"TO STUDY THE PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG"

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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to

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Certificate

This is to certify that the work which is being presented in the project title **"*TO STUDY THE PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE BY COPPER SLAG*"** in partial fulfillment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Abhimanyu Arya (121634) & Ravi Kumar (121660)** during a period from July 2015 to June 2016 under the supervision of **Mr.Abhilash Shukla**(Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.)

The above statement made is correct to the best of my knowledge.

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Table of Contents

List of Figures

List of Tables

Abstract

Due to higher no of growing industries in India, the production of goods has also increased. But at the same time the waste coming out of these industries has also been increased. And proper disposal of such waste materials has become a major problem. If these materials are not treated or disposed properly, these will be in the environment for a long time and will harm the environment. Copper slag is one of the waste materials which can be used in the construction, as partial or full replacement of fine aggregate. This paper presents the various tests performed on the copper slag as partial replacement for fine aggregate in concrete. M30 grade concrete was used and various tests like compressive, flexural, split tensile strength were conducted for different proportions of copper slag and sand from 0 to 50%.

Copper slag is a by-product obtained during matte smelting and refining of copper. The common management options for copper slag are recycling, recovering of metal, production of value added products such as abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements. Despite increasing rate of reusing copper slag, the huge amount of its annual production is disposed in dumps or stockpiles to date. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Many researchers have investigated the use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. This paper reviews the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete.

Chapter 1: Introduction

Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete matrix. In many countries there is scarcity of natural aggregates that are suitable for construction while in other countries there is an increase in the consumption of aggregates due to the greater demand by the construction industry. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry. Therefore, utilization of aggregates from industrial wastes can be alternative to the natural and artificial aggregates. Without proper alternative aggregates being utilized in the near future, the concrete industry globally will consume 8–12 billion tons annually of natural aggregates after the year 2010. Such large consumption of natural aggregates will cause destruction to the environment.

The beneficial use of by-products 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, bottom ash, blast furnace slag and silica fume as partial replacements for Portland cement or as fine aggregate.

Copper slag is a by-product obtained during matte smelting and refining of copper. The common management options for copper slag are recycling, recovering of metal, production of value added products such as abrasive tools, roofing granules, cutting tools, abrasive, tiles, glass, road-base construction, railroad ballast, asphalt pavements. Despite increasing rate of reusing copper slag, the huge amount of its annual production is disposed in dumps or stockpiles to date. One of the greatest potential applications for reusing copper slag is in cement and concrete production. Many researchers have investigated the use of copper slag in the production of cement, mortar and concrete as raw materials for clinker, cement replacement, coarse and fine aggregates. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. This paper reviews the characteristics of copper slag and its effects on the engineering properties of cement, mortars and concrete.

1.1 General

Concrete is one of the prime materials for structures and it is widely used for various applications all over the world. The usage of concrete is inevitable throughout the globe .Aggregates and cement play a major role in concrete. In India there is a great shortage of natural aggregates. Recently Tamil Nadu government (in India) has imposed restrictions on removal of sand from the riverbeds due to its threatening effects. Production of cement liberates same amount of carbon dioxide which is the great cause of ozone depletion. This effect creates a question on the sustainability of concrete. In order to make concrete a sustainable material, suitable engineering approaches can be done. Apart from this waste generation has increased considerably and find no way for disposal. In order to overcome this, industrial and agro- waste materials can be used as alternate building materials. In our present study we made an attempt by utilizing copper slag an industrial waste.

1.2Copper slag

Copper slag is an industrial by-product obtained during the matte smelting and refining of copper Large quantities of slag are produced as a by product of metallurgical operations, resulting in environmental concerns with disposal. CS used in this work was brought from Sterlite Industries Ltd (SIL), Tuticorin, Tamil Nadu, India. Currently, about 2600 tons of CS 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 .Copper Slag is glassy granular in nature with high specific gravity . Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. The presence of silicain slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used in normal concreting operations. Copper slag can be used as a replacement for fine aggregates in order to obtain a concrete with good strength and durability requirements.

Fig 1.Copper Slag

1.2.1Properties of copper slag

Copper slag (CS), the glassy material, produced during matte smelting .

- Copper conversion was previously considered waste and disposed as landfill. It has been estimated that for every ton of copper production about 2.2-3 tons of slag are generated. Copper slag, a copper production residue, shows in its chemical composition high

- Contents of aluminum, silica and iron oxides, similar to that of cement. Additionally, its hardness and gradation seems to indicate its suitability for use as alternative aggregate for applications in construction products.

- Aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix.

- Slag containing < 0.8% copper are either discarded as waste or sold cheaply.

- Mineralogical characterization and environmental classification of copper slag is presented. Copper slag is similar to sand in grading and its hard, non-absorptive, non-reactive

- Properties make it an ideal fine filler material for concrete after it is suitably washed to remove all impurities. Even though Waste Copper Slag produces no dust, has low crystalline silica (less than0.1%).

- Making it an environmentally friendly product, its usage was not explored to its full potential due to the conservative nature of the industry. Slag was used in Pavement Quality Concrete (PQC) as well as in Dry Lean Concrete (DLC) mixes and its influence on workability, compressive strength, and flexural strength was determined.

Physical Properties of Copper Slag

Physical Properties	Copper Slag
Particle Shape	Irregular
Appearance	Black & glassy
Type	Air cooled
Specific Gravity	3.91
Percentage of Voids	43.20%
Bulk Density	2.08g/cc
Fineness Modulus of Copper Slag	3.47
Angle of Internal Friction	51°20’

Table no. -1 : Physical Properties of Copper Slag

Chemical Properties of Copper Slag

S.No	Chemical Component	% Of Chemical Component
1	SiO_2	25.84
2	Fe_2O	68.29
3	Al_2O_3	0.22
4	CaO	0.15
5	Na_2O	0.58
6	K_2O	0.23
7	LoI	6.59
8	Mn_2O_3	0.22
9	TiO_2	0.41
10	SO_3	0.11
11	CuO	1.20
12	Sulphide Sulphur	0.25
13	Insoluble Residue	14.88
14	Chloride	0.018

Table no. 2 : Chemical Properties of Copper Slag

1.3Cement

Fig-2 Cement

Cements are adhesive materials which have the ability of bonding particles of solid matter into a compact whole . This broad definition encompasses a wide variety of adhesive materials. However, for engineering purposes it is restricted to calcareous cements that contain compounds of lime as their main principal constituent. The main raw materials used in producing Portland cement are the oxides: lime (CaO), produced by heating calcium carbonate; silica (SiO_2), found in natural rocks and minerals; alumina (Al_2O_3), found in clay minerals; and ferric oxide (Fe_2O_3), found in clays. Cement as a binder is a vital element in concrete and the quality of concrete depends on the cement or binder, the aggregate, the mix design and the handling involved in making, placing and subsequent curing. The performance of cement used in concrete is influenced by its chemical composition.

The principle raw materials used in the manufacture of cement are:- Argillaceous or silicates of alumina in the form of clays and shale's. Calcareous or calcium carbonate, in the form of lime stone, chalk and marl which is a mixture of clay and calcium carbonate.

The ingredients are mixed in the proportion of about two parts of calcareous materials to one part of argillaceous materials and then crushed and ground in ball mills in a dry state or mixed in wet state. The dry powder or the wet slurry is then burnt in a rotary kiln at a temperature between 1400 degree C to 1500 degree C. the clinker obtained from the kiln is first cooled and then passed on to ball mills where gypsum is added and it is ground to the requisite fineness according to the class of product.

1.4 - Comparison Between Chemical Composition of Copper Slag and Cement

Compounds	Cement (%)	Copper slag (%)
CaO	63-68	2-9
SiO_2	19-24	25-35
Al_2O_3	4-7	2-9
Fe_2O_3	1-4	45-55
MgO	0.5-3.5	1-5
K_2O	0.2-0.8	1-5
Mn_2O_3	0.05	-
CI	0.001	0.0
TiO_2	0.25	0-2%

Table 3- Comparison between Chemical Composition of Cement and Copper Slag

Chapter 2: Literature review

1. Jag meet Singh et al. (2015)[3] - This paper investigated the effect of copper slag as partial replacement of cement on the compressive strength of concrete .The reduction in compressive strength is minor up to 10% of CS but beyond 10% of CS, there is significant reduction in compressive strength due to the increase in free water content in mixes. The optimum content of copper slag as replacement of cement is recommended as 10%.

2. Binaya Patnaik et al. (2015)[2] - An experiment was conducted to investigate the strength and durability properties of concrete having copper slag as a partial replacement of sand (fine aggregate) . Two different types of Concrete Grade (M20 & M30) were used with different proportions of copper slag replacement (0 to 50%) in the concrete. Strength & Durability properties such as Compressive Strength, Flexural Strength were evaluated for both mixes of concrete. Test results shows that the strength properties of concrete has improved having copper slag as a partial replacement of Sand (up to 40%) in concrete however in terms of durability the concrete found to be low resistant to acid attack and higher resistance against Sulphate attack.

3. T.Poovizhi et al. (2015)[1] - This paper present the optimization of partial replacement of natural sand and cement by copper slag. Concrete mixes of M25 grade were evaluated for compressive strength, flexural strength and split tensile strength. Natural sand was replaced with copper slag by five proportions (ie 10%, 20%, 30%, 40%,50%) and cement was replaced with copper slag by four proportions (ie 5%, 10%, 15%, 20%). Addition up to 40% of copper slag as sand, and 15% of copper slag as cement yielded comparable strength with that of the control mix.

4. M. V. PATIL (2015)[5] -This research work, M30 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%, to100 % in concrete. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate, and up to 80% replacement ,concrete gain more strength than normal concrete strength.. It is observed that up to 30% replacement of natural sand by copper slag, the flexural strength of concrete is increased by 14%. And all percentage replacement of fine aggregate by copper slag the flexural strength of concrete is more than normal mix.

5. R R Chavan et. al. (2013)[9] - This paper reports on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. For this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag, and up to 75% replacement, concrete gain more strength than control mix concrete strength.

6. Amit S. Kharade et al. (2013)[10] - This paper presents the results of an experimental investigation carried out to evaluate the mechanical properties of concrete mixtures in which fine aggregate (sand) was replaced with Copper Slag. The fine aggregates (sand) was replaced with percentages 0% (for the control mixture), 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 100% of Copper Slag by weight. Tests were performed for properties of fresh concrete and Hardened Concrete. Compressive strength and Flexural strength were determined at 7, 28 and 56days. The results indicate that workability increases with increase in Copper Slag percentage. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of up to 80% Copper slag as replacement of fine aggregate (sand), and can be effectively used in structural concrete.

7. M. Najimi et al. (2011)[11] - In this paper the performance of copper slag contained concrete in sulfate solution is investigated. In this the concretes made by replacing 0%, 5%, 10% and 15% of cement with copper slag waste. The copper slag contained concretes showed better compressive strength performance in sulfate comparing with the control concrete specimens. Although the strength of copper slag contained concretes observed to be lower than control concerts in normal condition, they could develop their strength up to or even more than.

8. D.Brindha et al. (2010)[12] - This paper presents the results of an experimental study on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement. For this research work , M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%, 20%, 40%, and 60%, cement of 0%, 5%, 15%. The results of compressive have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions and 15% of cement.

9. C.H. Srinivas and S. M Muranal (2010)[14] - This paper presents the results of an experimental study on various durability tests on concrete containing copper slag as partial replacement of sand. In this report, M30 grade of concrete was designed and tests were conducted with different percentage of copper slag as fine aggregate in concrete. The result shows maximum compressive strength of concrete increases up to 8.63 % for 20 % percentage replacement of fine aggregate, but up to 40 % percentage of copper slag can be replaced which is greater than the target strength.

10. Wei Wu et al. (2010)[13] - This study investigated the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate and concluded that less than 40% copper slag as sand substitution can achieve a high strength concrete that comparable or better to the control mix, beyond which however its behaviors decreased significantly.

2.1 Objectives

1. To determine the workability of concrete at different replacement of fine aggregate by copper slag.
2. To determine the compressive, flexural and split tensile strength of concrete at different replacement of fine aggregate with copper slag.
3. To determine the durability of concrete at different replacement of fine aggregate with copper slag.

Chapter 3: Experimental Programme

3.1 General

The aim of this experimental program is to compare the behavior of copper slag in use as a supplementary material when subjected to different tests. All the tests carried out on concrete are mentioned here in this chapter followed by a brief description about mix design &aggregates .

3.2 Material used

3.2.1 Cement

Cement is a fine, grey powder. It is mixed with water and sand, gravel and crushed stone to generate concrete. Cement and water form a paste that binds the other materials together as concrete hardens .

Compounds	Cement (%)
CaO	63-68
SiO2	19-24
Al2O3	4-7
Fe2O3	1-4
MgO	0.5-3.5
K2O	0.2-0.8
Mn_2O_3	0.05
CI	0.001
TiO_2	0.25

Table 4- Percentage of Different Compound in Cement

3.2.2 Fine Aggregates

Sand used was locally procured and was found to be conforming to Indian Standard specifications IS 383-1970. The sand was first sieved through 4.75 mm sieve to remove any particles larger than 4.75 mm and then was washed to remove the dust.

Sr. No.	**Characteristics**	**Value**
1	Specific gravity	2.46
2	Bulk density	1.4
3	Fineness modulus	2.56
4	Water absorption	0.85
5	Grading Zone (Based on percentage passing 0.60 mm)	Zone Ⅲ

Table 5– Properties of Fine Aggregates

Properties of fine aggregates used have been presented in following table .the aggregates were sieved through a set of sieves to obtain sieve analysis presented in table 4. The aggregates was found to belong to zone Ⅲ.

Sr. No.	Sieve size	Mass retained	Percentage Retained	Cumulative percentage retained	Percentage passing
1	4.75 mm	4.0 g	0.4	0.4	99.6
2	2.36 mm	75.0 g	7.50	7.90	92.1
3	1.18 mm	178.0 g	17.80	25.70	74.3
4	600 µ	220.0 g	22.0	47.70	52.3
5	300 µ	274.0 g	27.4	75.10	24.9
6	150 µ	246.5 g	24.65	99.75	0.25
7				$\sum$=256.55	

Table 6- Sieve Analysis of Fine Aggregates

Total weight taken = 1000 gm

Fineness Modulus of Sand = 2.56

3.2.3 Coarse Aggregate

Coarse aggregate can be defined as any material Retained on IS no. 4.75 . The crushed stone is generally used as a coarse aggregate .The size of work decides the maximum size of coarse aggregate. 10 mm aggregate was used for this work which was locally available. The aggregate was washed to remove dust and dirt and were dried to surface dry condition . The aggregate were tested as per IS : 383-1970. The results of various tests conducted on coarse aggregate are mentioned in table given below shows the sieve analysis.

Sr. No.	Sieve size	Mass retained	Percentage Retained	Cumulative percentage retained	Percentage passing
1	20 mm	0 g	0	0	100
2	10 mm	2156 g	83.9	83.87	16.13
3	4.75 mm	474 g	15.8	99.67	0.33
4	PAN	10 g	0.33	∑=183.54	

Table 7- Sieve Analysis of Coarse Aggregates

Total weight taken = 3 Kg

FM of Coarse aggregate = [183.54 + 500] / 100 = 6.83

3.2.4Water

Curing is a procedure that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. Water that is suitable for drinking should be used in concrete. Water from lakes and streams that contain marine life can also be used . No sampling is necessary when water is obtained from above mentioned source . If there is any suspicion that water may contain sewage, mine water or wastes from industrial plants or canneries , it should not be used until tests indicate them as satisfactory.

3.2.5Supplementary materials

Copper slag **-** Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial substitute of either aggregates and cement. It is a by product obtained during refining of copper. Production of concrete using copper slag (ground) in place of cement (partial replacement) gives strength. It has good pozzalonic properties.

Sr. No.	Sieve size	Mass retained	Percentage Retained	Cumulative percentage retained	Percentage passing
1	4.75 mm	0 g	0	0	0
2	2.36 mm	12.8 g	2.56	2.56	97.44
3	1.18 mm	433.4 g	86.68	89.24	10.76
4	600 µ	52.8 g	10.56	99.8	0.2
5	300 µ	0.6 g	0.12	99.92	0.08
6	150 µ	0.4 g	0.08	100	00
7				∑=391.52	

Table No.8- Sieve Analysis of Copper Slag

Total weight taken = 1000 gm

Fineness Modulus of copper slag = 2.91

3.3 Mixture Proportioning

- **Mix proportioning (M30) :**

Cement = 440kg/m^3

Coarse aggregate = 1071 kg/m^3

Fine Aggregate = 656 kg/m^3

W/C ratio= 0.45

- **M30 with partial replacement of sand by 10% of copper slag (C10) –**

Cement = 440 kg/m^3

Coarse aggregate = 1071 kg/m^3

Fine aggregate = 590.4 kg/m^3

Copper slag = 65.6kg/m^3

W/C ratio = 0.45

- **M30 with partial replacement of sand by 20% of copper slag (C20) –**

Cement = 440 kg/m^3

Coarse aggregate = 1071 kg/m^3

Fine aggregate = 524.8 kg/m^3

Copper slag =131.2 kg/m^3

W/C ratio = 0.45

- **M 30 with partial replacement of sand by 30% of copper slag (C30)–**

Cement = 440 kg/m^3 m3

Coarse aggregate = 1071 kg/m^3

Fine aggregate = 459.2 kg/m^3

Copper slag =196.8 kg/m^3

W/C ratio = 0.45

- **M 30 with partial replacement of sand by 40% of copper slag (C40) –**

Cement = 440 kg/m^3 m3

Coarse aggregate = 1071 kg/m^3

Fine aggregate =393.6 kg/m^3

Copper slag =262.4 kg/m^3

W/C ratio = 0.45

- **M 30 with partial replacement of sand by 50% of copper slag (C50) –**

Cement = 440 kg/m^3 m3

Coarse aggregate = 1071 kg/m^3

Fine aggregate =328 kg/m^3

Copper slag =328 kg/m^3

W/C ratio =0.45

Composition ↓	Mix Proportion					
	M30	C10	C20	C30	C40	C50
Cement kg/m^3	440	440	440	440	440	440
Coarse aggregate kg/m^3	1071	1071	1071	1071	1071	1071
Fine Aggregate kg/m^3	656	590.4	524.8	459.2	393.6	328
Copper slag kg/m^3	0	65.6	131.2	196.8	262.4	328
W/C ratio	0.45	0.45	0.45	0.45	0.45	0.45

Table No. 9 - Mix Proportioning

3.4 Batching, Mixing and Casting of Specimens

Cubical moulds of size 150mm x 150mm x 150mm were used to prepare the concrete specimens for the determination of compressive strength of concrete. Care was taken during casting . The moulds were placed upon the compaction table for proper compaction. All the specimens were prepared in accordance with Indian Standard Specifications IS: 516-1959. All the moulds were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage of slurry. A careful procedure was adopted in the batching, mixing and casting operations. The coarse aggregates and fine aggregates were weighed first with an accuracy of 0.5 grams. The concrete mixture was prepared by the concrete mixer. It was cleaned first by water and dried then , to ensure any impurities were not adhering to its surface form prior use . Dry fine aggregates are introduced first in the mixer & are thoroughly mixed. After that coarse aggregates are added to it. Sand is replaced by copper slag in different proportions. Then water was added carefully so that no water was lost during mixing. A total of 24 cubes were prepared which consists of cubes incorporated with copper slag. Proposed checks were made at 7, 14 and 28 days . The compaction machine was stopped as soon as the cement slurry appeared on the top surface of the mould. All the specimens were left in the steel mould for the first 24 hours at ambient condition. After that they were de-moulded with care upon requirement of aging so that no edges were broken and were placed in the curing tank at the room temperature for curing. The room temperature for curing was 27 ± 20 (IS: 10262-1982).

3.5 Tests Conducted

3.5.1 Compression test (IS: 516 – 1959)

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load a without shock and increased continuously at a rate of approximately 140 kg/cm2/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The permissible error shall be not greater than ± 2 percent of the maximum load. The testing machine shall be equipped with two steel bearing platens with hardened faces. One of the platens (preferably the one 58 that normally will bear on the upper surface of the specimen) shall be fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the platen. The other compression platen shall be plain rigid bearing block. The bearing faces of both platens shall be at least as large as, and preferably larger than the nominal size of the specimen to which the load is applied. The bearing surface of the platens, when new, shall not depart from a plane by more than 0.01 mm at any point, and they shall be maintained with a permissible variation limit of 0.02 mm. The movable portion of the spherically seated compression platen shall be held on the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest kg per sq cm. Average of three values shall be taken as the representative of the batch provided the individual variation is not more than ± 15 percent of the average. Otherwise repeat tests shall be made.

3.5.2 Slump test

The concrete slump test is an empirical test that measures workability of fresh concrete. The test measures consistency of concrete in that specific batch. It is performed to check consistency of freshly made concrete. Consistency refers to the ease with which concrete flows. It is used to indicate degree of wetness.

Work-ability is the ease with which the given concrete mix can be mixed together, transported to the application place and can be placed/applied/compacted their within the initial setting time of cement. This property depends largely on the amount of water added i.e. water cement ratio of the concrete mix and kind of aggregates used. Generally work-ability increases with the addition of the water, however it results in the less strength of concrete. So we have to settle for an intermediate value of water cement ratio at which it may have the sufficient work-ability as well as sufficient strength.

3.5.3 Compaction factor test

This is defined as the ease with which concrete can be compacted fully without Segregating and bleeding. It can also be defined as the amount of internal work required to fully compact the concrete to optimum density.

The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete. To test the workably of freshly concrete, compaction factor test is carried out. This test works on the principal of determining the degree of compaction achieved by standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction factor is the ratio of weight partially compacted concrete to the weight of fully compacted concrete.

3.5.4 Split tensile test

A compression machine of sufficient capacity & reliability shall be used for the tests an should be capable of applying the load without shock and accelerated continuously at a nominal rate within the range 1.2 N/(mm^2/min) to 2.4 N/ (mm^2/min) should be used. It shall comply with the requirements given in IS 516 as far as applicable except that the bearing faces of both platens shall provide a minimum loading area of 12 mm multiplied by the length of the cylinder, as the case may be so that the load is applied over the entire length of the specimen. If necessary, a supplementary bearing bar or plate of machined steel may be used. A steel loading plate having minimum hardness value, when tested in accordance with IS 1500 shall be used between the platen of the machine and the hardboard packing strips. The piece shall not be shorter than the specimen.. Tests shall be made at the required ages of the test specimens, that is at 7 and 28 days. The ages shall be calculated from the time of the casting of the moulds.

Unless other conditions are required for specific laboratory investigation specimen shall be tested immediately on removal from the water whilst they are still wet . Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces if any. Central lines shall be drawn on the two opposite faces of the cube using any suitable procedure and a device that will ensure that they are in the same axial plane. The mass and dimensions of the specimen shall be noted before testing. The sides of the specimen, lying in the plane of the pre-marked lines, shall be measured near the ends and the middle of the specimen and the average taken to the nearest 0.2 mm. The length of the specimen shall be taken to the nearest 0.2 mm by averaging the two lengths measured in the plane containing the pre-marked lines. Before commencement of testing the bearing surfaces of the testing machine and of the loading strips have to be wiped clean and the test specimen shall be placed in the centering jig with packing strip and loading pieces carefully positioned along the top and bottom of the plane of loading of the specimen. The jig shall then be placed in the machine so as to locate the specimen centrally. For cylindrical specimen it shall be ensured that the upper platen is parallel with the lower platen. On manually controlled machines as failure is approached the loading rate decreases at this stage the controls shall be operated to follow possible the specified loading rate as far as. The maximum load applied shall then be recorded. The appearance of concrete and any unusual features in the pattern of failure are to also be noted.

$$fct = 2P/ \pi ld \text{ ; where}$$

P = maximum load in Newton applied to the noted before testing.

I = length of the specimen as shown in (in mm), and

d = cross sectional dimension of the specimen (in mm).

3.5.5 Flexural Bending Test (IS: 516 – 1959)

The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate such that the extreme fiber stress increases at approximately 7 kg/cm2/min, that is, at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens. The center-point loading method shall be used in the laboratory. The apparatus shall incorporate the following requirements. The load shall be applied at the center point of the span, normal to the loaded surface of the beam, employing bearing blocks designed to ensure that forces applied to the beam will be vertical only and applied without eccentricity. The direction of the reactions shall be parallel to the direction of the applied load at all times during the test. The load shall be applied at a uniform rate and in such a manner as to avoid shock. The edges of the load-applying block and of the supports shall not depart from a plane by more than .002 in. (0.051 mm).

Calculation — The flexural strength of the specimen shall be expressed as the modulus of rupture fb,

$$f_b = 3*p*l/2b*d^2$$

p = load applied on beam

b= effective width of beam

d=effective depth of beam

l=length of the specimen

3.5.6 Durability tests

A long service life is considered synonymous with durability. Since durability under one set of conditions does not necessarily mean durability under another, it is customary to include a general reference to the environment when defining durability. According to ACI Committee 201, durability of Portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration; that is, durable concrete will retain its original form, quality, and serviceability when exposed to its environment. No material is inherently durable; as a result of environmental interactions the microstructure and, consequently, the properties of materials change with time. A material is assumed to reach the end of service life when its properties under given conditions of use have deteriorated to an extent that the continuing use of the material is ruled either unsafe or uneconomical.

Sulphate Attack-

Most soils contain some Sulphate in the form of calcium, sodium, potassium and magnesium. They occur in soil or ground water. Because of solubility of calcium sulphate is low, ground waters contain more of other sulphates and less of calcium sulphate. Ammonium sulphate is frequently present in agricultural soil and water from the use of fertilizers or from sewage and industrial effluents. Decay of organic matters in marshy land, shallow lakes often leads to the formation of H_2S, in which can be transformed in to sulphuric acid by bacterial action. Water used in concrete cooling towers can also be a potential source of sulphate attack on concrete. Therefore sulphate attack is a common occurrence in natural or industrial situations. Solid sulphates do not attack the concrete severely but when the chemicals are in solution, they find entry into porous concrete and react with the hydrated cement products. Of all the sulphates magnesium sulphate causes maximum damage to concrete. A Characteristic whitish appearance is the indication of sulphate attack. The term sulphate attack denote an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates. In the hardened concrete, calcium sulphoaluminate, forming within the framework of hydrated cement paste. Because of the increase in volume of the solid phase which can go up to 227 percent, a gradual disintegration of concrete takes place. Another factor influencing the rate of attack is the speed in which the sulphate gone into the reaction is replenished. For this it can be seen that when the concrete is subjected to the pressure of sulphate bearing water on one side the rate of attack is highest.

Chloride Attack-

The free chloride content in concrete has been found to be one of the major causes for corrosion of steel and it is one of the critical issues being dealt today by civil engineers globally. In fact, in the marine environment, a large number of concrete bridges, dams, and other mega structures have suffered from safety and serviceability problems due to the deterioration of concrete, can be directly attributed to the chloride penetration into the concrete. It is also understandable from the reported literature that, most of the concrete structures failed in the past are not necessarily due to inadequate design but due to failure of concrete to protect reinforcing steel from aggressive elements like chlorides. The chlorides that are penetrated through concrete pores depend upon the pore structure of concrete and the improvement in pore structure is mainly achieved by the use of mineral admixtures.. In addition, these admixtures reduce the mobility of chloride ions by changing the mineralogy of the cement hydrates. The chloride permeability depends on several factors like chemical composition of cement, water-to cement ratio, types and amounts of mineral admixtures etc. Therefore, in order to improve the resistance of concrete to chloride penetration, the mix proportions of concrete should be carefully selected considering the above parameters. Many studies have been carried out on the use of admixtures, however search for efficient alternative admixture is still continuing.

Curing in acid solution-

Curing is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. 6 cubes of five different mixes of M30 Grade namely referral

M30, C10, C20, C30, C40, C50 by replacing (0%, 10%, 20%, 30%, 40%, 50%) of sand bycopper slag. . The cubes were demoulded after 1 day of casting and then kept in respective solutions of 5% H_2SO_4 for curing, at room temperature with a normal humidity. The cubes are taken out from curing after 30 days .The surface of specimen was cleaned and weights were measured. The mass loss and strength of specimen due to acid attack will be determined in 30 days.

Chapter 4: Results and discussions

In this chapter, Compressive strength, slump of M30 concrete mix incorporating copper slag in varying percentages is discussed. All the tests conducted were in accordance with the methods described in chapter three. Results were compared and checked for compressive strength of concrete.

4.1 Compressive Strength test

Concrete was prepared under moderate exposure condition and quality control was good. It was poured into cubical moulds and placed on vibrating table to minimize air entrapped which would otherwise affect the compressive strength. After 24 hrs the moulds were removed and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days and 28 days compressive strength. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached.

	Compressive strength in N/mm^2 at 7 days	Compressive strength in N/mm^2 at 28 days
M30	19.16	31
C10	23.72	37.90
C20	25.92	42.88
C30	27.20	44.16
C40	28.48	45
C50	26.92	43.72

Table No10 - Compressive Strength at 7 & 28 Days

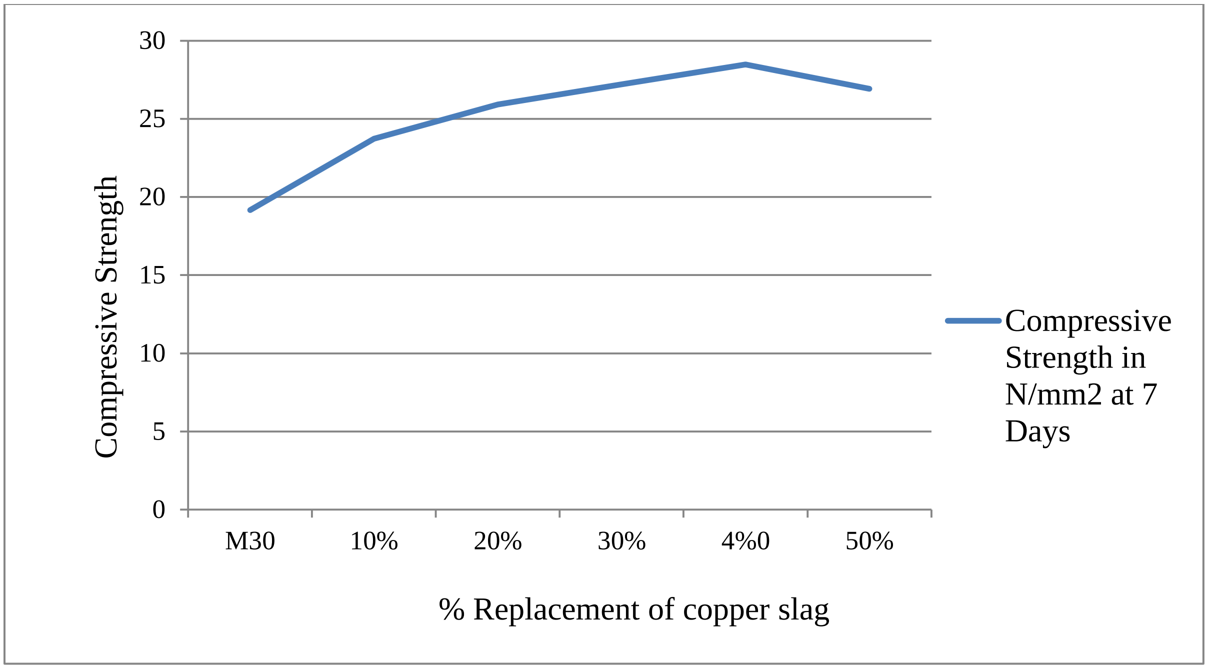

Fig -3 Graph For Compressive Strength at 7 Days

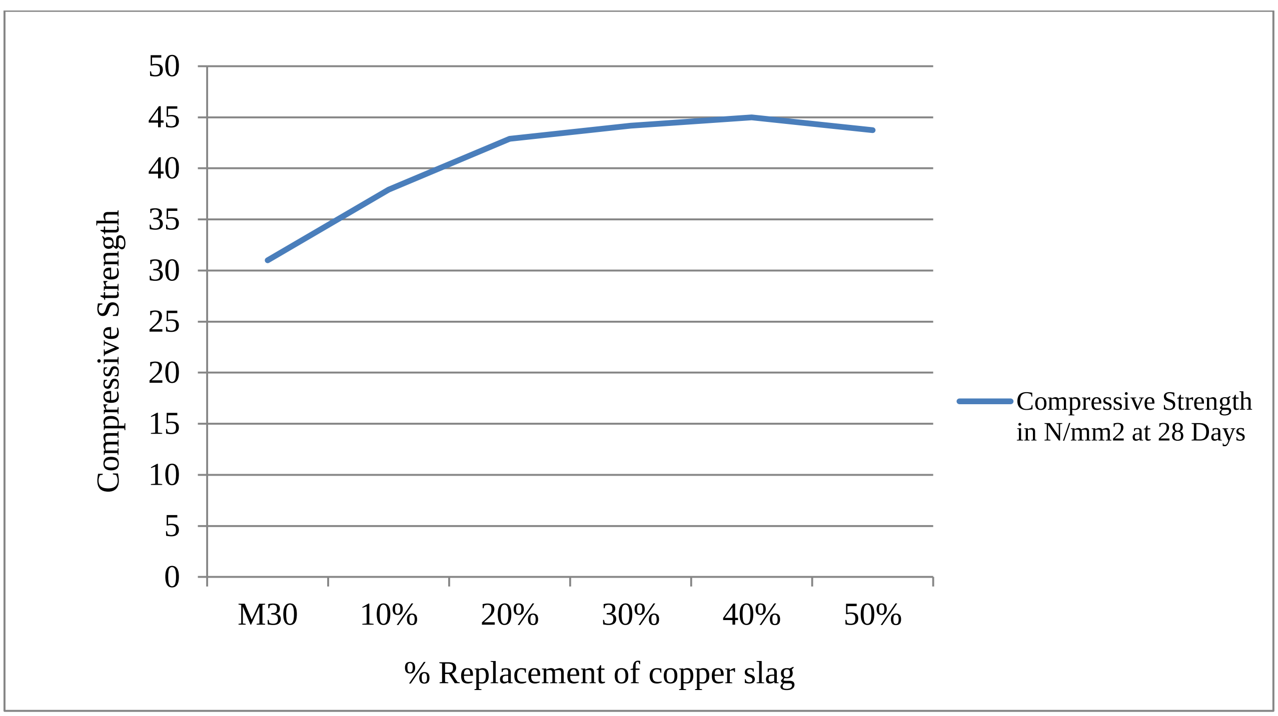

Fig -4 Graph for Compressive Strength at 28 Days

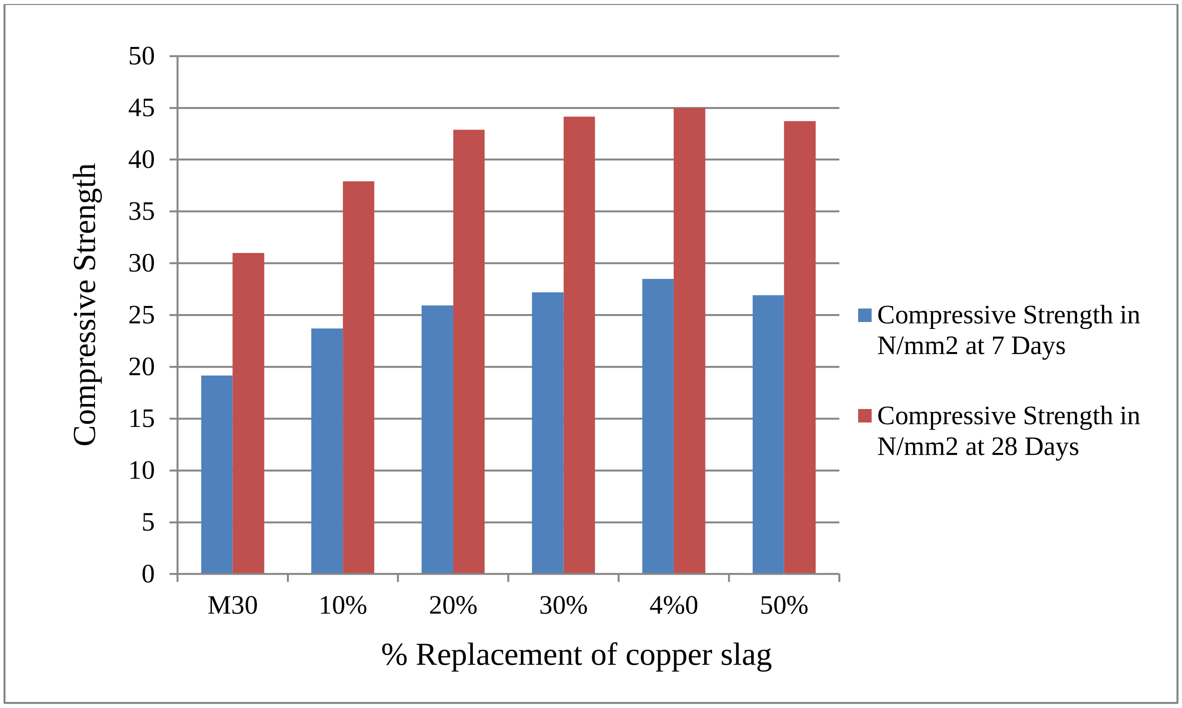

Fig -5 Bar Chart for Compressive Strength

- Fig 5 showing the results of compression test, after completing the compression test i concluded that the Optimum content of copper slag is 40% by weight replacement of copper slag with sand in M30 mix. Maximum Compressive strength of concrete increased by 32.72% at 40% replacement of fine aggregate by copper slag at 7 days , and 31.11% at 40% replacement of fine aggregate by copper slag at 28 days.

Fig. 6(a) : Compressive Strength Test

Fig. 6(b) : Compressive Strength Test Reading

4.2 Slump test

In order to study slump of M30 mix containing different proportion of copper slag were prepared and checked for workability.

Workability	Slump (mm)
Very low	0-25
Low	25-50
High	50-100
Very high	100-175

Table No 11 - Standard Values of Slump

Mix	Slump (mm)
M30	40
C10	47
C20	55
C30	62
C40	75
C50	87

Table No 12 - Slump Values of Different Mix

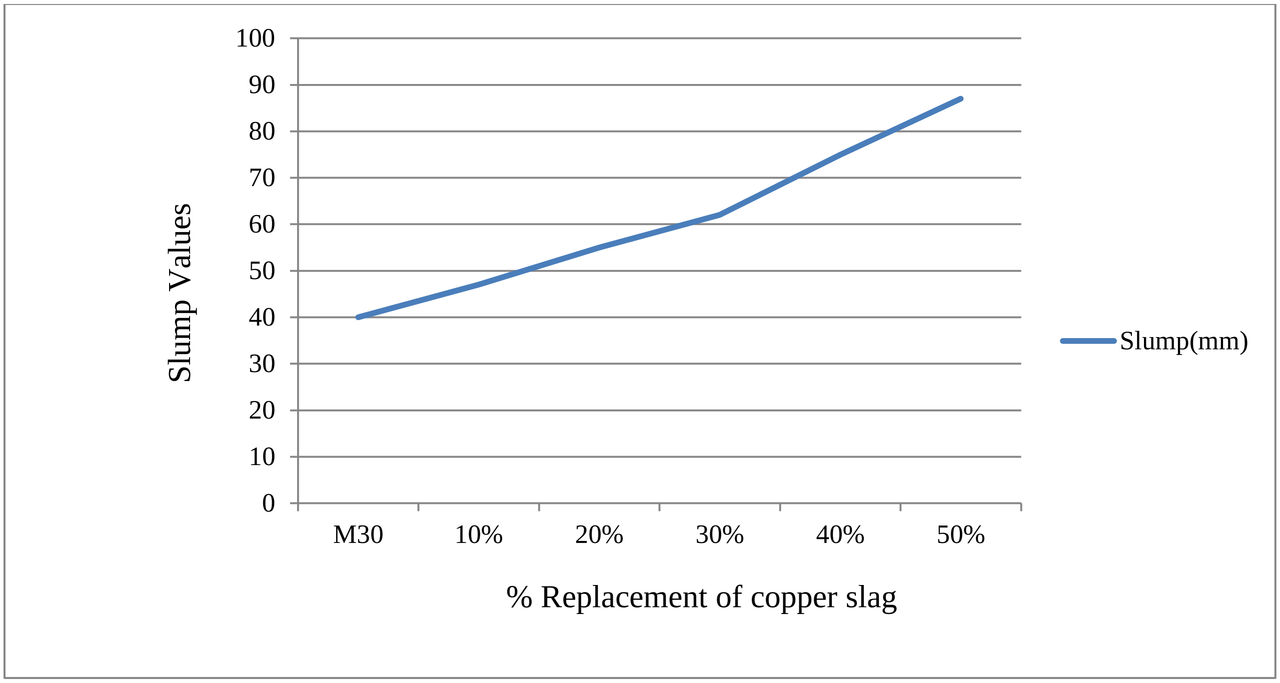

Fig7- Graph for Slump Values

Fig 8(a) - Slump Test

Fig 8 (b) - Slump Test at 30% Replacement

Fig 8 (c)- Slump Test at 40%Replacement

- Above fig 10 shows the decrement in the height of concrete (called as slump) for different proportions of copper slag in M30 grade of concrete and from fig 6 and table 12, it is observed that, the workability of concrete increases for all percentage replacements done in design mix.

4.3 Compaction factor test

In order to find the compaction factor of M30 mix containing different proportion of copper slag were prepared and checked for workability.

Mix	Compaction Factor
M30	0.70
C10	0.74
C20	0.79
C30	0.85
C40	0.87
C50	0.91

Table 13 - Compaction Factor for Different Mixes

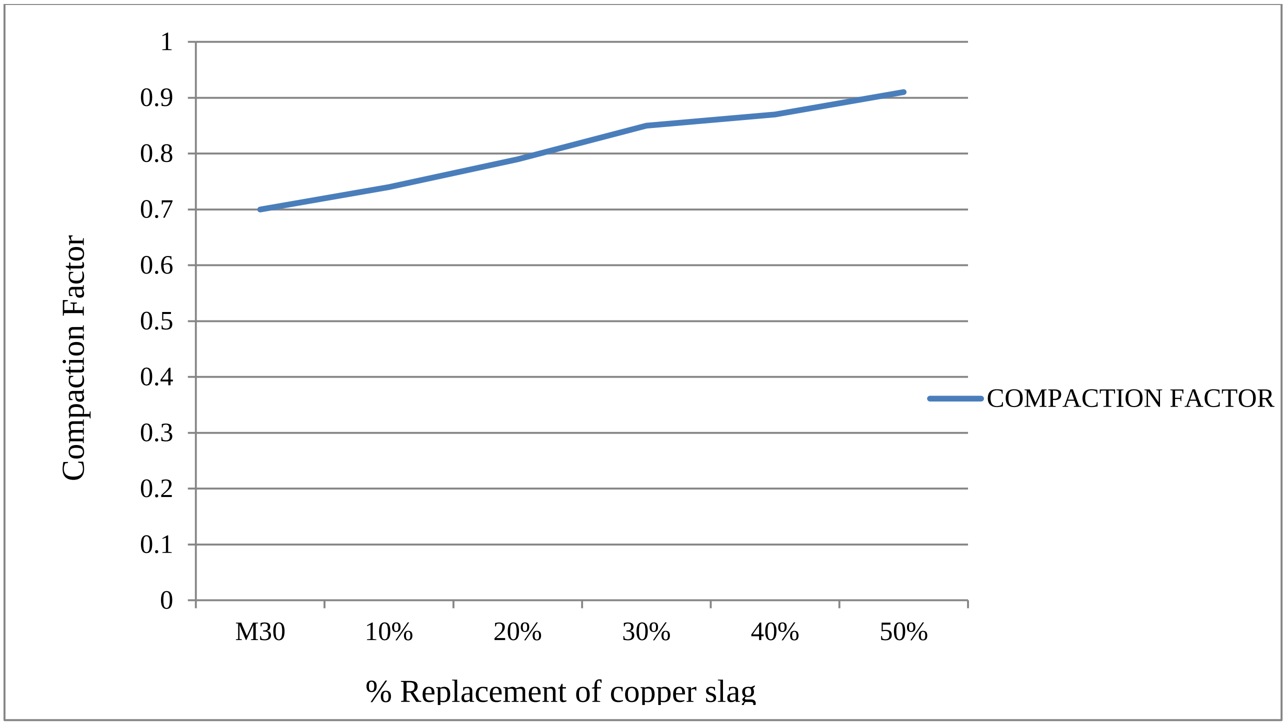

Fig9- Graph for Compaction Factor

Fig shows the test procedure of compaction test of the concrete and from fig and table, it is observed that, the compaction factor of concrete increases for all percentage replacements done in design mix.

4.4 Flexural strength

In order to study the effect on flexural strength, the beams containing different proportion of copper slag were prepared and kept for curing for 28 days. The test was conducted on U.T.M as per I.S.516-1959.

Results-

Mix	Flexure strength (N/mm^2) at 28 days			Average flexure strength (N/mm^2)
M30	4.07	4.12	4.11	4.10
C10	4.19	4.36	4.20	4.25
C20	4.37	4.39	4.44	4.40
C30	4.6	4.55	4.56	4.57
C40	4.59	4.57	4.64	4.60
C50	4.44	4.51	4.31	4.42

Table 14 – Flexure Strength Test

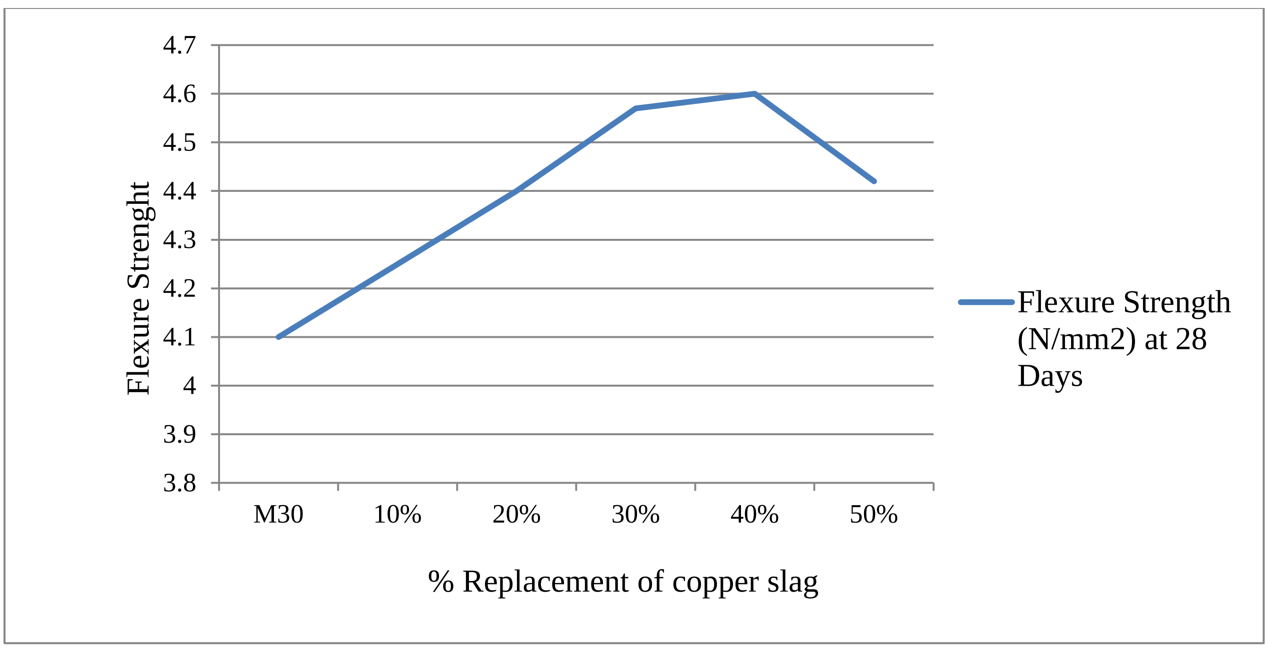

Fig 10 – Graph for Flexure Strength

4.5 Split tensile test

Concrete mixed with copper slag was prepared under moderate exposure condition and quality control was good. It was poured into cylindrical mould and was hand compacted by tamping rod to ensure homogenous distribution of copper slag to minimize air entrapped which would otherwise affect the compressive strength. After 24 hrs the moulds were removed and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days and 28 days for split tensile test. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached.

Fig 11- Split Tensile Testing

Mix	Avg. Split tensile strength (N/mm^2) at 7 days	Avg. Split tensile strength (N/mm^2) at 28 days
M30	2.67	3.22
C10	2.75	3.27
C20	3.01	3.44
C30	3.19	3.92
C40	3.44	4.01
C50	3.08	3.78

Table 15 – Split Tensile Strength Values

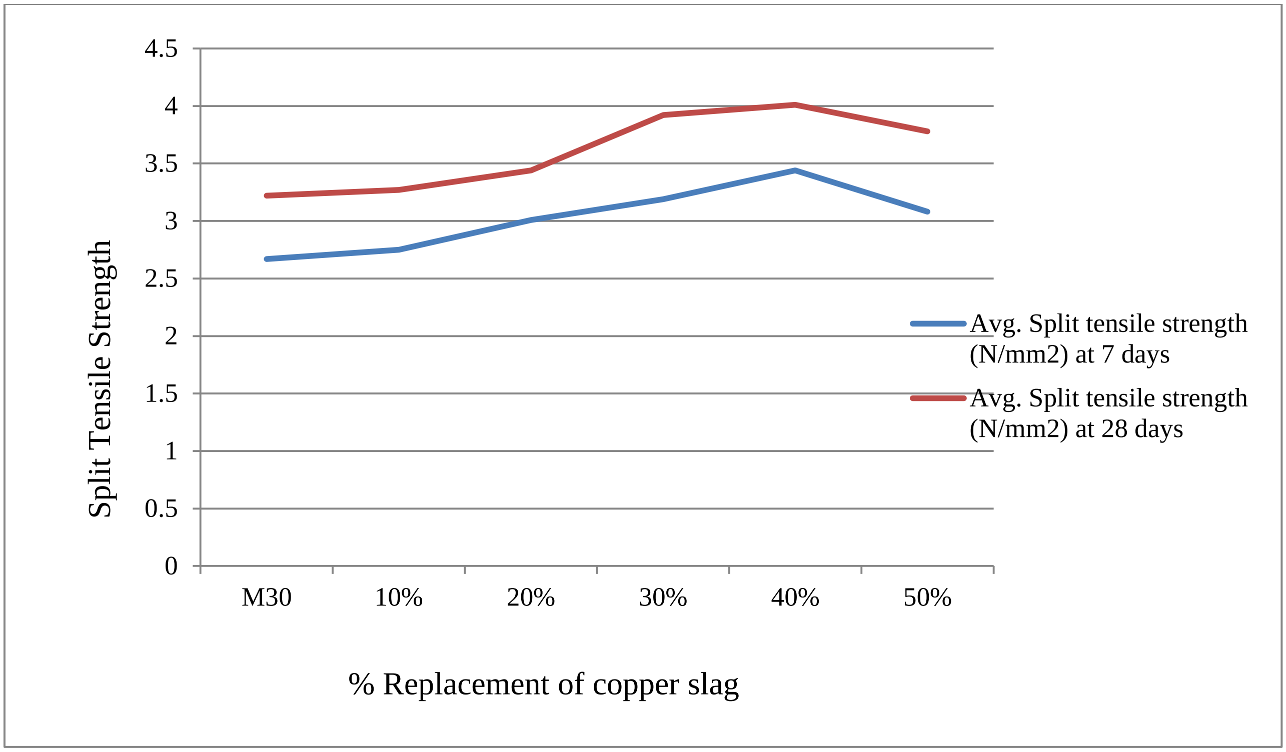

Fig 12 – Graph for Split Tensile Strength at 7 and 28 days

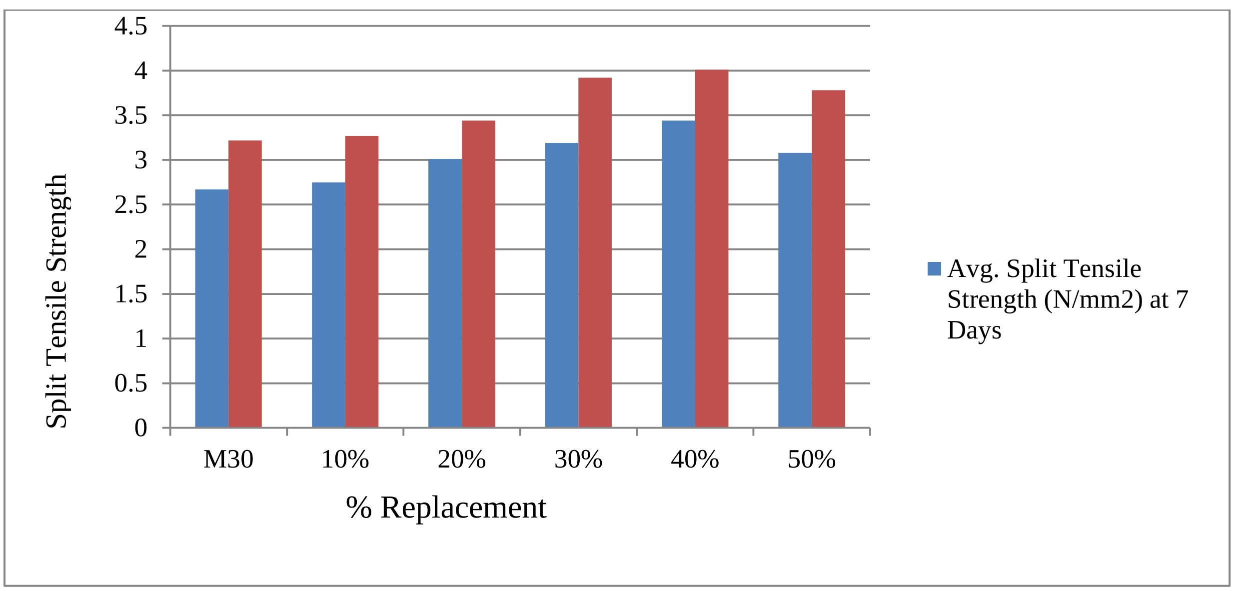

Fig 13 – Bar Chart for Split Tensile Strength at 7 and 28 days

- Fig 16 showing the process of split tensile test, maximum split tensile strength of concrete increased by 22.38% and 19.70% at 40% replacement of fine aggregate by copper slag at 7 and 28 days.

4.6 Durability Analysis

Initially the constituent materials were weighed and dry mixing was carried out for cement, sand and coarse aggregate and ultra fine slag. This was thoroughly mixed manually to get uniform colour of mix. The mixing duration was 2-5 minutes and then the water was added as per the mix proportion. The mixing was carried out for 3-5 minutes duration. Then the mix poured in to the cube moulds of size 100 x 100x 100 mm and then compacted by placing on compaction table. In this study we prepared 6 sets of six different mixes of M30 Grade namely referral as M30, C10, C20, C30, C40, C50 by replacing (0%, 10%, 20%, 30%, 40%, 50%) of sand by copper slag. The cubes were de-moulded after 1 day of casting and then six cubes kept in respective solutions of, 5 % H_2SO_4 & in referral solution of 100 % H_2O and six other cube in 5% NaCl solution for curing, at room temperature with a normal humidity. After 30 days the specimens were taken out from respective solution. The surface of specimen was cleaned and weights were measured. The mass loss and strength of specimen due to acid attack will be determined.

Fig14 (a) – Chloride Attack Test

Fig14 (b)– Sulphate Attack Test

Fig15 – Durability Test Samples After 28 days Curing

Mix	Compressive strength (mpa)	Reduction in compressive strength in percentage	Weight of cube (kg)	weight of cube (kg) after curing in H_2SO_4
M30	28.26	8.81%	2.05	2.20
C10	34.92	7.85%	2.10	2.16
C20	40.45	5.65%	2.15	2.27
C30	42.66	3.38%	2.20	2.32
C40	43.69	2.90%	2.22	2.24
C50	42.89	1.89%	2.25	2.29

Table 16 - Durability Test for Sulphate Attack

Mix	Compressive strength (mpa)	Reduction in compressive strength in percentage	Weight of cube (kg)	weight of cube (kg) after curing in NaCl
M30	25.11	19%	2.00	2.30
C10	31.94	15.7%	2.08	2.22
C20	37.34	12.9%	2.12	2.24
C30	39.65	10.2%	2.17	2.25
C40	41.18	8.5%	2.20	2.29
C50	40.26	7.9%	2.25	2.30

Table 18 - Durability Test for Chloride Attack

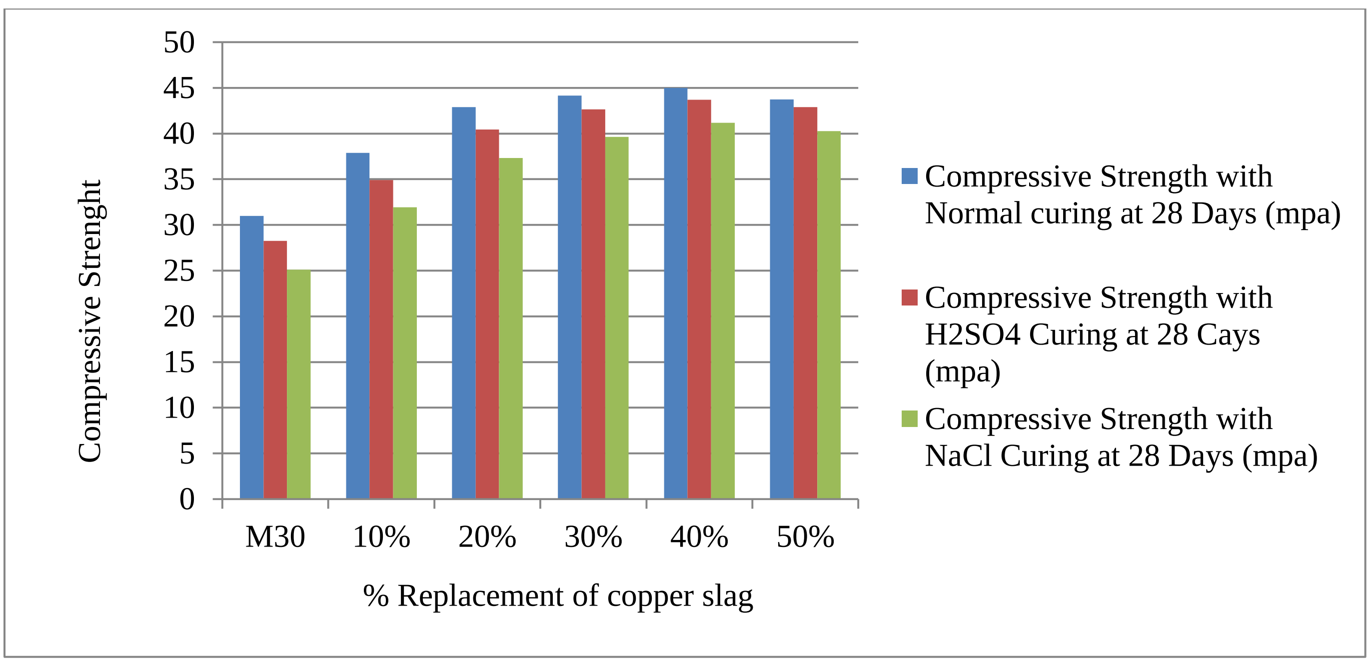

Fig 16 - Bar Chart for Compressive Strength in Different Type Curing

- From table 17 and 18 we can conclude that increment in weight and decrement in compressive strength of cubes is more in sulphate attack than chloride attack , it is just because Cl^- ion has higher mobility due to its smaller size.

Chapter 5 : Conclusions

In the present scenario, the use of copper slag is increasing day by day both in research as well as in the construction companies. Since, the physical and mechanical properties of copper slag have maximum advantages. Therefore, replacement or reuse of it can be done in several manners. Keeping in mind about the rapid urbanization in the country, the safe disposal and judicial resource management is the important issue which can be balanced by the reuse of slag. The well defined scope in the future studies of copper slag is that it can also be replaced by cement and fine aggregate very easily and has an application in concrete as a admixture. Maximum compressive, tensile and flexural strength is obtained when copper slag is replaced with fine aggregate up to 40%. With such important properties of copper slag, further research is advised to analyze the scope of replacement extensively.

- The replacement of fine aggregate using copper slag in concrete increases the density of concrete thereby increases the self weight of the concrete.

- Form the results of compressive strength, split tensile strength and flexural strength, the concrete shown higher value at 40% replacement of fine aggregate using copper slag. So it is recommended that 40% of fine aggregate can be replaced by copper slag.

- The workability of concrete increased with the increase in copper slag content of fine aggregate replacements at same water-cement ratio.

- According to literature review the workability should be between high to very high but in our experimental work we found workability between low to high because in our laboratory the cement available was prehydrated and there was some amount of lumps in cement and the another reason was that the coarse aggregate we used were angular in shape so that the friction increased and we got less workability.

- Compressive strength and Flexural strength was increased due to the high toughness property of Copper slag.

- As the percentage of Copper slag in design mix as replacement increases, the density of harden concrete observed to be increased.

- Acid resistance test showed that the concrete containing copper slag has a low resistance to H_2SO_4 and HCl solution than the control concrete

- Concrete with Copper slag as Partial replacement of Sand shows good resistance to sulphate attack.

- Form the results of compressive strength, split tensile strength and flexural strength, the concrete shown higher value at 40% replacement of fine aggregate using copper slag. So it is recommended that 40% of fine aggregate can be replaced by copper slag.

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APPENDIX 1

Mix Proportion designations

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates. For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water-cement ratio is usually expressed in mass

Procedure

1. Determine the mean target strength f_t from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.

   $f_t = f_{ck} + 1.65\ S$

   where S is the standard deviation obtained from the Table of approximate contents given after the design mix.
2. Obtain the water cement ratio for the desired mean target using the emperical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.
3. Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.
4. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.
5. Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
6. Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.
7. Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
8. From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p} \frac{f_a}{S_{fa}} \right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p} \frac{C_a}{S_{ca}} \right] \times \frac{1}{1000}$$

where V = absolute volume of concrete

= gross volume ($1m^3$) minus the volume of entrapped air

S_c = specific gravity of cement

W = Mass of water per cubic metre of concrete, kg

C = mass of cement per cubic metre of concrete, kg

p = ratio of fine aggregate to total aggregate by absolute volume

f_a, C_a = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and

S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively

9. Determine the concrete mix proportions for the first trial mix.
10. Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.