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Experimental Study on Flexural Behavior of Reinforced Concrete Beams by Replacing Copper Slag as Fine Aggregate

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Abstract: **Many countries are witnessing a rapid growth in construction industry which involves use of natural resources for the development of infrastructure. This growth poses a threat to natural resources that are available. Copper slag is considered as waste material and can be used as replacement of fine aggregates. M30 grade of concrete mix with water-cement ratio of 0.45 is used to determine the various mechanical properties. This research work mainly consist of two parts, In the first part, substitution of natural sand partially by copper slag in concrete is done with replacement of 0%, 35%, 40% and 45%. The optimum value obtained for 40% replacement of copper slag. The 28 days average compression strength was observed to increase by about 0.45% - 23.6%, split tensile strength by 16.61% - 34.98% and flexural strength of concrete by 27.78% - 38.89% when compared with control mix. In the second part, the flexural behavior of reinforced concrete beams with optimum copper slag content is studied. The reinforcement is varied from 0.62% - 0.89% in the flexure zone and the parameters like deflection, surface strain, cracking load, ultimate load and crack width of reinforced concrete beams was experimentally noted and compared with theoretical values as per code IS: 456-2000.**

Keywords: **Copper slag, workability, compressive strength, split tensile strength, flexural strength, deflection, surface strain, crack width, cracking moment, ultimate moment.**

I. INTRODUCTION

Concrete is one of the major construction material being used worldwide. The production of cement adds pollution to environment. Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the mix. Copper slag is a by-product form industry and is utilized only about 20% of the production. The purpose of this research work is to study the feasibility of utilizing copper slag produced by Sterlite industries (India) ltd, Tuticorin, Tamil Nadu, as a replacement for natural sand in concrete. The main aim is to utilize the remaining 80% of copper slag as fine aggregate which is been disposed to the land. D. Brindha [1] studied the potential use of granulated copper slag as a replacement for natural sand in concrete mix and by studying the compressive, split tensile and flexural strength. Pazhani. K [2] studies an experimental investigation to assess the durability parameters of high performance concrete by replacing copper slag as fine aggregate and GGBS as cement. Hossam. F Hassan [3] investigated the effect of using copper slag as a fine aggregate on the dynamic modulus and indirect tensile strength of hot-mix asphalt. Khalifa S. Al-Jabri [4] carried out an investigation to study the effect of using copper slag as fine aggregate on the properties of cement mortars and concrete. A S Alnuaimi [5] investigated the use of copper slag as a replacement for fine aggregates in reinforced cement slender columns.

II. EXPERIMENTAL PROGRAMME

1. Materials used

Ordinary portland cement of grade 53 is used for this experimental work . The fine aggregates used was natural sand and copper slag. The basic material test was done as per code IS: 383-1970. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and down. Campus water is used with pH value of 7.5. The Super plasticizer, complast SP430 is used for this experimental work. The physical properties are given in table 1.

TABLE I: PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATES

Particular	Natural sand	Copper slag	Coarse aggregate
Specific gravity	2.60	3.64	2.65
Water absorption (%)	1	0.82	0.5
Fineness modulus	2.61	3.33	7.30
Bulk density (g/cc)	1.47	2.21	-
Percentage of voids	43.46	39.29	-
Grading	Zone II	Zone I	-

2. Mix design:

The mix proportion chosen for this study is M30 grade (1:2.13:2.84) with water-cement ratio of 0.45. Cubes of standard size 150x150x150mm of total 24 no. and cylinders of standard diameter 150mm and height 300mmof total 12 no. and prisms of side 500x100x100mm are casted and cured for 7 and 28 days and tested as per code IS: 516-1959 and IS: 5816-1999.

TABLE II: MIX PROPOTION FOR M30 GRADE CONCRETE

Unit of batch	Water (litres)	Cement (Kg)	Sand (Kg)	Coarse aggregate (Kg)	Super plasticizer
Meter cube content	168	375	800	1066	3.75
Ingredient ratio	0.45	1	2.13	2.84	1%

3. Workability

Slump test was conducted to determine the workability of concrete. In this experimental work , as the percentage of copper slag increases, the workability of concrete mix also increases. The slump value obtained from different percentage of copper slag mixes are shown in figure 1.

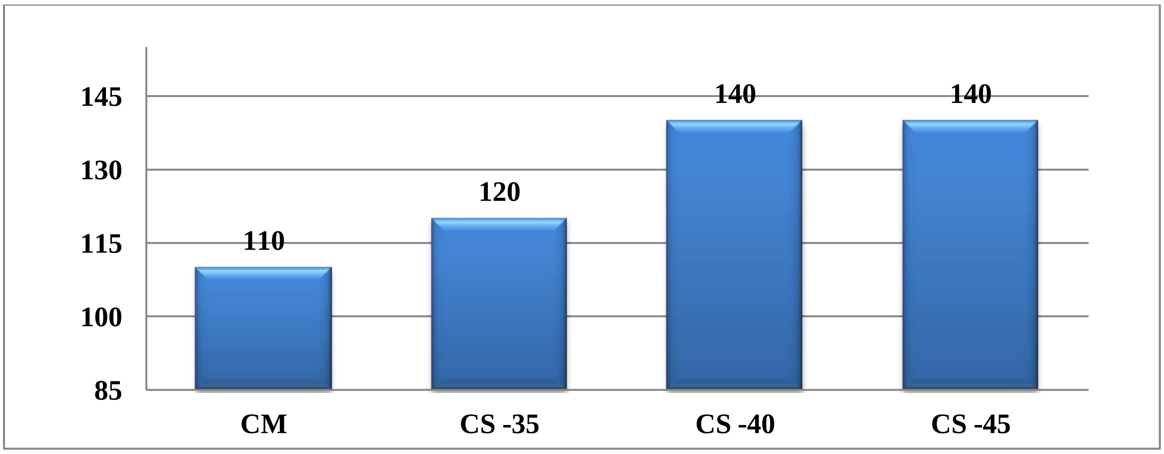

FIG 1: SLUMP VALUES FOR DIFFERENT MIX PROPORTIONS

4. Compressive strength test

The compressive strength test is carried out on various mixes by varying the percentage of copper slag by 0%, 35%, 40% and 45% and keeping all other parameters as constant. Cubes of standard size 150x150x150mm is casted and for each

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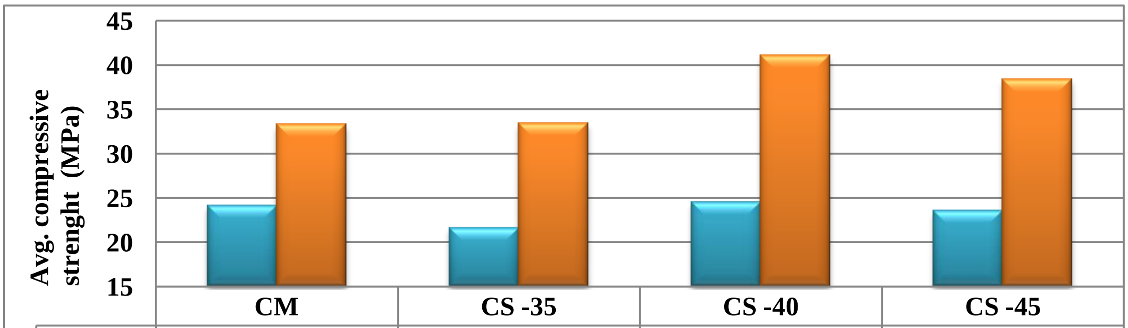
mix 6 cubes were cased and cured for 7 and 28 days. Test were conducted using 2000kN compression testing machine as per code IS: 516-1959. The maximum value obtained for 40% replacement of copper slag with natural sand.

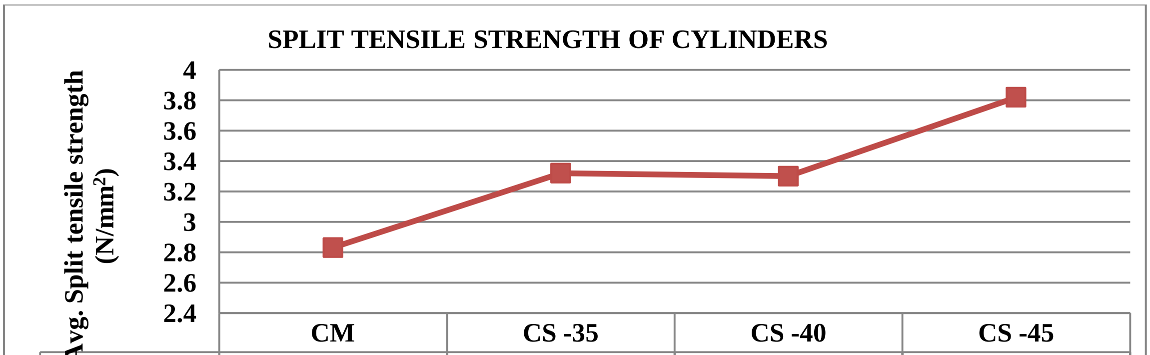


	CM	CS -35	CS -40	CS -45
7 days	24.12	21.65	24.56	23.54
28 days	33.28	33.43	41.13	38.37

FIG 2: COMPRESSION STRENGTH VARIATION OF DIFFERENT MIX FOR 7 & 28 DAYS

5. Split tensile strength test

The size of cylinder used for this test was of diameter 150mm and height 300mm. For each mix, 3 cylinders were casted and cured for 28 days. Then testing was done in 2000kN compression testing machine as per code IS:516-1959.The calculation was done by using the formula $f_{cr}=(2P)\div(\pi dl)$.

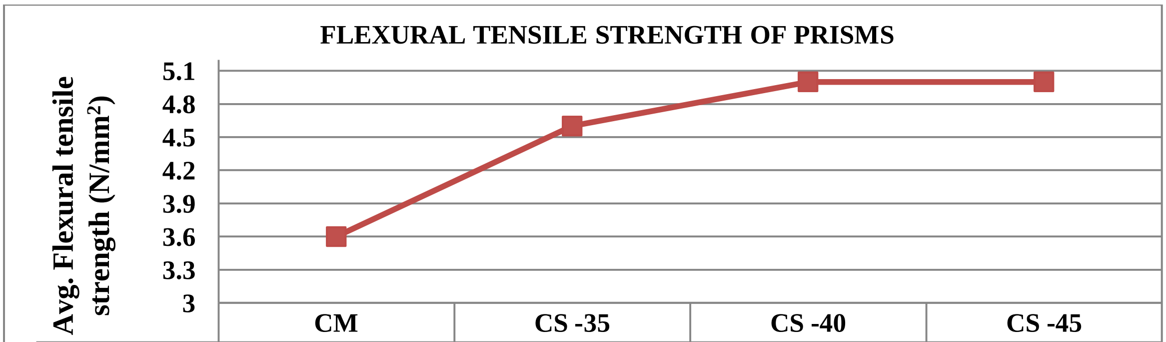


	CM	CS -35	CS -40	CS -45
fct (Mpa)	2.83	3.32	3.3	3.82

FIG 3: SPLIT TENSILE STRENGTH VARIATION OF DIFFERENT MIX

6. Flexural strength test

The prism of size 500x100x100mm is casted and cured for 28days. Testing is done under 2-point load according to code IS: 516-1959.



	CM	CS -35	CS -40	CS -45
fcr (Mpa)	3.6	4.6	5	5

FIG 4: FLEXURAL STRENGTH VARIATION OF DIFFERENT MIX

7. Flexural behavior of reinforced concrete beam:

The dimension of the test beam having overall length 'L' as 1700mm, effective length 'L_{eff}' as 1500mm, total depth 'D' as 200mm, effective depth 'd' as 170mm, breadth 'b' as 150mm and clear cover 'c' a 20mm is used. High yield strength deformed (HYSD) bars having 500 N/mm^2 yield strength is used in two different ways in test beams.

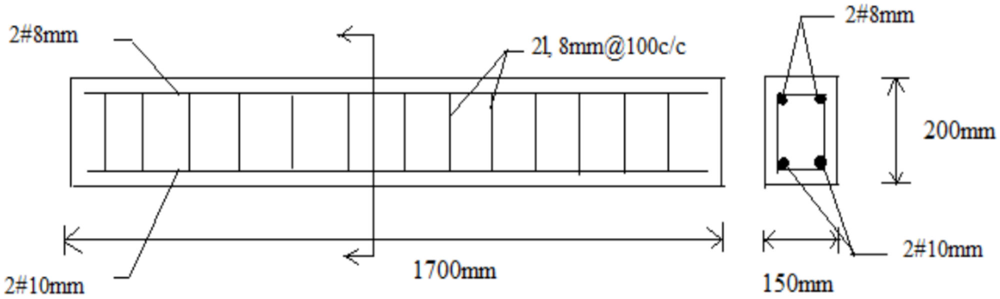


FIG 5: REINFORCEMENT DETAILS OF TEST BEAM-1, 2, 3 & 4

The test beams are white washed in lime and markings are made such as to indicate the support points, centre of beams and also to measure surface strain. Then the test beam is placed in loading frame on the supports. Then steel roller is kept on the loading frame points and eccentricity is checked. Then channel ISMC 250 is rested on the roller and hydraulic jack is placed on it centrally. The load is applied at the interval of 2kN and the deflection for every 2kN is noted by using digital dial gauge and surface strain is measured using demec gauge. The loading is continued till the test beam fails.

FIG 6: SET-UP OF TEST BEAM IN LOADING FRAME

III. RESULTS AND DISCUSSION

1. Crack pattern and modes of failure

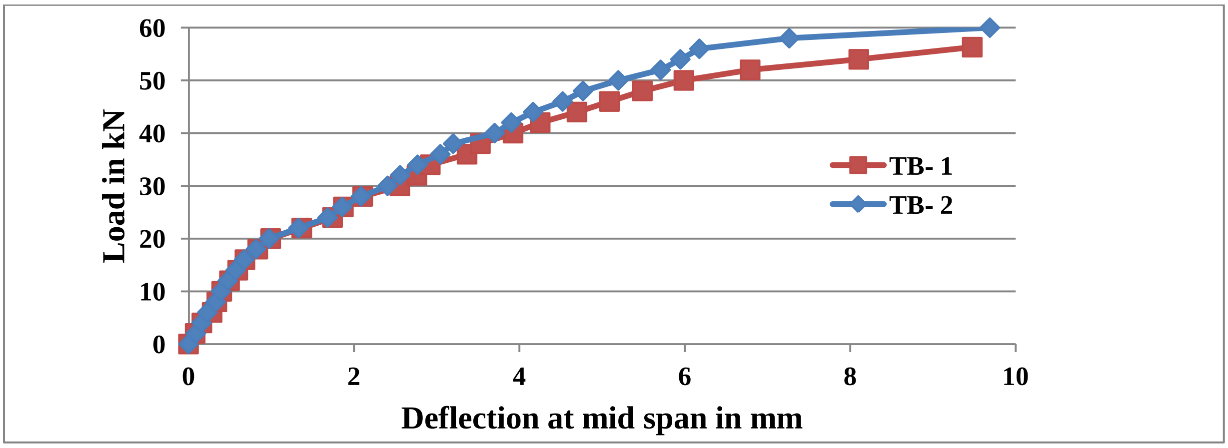
All the test beams were designed as under reinforced section. As the load was applied the beams started cracking at the tension zone and as the load was increased the crack started propagating toward the neutral axis. The mode of failure of all the beams were flexural failure. There was no horizontal cracks at the level of the reinforcement, which shows that there was no bonding failure.

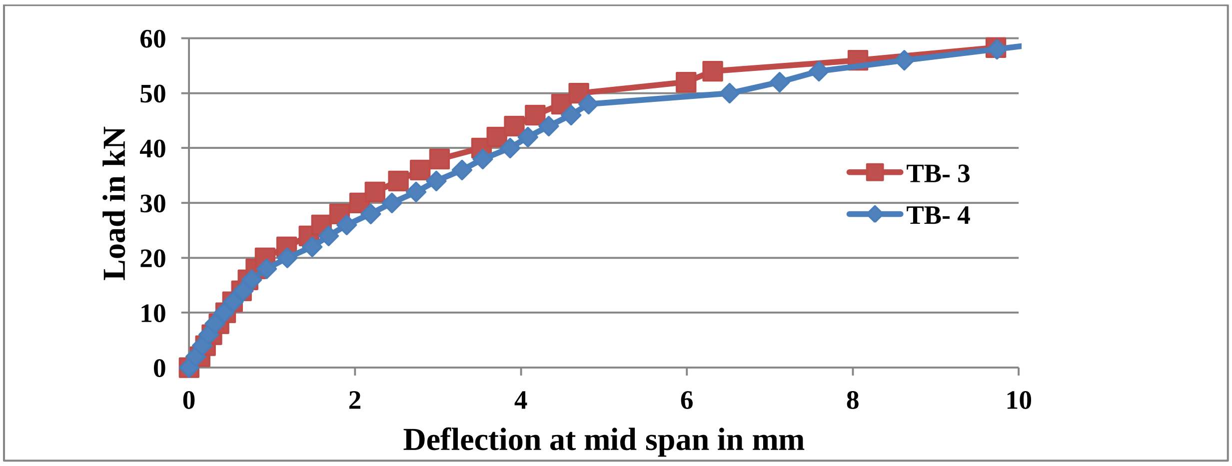
***2. Experimental results*:**

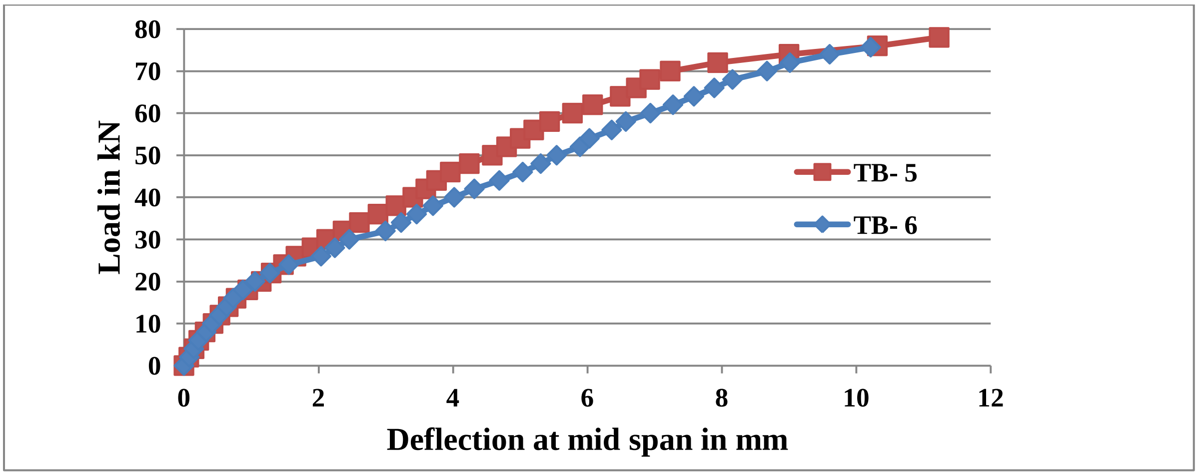
Structural parameters like cracking load, service load and ultimate load with their deflections are investigated. Totally 8 no. of test beams were casted and tested, in that 2 were control mix of 10 diameter bars, 2 were copper slag-40% of 10 diameter bars, 2 were control mix of 12 diameter bars, 2 were copper slag-40% of 12 diameter bars. The results of the deflections are shown in the table III and in figure 7.

TABLE III: EXPERIMENTAL RESULTS OF CRACKING LOAD, SERVICE LOAD AND ULTIMATE LOAD WITH THIER RESPECTIVE DEFLECTIONS AND CRACK WIDTH

Beam designation	A_{st} (%)	Experimental results								
		P_{cr} (kN)	Δ_{cr} (mm)	W_{cr} (mm)	P_s (kN)	Δ_s (mm)	W_s (mm)	P_u (kN)	Δ_u (mm)	W_u (mm)
Test Beam - 1	0.62	18	0.838	0.01	38	3.530	0.14	56.34	9.478	0.23
Test Beam - 2		22	1.330	0.01	40	3.702	0.19	60.00	9.691	0.29
Test Beam - 3	0.62	24	1.445	0.01	40	3.525	0.21	58.34	9.725	0.32
Test Beam - 4		26	1.900	0.01	40	3.870	0.16	59.67	10.637	0.26
Test Beam - 5	0.89	26	1.666	0.01	52	4.800	0.20	78	11.236	0.32
Test Beam - 6		24	1.559	0.01	51	5.716	0.22	75.67	10.217	0.37
Test Beam - 7	0.89	28	2.372	0.01	53	4.816	0.19	79	11.812	0.29
Test Beam - 8		26	1.625	0.01	52	4.328	0.23	77.67	10.680	0.34







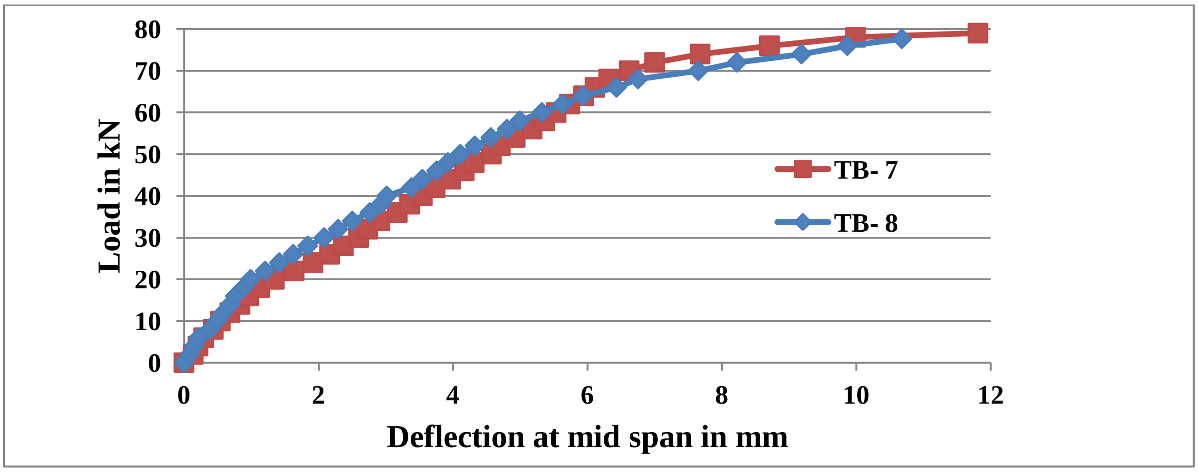


FIG 7: AVERAGE DEFLECTION OF ALL TEST BEAMS

The surface strain were measured using demec gauge. The strain reading were taken at approximately 95% of the failure mode. The load at which the first crack was observed was calculated as cracking moment. The load at which the beam fails and the crack observes was calculated as ultimate moment.

TABLE IV: EXPERIMENTAL RESULTS OF SURFACE STRAIN, CRACKING MOMENT AND ULTIMATE MOMENT

Beam designation	Load (kN)	Maximum surface strain		Avg cracking moment (kNm)	Avg ultimate moment (kNm)
		Compression	Tension		
Test beam -1	52	-0.000126	0.000158	5	14.50
Test beam -2	54	-0.000183	0.000324		
Test beam -3	54	-0.000241	0.000312	6.25	14.75
Test beam -4	54	-0.000269	0.000283		
Test beam -5	72	-0.000357	0.000372	6.25	19.25
Test beam -6	68	-0.000331	0.000347		
Test beam -7	72	-0.000363	0.000341	6.75	19.75
Test beam -8	72	-0.000336	0.000371		

IV. CONCLUSION

Based on the experimental investigations, the following conclusions were drawn.

1. The basic material test results showed that the properties of copper slag is similar to that of natural sand and can be used as natural sand.
2. The control mix for M30 grade and the replacement of copper slag by 0%, 35%, 40% and 45% by weight of natural sand were designed.
3. The optimum level of replacement of copper slag was found to be 40% and the results were better than that of control mix.
4. The workability of fresh concrete increases with increase in the replacement of copper slag content for the same dosage of super-plasticizer.
5. The compressive strength gradually increases from 0%, 35%, 40% replacement of copper slag and decreases for 45% replacement of copper slag.
6. The 28 days average compressive strength obtained for copper slag mix concrete shows 0.45% to 23.6% increase in compressive strength when compared to control mix concrete.
7. The 28 days average split tensile strength obtained for copper slag mix concrete shows 16.61% to 34.98% increase in split tensile strength when compared to control mix concrete.
8. The 28 days average flexural strength obtained for copper slag mix concrete shows 27.78% to 38.89% increase in flexural strength when compared to control mix concrete.
9. The deflection of the test beams are increase as the tensile reinforcement is increased by 0.62% to 0.89% due to increase in the load capacity of the test beams.
10. The maximum strain at service load should not exceed 0.0035 as per code IS: 456-2000. Therefore the experimental results shows that the maximum strain in all test beams are well within the limits.
11. The flexural results shows that there is an increase in cracking moment by 31.84% for 0.62% tensile reinforcement and 41.01% for 0.89% tensile reinforcement.
12. The ultimate moment obtained from experimental results are greater that the theoretical results by 27.58%.
13. concrete incorporating copper slag exhibits good mechanical properties and therefore up to 40% by weight of natural sand can be replaced by copper slag.

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