggregates, fine aggregates and cement were tested as per relevant Indian standards. Copper slag which was procured from Birla Copper plant was investigated for various physical properties such as gradation, specific gravity and water absorption. The physical properties of coarse and fine aggregates such as gradation, specific gravity and water absorption were determined in the laboratory. The normal consistency, initial setting time and final setting time tests for cement were carried out as per relevant Indian standard.

1) *Mix Design:* The mix design as per IS : 10262-2009 for concrete of grade M-25 and M-30 was done by using conventional materials for a design slump of 100-125 mm. After that fine aggregates were replaced by copper slag with 10, 20, 30 and 40%, by weight of aggregates in the both mixes

Table-3: Different combinations of mixes

Mix Designation	Mix details (Sand + Copper Slag)
C-1	100% Sand + 0%CS
C-2	90% Sand + 10%CS
C-3	80% Sand + 20%CS
C-4	70% Sand + 30%CS
C-5	60% Sand + 40%CS

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A. Tests Conducted

1) *Slump Cone Test:* The Slump Cone apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions such as given: Bottom diameter: 20 cm, Top diameter: 10 cm, Height: 30 cm and also the thickness of the metallic sheet for the mould should not be thinner than 1.6 mm.
2) *Compressive Strength Test:* One of the most important properties of the concrete is the measurement of its ability to withstand compressive loads. This load withstand capacity is referred to as acompressive strength and is expressed as load per unit area. One method for determining the compressive strength of concrete is to apply a load at a constant rate on a cube (having dimensions 150×150×150 mm), until the sample fails. The compression tests performed in this were completed in accordance with IS code 516 “Methods of Tests for Strength of Concrete”. For this study samples were tested for compression testing at 7 and 28 days of curing.
3) Flexural Strength

IV. RESULTS AND DISCUSSION

Table-4: Workability of concrete with partial replacementof sand by Copper Slag

Mix Designation	Copper slag (%)	Slump Value (mm)
C-1	0	110
C-2	10	120
C-3	20	130
C-4	30	142
C-5	40	160

Table-5: Cube Compressive Strength of concrete (M25) withpartial replacement of sand by Copper Slag at 28 days curing period

Mix Designation	Replacement of fine aggregate by copper slag (%)	28th day Compressive strength (N/mm^2)
C-1	0	31.92
C-2	10	32.51
C-3	20	33.56
C-4	30	28.71
C-5	40	25.52

Table-6: Cube Compressive Strength of concrete (M30) withpartial replacement of sand by Copper Slag at 28 dayscuring period

Mix Designation	Replacement of fine aggregate by copper slag (%)	28th day Compressive strength (N/mm^2)
C-1	0	32.02
C-2	10	32.99
C-3	20	33.59
C-4	30	31.75
C-5	40	29.07

Table-7: Flexural Strength of concrete (M25) withpartial replacement of sand by Copper Slag at 28 dayscuring period

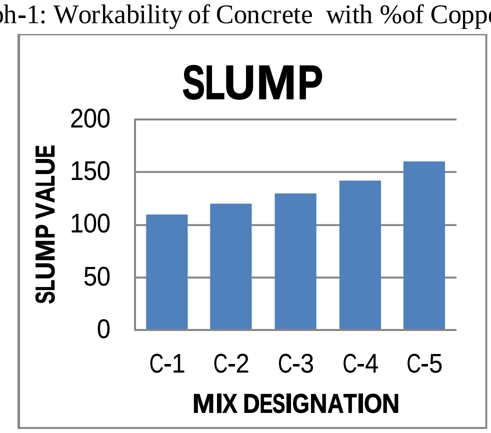
Mix Designation	Replacement of fine aggregate by copper slag (%)	28th day flexural strength (N/mm^2)
C-1	0	3.68
C-2	10	4.11
C-3	20	4.24
C-4	30	3.84
C-5	40	3.42

Table-7: Flexural strength of concrete(M30) with partialreplacement of sand by Copper Slag

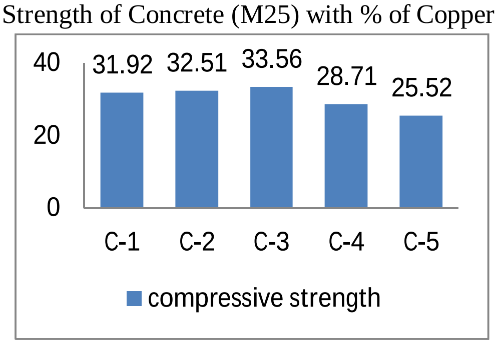
Mix Designation	Replacement of fine Aggregate by copper slag (%)	Flexural strength (N/mm^2)
C-1	0	4.34
C-2	10	4.63
C-3	20	5.17
C-4	30	4.72
C-5	40	4.13

A. Graphs

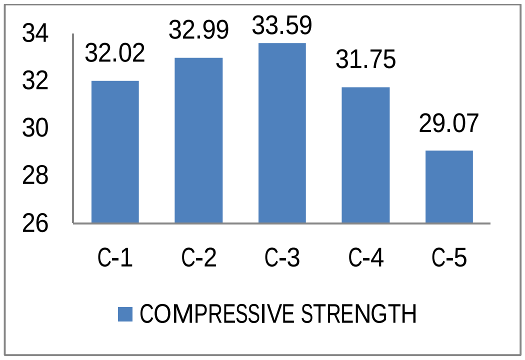
Graph-1: Workability of Concrete with %of CopperSlag



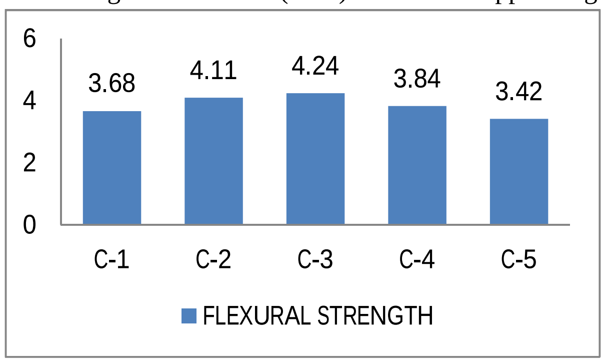
Graph-2: Cube Compressive Strength of Concrete (M25) with % of Copper Slag at 28 days curing period



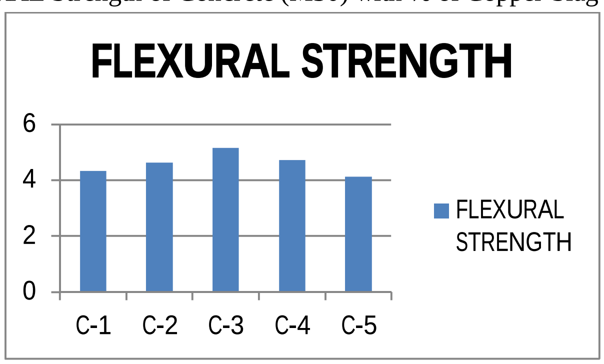
Graph-3: Cube Compressive Strength of Concrete (M30) with % of Copper Slag at 28 days curing period



Graph-4: Cube FLEXURAL Strength of Concrete (M25) with % of Copper Slag at 28 days curing period



Graph-4: Cube FLEXURAL Strength of Concrete (M30) with % of Copper Slag at 28 days curing period



V. DISCUSSION

A. The compressive strength at 7 days of M-25 increases up to 20% addition of copper slag and then started decreasing as shown by Figure 4.1. The compressive strength at 28 days of M-25 also increases up to 20% replacement of fine aggregates by copper slag and beyond that decreases

B. The compressive strength test results at 28 days of M-30 grade of concrete increases by the replacement of fine aggregates by copper slag up to 20% and then decreses with the highest level of replacement

C. The increase in the compressive strength at the initial level of replacement might be due to less number of copper slag particles in the same weight of the mix as compared to fine aggregates; hence more cement is available for bonding. Furthermore additions of copper slag causes reduction in strength due to an increase of free water content in the mix, as the water absorption of copper slag (0.33%) is less as compared to fine aggregates(1.1%).

D. The flexural strength increases up to 20% replacement of fine aggregates by copper slag in M-25 and M-30 grade of concrete and, after that it started decreasing. The values of flexural strength with 20% copper slag was increased by 15.21% for M-25 and by 19.12% for M-30. The flexural strength with 40% copper slag fall below the values of control mix for both grade of concrete.

E. Flexural strength might be increased at the initial level of replacement due to less number of copper slag particles in the same weight of the mix as compared to fine aggregates; hence more cement is available for bonding.
F. Furthermore additions of copper slag causes reduction in strength due to an increase of free water content in the mix, as the water absorption of copper slag (0.33%) is less as compared to fine aggregates (1.1%).

VI. CONCLUSIONS

The present study documents the findings of an experimental research on the characterization and its utilization of copper slag by the partial replacement of fine aggregates in the concrete which can be utilized in the rigid pavement for low traffic roads near copper production industries. The bulk utilization of copper slag may lead to less utilization of natural resources of river sand. On the basis of experimental study, it has been observed that copper slag is one of the most suitable waste materials which can be utilized as partial replacement of fine aggregates in the concrete. The research work can be concluded in following points as follows:

A. The technical feasibility for utilization of copper slag in M-25 and M-30 grade of concrete has been carried out. The experimental results revealed that copper slag has potential for being utilized in the concrete as partial substitution of fine aggregates.
B. Copper slag particles used in this study was in the size range of passing 2.36 mm sieve and retained on 600 micron sieve. The natural fine aggregates also having particle size distribution almost in the same range. Hence copper slag particles can be directly used in the production of concrete for its practicalutilization.
C. Theslumpvaluesofcopperslagblendedconcreteincreasedforallreplacementlevel
D. i.e. from 10% to 40% in both M-25 & M-30 mixes.
E. The compressive strength of M-25 and M-30 grade of concrete increased up to 20% replacement of fine aggregates by copper slag and beyond that started decreasing.
F. The flexural strength test results also showed increment with 10% and 20% copper slag in M-25 and M-30 concrete as compared to control mix. The flexural strength got decreased with 30% and 40% replacement of fine aggregates by copper slag.

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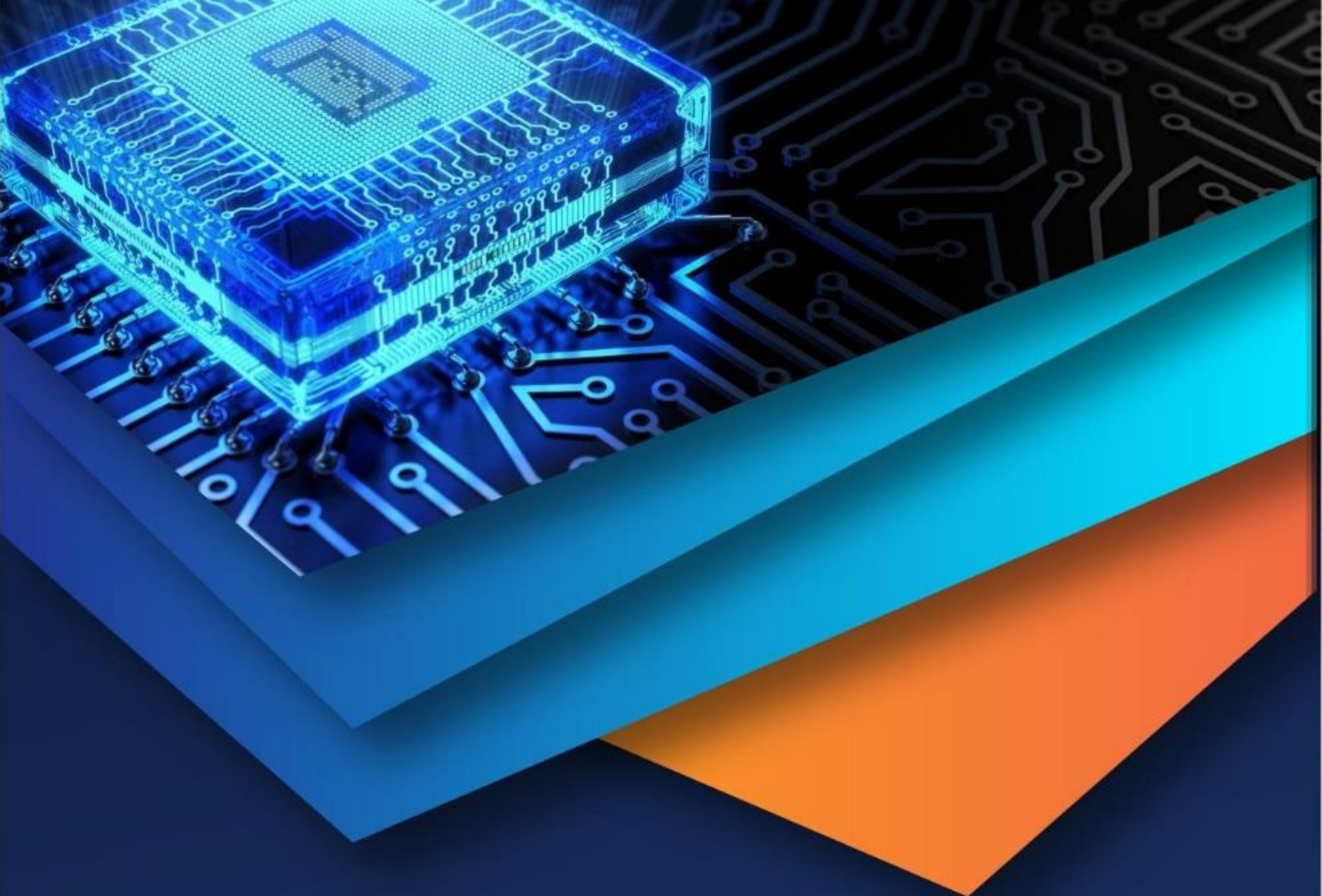

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