Available online at: http://www.ijmtst.com/vol3issue11.html
International Journal for Modern Trends in Science and Technology
ISSN: 2455-3778 :: Volume: 03, Issue No: 11, November 2017

Evaluating the Strength Properties of Concrete by Partial Replacement of Sand with Copper Slag

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To Cite this Article
Chittimemu Siva, Dr.D.Venkateswarlu and Divya Anusha Naidu, "Evaluating the Strength Properties of Concrete by Partial Replacement of Sand with Copper Slag", *International Journal for Modern Trends in Science and Technology*, Vol. 03, Issue 11, November, 2017, pp.-82-93.

ABSTRACT

Due to environmental concern and limited availability of resources it is desirable to hunt (Search) for a new source which not only replaces the limited but also matches the modern trends of construction. This study reports the potential use of granulated copper slag from sterlite industries as a Partial replacement for sand in concrete. The effect of replacing fine aggregate by copper slag on the compressive strength, split tensile strength and flexural strength of concrete are attempted in this work. The percentage replacement of sand by granulated copper slag were 0%,10%,20%,30%,40%,50%,60% and 70%. Required numbers of cubes, cylinders, beams were cast for grades of M30. Curing should be done for a period of 7, 28 days of hydration with partial replacement of sand by Copper slag. 7, 28days of curing has been done and the results have been compared to obtain the optimum replacement of copper slag with fine aggregate. The experimental investigation showed that percentage replacement of sand by copper slag shall be up to 60%.

Keywords- *Copper slag, physical & chemical properties, compressive strength, split tensile strength, flexural strength, etc.*

I. INTRODUCTION

1.1 General

Copper slag is an abrasive blasting grit made of granulated slag from metal smelting process (also called iron silicate).Copper slag is a by-product extracted during the copper smelting and refining process. Slag is usually a mixture of metal oxides and silicon dioxide. However, slag can contain metal sulphides and metal atoms in the elemental form. Copper slag is one of the materials that are considered as a waste, which could have a promising future in construction Industry as partial or full substitute of either cement or fine aggregates. Copper slag has also gained popularity in the building industry for use as a fill material. Copper slag can also be used as a building material, formed into blocks .Dumping or disposal of such huge quantities of slag cause environmental problems. During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization. For every ton of copper produced about 2.2 ton of slag is generated

The slag is a black glassy and granular in nature and its size range like sand.

Fig1.1:copper slag in black glassy

1.2 Purpose of Replacement of Natural resource in concrete

In concrete construction, sometimes the prime supply of fine mixture is of course watercourse sand that, possess a tangle of its non handiness flood and in rainy seasons furthermore as because of immense would like of housing industry. So as to resolve this downside, reliable supply and continuous provider of other material for these ingredients ought to be thought of and their use ought to be counselled. It is essential that this different materials are ought to be eco-friendly and cheaper value.

Copper slag could be a byproduct obtained throughout the matter smelting and purification of copper. To produce each ton of copper, some 2.0-3.0 tons copper slag is generated as a byproduct. Utilization of copper slag in applications like hydraulic cement substitution and or as aggregates has threefold of advantage of eliminating the prices of marketing, reducing the value of concrete and minimizing air waste product wastes issues. Consequently, conducting researches on the appliance of those environmental waste product within the concrete business is a few most vital movements towards proper development.

1.3 Objectives

- The main objective of my project is to carry out the following systems:
- To design and proportions for the concrete mix for M30 grade concrete. As per recommendation ofIS:10262:2007
- To check the variation of Compressive Strength results by replacing the fine aggregate with CS and plotting the corresponding graphs.
- To check the variation of Split Tensile Strength results by replacing the fine aggregate with CS and plotting the corresponding graphs.
- Finally Finding the Optimum Usage of Copper Slag in each case of replacement.

1.4 *Applications of copper slag*

- Utilization of Copper Slag as Fine Aggregate in Cement Concrete
- Use of waste plastics and copper slag for low cost bituminous roads
- Application of copper slag in geomagnetic archaeointensity research
- Use of waste plastics and copper slag (CS) for low cost bituminous roads
- A Study on the Application of Copper Slag s a Sand Substitute of Sand Compaction Pile
- Testing the accuracy of absolute intensity estimates of the ancient geomagnetic field using copper slag material
- Use of copper slag as construction material in bituminous pavements

1.5 Methodology of the thesis

In part-II, literature review of the previous works done by various researchers on copper slag concrete, replacement of cement and fine aggregate with copper slag has been discussed.

In part-III, information regarding the experiments carried out on the properties of cement copper slag, fine aggregate (river sand), coarse aggregate, water. Also information regarding the mix design for M25 grade for both conventional aggregate concrete and concrete made with copper slag was presented.

In part-IV, the test results pertaining to the strength properties of the copper slag concrete, prepared with replacement of fine aggregate and cement with copper slag in different proportions were presented, workability aspects and strength properties were also presented.

In part-V, total summary of the work done is presented and the general conclusions obtained based on the test results were discussed. Also future work is proposed as a continuation of this work

II. LITERATURE SURVEY

Antonio Arino et al (1999) indicated that **copper slag has the potential for application as**

a cementations material. Although it has successfully been used in ground form as a concrete mineral admixture in Canada, Europe, and Australia, the construction industry in the U.S. has been slow in adopting this slag. There is a considerable interest in the southwestern U.S. to use ground copper slag(GCS) as a partial substitute of Portland cement since custom smelters are capable of producing as much as half a million tons of copper slag per year. By evaluating its potential use in concrete, there is an opportunity for both the copper and construction industries to benefit from using this material. The compression-test results indicated that GCS concrete was stronger but more brittle than ordinary Portland cement concrete. As long as rapid strength gain is not a major design constraint, it was shown that use of GCS increased the strength significantly.

Arivalagan (2013) investigated **the effects of replacing fine aggregate by copper slag on the compressive strength of cubes, split tensile strength of cylinders and flexural strength of beams.** Copper slag is obtained as waste product from the sterlite industries. Investigations were carried out to explore the possibility of using copper slag as a replacement of sand in concrete mixtures. The test results of concrete were obtained by adding copper slag to sand in various percentages ranging from 0%, 20%., 40%, 60%, 80%, and 100%. All specimens were cured for 28 days before compression strength test, split tensile test and flexural strength. The highest compressive strength obtained was 35.11MPa for 40% replacement and the corresponding strength for control mix was 30MPa. The results of the research paper shown the possibility of using copper slag as fine aggregate in concrete. The results showed the effect of copper slag on RCC concrete elements has a considerable amount of increase in the compressive, split tensile, flexural strength characteristics and energy absorption characteristics. The addition of copper slag has improved the compressive strength, split tensile strength and flexural strength of concrete. While replacement of copper slag in concrete increases the density of concrete. The slump value of copper slag concrete lies between 90 to 120 mm. The flexural strength of the beam increased by 21% to 51% while replacement of copper slag. The uses of copper slag as a partial replacement for sand strength increasing up to 40%replacement level. Higher level replacement ends to segregation and bleeding due to less water absorption capacity of copper slag. It was also observed that the sand replaced copper slag beams showed an increase in energy absorption capacity.

Mobasher et al (1966) stated that **utilization of copper slag for applications such as Portland cement replacement in concrete,** and/or as a cement raw material has the dual benefit of eliminating the costs of disposal, while lowering the cost of the concrete. Copper slag however is not effectively utilized in the United States, whereas in Canada, approximately 45% of it is used in base construction, railroad ballast, and engineered fill. In the early days of copper mining, high-grade oxidized ores were smelted directly in blast furnaces. The copper content of the slag was quite high while the produced copper was impure and requires considerable refining. Eventually, the practice of smelting in blast furnaces was abandoned. Currently, the high-grade oxide ores are mixed with sulfide ores and smelted. Copper slag is shown to significantly increase the compressive strength of concrete mixtures. Pozzolanic reactions are verified by means of XRD techniques. Use of lime as a hydration activator was evaluated and shown to improve the rate of strength gain. Results obtained from this study indicate the tremendous potential of copper slag as a mineral admixture.

III. MATERIALS& MIX DESIGN

3.*1 Cement*

Cement is most essential & most commonly used in the construction industry. The most type of cement is Portland cement .port land cement is used generally used everywhere in the construction industry. It is ingredient of concrete mortar & plaster. It is a mixture of calcium, silicon and aluminium, by heating limestone Portland cement and similar materials are made with clay and grinding this product (called clinker) with a source of sulphate (most commonly gypsum). Main Constituents of cement and their composition is shown in the table 3.1

Table-3.1 Chemical Composition of Cement

Compound	Mass (%)
SO_3	2.98
Free CaO	1.59
MgO	2.91
Al_2O_3	4.44
SiO_2	19.49
Fe_2O_3	2.86
CaO	62.52
Na_2O and K_2O	0.56
Residue	0.66

In addition to the above, there are other minor compounds such as MgO, TiO2, Mn2O3, K20 and N2O. They are in small quantity. Of these K2O and Na2O are found to react with some aggregates and the reaction is known as Alkali Silica Reaction (ASR) and causes disintegration at later stage. The silicates C3S and C2S are the most important compounds and are mainly responsible for the strength of the cement paste. They constitute the bulk of the composition. C3A and C4AF do not contribute much to the strength but in the manufacturing process they facilitate combination of lime and silica, and act as a flux. In a typical Portland cement, the composition of mineralogical compounds could be as shown in Table 3.2

Table 3.2 Composition of hydrated Cement

S NO	Compounds	Composition as %
	C3S	48-52 %
2	C2S	22-26 %
3	C3A	6-10 %
4	C4AF	13-16 %
5	Free lime	1-2 %

3.2 *Aggregate*

In Construction industry aggregates are most commonly used material. It is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, etc. Aggregates are the most mined material in the world. These 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. Aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and roadside edge drains. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building), or as a low-cost extender that binds with more expensive cement or asphalt to form concrete.

Because at least three-quarters of the volume of concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only may the aggregate limit the strength of concrete, as aggregate with undesirable properties cannot produce strong concrete, but the properties of aggregate greatly affect the durability and structural performance of concrete.

Aggregate physical properties are the most readily apparent aggregate properties and they also have the most direct effect on how an aggregate performs as either a pavement material constituent or by itself as a base or sub base material.

3.2.1 Fine Aggregate

Locally available good quality sand is used as fine aggregate. Following tests have been performed on the fine aggregate.

- Specific gravity
- Water absorption
- Moisture content
- Sieve analysis

- **Specific Gravity**
  The common procedure adopted for determination of specific gravity of fine aggregate is as per IS code 4. The specific gravity obtained is 2.71.
- **Water Absorption**
  It is the capability of holding water over oven-dried sample. Water absorption plays a key role in the determination of water content in concrete. The quantity of water that can be absorbed by coarse aggregate shall be added to the total water content and shall be deducted an equivalent amount of course aggregate from the total quantity.The common procedure adopted for the determination of water absorption of fine aggregate is as per IS code 4.
- **Moisture Content**
  The moisture content of fine aggregate is obtained using rapid moisture matter and the values thus obtained are compared with the field method given in the IS code 4.for the test sample moisture content is 1%.
- **Sieve Analysis**
  Sieve analysis is carried out on locally available river sand. The procedure adopted for the sieve analysis is as per IS code 4.

Table 3.3 results of tests on fine aggregate

Sl. No	Properties of sand tests	Result
1	Specific gravity	2.6
2	Bulk density(g/cc)	1.71
3	% voids	49.1%
4	Fineness modulus	2.30
5	Zone	III

3.2.2 Coarse Aggregate

Locally available crushed granite stone is used as coarse aggregate. Following tests have been performed on the coarse aggregate.

The common procedure adopted for determination of specific gravity of coarse aggregate is as per IS code 4. The specific gravity obtained is 2.71

Tests of Coarse Aggregate are conducted similar to that of Fine Aggregate and the final result is shown in Table 3.4

Table 3.4 results of tests on coarse aggregate

Sl. No	Properties of sand tests	Result
1	Aggregate size	20mm
2	Bulk density(g/cc)	1.75
3	% voids	48
4	Specific gravity	2.7
5	Fineness modulus	1.45

3.3 *Water*

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. Lower water to concrete ratio yields a stronger, more durable concrete, while more water gives a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete, to form a solid mass.

Reaction:

Cement chemist notation: C3S + H → C-S-H + CH

Standard notation: $Ca_3SiO_5 + H_2O \rightarrow (CaO)\cdot(SiO_2)\cdot(H_2O)(gel) + Ca(OH)_2$

Balanced: $2\ Ca_3SiO_5 + 7\ H_2O \rightarrow 3(CaO)\cdot 2(SiO_2)\cdot 4(H_2O)(gel) + 3\ Ca(OH)_2$

3.4 COPPER SLAG

Copper Slag (CS) used in this work was brought from Sterlite IndustriesLtd (SIL), Kolkata, India. SIL is producing CS during the manufacture of copper metal. 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.In order to reduce the accumulation of CS and also to provide an alternate material for sand as well as cement we have decided to study its use in the field of construction industry. But before we opt this material as replacer we have check its physical and chemical properties

- Size – Grained to a size of less than 60µ
- Fineness – Copper Slag fineness is found to be 210 m^2/kg(for size < 60µ)
- Normal consistency which is found to be 22

Finally these properties are almost similar to that of cement and hence these are satisfied for Substituting as cement

3.4.1 Physical Properties Of Copper Slag

The slag is a black glassy and granular in nature and has a similar particle size range like sand. The specific gravity of slag lies between 3.4 and 3.98. The bulk density of granulated copper slag is varying between 1.9 to 2.15 kg/ m3, which is almost similar to the bulk density of fine aggregate.

Table 3.5 Physical Properties Of Copper Slag

Physical properties	Sand	Copper slag
Particle shape	Irregular	Irregular
Appearance	Brownish Yellow	Black & glassy
Bulk density (g/cc)	1.71	1.90
Specific gravity	2.6	3.5
Fineness modulus	2.30	3.25
Water absorption %	1.25	0.18

The above tests are done as stated similar to as fine aggregate tests.

3.4.2 Sieve Analysis

Sieve analysis is a methodology used to access the particular size distribution of the material. The size distribution is important to the way of material performs to use. It can be performed on organic or non-organic granular materials including sand, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common method adopted in India.

Fig: Different types of sieves

Table 3.6 Sieve Analysis Of Fine Aggregate

SL.NO	Sieve size	WT retained	% WT Retainer	Cumulative % WT retained	Cumulative % WT Passed	Remarks
1	4.75	9.6	0.96	0.96	99.04	
2	2.36	14.7	1.47	2.43	97.57	
3	1.18	87.5	8.75	11.18	88.82	
4	600	228	22.8	33.98	66.02	Zone III
5	300	515.6	51.56	85.54	14.46	
6	150	112.2	11.22	96.76	3.24	
7	75	27.6	2.76	99.52	0.48	
8	pan	4.8	0.48	100	0	

Table 3.7 Sieve Analysis Of Copperslag

SL.NO	Sieve size	WT retained	% WT Retained	Cumulative %WT retained	Cumulative % WT Passed
1	4.75	10 gm	1	1	99
2	2.36	110 gm	11	12	88
3	1.18	315 gm	31.50	43.5	56.5
4	600	305 gm	30.50	74	26
5	300	220 gm	22	96	4
6	150	30 gm	3	99	1
7	75	10 gm	1	100	0

Where as chemical properties of copper slag depends on the constituents but the chemical properties generally are in the proportion as shown in the table 3.8

Table 3.8 Chemical Composition Of Copper Slag

SL.NO	Chemical compounds	% of chemical Compounds
1	Fe2o3	68.29
2	Al2o3	0.22
3	Sio2	25.2
4	Mgo	0.3
5	Cao	0.15
6	Na2o	0.58
7	K2o	0.3
8	Cuo	1.2
9	Lio	6.59
10	Insoluble residue	13.45

Ordinary Portland cement has a lime content of 63%, whereas copper slag has a very low lime content of <1%. Generally, the free lime content of Copper slag is very low. This indicates that Copper slag is not highly chemically reactive material in order to be used as cementitious materials. Copper slag must have a sufficient quantity of lime to reach the required rate of hydration and to achieve the required early age strength. Therefore, in this case, in order to increase its Pozzolanic reaction, hydrated lime was added up to 2.0% to the weight of cement.

3.5 Significance of Concrete Mix Design

Concrete is a major building material, which is used in construction throughout the world. It is used is all type of structures. Due to growth in construction industry, the consumption of concrete increases every year. This results in excessive extraction of natural aggregates. The use of these materials is being constrained by urbanization, zoning regulations, increased cost and environmental concern.

3.6 Mix design

Definition: It is a process of arriving at proportions after understanding of all materials

Aim: In this chapter the details of design of concrete mixes are discussed. In the present work the studies were carried out for M30 grade of concrete keeping strength, durability and workability of concrete as main view. The mix proportions were designed based on IS recommendations.

3.7 M30 MIX DESIGN AS PER IS: 10262-2009

Stipulations for proportioning:

Grade designation	: M30
Type of cement	: OPC 53 grade confirming to IS 12269-1987
Maximum nominal size of aggregate	: 20 mm
Exposure condition	: Severe (for reinforced concrete)
Degree of supervision	: Good
Minimum cement content	: 320 Kg/m³
Type of aggregate	: Crushed angular aggregate
Maximum cement content	: 450Kg/m³

Test data for Materials

Cement used: OPC 53 grade confirming to IS 8112

Specific gravity of cement: 3.15

Specific gravity of

- Coarse aggregate :2.7
- Fine aggregate :2.6

STEP-1: Target mean strength for mix proportioning

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

ft = Target average compressive strength at 28 days

Fck = Character compressive strength at 28 days

S = Standard deviation (taken from Table1 of IS: 10262-2009)

S=5

ft=30+1.65(5)=38.25N/mm²

STEP-2: Selection of Water-cement ration

From IS: 456-2000, Table 5 by taking severe exposure condition for M30 grade, the maximum water cement ratio is 0.45

W/C = 0.45

STEP-3: Selection of water content

From IS: 10262-2009, Table 2 depending upon the nominal size of aggregate (20mm), the maximum water content is 186 litres.

∴ Maximum water content per cubic meter of concrete for 20mm aggregate is 186 Kg (litres).

STEP-4: Calculation of cement content

The minimum cement content required for M30 as per IS: 456-2000 of table is $320Kg/m^3$ (Severe exposure condition)

W/C =0.45

186/C = 0.45

C = 413 kg

Hence we obtained cement content as 437 Kg

But, we are approximating this value of cement =380Kg

W/C = 0.45

W/380 = 0.45

W = 171 kg

$380Kg/m^3 > 320Kg/m^3$, hence, OK

IV. EXPERIMENTAL WORK

4.1 TESTS ON FRESH CONCRETE

4.1.1 Preparation of Test Samples

The specimens used for test cubes are of size 150*150*150 mm and those of cylinder are of 150 mm diameter and 300 mm height. All the materials are brought to a temperature of 27±⁰C before commencing the tests. The materials are proportioned as per the design calculations by proper weighing. The concrete is mixed by using a laboratory batch mixer. After thorough mixing of concrete, workability of the batch is estimated by slump cone test or compaction factor test. The concrete is then filled in the moulds of specified size and compacted by hand compaction. The prepared specimen is kept under moist condition (27±2⁰C) for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds and cured under controlled conditions till the day of testing.

4.1.2 Tests on Fresh Concrete:

Workability tests have been conducted on fresh concrete, keeping in view the present project.
The following tests are generally used to determine workability of a concrete mix:

1.Slump Cone Test:

This method can be employed both in the laboratory and the site of work. It is not suitable for very wet or very dry concrete. This method is suitable for medium slump. For the present work slump tests were conducted as per IS 1199-1959 for all mixes. The target slump was taken from IS 456-2000.

2.Compaction Factor Test:

This test is more suitable for concrete mixes of low workability since such dry concrete is insensitive to slump test. It works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height, the test was conducted as per IS 1199-1959.

On fresh concrete, the tests related to workability measure are conducted as per IS code specifications.

4.1.3 Curing of Concrete Samples

Later on after Casting of cubes concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. Of course the rate of hydration is fast to start with, but continues over a long time at decreasing rate. The quantity of product of hydration and consequently the amount of gel formed depends upon the extent of hydration. Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. Concrete while hydrating releases high heat of hydration. This heat is harmful from the point of view of volume stability. If the heat generated is removed by some means the adverse effect due to generation of heat can be reduced. This can be done by through water curing. Generally curing is done for 28days in water tub.

Fig : **Curing of specimens**

4.2 TESTS ON HARDENED CONCRETE

There are certain number of tests on Concrete to test the strength of Concrete at the later stage after the curing namely

1. Compressive Strength Test
2. Split Tensile Strength Test
3. Flexural Strength Test
4. Tensile Test

4.3 EXPERIMENTAL RESULTS

4.3.1 Compressive Strength Test

of all the test applied to the concrete compressive test is the most important test, it gives an idea about concrete characteristics by this test we can tell concrete is done properly or not.

140kg/cm^2 load should be applied per minute till it fails. load at failure gives the compressive strength of concrete.

Partial Replacement of Sand with Copper Slag (M30 Grade):

We have designed for 9cubes each with considering 3cubes as safety

4.3.1.1 Sand Replaced By 0% (S00)

Materials:

Cement: 13.32Kgs

Sand: 23.84Kgs

CA: 20mm – 43.83Kgs

Copper Slag: 0Kgs

Slump: 85mm

Water: 6 lts

Table 4.1 average compressive strength for 7 & 28 days by 0% replacement

Cubes	Compressive Load @ 7 days	Average Compressive Strength @ 7 days	Compressive Load @ 28 days	Average Compressive Strength @ 28 days
1	720		800	
2	700	31.40	810	36.0
3	700		800	

4.3.3 Flexural Strength

Flexural strength is the main aim in casting beam specimens. In this modulus of rupture is calculated by the universal testing machine. The modulus of rupture is denoted by " f ".The 'f' value is mainly based on the shortest distance of line fracture 'a'

If 110mm < a < 133mm, $f = 3PL/bd^2$

If a > 133mm, $f = PL/bd^2$

Table 4.19 Final Analysis On Flexural Strength

s.no	% of slag	flexural strength for 7 days	flexural strength for 28 Days
1	0	4	4.60
2	10	4.5	4.95
3	20	5.20	5.90
4	30	5.75	6.03
5	40	6.10	6.83
6	50	6.50	7.92
7	60	7.80	8.95
8	70	6.85	7.90

4.4. Slump Results

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in the laboratory or at site of work.it is not a suitable method for very dry or very wet concrete and stiff mix.it does not measure all factors contributing to workability.the diameter of the rod is 16mm and its length is 60cm, the strokes to be given for ramming vary from 20 to 30.

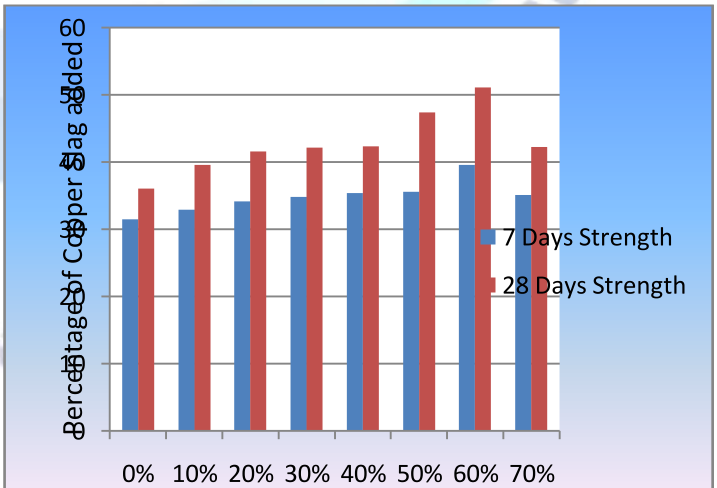
Table 4.20 Final result on Slump Vs % Sand Replacement for M30 Grade

SAND REPLACEMENT in %	SLUMP in mm
S00	85
S10	90
S20	95
S30	98
S40	102
S50	108
S60	112
S70	106

V. RESULTS AND DISCUSSIONS

Table 4.9 Final result On Compressive Strength for 7&28 days

% of Slag added	7 days strength	28 days strength
0	31.40	36.0
10	32.9	39.5
20	34.1	41.5
30	34.8	42.1
40	35.3	42.3
50	35.5	47.3
60	39.5	51.06
70	35.05	42.2

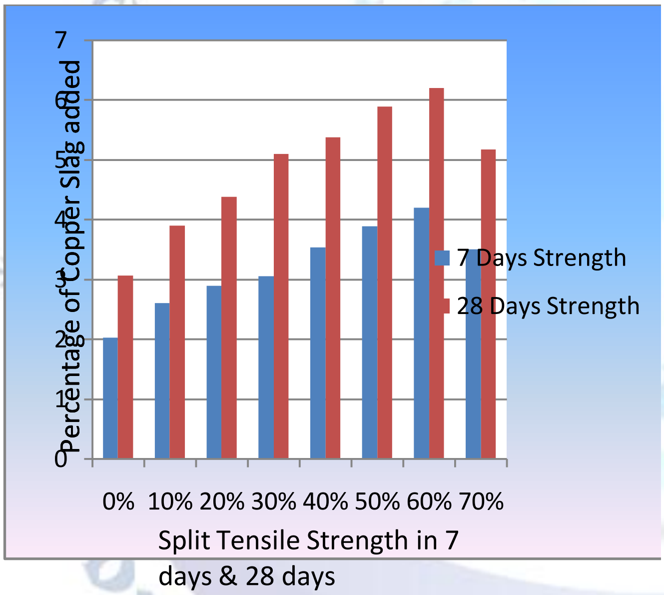


Compressive Strength in 7 days & 28 days

Table 4.18 Final result on split tensile strength for 7&28 days

% of slag Added	7 days Strength	28 days strength
0	2.02	3.06
10	2.60	3.90
20	2.89	4.38
30	3.05	5.09
40	3.53	5.37
50	3.88	5.89
60	4.20	6.20
70	3.50	5.17

Table 4.18 Final result on split tensile strength for 7&28 days



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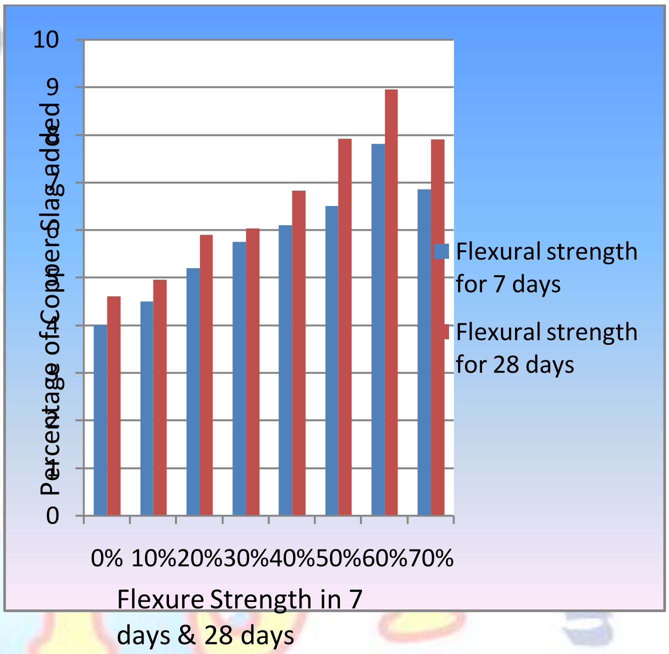
7	60	7.80	8.95
8	70	6.85	7.90



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S70	106

VI. Conclusion

Results are analyzed to derive useful conclusions regarding the workability, strength characteristics of concrete on partial replacement of cement and sand with copper slag for M30 grade.

- The density of the copper slag concrete is found to be higher than the normal aggregate concrete.
- The slump values of the copper slag concrete are observed to be relatively more when compared to normal concrete as absorption of copper slag was more compared sand. Therefore, the workability of concrete increases significantly with the increase of copper slag content.
- The maximum slump of concrete with copper slag is about 112mm respectively, with the replacement of fine aggregate with copper slag in the range of 60%.
- When compared to normal concrete, strength variation in all the copper slag concrete mixes is observed to be marginal.
- For concrete made with replacement of sand with copper slag, the compressive strength increases as the % of replacement increases and all the mixes reached the target mean strength.
- The recommended optimum % replacement of sand by copper slag is 60%.
- The maximum compressive strength of copper slag is about 51.06 N/mm2 respectively, with the replacement of fine aggregate with copper slag in the range of 60%.
- The spilt tensile strength of concrete is a maximum of 6.20 with 60% replacement of fine aggregate and copper slag when compared with controlled concrete.
- The flexural strength of concrete is a maximum of 8.95 with 60% replacement of fine aggregate and copper slag when compared with controlled concrete.
- From the above results, copper slag concrete can be considerable as an alternative to fine aggregate and found to be potential.
- By substitution the sand with copper slag, the reduction within the consumption of sand may be achieved. By reducing the consumption of sand, the ecology of the world may be improved tremendously and also the pollution owing to the assembly of cement also can be reduced.

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