Copper Slag as a Partial Replacement for Fine Aggregate

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Abstract- *Copper slag is a byproduct obtained during refining of copper. The common management options for copper slag are recycling of metal, production of value added products, roofing granules, cutting tools, abrasive tiles, glass, road base construction, railroad ballast. Copper slag is totally inert material and its physical properties are similar to natural aggregates*

According to studies it has been conclude that fine aggregates can replace by copper slag in Cement. Copper slag is a by-product obtained during the production of copper metal, which can be used as pozzolana in the production of cementing materials. One of the primary advantages to copper slag is the the low risk it poses to health and the environment. Copper slag also has a high strength-to-weight ratio, making it an effective option in concrete, or as a fill material under the roadway. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.

Keywords: copper slag , fine aggregate , compressive strength, durability, concrete

I. INTRODUCTION

Concrete is the Concrete is a composite construction material made primarily with aggregate, cement, and water. There are many formulations of concrete, which provide varied properties, and most-used man-made product in the world. “Coarse Aggregate" consists of large chunks of material in a concrete mix, generally coarse gravel or crushed rocks such as limestone, or granite, along with finer materials such as sand."Cement", commonly Portland cement, and other cementations materials such as fly ash and slag cement, serves as a binder for the aggregate. Varying the proportions of the main ingredients or by substitution for the cementations and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.“Water” is then mixed with this dry composite, which produces a semi-liquid that workers can shape (typically by pouring it into a form). The concrete solidifies and hardens to rock-hard strength through a chemical process called “hydration”. The water reacts with the cement, which bonds the other components together, creating a robust stone-like material. Fine aggregate is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz

Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Copper slag is a by-product created during the copper smelting and refining process.

II. MATERIALS AND METHODS

Cement – cement is a binder, a substance that sets and hardens and can bind other material to gether. Though all cement conforming to various IS code suitable, selection of cement should be based on thei compressive strength, fineness and compatibility with other ingredients.

Fine aggregate- Sand is an extremely needful material for construction but this important material must be purchased with all care and vigilance. Sand which is used for construction purpose must be clean , free from waste stones and impurities.

Coarse aggregate- Coarse aggregate are used for making concrete. They may be in the form of irregular Broken stone or naturally occurring gravel. Material which large to be retained on 4.75mm sieve size are called coarse aggregate . Its maximum size can be up to 63mm.

Copper slag- Copper slag is a by- product during copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot, and rock. Collectively, these materials make up slag, which can be used for number of applications in the building and industrial fields, the slag serves as a binding

agent, which helps to hold the larger gravel particles within the concrete together, One of the primary advantages of copper slag is the low risk it poses to health and the environment.

TABLE 1: PROPERTIES OF CEMENT

PROPERTIES	ANALYTICAI VALUES
TYPE AND COMPANY	O.P.C - GRADE 53 ULTRATECH CEMENT
SPECIFIC GRAVITY	3.15
% VOIDS	40.42
BULK DENSITY	1.87
FINAL SETTING TIME	275 MIN.

As per IS269:2013,the result are within the maximum limits.

TABLE 2: PROPERTIES OF COARSE AGGREGATE

PROPERTIES	ANALYTICAI VALUES
PARTICLE SHAPE	ANGULAR
SPECIFIC GRAVITY	2.67
BULK DENSITY	1.94 kg/lit
WATER ABSORPTION	0.5%
CRUSHING VALUE	15.99%
IMPACT VALUE	3.44%
ABRASION VALUE	2%

As per IS 383:1970,the result are within the maximum limits.

TABLE 3: PROPERTIES OF COPPER SLAG

PROPERTIES	ANALYTICAI VALUES
SPECIFIC GRAVITY	3.43
WATER ABSORPTION	0.4%
FINENESS MODULUS	2.9
WATER CONTENT	0.1%

Flaexural Test-

The experimental investigation has been carried out on the test specimen to study the strength properties as result of replacing fine aggregate by copper slag in various percentage as by 10%,20% &30% . The inside of the mould was applied with oil to facilitate the easy removal of specimen .the mixing of raw materials was continued until a uniform colour was obtained.fresh concrete was placed in mould in three layer and each layer was compacted using tamping rod. The size of the beam mould is 100 x 100 x 500 mm.after 24 hours the specimen were taken out from the mould and placed in curing tank.flexural strength test were carried out after 14 & 28 days.

- CONCRETE MIX DESIGN

1.M20 DESIGN [AS PER I.S.10262-1982]

- DESIGN STIPULATION
  - Compressive strength at 28 days= 20 MPA
  - Maximum size of aggregate= 20mm
  - Degree of workability= 0.89
  - Type of exposure= mild
- TEST DATA FOR MATERIAL
  - Sp. Gravity of cement= 3.15

Sp. Gravity of coarse aggregate= 2.67

- Specific gravity of fine aggregate= 2.66
- Water absorption-
  - coarse aggregate= 0.5%
  - fine aggregate= 1.0%
  - Free moisture-
  - coarse aggregate= nil
  - fine aggregate= 2%

- TARGET MEAN STRENGTH

$f_{ck} = f_{ck} + t.S$
$20 + 1.65 \times 4$
26.6 MPa

- SELECTION OF WATER-CEMENT RATIO
  W/C Ratio = 0.4

- SELECTION OF WATER & FINE AGGREGATE CONTENT

Water content per cubic metre of concrete= 186 kg
Sand content of total aggregate by absolute volume= 35%

- required water content =186 +6% of 186 = 197 litres/m^3

- DETERMINATION OF CEMENT
  - W/C ratio= 0.4
  - water =197 litres
  - cement= 197/ 0.4 = 492.5 kg/m^3

- DETERMINATION OF COARSE AGGREGATE & FINE AGGREGATE

$V = [W + C/Se + f_a/S_{fa}] \times 1/1000$
$0.98 = [191.02 + 306.63/3.15 + 1/0.39 + f_a/2.66] \times 10^{-3}$
$f_a = 690.59$ kg/m^3
$C_a = (1-P)/P \times f_a \times (S_{ca}/S_{fa})$
$C_a = (1- 0.39)/ 0.39 \times 690.59 \times 2.67/2.66$
$= 1084.42$ kg/m^3

- Actual proportion required by applying correction of water content
  1. Extra quantity of water to be added for absorption in case of CA at 0.5% mass.= 0.01770 litrers.
  2. Quantity of water to be deducted for moisture present in sand ,at 2% by mass= 0.0452.

3. Actual quantity of water required to be added =0.4 + 0.01770 – 0.0452= 0.38
4. Actual quantity of sand required after =1.15
5. Actual quantity of CA required= 2.15

Table 2-Final mix proportion

WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
0.4	1	1.15	2.15

ESTIMATION OF SAND, CEMENT & AGGREGATE FOR BEAM

CALCULATION OF VOLUME

- SIZE OF BEAM = 100 mm x 100 mm x 500 mm
- VOLUME OF BEAM =0.1x0.1x0.5 = 0.005 m^3

1. ESTIMATION OF SAND, CEMENT & AGGREGATE FOR ONE BEAM

1. CEMENT = 492.5 x 0.005 = 2.46 kg
2. FINE AGGREGATE = 567.9 x 0.005 = 2.839 kg
3. COARSE AGGREGATE = 1063.02 x 0.005 =5.31 kg

2. ESTIMATION OF SAND, CEMENT & AGGREGATE FOR 24 BEAMS

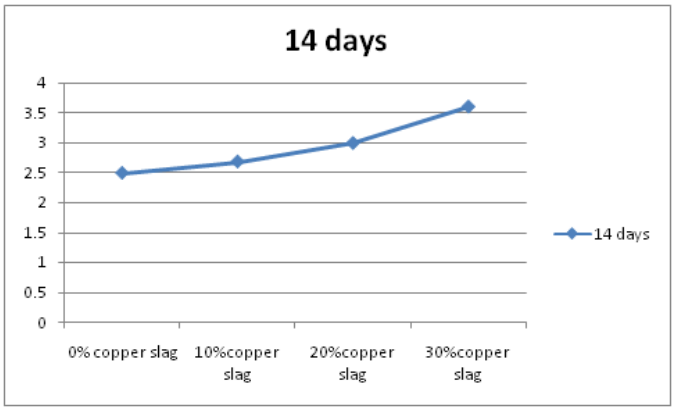
1. CEMENT = 24 BEAMS x 2.46 KG = 59.04 kg ~ 65 KG
2. COARSE AGGREATE = 24 BEAMS x 5.31 =127.4 kg ~ 130 KG
3. FINE AGGREGATE:-
   - FOR 6 BEAMS: - 6x 2.84 =17.04 ~ 18 kg
   - FOR 18 BEAMS :- 51.12 kg ~ 52 KG
   - TOTAL FINE AGGREGATE = 70 kg
4. COPPER SLAG:-
   - 10% x 2.84kg =284 gm x 6 =1704 gm
   - 20% x 2.84 kg =586 gm x 6 =3408 gm
   - 30% x 2.84 kg =852 gm x 6 =5112gm
   - TOTAL COPPER SLAG = 10.224 kg ~ 12 kg.

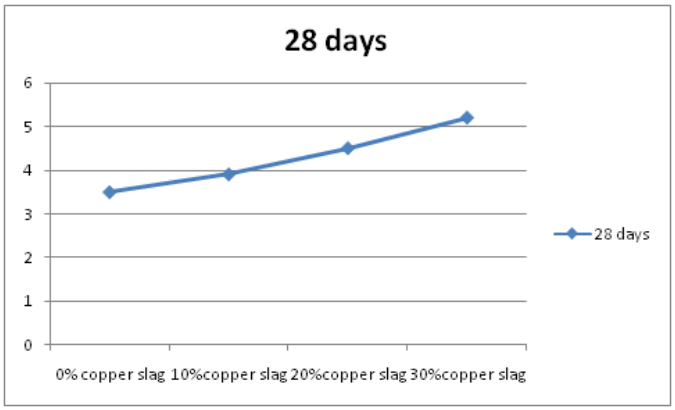
III. RESULTS AND DISCUSSION

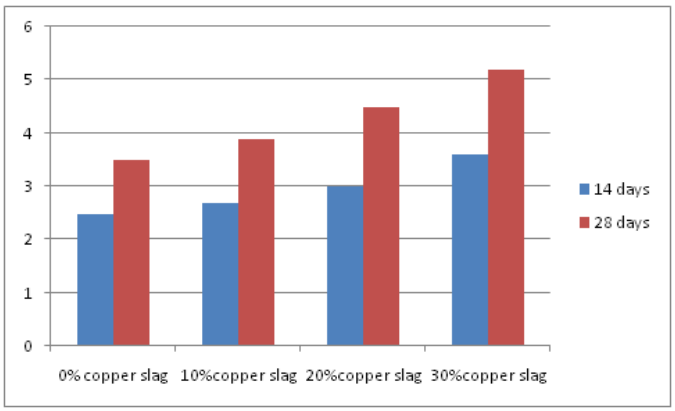
The specimen containing different percentage of copper slag were tested in the compressive strength. Testing machine after 14& 28 days of curing process. The results are given below in the table and the results are also illustrated in the following graphs

BEAM GRAPH

	0% COPPER SLAG	10 %COPPER SLAG	20% COPPER SLAG	30% COPPER SLAG
14 DAYS	2.49	2.68	2.99	3.6
28 DAYS	3.49	3.9	4.6	5.2







IV. CONCLUSION

The experiment was conducted only for M20 grade of concrete. This study also conducted by varying grades of concrete. The results of flexural test have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 30% of additions. f lexural strength is found to be maximum at 30% replacement of copper slag. We can save the fine aggregate in large quantity if we replace those 20%-30% of copper slag which also reduces waste quantity of copper slag. The utilization of copper slag in concrete provides additional environmental as well as technical benefits for all constructional industries. The initial and final setting time of copper slag admixed concrete is higher than control concrete.

REFERENCES

[1] AS Alnuaimi Department of Civil and Architectural Engineering, Sultan Qaboos University, Al-Khoud, Muscat, Sultanate of Oman(2012) "Effects of Copper Slag as a Replacement for Fine Aggregate on the Behaviour and Ultimate Strength of Reinforced Concrete Slender Columns" (TJER 2012, Vol. 9, No. 2, 90-102)

[2] Bipra gorai , R.K. Jana , Premchand, "Characteristics and utilisation of copper slag a review". Resources, Conservation and Recycling 39 (2003) pp 299 313

[3] C. D. Atif and O.N. elik, "Relation between abrasion resistance and flexural strength of high volume fly ash concrete".Materials and Structures/Mat6riauxet Constructions, Vol. 35, May 2002, pp 257260

[4] D. Brindha, Baskaran T., Nagan S. (2010) "Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete" (International Journal of Civil & Structural Engineering, Vol. 1, No.2)

[5] Harvey Alter, "The composition and environmental hazard of copper slags in the context of the Basel Convention." Resources, Conservation and Recycling 43 (2005) pp 353–360

[6] JOZEFITA MARKU, KOZETA VASO (2010) "Optimization of copper slag waste content in blended cement production" (Scientific paper UDC: 620.196:666.943.022)

[7] Khalifa S. Al-Jabri , Makoto Hisada , Salem K. Al-Oraimi , Abdullah H. Al-Saidy " Copper slag as sand replacement for high performance concrete"

[8] Kharade A.S., Kapadiya S.V."An experimental investigation of properties of concrete with partial or full replacement of fine aggregates through copper slag"(International Journal of Engineering Research & Technology, vol.2, Issue 3, March 2013).

[9] M. Najimi, J. Shobhani, A. R. Pourkhorshidi "Durability of copper slag contained concrete exposed to sulphate attack"

[10] Meenakshi Sudarvizhi. S, Ilangovan. R (2011) "Performance of Copper slag and ferrous slag as partial replacement of sand in Concrete" (INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING Volume 1, No 4)

[11] Moura W, Masuero A, Dal Molin D, Vilela A. "Concrete performance with admixtures of electrical steel slag and copper concerning mechanical properties." ACI SP186; 1999. pp. 81–100.

[12] Mostafa Khanzadi, Ali Behnood "Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate"

[13] Report on "Utilization of copper slag as performance improver in Ordinary Portland cement" for M/s Sterlite Industries (India) Ltd., Tuticorin, Tami Nadu, submitted by National Council for cement and building materials, New Delhi, Jan 2009.

[14] TeikThye Lim, J.Chu, "Assessment of the use of spent copper slag for land reclamation". Waste Manage Res 2006: 24: pp 67–73.

[15] Tobisaka Motoo, Oshima Akira, "Colors of Concrete Using Copper SlagFineAggregate."ISSN:02896026 VOL.35;NO.6;PAGE.1113(1999).