Strength and Durability Characterestics of Steel Fibre Reinforced Concrete Containing Copper Slag as Partial Replacement of Fine Aggregate

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Abstract **- This paper focuses on the strength and durability characterestics of steel fibre reinforced concrete containing copper slag as partial replacement of fine aggregate. Mix proportioning has to be done for M20 normal concrete. Sand is replaced with copper slag in proportions of 0%, 10%, 20%, 30%, 40%, 50% & 60%. In all mixes, the proportion of steel fibre is kept constant i.e., 0.2% by volume of concrete. All hybrid mixes were tested and then found that Steel fibre reinforced concrete containing copper slag as 40 % Partial replacement of fine aggregate gives maximum strength and durability criteria.**

Key Words: Copper Slag, Steel Fibre, Partial Replacement, Compressive Strength, Optimum Mix, Accelarated Corrosion Process etc.

I. INTRODUCTION

Normal concrete, widely used as a construction material, has many advantages including an ability to be cast, low cost, good durability, fire resistance, energy efficiency, onsite fabrication and aesthetics. However, concrete also has many disadvantages including low tensile strength, low ductility and large variability. Concrete is a most versatile construction material because it is designed to withstand the harsh environments. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary materials. The use of these by products not only helps to utilize these waste materials but also enhances the properties of concrete in fresh and hydrated states.

Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. Hence substitute or replacement product for concrete industry needs to be found.. Copper slag is an industrial by-product material produced from the process of manufacturing of copper. Due to its less tensile strength, concrete is subjected to crack on loading. These cracks will propagate in all the three directions. Concrete technologists have found that reinforcement with randomly distributed short fibres may improve the toughness of the cementitious materials by preventing or controlling the initiation, propagation of crack.

This work aims at the study of strength and durability variations observed by the incorporation of copper slag as partial replacement of sand in steel fibre reinforced concrete and then compared with the strength & durability properties of conventional concrete.

II. OBJECTIVES

To investigate the development of strength and durability characteristics of copper slag admixed steel fibre reinforced concrete and compare with normal concrete.

III. TESTING OF MATERIALS

Cement

Ordinary Portland cement (OPC) confirming to **IS-12269** (53 Grade) having specific gravity of 3.14 and fineness of 4 % was used.

Copper slag

Copper slag with specific gravity 3.91 and fineness modulus 3.47 was used.

Fine aggregate

Manufacture sand conforming to **Grading zone II of IS: 383 1970** having specific gravity of 2.6 and fineness modulus 2.47 was used.

Coarse aggregate

Crushed angular metal of 12 mm size having specific gravity of 2.78 and fineness modulus of 6.92 was used.

Steel fibre

Steel fibre of crimpled type, density 7.2 gm/cc having aspect ratio 56 was used.

Water

Potable clean water was used.

IV. MIX PROPORTION

The mix design is done for **M20** concrete as per **IS: 10262-1982.**

Table.1 Mix proportions (Kg/m^3) and Mix ratio

Cement	Coarse Aggregate	Fine Aggregate	Water
333	1020	925	170
1	3.08	2.78	0.51

V. MIX DESIGNATION

Table.2 Mix Designation

Mix Designation	**Copper slag (%)**	**Steel fibre (%)**
CS0	0	0
CS1	10	0.2
CS2	20	0.2
CS3	30	0.2
CS4	40	0.2
CS5	50	0.2
CS6	60	0.2

VI. EXPERIMENTAL RESULTS

The various tests of strength and durability were performed, tabulated and analysed the results.

A) Results of Strength Tests

Compressive Strength

Table.3 Compressive Strength

Mix Designation	Compressive Strength (MPa)		
	3 day	7 day	28 day
CS0	24	26	35
CS1	25.5	28	37
CS2	27	29.5	38.5
CS3	28	31	40
CS4	29.5	33	42.5
CS5	27.5	29	39
CS6	25	26.5	36

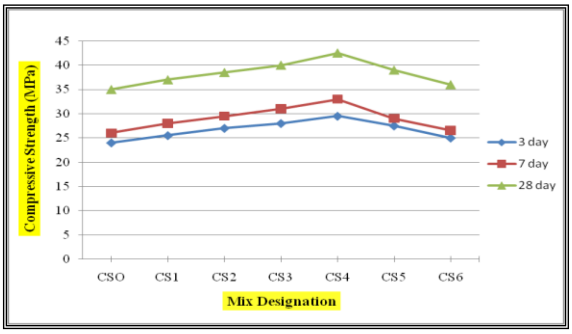

Fig.1 Variation of Compressive Strength at 3rd, 7th & 28th days

Flexural Strength

Table.4 Percentage Increase in Flexural Strength at 28th day

Mix Designation	Flexural Strength (MPa)	Increase in Flexural Strength (%)
CS0	3.41	-
CS1	3.72	9.09
CS2	4.02	17.89
CS3	4.10	20.23
CS4	4.19	22.87
CS5	4.01	17.59
CS6	3.60	5.59

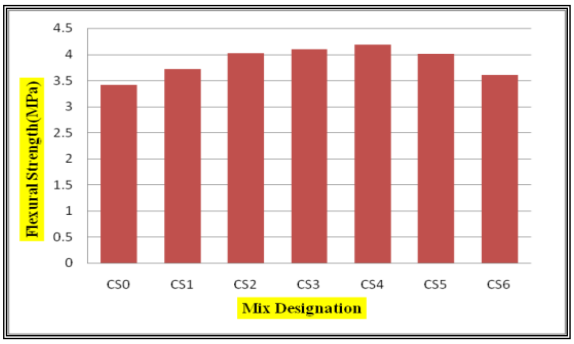

Fig.2 Variation of Flexural Strength at 28th day

Split Tensile Strength

Table.5 Percentage Increase in Split Tensile Strength at 28th day

Mix Designation	**Split Tensile Strength (MPa)**	**Increase in Split tensile strength (%)**
CS0	2.83	-
`CS1	3.12	10.25
CS2	3.47	22.61
CS3	3.60	27.21
CS4	3.75	32.51
CS5	3.33	17.67
CS6	3.25	15.19

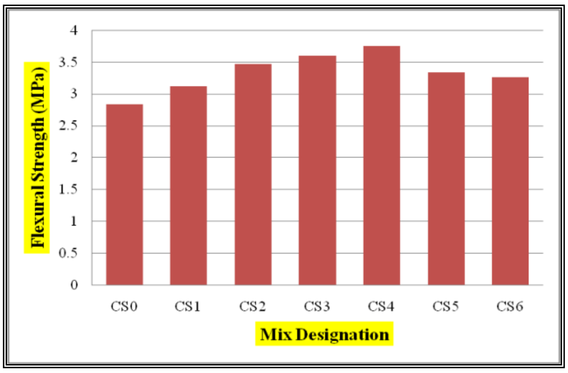

Fig.3 Variation of Split Tensile Strength at 28th day

Modulus of Elasticity

Table.6 Modulus of Elasticity at 28th day

Mix Designation	Modulus of Elasticity (MPa)	Increase in Modulus of Elasticity (%)
CS0	40401	-
CS1	42365	4.86
CS2	51044	26.34
CS3	52490	29.92
CS4	54752	35.52
CS5	45132	11.71
CS6	43844	8.52

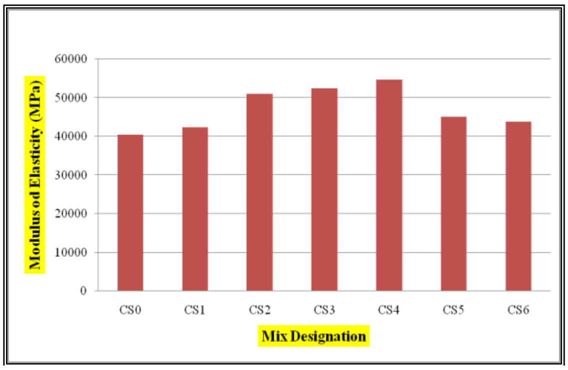

Fig.4 Variation of Modulus of Elasticity at 28th day

Impact Resistance

Table.7 Impact Resistance at 28th day

Mix Designation	No. of blows required for first crack (X)	No. of blows required for Ultimate failure (Y)
CS0	11	20
CS1	18	36
CS2	26	60
CS3	33	72
CS4	53	108
CS5	49	90
CS6	40	79

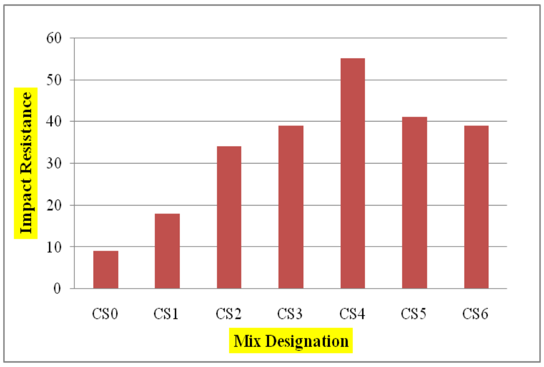

Fig.5 Variation of Impact Resistance at 28th day

B) Fixing the Optimum Mix

Optimum mix in the view of Strength consideration is Steel Fibre Reinforced Concrete Containing Copper Slag as 40 % Partial Replacement of Fine Aggregate (CS4) and that mix is selected for studying the Durability characteristics by comparing with Normal mix.

C) Results of Durability Tests

Accelerated Corrosion Process (Galvano Static Weight Loss Method)

Table.8 Results of Accelerated Corrosion Process (Uncoated rebar)

Mix Designation	Weight of rod (gm)		Loss in Weight (gm)	Corrosion Rate (mm/yr)
	Before corrosion	After corrosion		
CS0	230	228	2	0.35
CS4	230	220	10	1.75

Table.9 Results of Accelerated Corrosion Process (Coated rebar)

Mix Designation	Weight of rod (gm)		Loss in Weight (gm)	Corrosion Rate (mm/yr)
	Before corrosion	After corrosion		
CS0	230	230	NIL	NIL
CS4	230	230	NIL	NIL

Acid Attack

Copper slag admixed concrete shows 23.59 & 34.29 % reduction of in compressive strength when compared to normal mix at 56 & 90 days due to acid attack.

Sulphate Attack

Copper slag admixed concrete shows 1.18 & 4.71 % reduction in compressive strength when compared to normal mix at 56 & 90 days due to sulphate attack.

Bulk Diffusion

Table.10 Penetration of Chloride Ions

Mix Designation	Depth of Penetration of Chloride Ions (mm)	
	at 56 day	at 90 day
CS0	30	33
CS4	25	27

Table.11 Diffusion Coefficient

Mix Designation	Diffusion coefficient (10^{-12}) m^2/Sec	
	at 56 day	at 90 day
CS0	11.63	8.75
CS4	8.07	5.84

Carbonation

Table.12 Carbonation Depth

Mix Designation	Carbonation Depth (mm)	
	at 56 day	at 90 day
CS0	5	8.3
CS4	2	3.2

Rapid Chloride Permeability Test

Table.13 Chloride Permeability at 56 day

Mix Designation	Total Charge Passed (Coulombs)	ASTM C-1202 Classification
CS0	405	Very Low
CS4	520	Very Low

Table.14 Chloride Permeability at 90 day

Mix Designation	Total Charge Passed (Coulombs)	ASTM C-1202 Classification
CS0	558	Very Low
CS4	710	Very Low

VII. CONCLUUSION

1. The strength parameters are optimum when the concrete containing 40 % replacement of fine aggegate by copper slag.

2. Due to low water absorption, coarser & glassy surface of copper slag, the workability of concrete increases when the % of copper slag increases.

3. High toughness of copper slag attributes to the increased compressive strength. Maximum percentage increase in compressive strength is 21.43 %. When copper slag % is greater 40, there is a reduction in compressive strength. This is due to the increased voids and increased free water content.

3. Copper slag admixed concrete shows higher energy absorption value and this is attributed to the ductile nature of copper slag admixed beams. Maximum percentage increase in flexural strength is 22.87 %.

4. Maximum percentage increase in split tensile strength is 32.51 %.

5. Maximum percentage increase in modulus of elasticity is 35.52 %.

6. It is recommended that if the copper slag admixed concrete is to be used in corroded environment, the reinforcement should be coated with some protective coating.

7. Copper slag admixed concrete specimens showed lesser resistance to acid attack due to its higher mass and higher resistance to sulphate attack, chloride attack and carbonation.

8. Chloride penetration of copper slag admixed concrete is graded under the category "very low". It is indicating the lesser permeability of slag admixed concrete.

VIII. REFERENCES

[1] D. Brindha and S. Nagan (2010), Durability Studies on Copper Slag Admixed Concrete, *Asian Journal Of Civil Engineering (Building And Housing)*, Vol. 12, No. 5 563-578

[2] D. Brindha et al. (2010), Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete, *International Journal Of Civil And Structural Engineering*, Volume 1, No 2, 192-211

[3] Binaya Patnaik et al. (2015), Strength and Durability Properties of Copper Slag Admixed Concrete, *International Journal of Research in Engineering and Technology*, Volume 4, 158-166

[4] Amit Rana (2013), Some Studies on Steel Fibre Reinforced Concrete, *International Journal of Emerging Technology and Advanced Engineering*, Volume 3, 120-127

[5] A. Sivakumar and Manu Santhanam, Mechanical Properties of High Strength Concrete Reinforced with Metallic and Non-metallic Fibres, *Cement and Concrete Composites*, 29(8), 603-608