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Use of Copper Slag for Partial Replacement to Fine Aggregate in Concrete

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Abstract--- Copper slag is an excellent by-product or waste material which retains its original properties. Due to its chemical composition which includes high iron, silica and aluminum oxide content, it can be used as a partial replacement for sand in concrete mixes. Mix design of concrete is done on weight basis, by adding various percentages of copper slag (10%, 15%, 20%, 25%, 30% and 35%) instead of sand and concrete mixtures were prepared based on it. The cube, beam and cylindrical specimens were then prepared, demoulded after 24 hours and properly cured. The specimens were subjected to compression testing, split tensile strength testing and flexural testing at 7 and 28 days. It was observed from the test results that the compressive strength of the specimens was higher than the control specimen on adding 10 to 30% of copper slag and on further increasing it, the compressive strength was observed to be reducing. In particular, 10% addition gave more strength than 30% addition. Delay in hardening of concrete specimens was observed. Replacement of copper slag increased the self-weight of the specimens of about 15%.

Keywords--- Copper slag, compressive strength, fine aggregates, hardening, self-weight of concrete.

I. INTRODUCTION

Sustainability in adopting various construction materials has become essential nowadays. Utilization of by-products of manufacturing industries could provide solution to the problems of using natural materials for concrete. Among the other ingredients of concrete, it is fine aggregates are considered to be highly cost to concrete. Alternate material to such fine aggregate becomes necessary so as to reduce the cost of construction while improving both fresh and hardened properties of concrete. In this present investigation, copper slag, an industrial by-product obtained during the manufacturing of copper has been used to partially replacement to fine aggregate. In the last few decades there has been rapid increase in the waste metals and by-products production due to the exponential growth rate of population, development of industry and technology and the growth of consumerism. The basic strategies to decrease solid waste disposal problems have been focused at the reduction of waste production and recovery of usable materials from waste as raw materials as well as utilization of waste as raw materials whenever possible [2]. 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, blast furnace slag and silica fume as partial replacements for Portland cement. Such materials are widely used in the construction of industrial and chemical plants because of their enhanced durability compared with Portland cement. The other main advantage of using such materials is to reduce the cost of construction. Copper slag is obtained as a by-product during the manufacturing and refining process of copper and hence, it could be used as either partial or full replacement to fine aggregates [1], [6-8]. Also, the production of approximately 0.36, 0.244, 2.0, and 4.0 million tons of copper slag is reported in Iran, Brazil, Japan and the United States respectively. Copper slag has been used for reduction pollution due to air-borne, cost of concrete and waste. Although there are some studies that have been reported on the effect of copper slag as fine aggregates on the performance of normal strength concrete, there has been little research concerning the incorporation of copper slag as fine aggregates to produce concrete [4]. Thus this research was performed to evaluate the potential use of Copper slag as sand replacement in the production of concrete.

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II. EXPERIMENTAL INVESTIGATION

Introduction

In this, the details of laboratory tests like compressive strength, flexural strength, split tensile strength, of concrete admixed with copper slag as a partial replacement to fine aggregate were presented.

Properties of materials

- *Cement* **-** OPC 53 grade cement was used with a specific gravity of 3.15.
- *Coarse aggregate* **-** Coarse aggregates of broken granites passing 12.5mm and 20mm were used with a specific gravity of 2.65.
- *Fine aggregate* – Sand conforming to zone III was used as fine aggregated with a specific gravity of 2.57.
- *Copper slag* – [3,5] Physical and Chemical properties of the copper slag as obtained were provided in the following tables:

TABLE I. Physical property of copper slag

Physical properties	Copper slag
Particle shape	Irregular
Appearance	Black & glassy
Specific gravity	2.79
Percentage of voids %	43
Bulk density g/cc	2.08
Water absorption %	0.18
Moisture content %	0.1

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TABLE II. Chemical Compositions

S. No	Chemical component	% of chemical components
1	SiO_2	25.84
2	Fe_2O_3	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

- *Water* - Tap water was used for preparation and curing of concrete specimens.

Mixing

Hand mixing was adopted with required quantities of ingredients.

Casting

Specimens were prepared as per the standard procedure.

Fig. 1. Casting of Specimen

Curing

Curing period of 7days and 28days were adopted.

Test conducted

The following tests were conducted to determine the Strength of the samples taken

- *Compressive strength test* - Compressive strength test was carried out with specimens of size 150mm × 150mm.
- *Flexural strength test* - Flexure test was carried out with beams of size 500mm × 100mm ×100mm.
- *Split tensile strength test* - Split tensile test was carried out with specimens of size 150mm × 300mm.

III. MIX DESIGN

Design stipulations

Mix design was done as per Indian standard method for **M30** is **1: 1.17: 2.55** and water content is 0.42.

Material calculation

i) Materials calculation for cube casting

Volume of concrete V = $0.0101m^3$

Total weight of concrete W = 27.3kg

Quantity of cement = 5.78kg

Quantity of fine aggregate = 6.76kg

Quantity of coarse aggregate = 14.8kg

Amount of water = 2.5litres

ii) Materials calculation for beam casting

Volume of concrete V = $15 \times 10^{-3} m^3$

Total weight of concrete W = 36kg

Quantity of cement = 7.7kg

Quantity of fine aggregate = 8.9kg

Quantity of coarse aggregate = 19.5kg

Amount of Water = 3.3 litres

iii) Materials calculation for cylinder casting

Volume of concrete V = $15.9 \times 10^{-3} m^3$

Total weight of concrete W = 38.2kg

Quantity of cement = 8.1kg

Quantity of fine aggregate = 9.5kg

Quantity of coarse aggregate = 20.5kg

Amount of water = 3.4 litres

IV. RESULTS AND DISCUSSION

Compression strength of samples

i) The determined Compression strength of sample after 7 days curing was as per the following table and average strength is represented in charts below:

TABLE III. Compression Strength Of Sample After 7 Days Curing

% Of Copper Slag Replacement	Compressive Strength in N/mm^2 (σ_{cc})			
	7 days curing			
	1	*2*	*3*	*Average*
0%Control concrete	25.8	28.2	28.6	27.54
10%	26	24.8	28.2	26.32
15%	25.6	24.4	26.6	25.53
20%	24.8	27.2	22.5	24.83
25%	25.3	22.4	26.4	24.7
30%	24.2	22.6	20.4	22.4

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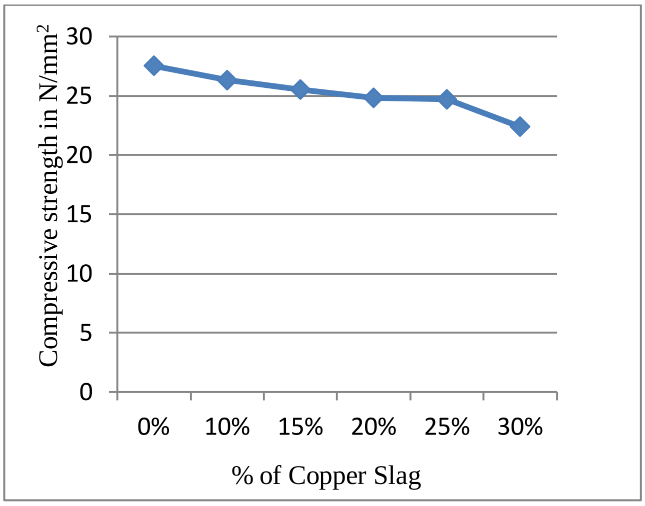

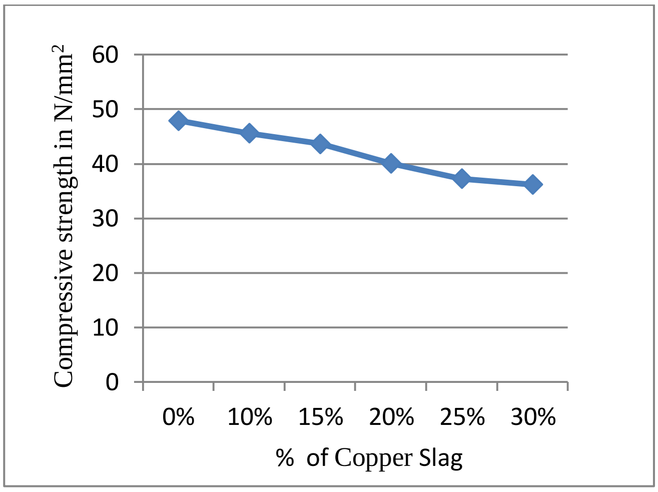

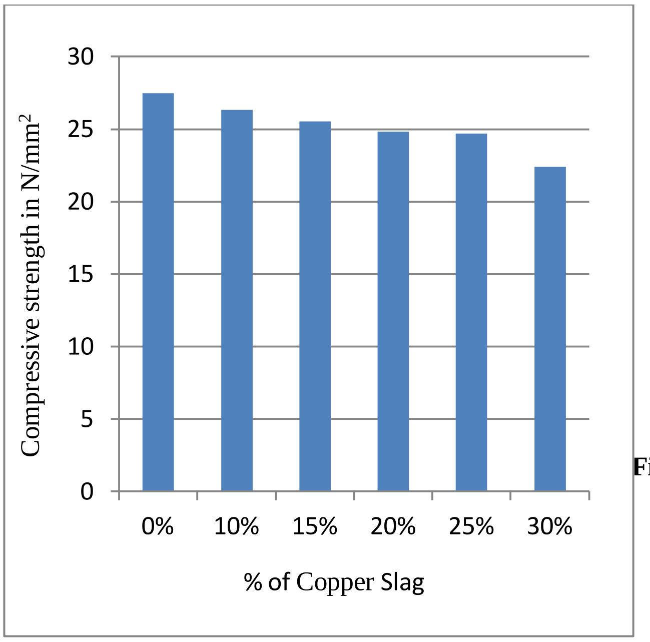

Fig. 2. Average compression strength after 7 days curing

ii) The determined Compression strength of sample after 28 days curing was as per the following table and average strength is represented in charts below:

TABLE IV. Compression Strength Of Sample After 28 Days Curing

% OF COPPER SLAG REPLACEMENT	COMPRESSIVE STRENGTH in N/mm^2 (σ_{cc}) 28 DAYS CURING			
	1	*2*	*3*	*AVERAGE*
0%CONTROL CONCRETE	47.98	45.87	49.9	47.91
10%	45.3	47.8	43.8	45.63
15%	44.9	42.3	43.5	43.66
20%	42.5	39.6	38.2	40.1
25%	36.7	38.4	36.8	37.3
30%	36.8	35.2	36.7	36.23

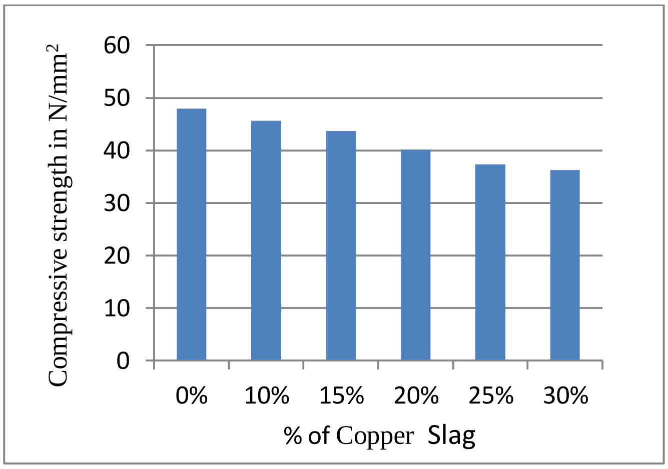

Fig. 3. Average compression strength after 28 days curing

Flexural strength of samples

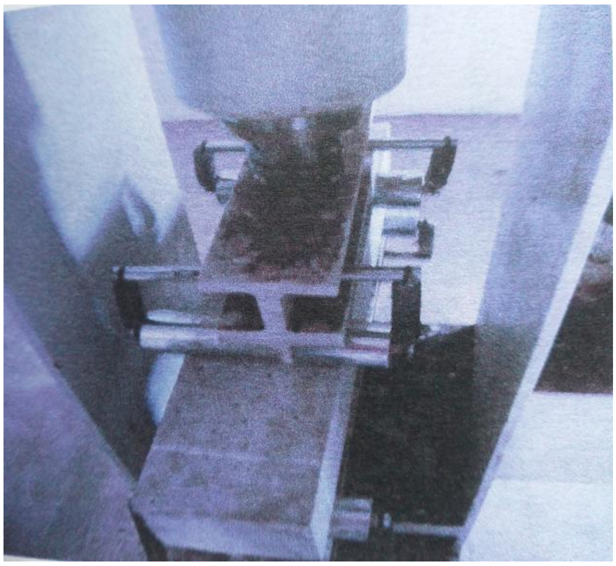

Fig. 4. Flexural test

i) The determined Flexural strength of sample after 7 days curing was as per the following table and average strength is represented in charts below:

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TABLE V. Flexural Strength Of Sample After 7 Days Curing

% Of Copper Slag Replacement	Flexural Strength In N/mm²			
	7 days curing			
	1	*2*	*3*	*Average*
0% Control Concrete	5.2	4.2	4.89	4.76
10%	5.2	4.4	3.96	4.52
15%	4	4.8	3.6	4.13
20%	3.96	4	3.6	3.85
25%	3	4.8	1	2.93
30%	1.5	2.4	1.5	1.8

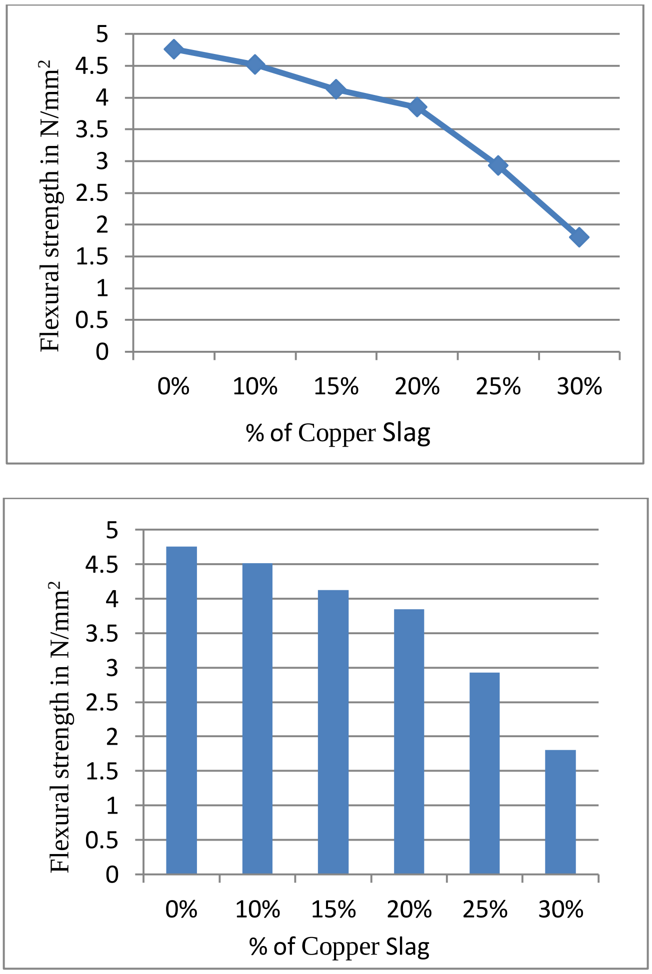


Fig. 5. Average Flexural strength after 7 days curing

i) The determined Flexural strength of sample after 28 days curing was as per the following table and average strength is represented in charts below:

TABLE VI. Flexural Strength Of Sample After 28 days Curing

% Of Copper Slag Replacement	Flexural Strength In N/mm²			
	28 days curing			
	1	*2*	*3*	*Average*
0% ControlConcrete	5.2	6.4	6.2	5.93
10%	5.8	5.2	6.24	5.74
15%	4.8	6.4	5.8	5.67
20%	5.04	5	4.2	4.75
25%	4.125	5.6	1.76	3.82
30%	2.24	3.2	2.4	2.61

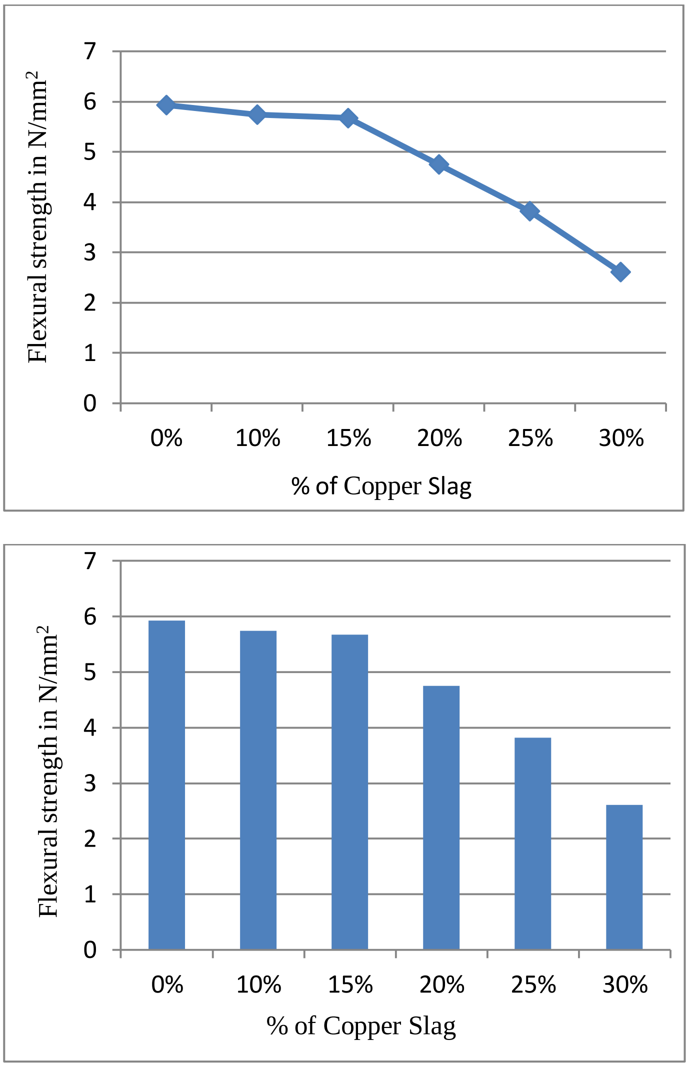


Fig. 6. Average Flexural strength after 28 days curing

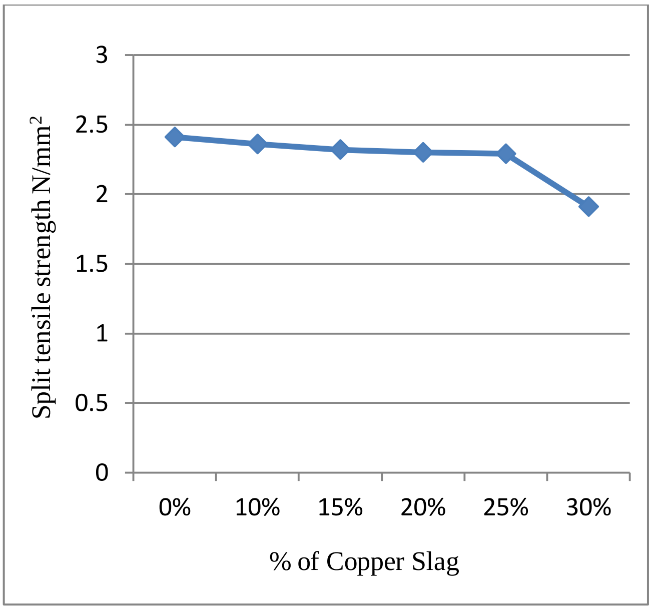
Split tensile strength

i) The determined Split tensile strength of sample after 7 days curing was as per the following table and average strength is represented in charts below:

Fig. 7. Split tensile test

TABLE VII. Split Tensile Strength Of Sample After 7 days Curing

% Of Copper Slag Replacement	Split Tensile Strength In N/mm^2 (T_{sp})			
	7 days curing			
	1	***2***	***3***	***Average***
0% ControlConcrete	2.4	2.38	2.46	2.41
10%	2.54	2.15	2.39	2.36
15%	2.54	2.15	2.39	2.32
20%	2.13	2.27	2.50	2.3
25%	2.46	2.04	2.38	2.29
30%	1.95	1.87	1.92	1.91



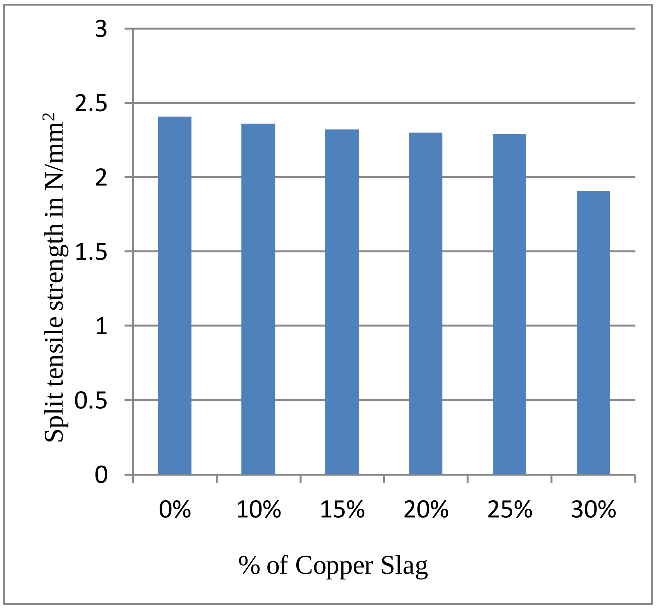
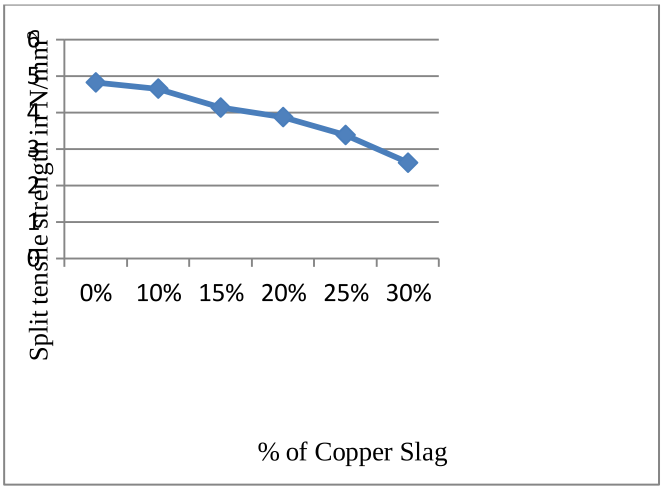


Fig. 8. Average Split tensile strength after 7 days curing

ii) The determined Split tensile strength of sample after 28 days curing was as per the following table and average strength is represented in charts below:

TABLE VIII. Split Tensile Strength of Sample After 28 days Curing

% Of Copper Slag Replacement	Split Tensile Strength In N/mm^2 (T_{sp})			
	28 days curing			
	1	***2***	***3***	***Average***
0% ControlConcrete	4.66	5.40	4.42	4.82
10%	4.66	4.10	5.20	4.65
15%	4.39	3.8	4.20	4.13
20%	3.92	3.9	3.8	3.87
25%	3.7	3.2	3.24	3.38
30%	3.55	1.89	2.44	2.62



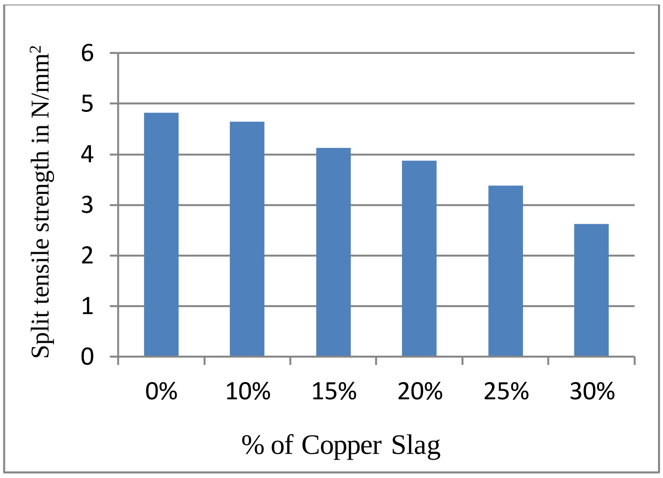


Fig. 9. Average Split tensile strength after 28 days curing

V. CONCLUSIONS

1) Copper slag is an excellent admixture replacing 30% of fine aggregate. However, further research works were needed in durability aspects.

2) Addition of Copper slag increased self-weight of concrete specimens up to 18%.

3) Although strength of control sample has shown higher than test sample, the cost of replacement of Copper slag is less cost.

4) It was observed that test sample has shown a delay in the hardening stage.

5) Copper slag can be used as a mineral admixture along with suitable chemical admixture to control the movement of water. This requires further investigation.

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