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FLEXTURAL BEHAVIOUR OF RCC BEAMS MADE OF CONCRETE WITH COPPER SLAG AS FINE AGGREGATE

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***Abstract*— Copper slag, a slag from metal smelting process, is efficiently used as a replacement for sand in conventional concrete which is highly efficient in increasing the strength without affecting its properties in fresh and hardened state. 1:1.23:2.19 mix is adopted for partial and full replacement of sand with copper slag. Cubes and cylinders for control mix is cast and cured to conduct compressive strength and split tensile test on 7 days and 28 days test. Slump of concrete mix with different proportions are measured and recorded. The optimum strength is taken to cast the beams of length 2m. This report contains the design criteria for the beam with reinforcement details. Totally four beams are cast. Among the four, two for control mix and remaining two for optimum replacement of copper slag. The cast specimens are subject to test and the parameters like load to deflection and crack pattern study are done and discussed.**

***Index Terms*— copper slag, flexural member.**

I. Introduction

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable.

For many years, byproducts such as fly ash, silica fume and slag were considered as waste materials. They have been successfully used in the construction industry for partial or full replacement for fine and coarse aggregates (Akihiko Y, Takashi Y 1 & Ayano Toshiki, Kuramoto Osamu , Sakata 2). Some of the byproducts are also used as a Portland cement substitute (AlJabri K, Taha R et al 3). Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools. Recent research papers (Gorai P, Jana RK, Premchand 4) reviewed the potential use of copper slag as a partial substitute of cement and aggregates in concrete and asphalt mixtures.

The effect of copper slag on the hydration of cement based materials was investigated by Mobasher et al 5 and Tixier et al 6. The Pozzolanic activity of copper slag has been investigated by O.Pavez, F.Rojas et al 7. Since copper slag is glassy and granular in nature and has a similar particle size range to sand, indicating that it could be used as a replacement for the sand present in the cementitious mixes (Caijun Shi, Christian Meyer , Ali Behnood 8). Some studies were carried out using grained copper slag as fine aggregate and fine powder copper slag for partial replacement of cement. Khalifa S, Aljabri, Makota Hisada 9 has investigated the performance of high strength concrete made with copper slag as a fine aggregate. Caijun shi and Jueshi Qian 10 has reviewed the recent progresses in the activation of latent cementitious properties of different slags like blast furnace slag, steel slag, copper slag and phosphorous slag. When Reinforced concrete structures are exposed to harsh environments, deterioration of concrete will occur due to many reasons like chloride and sulphate attack, acid attack, corrosion failure etc.

It is now recognized that the strength of concrete alone is not sufficient, the degree of harshness of the environmental condition to which concrete is exposed over its entire life is also equally important. Since copper slag contains more than 50% of ferrous content, corrosion and durability factors are necessary to find out, when it is replaced with sand and cement in concrete.

Although there are many studies that have been reported by investigators on the use of copper slag in cement concrete, not much research has been carried out in India and other countries concerning the incorporation of durability effect of copper slag in concrete. Therefore, to generate specific experimental data on corrosion and durability characteristics of copper slag as sand and cement replacement in concrete, this research was performed.

A. *Copper Slag*

Copper slag is a byproduct of operation of reverberatory furnaces. A large amount of concentrate, up to about 300 tons, may be placed in the furnace at one time. Impurities form a less dense liquid that floats on top of the copper melt. These impurities include iron, lime, and silica, and form the slag. The slag is skimmed off the top, while the melted material, which has up to 50 percent copper, is called matte.

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The copper matte goes through a converter to blow forced air into it. The air forces the silica back into the copper matte to collect the impurities and make more slag. The slag is skimmed off and air cooled. The slag is subjected to a process of staged crushing using jaw and impact crushers and screened to achieve a uniform and angular particle shape.

II. Study of Materials

A. *Study and Composition of materials*

i. Cement

In the most general sense of the world, cement is a binder, a substance which sets and hardens independently, and can bind other materials together. The volcanic ash and pulverized brick additives which were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, and cement. Cements used in the construction are characterised as hydraulic or non-hydraulic.. The use of Portland Cement is the production of concrete.

ii. Fine Aggregate

Fine aggregate is the natural material that fills voids in between the coarse aggregate.

iii. Copper Slag

Copper slag is a byproduct of operation of reverberatory furnaces.

iv. Coarse Aggregate

It gives body to the concrete, reduce shrinkage and effect economy the aggregate occupy 70-80% of volume of the concrete

B. *Composition of Materials*

The concrete was produced with Copper slag are replacement of river sand in variable proportion. The replacement of river sand by copper slag was done as 20%, 40%, 60%, 80% and 100%.

Table 2.1: Composition of ordinary cement

Ingredient	Percentage (%)	Range
Lime (CaO)	62	62-67
Silica (SiO_2)	22	17-25
Alumina (Al_2O_3)	5	3-8
Calcium Sulphate ($CaSO_4$)	4	3-4
Iron Oxide (Fe_2O_3)	3	3-4
Magnesium (MgO)	2	0.1-3

III. Testing Of Materials and Casting

A. *Fineness test*

100g of the given cement is weighed accurately and is placed on IS 90 micron sieve and is sieved continuously for 15 minutes by circular and vertical motion. The underside of the sieve is lightly brushed with the given brush after every 5 minutes of sieving. The weight of the residue is found accurately and thus the fineness of the cement is found out by the ratio of weight of residue and weight of sample taken which is expressed in percentage. The experiment is repeated with fresh samples and results are tabulated.

Table 3.1: Fineness test for cement

Sl.no	Wt of sample taken (w1)g	Wt of residue (w2)g	Percentage weight of residue (w2/w1)x100
1	100	6	6
2	100	5	5

Thus from the results we infer that the fineness of the cement is 5.5% and the fineness requirement of cement as a residue should not exceed 10% for ordinary Portland cement.

B. *Consistency test*

The basic aim to find out the water content required to produce a cement paste of standard consistency as specified by the IS specifications. The principle is that standard consistency of cement is that consistency at which the Vicat plunger penetrates to a point %-7 mm from the bottom of Vicat mould.

Table 3.2: Consistency test for cement

Sl.No	Wt of cement(g)	Quantity of water added (mL)	Penetration of plunger
1	300	72	36
2	300	74	32
3	300	76	26
4	300	78	10
5	300	79	5

C. *Setting Time Test*

Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency. Start a stop-watch, the moment water is added to the cement. Fill the Vicatmould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block. Allow the needle to penetrate the block and find the initial and final setting times of the specimen.

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Table 3.3: Initial setting time for cement

S.No	Wt of cement in gms	% of water added	Volume of water added (ml)	Initial setting time(min)	Depth of penetration
1	300	0.7	79	5	40
2	300	0.7	79	10	40
3	300	0.7	79	15	40
4	300	0.7	79	20	40
5	300	0.7	79	25	39
6	300	0.7	79	30	39
7	300	0.7	79	35	38
8	300	0.7	79	40	38
9	300	0.7	79	45	37
10	300	0.7	79	50	35

IV. MIX DESIGN

The grade of concrete to be adopted for this project work has to be similar to M_{30}. Since comparison is to be made with the standard M_{30} mix.

- Tests are done with constant strength for conventional Mix of strength = 30 Mpa N/mm^2
- Mix design calculation was done as per IS 10262 : 2009
- Based on the % of Copper Slag the strength and density of conventional concrete mix will get vary.
- % of Copper Slag added = 0%, 20%, 40%, 60%,80% 100%.

A. Determination of target mean strength

The target mean compressive strength at 28 days = f_{ck}+ tS

= 30 + (1.65x5)

= 38.25 Mpa

B. Determination of water cement ratio

Strength of concrete primarily depends upon the strength of cement paste. Various parameters like types of cement, aggregate, maximum size of aggregate, surface texture of aggregate etc and influencing the strength of concrete, when water cement ratio constant. Hence it is desirable to establish a relation between concrete strength and free water cement ratio with materials and condition to be used. Here the water cement ratio adopted is 0.38.

C. Determination of water and sand content

Required sand content as percentage of total aggregate by absolute volume

= 35+0.5

= 35.5%

Required water content = 186 Kg/ m^3

D. Determination of cement content

The cement content per unit volume of concrete may be calculated from free water cement ratio. And the quantity of water per unit volume of concrete (cement by mass= water cement /water cement ratio)

W/C ratio = 0.38

Water = 191.6 L

Cement = 504.21 Kg/m^3

E. Determination of fine aggregate

Aggregate content can be determined from the following equation.

$$V = W + \frac{C}{Sc} + [\frac{1}{e} \times \frac{fa}{Sfa}] \times \frac{1}{1000}$$

$$0.98 = 191.6 + \frac{504.21}{3.15} + [\frac{1}{0.355} \times \frac{fa}{2.29}] \times \frac{1}{1000}$$

f_a = 622.3 Kg/m^3

F. Determination of coarse aggregate content

$$V = [W + \frac{C}{Sc} + \frac{1}{e} \times \frac{fc}{Sfc}] \times \frac{1}{1000}$$

$$0.98 = [191.6 + \frac{504.21}{3.15} + \frac{1}{0.645} \times \frac{fc}{2.73}] \times \frac{1}{1000}$$

= 1106.41 Kg/m^3

The mix proportion then becomes

Table 4.1 Mix Proportion

Water	Cement	Fine Aggregate	Coarse Aggregate
191.6 (L)	504.21 Kg	622.3 Kg	1106.41 Kg
0.38	1	1.23	2.19

Table 4.2 shows the materials required per cubic meter. (W/C = 0.38)

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SI No	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water (L)	Copper Slag kg/m^3
1	504.21	622.3	1106.41	191.6	0
2	504.21	497.84	1106.41	191.6	124.46
3	504.21	373.38	1106.41	191.6	248.92
4	504.21	248.92	1106.41	191.6	373.38
5	504.21	124.46	1106.41	191.6	497.84
6	504.21	0	1106.41	191.6	622.3

- For the above mixes the fresh concrete properties and harden concrete properties are tested.
- Fresh concrete tests include the following.
  - Slump test
  - Compaction factor test
- Harden concrete properties studies include
  - Compression test
  - Split tensile test

Number of specimens required to calculate the harden properties of light weight concrete are as follows.

i) For compression test

Cubes - 7 days → 6 x 3 =`18
28 days → 6 x 3 =`18

ii) For split tensile strength

Cylinder - 28 days → 6 x 3 =18
(The Results Are Shown In Next Chapter)

V. Analyzing of Concrete Properties

A. General

Concrete specimens are tested to fine its compressive strength, for 7 days and 28 days and split tensile strength for 28 days.

B. Fresh Concrete Properties

Some of the tests measure the parameters very close to workability and provide useful information. The following tests are commonly employed to measure workability.

- Slump cone test
- Compacting factor test

i. Slump Cone test

Fig 5.1Slump Cone Test

Fig 5.2 Compacting Factor Test

Slump cone test is the most commonly used method of measuring consistency. It doesn't measure all factors contributing to workability. It is used as a control test and gives an indication of uniformity of batches.

Table- 5.1 Slump Cone Test

Copper Slag (%)	Slump in mm
0	28
20	29
40	27
60	31
80	31
100	32

Table- 5.2 Compacting Factor Test

Copper Slag (%)	Compaction factor
0	0.97
20	0.97
40	0.96
60	0.94
80	0.94
100	0.94

The slump test results given in Table 6.1 shows the slump increases as the percentage of Copper Slag increases.

ii. Compacting Factor Test

Compacting factor test is more precise and sensitive than the slump cone test. This test gives an idea for degree of compaction and adopted to find the workability of concrete where aggregate size does not exceed 20mm and the mixes

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are comparatively dry.

C. *Casting of specimen*

The concrete after workability was used for casting test specimens. Moulds were used to cast the specimen. Since the maximum size of the aggregate is 20 mm, cube moulds of size 150x150x150 mm were used. The cube moulds were used for compression test specimens. The inner surface of the mould was coated with a thin layer of waste oil in order to help the demoulding easy and to have sharp corners. Before applying oil, the inner surface was thoroughly cleaned and freed from moisture. The concrete was filled in three layers. Each layer was compacted with the standard tamping bar and the strokes of the bar were uniformly distributed across the cross section of the mould. The strokes were given such that it penetrated the underlying layer and the bottom layer was tamped throughout it its depth. The tamping bar of 16mm diameter and 60 cm long was, the lower end was butted pointed. After the top layer was compacted, the surface of the concrete was finished in level with top of the mould using a trowel.

D. *Compressive strength test*

- Compressive Strength of Concrete cube Specimens is tested after $7^{th}$and 28^{th} days. The test is done using Compression Testing Machine.
- As per IS456:2000 and IS516:1959 the compressive strength value of cube specimen should not less than 30 N/mm^2

E. *Split tensile strength test*

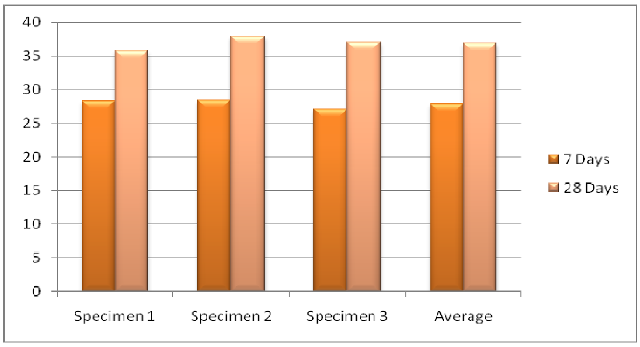
- Split Tensile Strength of Concrete Cylinder Specimens is tested after 28^{th} days. The test is done using Compression Testing Machine.
- As per IS456:2000 and IS5816:1999 the split tensile strength of concrete should not less than 1/10 of f_{ck}.

VI. RESULTS AND DISCUSSIONS

A. *Results for compression test*

Table 6.1 Compression Test results for specimens with 0% Copper Slag

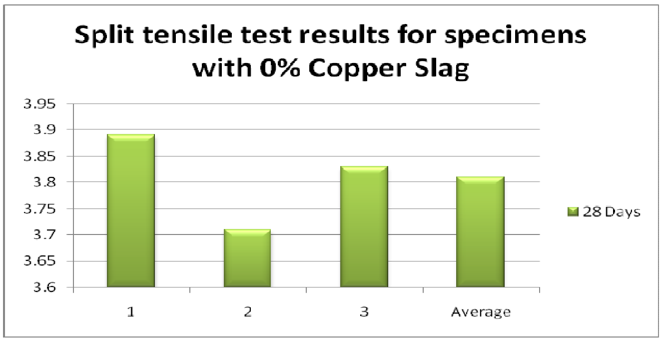
Mix	7 Days	28 Days
Specimen 1	28.26	35.78
Specimen 2	28.39	37.86
Specimen 3	27.03	37.04
Average	27.89	36.89



Graph 6.1 Compression Test results for specimens with 0% Copper Slag

Table 6.2 Split tensile test results for specimens with 0% Copper Slag

Mix	28 Days
1	3.89
2	3.71
3	3.83
Average	3.81



Graph 6.2 Spilt Tensile Test results for specimens with 0% Copper Slag

Table 6.3 Compression Test results for specimens with 20% Copper Slag

Mix	7 Days	28 Days
Specimen 1	28.75	38.44
Specimen 2	27.4	37.12
Specimen 3	29.33	38.33
Average	28.49	37.96

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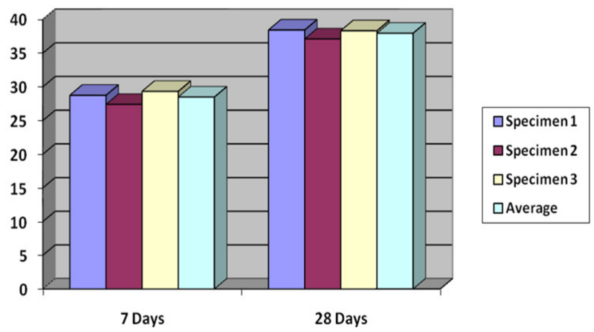
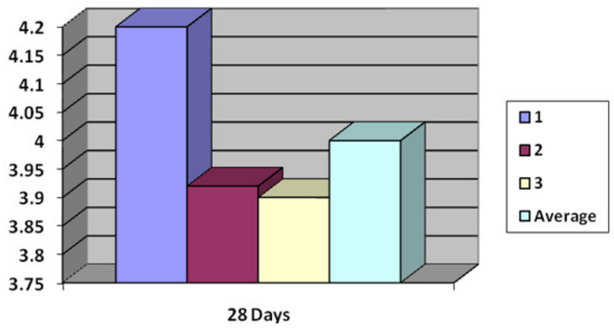


Graph 6.3 Compression Test results for specimens with 20% Copper Slag

Table 6.4 Split tensile test results for specimens with 20% Copper Slag

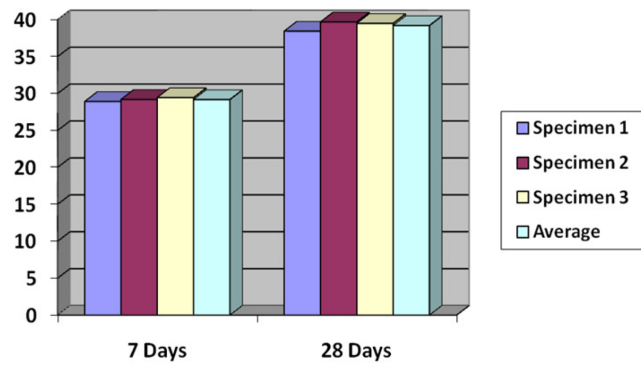
Mix	28 Days
1	4.2
2	3.92
3	3.9
Average	4.00



Graph 6.4 Spilt Tensile Test results for specimens with 20% Copper Slag

Table 6.5 Compression Test results for specimens with 40% Copper Slag

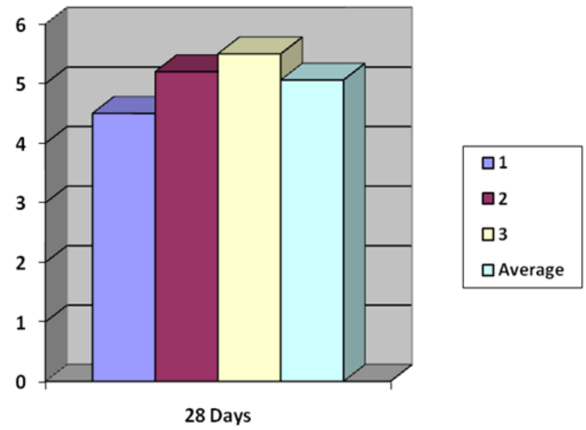
Mix	7 Days	28 Days
Specimen 1	28.92	38.45
Specimen 2	29.2	39.7
Specimen 3	29.45	39.5
Average	29.19	39.21



Graph 6.5 Compression Test results for specimens with 40% Copper Slag

Table 6.6 Split tensile test results for specimens with 40% Copper Slag

Mix	28 Days
1	4.5
2	5.2
3	5.5
Average	5.06



Graph 6.6 Spilt Tensile Test results for specimens with 40% Copper Slag

Table 6.7 Compression Test results for specimens with 60% Copper Slag

Mix	7 Days	28 Days
Specimen 1	28.92	37.4
Specimen 2	28.44	37.5
Specimen 3	27.4	36.8
Average	27.92	37.23

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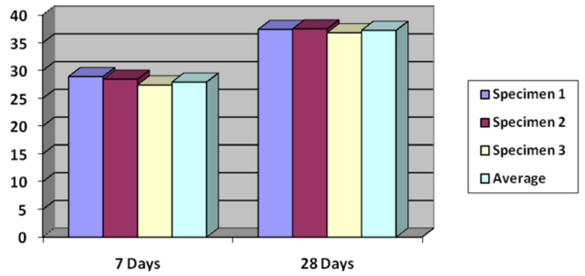
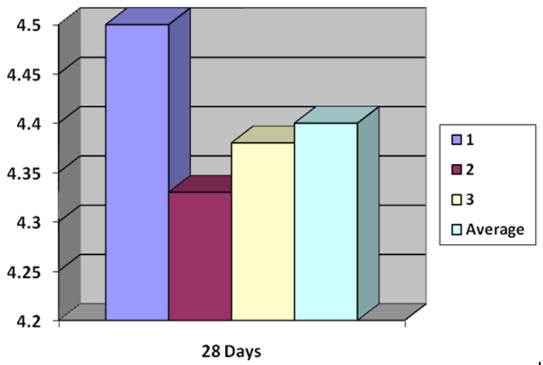


Graph 6.7 Compression Test results for specimens with 60% Copper Slag

Table 6.8 Split tensile test results for specimens with 60% Copper Slag

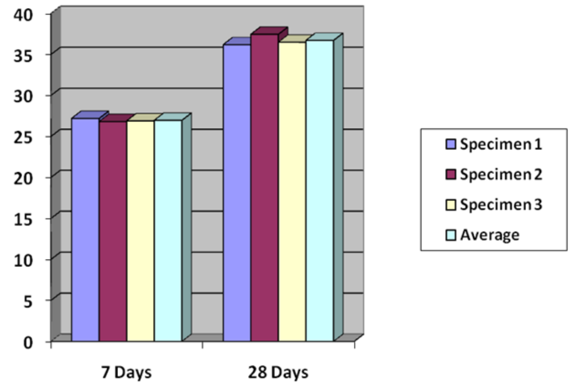
Mix	28 Days
1	4.5
2	4.33
3	4.38
Average	4.40



Graph 6.8 Spilt Tensile Test results for specimens with 60%Copper Slag

Table 6.9 Compression Test results for specimens with 80% Copper Slag

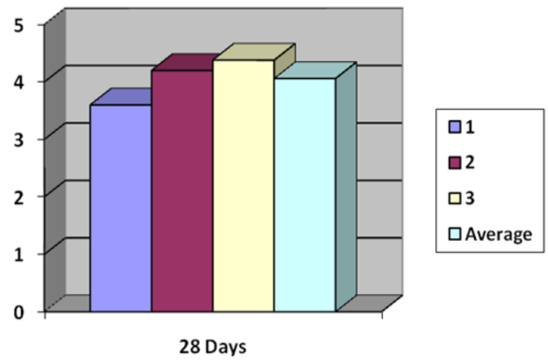
Mix	7 Days	28 Days
Specimen 1	27.2	36.2
Specimen 2	26.82	37.46
Specimen 3	26.9	36.5
Average	26.97	36.72



Graph 6.9 Compression Test results for specimens with 80% Copper Slag

Table 6.10 Split tensile test results for specimens with 80% Copper Slag

Mix	28 Days
1	3.6
2	4.2
3	4.38
Average	4.06



Graph 6.10 Spilt Tensile Test results for specimens with 80% Copper Slag

Table 6.11 Compression Test results for specimens with 100% Copper Slag

Mix	7 Days	28 Days
Specimen 1	24.68	36.18
Specimen 2	24.16	35.9
Specimen 3	25.32	35.12
Average	24.72	35.7

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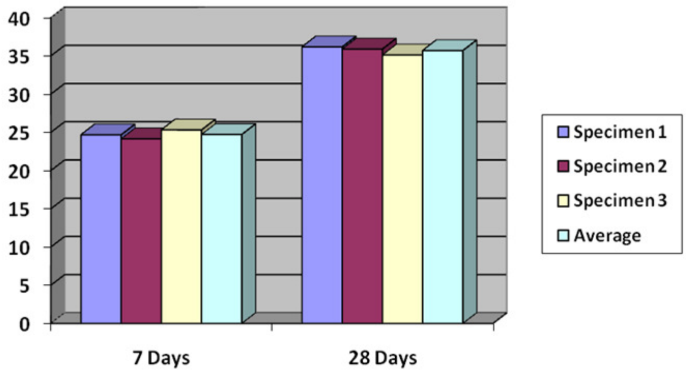
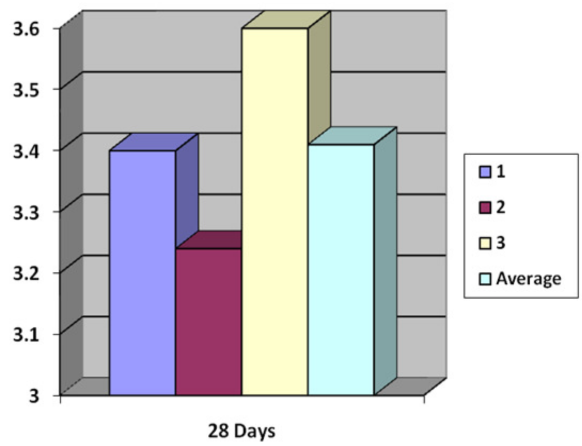


Graph 6.11 Compression Test results for specimens with 100% Copper Slag

Table 6.12 Split tensile test results for specimens with 100% Copper Slag

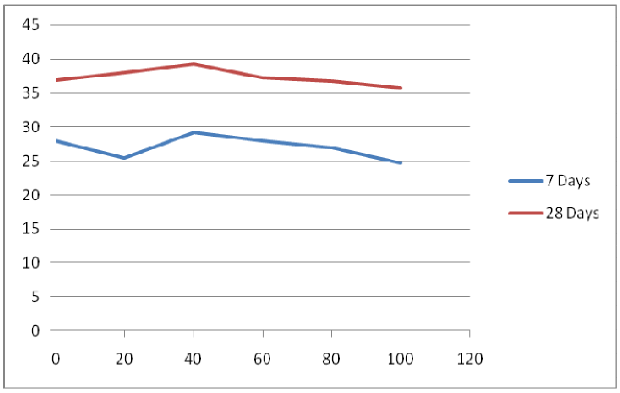
Mix	28 Days
1	3.4
2	3.24
3	3.6
Average	3.41



Graph 6.12 Spilt Tensile Test results for specimens with 100% Copper Slag

Table 6.13 Compression Test results for specimens with varying percentage of Copper Slag

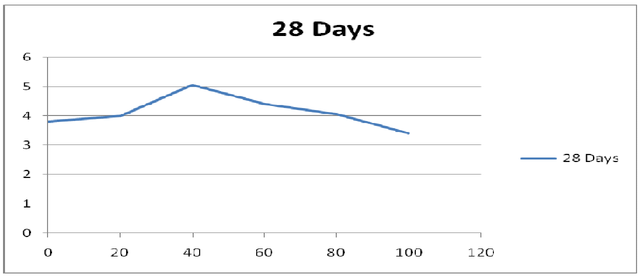
% of Copper Slag	7 Days	28 Days
0	27.89	36.89
20	25.49	37.96
40	29.19	39.21
60	27.92	37.23
80	26.97	36.72
100	24.72	35.7



Graph 6.13 Compression Test results for specimens with varying percentage of Copper Slag

Table 6.14 Split tensile test results for specimens with percentage of Copper Slag

% of Copper Slag	28 Days
0	3.81
20	4.00
40	5.06
60	4.4
80	4.06
100	3.41



Graph 6.14 Spilt Tensile Test results for specimens with percentage of Copper Slag

An excellent style manual and source of information for science writers is [9].

B. Design of beam for flexure

Grade of Concrete	M30
Grade of steel	Fe 415
Length of Beam	2.00m
Effective span Length	1.50m
Breath of beam	150mm
Depth of Beam	200mm
Loading Method	Two Point Load (Equal Distance (L/3))
End Condition	Simply Supported Beam

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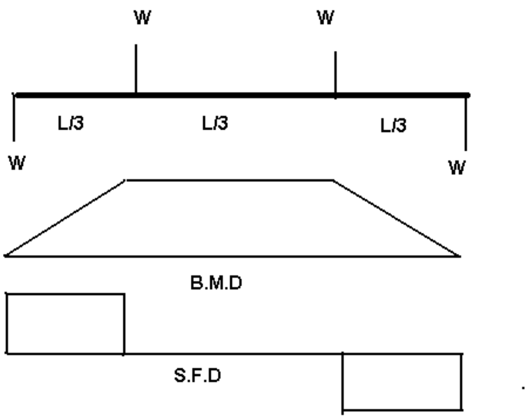


i. Reinforcement details of flexure beam

The reinforcement detailing for the beam to be tested for shear behaviour is shown in fig given below.

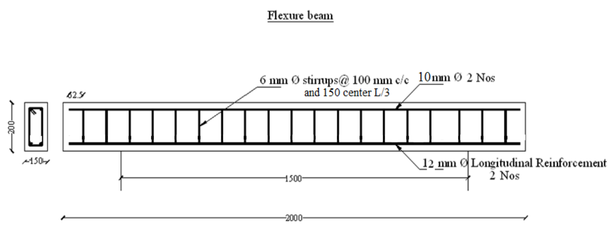
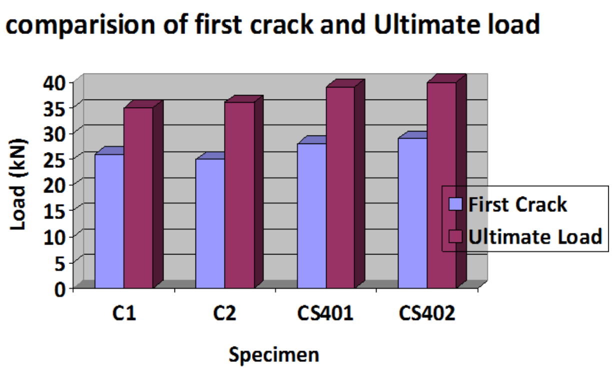


Fig 6.15 Reinforcemnt Detailing Of Flexure Beam

Table 6.15 - Flexural Test Results for Beam Specimen

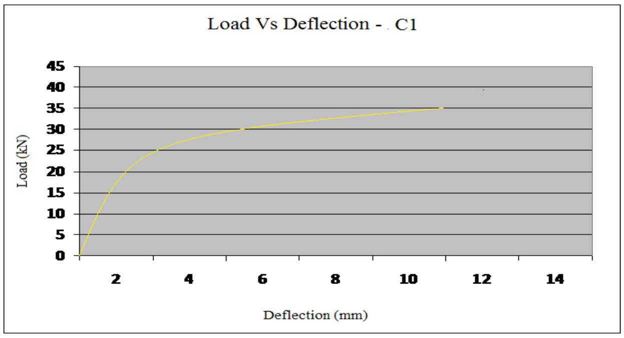
Description of test specimens	% of CS	First crack load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
C1	0	26	35	10.2
C2	0	25	36	10.5
CS401	20	28	39	12
CS402	20	29	40	11.9

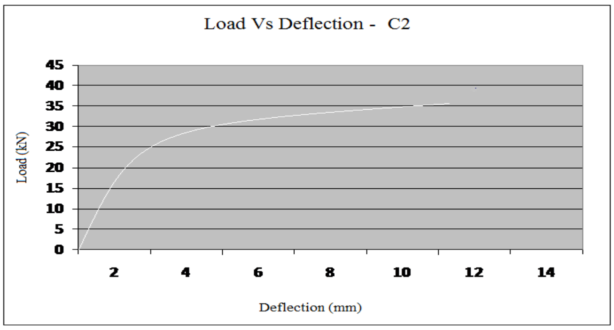


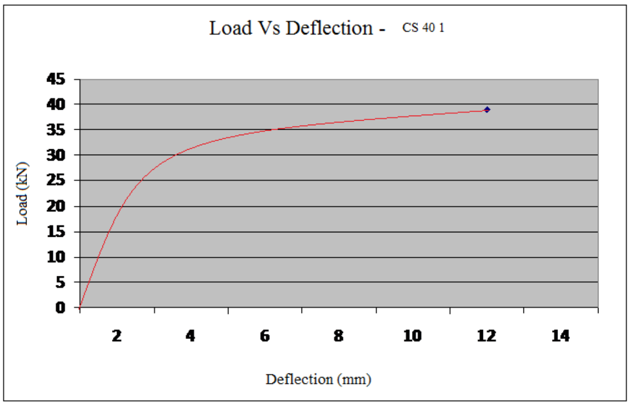
Graph 6.16: Comparison of first crack and ultimate load

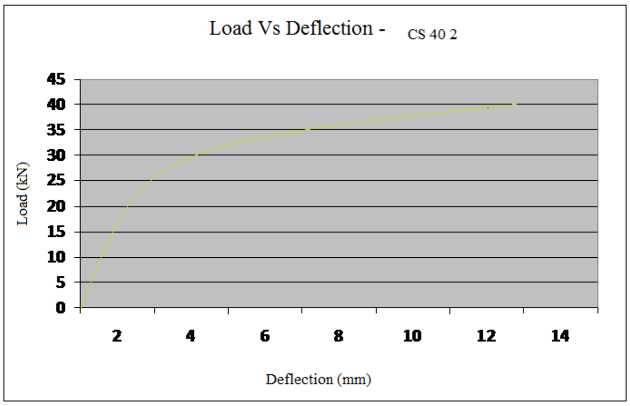
C. *Load versus Deflection (P-Δ) Curves*

Load versus Deflection curves for the beam specimen tested for Flexure are Shown below.









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VII. CONCLUSION

The replacement of fine aggregate with copper slag was done in effective manner. The fresh and harden properties of concrete with increase in copper slag content was found and discussed. An Optimum use of copper slag in concrete is found to be 40%. Finally Strength study of concrete was done. Among that, the concrete with 40 % copper slag attains good strength. Study of flexural behavior of R.C beams with copper slag also discussed. The parameters consist of load and deflection.

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V.ADLIN BELJA was born on 1994. Currently she is a post graduate scholar at Mahakavi Bharathiyar College Of Engineering And Technology in the Civil Department of Structural Engineering. She had completed her undergraduate at CSI Institute of Technology in the department of Civil Engineering. She is very well experience with many projects .She had done a project named as "Analysis and Design of Police Quarters" is located at Ozhuginasery, Nagercoil. She also had done a project named as "Strength Behavior Of Hybrid Fiber Reinforced Concrete". Her area of interest is working on many innovative ideas on the structural engineering concepts.