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Experimental Analysis of Design Mix Concrete with Copper Slag

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Abstract-
This paper presents the results of investigation on strength characteristics of concrete prepared using copper slag (CS) as partial replacement to fine aggregate and fly-ash (FS) as partial replacement to cement. CS & FS are the two industrial byproducts. Utilization of these industrial byproducts in concrete is the aim of this experimental work. Sustainability and resource efficiency are becoming increasing important issues. Here the potential use of granulated copper slag, a relatively heavy material, as a replacement to sand in concrete mixes is explored. The effect of replacing fine aggregate by copper slag on the compressive strength, flexural strength and split tensile strength of concrete are studied in this work

Keyword-
Copper Slag, concrete, Hardended Concrete Destructive Testing

1. INTRODUCTION-

In India, construction sector is under tremendous pressure to explore alternatives to the construction material, as the demand of construction materials like river sand and natural aggregates has been increasing greatly. Copper industries in India take up about 3% of the entire world market for copper. Indian copper companies - Sterlite Industries, Hindalco, and Hindustan have contributed to the production of major quantities of copper. Copper slag, which is produced during pyrometallurgical production of copper from copper ores, which contain materials like iron, alumina, calcium oxide, silica etc. The favorable physical-mechanical characteristics of copper slag can be utilized to make the products like cement, fill, ballast, abrasive, aggregate, roofing granules, glass, tiles etc

2. MATERIALS-

2.1-CEMENT

PHYSICAL PROPERTIES	RESULT
SPECIFIC GRAVITY	3.05
NORMAL CONSISTENCY (%)	36
INITIAL SETTING TIME (min)	90
FINAL SETTING TIME (min)	420

2.2- FLY ASH

PHYSICAL PROPERTIES	**RESULT**
SPECIFIC GRAVITY	2.2
TYPE	CLASS F

2.3- FINE AGGREGATE

PHYSICAL PROPERTIES	RESULT
SPECIFIC GRAVITY	2.51
TYPE	RIVER SAND
FINENESS MODULUS	2.79
GRADING ZONE	II
WATER ABSORPTION %	1.08

2.4- COPPER SLAG

PHYSICAL PROPERTIES	RESULT
SPECIFIC GRAVITY	3.52
FINENESS MODULUS	3.53
BULK DENSITY kg/m^3	1750
VOID RATIO	.8
WATER ABSORPTION %	.13

2.5- COARSE AGGREGATE

PHYSICAL PROPERTIES	RESULT
SPECIFIC GRAVITY	2.75
FINENESS MODULUS	7.6
BULK DENSITY kg/m^3	1380
VOID RATIO	.95
WATER ABSORPTION %	.45
GRADING ZONE	MAX SIZE 20mm

2.6- REINFORCEMENTS

S.N.	NOMINAL DIAMETER (mm)	UNIT WEIGHT (Kg/m)	ULTIMATE TENSILE STRENGTH(N/mm$^{2)}$	ELONGATION %
1	6	.25	542.3	13.96
2	8	.39	716.46	11.63
3	10	.6	693.57	14.11

2.7-CHEMICAL COMPONENTS OF FLY ASH AND COPPER SLAG

CHEMICAL COMPONENTS	FLYASH	COPPER SLAG
O	50.6	45.9
SI	18.7	12.9
FE	3.1	9.7
CA	10.2	8.8
C	6.5	8.5
MG	.22	5.7
AL	19.6	4.6
NA	-	1.3
TI	.5	1.3
K	.8	1.2

3. MIX COMPOSITION FOR M30 GRADE

24 mix proportions are prepared with, cement is partially replaced by FA from 0% to 30% with 10% increment by mass and the fine aggregate is replaced by CS from 0% to 100% with 20% increment by mass. Coarse aggregate and water cement ratio are kept constant as 1293 kg/m^3 and 0.4. Totally 24 concrete mix proportions are prepared and mix proportions of M30 grade is given in Table-

MIX IDENTIFICATION	CEMENT (kg/m$^{3)}$	Fly ash (kg/m$^{3)}$	FA (kg/m$^{3)}$	COPPER-SLAG (kg/m$^{3)}$	CA (kg/m$^{3)}$	WATER (kg/m$^{3)}$
FA0-CS0	380	0	596	-	1293	152
FA0-CS20	380	0	520	183	1293	152
FA0-CS40	380	0	390	366	1293	152
FA0-CS60	380	0	260	549	1293	152
FA0-CS80	380	0	131	738	1293	152
FA0-CS100	380	0	0	922	1293	152
FA10-CS0	342	38	596	-	1293	152
FA10-CS20	342	38	520	183	1293	152
FA10-CS40	342	38	390	366	1293	152
FA10-CS60	342	38	260	549	1293	152
FA10-CS80	342	38	131	738	1293	152
FA10-CS100	342	38	0	922	1293	152
FA20-CS0	304	76	596	-	1293	152
FA20-CS20	304	76	520	183	1293	152
FA20-CS40	304	76	390	366	1293	152
FA20-CS60	304	76	260	549	1293	152
FA20-CS80	304	76	131	738	1293	152
FA20-CS100	304	76	0	922	1293	152
FA30-CS0	266	114	596	-	1293	152

FA30-CS20	266	114	520	183	1293	152
FA30-CS40	266	114	390	366	1293	152
FA30-CS60	266	114	260	549	1293	152
FA30-CS80	266	114	131	738	1293	152
FA30-CS100	266	114	0	922	1293	152

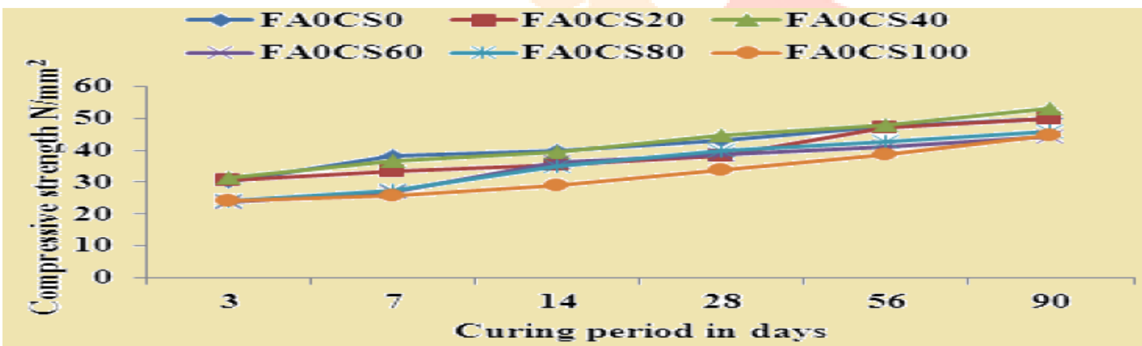
4. HARDENED CONCRETE DESTRUCTIVE TESTING

- COMPRESSIVE STRENGTH
- SPLITTING TENSILE STRENGTH
- FLEXURAL STRENGTH

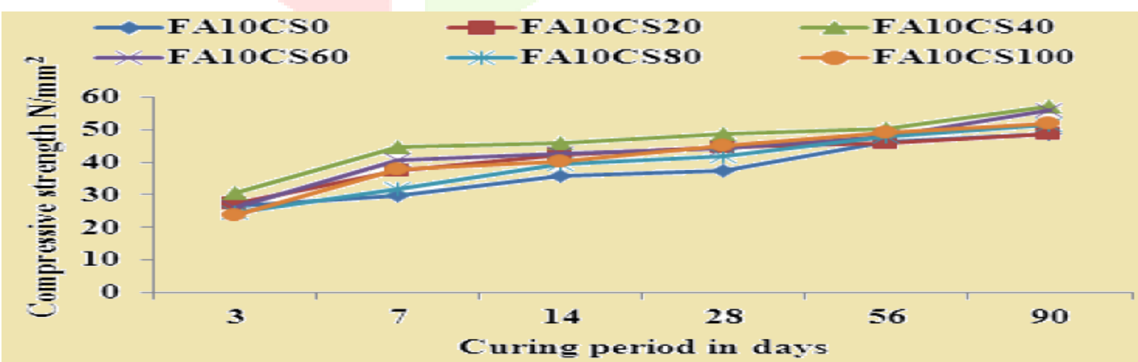
4.1 COMPRESSIVE STRENGTH TEST

As per Indian standard specifications BIS: 516-1959. Compressive strength test is conducted on cubes (150mm) at the required age. Compression tests are conducted using compression testing machine with 2000kN capacity. Sensitivity of this machine is 10kN. The load is applied at the rate of 10kN/sec and the compressive strength is calculated using the following equation-

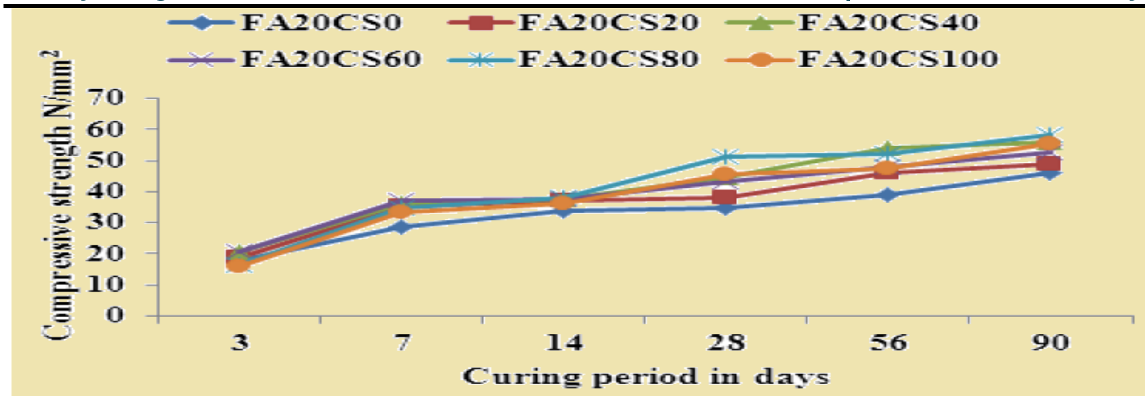
$$\text{Compressive strength} = \frac{P}{A}$$



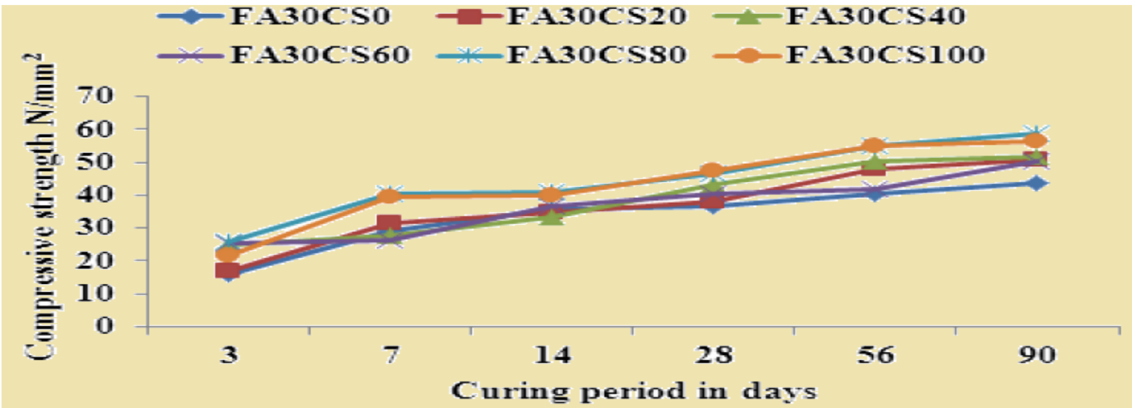
COMPRESSIVE STRENGTH OF FA0% AND CS FROM 0% TO 100%



COMPRESSIVE STRENGTH OF FA 10% AND CS FROM 0% TO 100%



COMPRESSIVE STRENGTH OF FA20% AND CS FROM 0% TO 100%

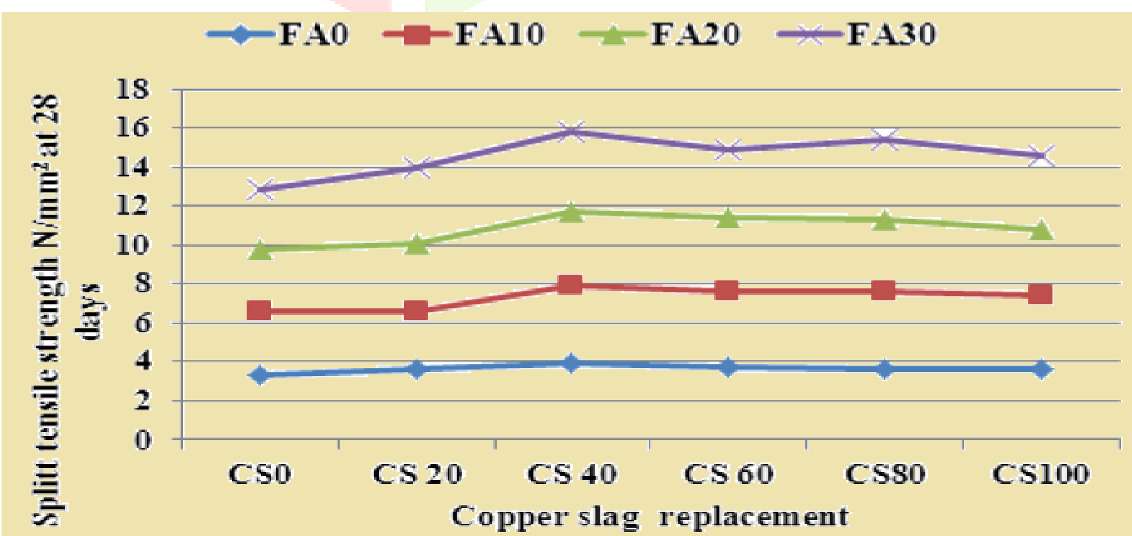


COMPRESSIVE STRENGTH OF FA30% AND CS FROM 0% TO 100%

4.2 SPLITTING TENSILE STRENGTH TEST

Tensile stress is developed in concrete due to drying shrinkage, rusting of steel reinforcement and temperature gradient. Tensile strength of the concrete is very important for unreinforced concrete structures, such as dams, under earthquake conditions. Other structures, such as highway and airfield pavements are designed on the basis of flexural strength of the concrete. Splitting tensile strength tests are carried out on 150mm diameter x 300mm long cylinders at 28 days of curing period by using compression testing machine. The maximum load at failure reading is taken and the splitting tensile strength is calculated using the equation-

$$\text{Splitting tensile strength } (N/mm^2) = \frac{2P}{\pi L D}$$

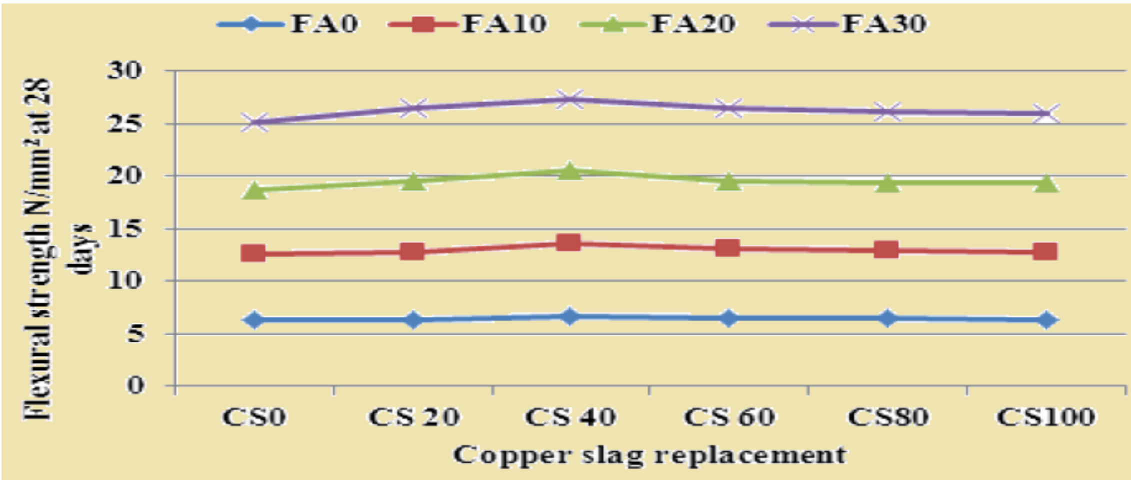


SPLITTING TENSILE STRENGTH AT 28 DAYS

4.3 FLEXURAL STRENGTH TEST

Flexural strength tests are carried out on 100mm x100mm x 500mm prisms with center point loading at 28 days of curing age by using 500 KN loading frame with applied at a rate of 1kN/30 second. The flexural strength is calculated by the following equation-

$$\text{Flexural strength} = \frac{Pl}{bd^2}$$



FLEXURAL STRENGTH AT 28 DAYS

5. CONCLUSION

- In concrete with FA alone, the initial rate of gain of compressive strength has been decreased, due to slow pozzolanic action, but th strength is developed at later ages (28-90 days).
- Based on 90 days compressive strength of concrete, optimum compressive strength is reached, when in the concrete, cement is replaced by 30% of FA and 80% of CS for fine aggregate. It is 17.75% better than the strength of control mix at 90 days and 36.83% better than the strength of control mix at 28 days. Hence, this mix proportion is suitable for concrete structures.
- From the compressive strength test results, it can be seen that, when the curing periods increased, higher strength is obtained for concrete with higher replacement of fly ash and copper slag, respectively.
- In 56-90 days curing period, compressive strength of the all the mix proportions are yielded higher than the target mean strength of M30 grade of concrete.
- Based on the tensile strength of concrete FA30CS40 mixture is suitable for pavement, runways and airfield constructions.
- Higher compressive strength reached at 28 days concrete shows higher tensile strength. Use of pozzalanic materials increases the tensile strength of concrete.

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