ISSN(Online) : *2456-8910*
International Journal of Innovative Research in Applied Sciences and Engineering (IJIRASE)
Volume 4, Issue 2, DOI: 10.29027/IJIRASE.v4.i2.2020.622-628, August 2020

Experimental Study on Strength and Durability Properties of High Strength Concrete Using Mineral Admixtures and Copper Slag

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Abstract:

Concrete is the most widely used building material. In worldwide the high rise buildings are constructed by using high strength concrete mode only. Growing demand for construction materials necessitated the usage of alternative materials in the production of conventional concrete. Now a day's fine aggregate source is reduced due to high consumption, so some material is needed to replacing of sand. The objective of this work is to study the strength and durability properties of concrete. Here M 70 grade concrete used and concrete containing copper slag as partial replacement of fine aggregate and mineral admixture as partial replacement of cement in the concrete mix design. Copper slag content has been 40% as a replacement of fine aggregate and silica fume 5%,10%,15% & 20% and GGBS 5%,10%,15% & 20% as a replacement of cement respectively .This research paper study on strength test& Durability test. The test results show 40% replacement of fine aggregate as copper slag gives them more strength. And Silica fume & GGBS as partial replacement of cement (up to 15%). From the results, it was observed that the use of copper slag and mineral admixture in concrete has shown a considerable increase in strength and reduction of the cost when compared with normal concrete.

Keywords: High Strength Concrete, Copper Slag, Silica Fume, GGBS.

I. INTRODUCTION:

Concrete is the second most consumed material in the world that is considered as durable and strong material and has relatively high compressive strength and significantly low tensile strength. The High Strength Concrete is the type of high-performance concrete which gives better strength with nominal quantities of the ingredients. The HSC is one which gives the compressive strength of concrete at a range of 50MPa and above (up to 120MPa). The different types of admixtures that can be used in the concrete are silica fumes, GGBS and it can be considered in the concrete as the replacement of fine aggregate is Copper Slag, M sand, etc... For in this thesis work considering the concrete of M70 grade as HSC concrete. Copper Slag is a steel industry waste product and it has similar properties of sand.

II. LITERATURE REVIEW:

- **Akshatha K. B (2018)** This paper generalizes the results of a study on silica fume based high-strength concrete. - Increase in the consumption of materials required in the production of concrete has led to the depletion of materials. In this thesis used M45 grade. The various proportion of silica fume used as 0 to 12.5%. The steel fibre used various percentages as 0.5%, 0.75% and 1% by volume fraction. The optimum. Proportion identified as 7.5% SF and 0.75% hooked fiber[1].

- **Abdullah Anwar (2018)** In this paper detailed study on Strength properties of concrete by replacement of fine aggregate with copper slag and cement with silica fume. M40 grade of concrete is used, the fine aggregate was replaced with Copper Slag (40%) and cement was replaced with Silica Fume from 5% to 15% at an interval of 5%. This research study on the mechanical property of concrete at 28 days. The optimum content of silica fume find out (up to 40%) and silica fume (up to 10%). Compressive Strength was increased significantly when compared to the Nominal mix[2].

- **Saini** has undergone research work based on High-Performance Concrete of the grade of M60 where SF was added @15% by weight of cement to ensure the durability of the structure. They found 28 days compressive strength of HPC varied b/w 78.6 to 81.3 Mpa indicating good control of the quality of concrete[3].

III. OBJECTIVES:

1. To locate the ideal extent of copper slag and mineral admixtures that can be utilized as a substitution/substitute material for fine total and concrete.
2. To assess the impact of copper slag and mineral Admixtures substitution on the usefulness and thickness of cement.
3. To locate the compressive quality, split elasticity, flexural quality and Durability investigations of copper slag and mineral admixtures supplanted solid examples.
4. To propose an observational connection between mechanical properties of cement.

IV. PROPERTIES OF MATERIAL

4.1 Cement

Ordinary Portland Cement (OPC) of 53 Grade used.

Table 1 Physical properties of cement

S.No	Properties	Result
1	Specific gravity	3.15
2	Consistency	34%
3	Initial setting time	34 miu
4	Fineness	2%

4.2 Fine Aggregate

Table 2 Physical properties of M sand

S.No	Properties	Result
1	Bulk density	1726kg/m^3
2	Finesse Modulus	3.96
3	Specific gravity	2.80
4	Water absorption	0.5%

4.3 Coarse aggregate

20 mm size crushed course aggregate was used

Table 3 Physical properties of Coarse aggregate

S.No	Properties	Result
1	Specific gravity	2.80
2	Water absorption	0.52%
3	Impact value	35%

4.4 Copper slag

Table 4 Physical properties of Copper slag

S.No	Properties	Result
1	Appearance	Black glassy granules
4	Specific gravity	3.6
5	Bulk density	2.00-2.33 g/cc
6	Fineness modulus	2.89
7	Water absorption	0.40

Table 5 Chemical properties of copper slag

Sr. No.	Component	% of the chemical component
1.	Sio2	25.84
2.	Fe2O3	68.29
3.	Al2O3	0.22
4.	CaO	0.15
5.	Na2O	0.58
6.	K2O	0.23

4.5 Silica Fume

Table 6 Physical properties of copper slag

S.No	Properties	Result
1	Physical state	Micronized powder
5	Density	0.77gm/cc
6	Specific gravity	2.64
7	Moisture	0.055%

Table 7 Chemical properties of silica fume

Sr. No.	Component	% of the chemical component
1	(Sio_2)	99.9
2	(Al_2O_3)	0.031
3	(Fe_2O_3)	0.012
4	(CaO)	0.0
5	(MgO)	0.0
6	(SO_2)	0.0
9	(LOI)	0.001

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4.6 Ground granulated blast furnace slag

Table 8 Chemical properties of GGBS

Element	App Conc.	Intensity Corrn.	Weight%	Weight% Sigma	Atomic%
O K	33.39	0.5588	50.64	0.65	67.19
Mg K	3.29	0.7255	3.84	0.18	3.36
Al K	7.91	0.7924	8.46	0.24	6.65
Si K	13.60	0.7963	14.48	0.30	10.94
Ca K	25.44	0.9861	21.86	0.37	11.58
Mn K	0.68	0.7943	0.72	0.16	0.28
Totals			100.00		

4.7 Water

Portable water is used and pH value is 6-7.

4.8 Superplasticizers

Polycarboxylate ether-based superplasticizers are used in this project.

V. EXPERIMENTAL WORK

In this research work, M70 grade of concrete is tested and mix proportions of M70 concrete are 1:1.94:3.8 with a water-cement ratio of 0.26[4].

5.1 Mix Proportion of Concrete Grade

As per IS 10262: 2019, mix design for M70 grade concrete is given in table 9

Table 9 Mix proportion by weight

S.no	Material name	Quantity in kg/m^3
1	Cement	320
2	Silica fume	107.7
3	GGBS	107.7
4	Water	141.3
5	Fine aggregate	621.2
6	Coarse aggregate	1245
7	Chemical admixture	2.67

5.1.1 Mix Identification

Table 10 Mix proportion identification

S. No	Description	Mix Identification
1	Conventional	M_0
2	5%of silica fume &5%GGBS&40%of copper slag	M_1
3	10%of silica fume &10%GGBS&40%of copper slag	M_2
4	15%of silica fume &15%GGBS&40%of copper slag	M_3
5	5%of silica fume &5%GGBS&40%of copper slag	M_4

VI. RESULT AND DISCUSSIONS

6.1 Fresh Concrete

6.1.1 Workability Test

Slump test was prepared by as per IS 1199-1959. Table 5.1 shows the results of the workability of a various mix of concrete.

Table 11 Workability of concrete mix

S.No	Mix Identify	Slump (mm)
1	M_0	95
2	M_1	88
3	M_2	90
4	M_3	93
5	M_4	85

6.2 HARDENED CONCRETE

6.2.1 Compressive Strength Test

For testing 150×150×150 mm cube mould were cast and 7.14, and 28 days compressive strength found.

Table 12 compressive strength value

S.No	Mix proportion	Compressive strength in N/mm^2		
		7day	14 day	28 day
1	M_0	45.7	66.6	75.6
2	M_1	51.1	75.12	82.22
3	M_2	52	75.6	81.87
4	M_3	50.3	72.0	80.8
5	M_4	49.7	70.2	79.1

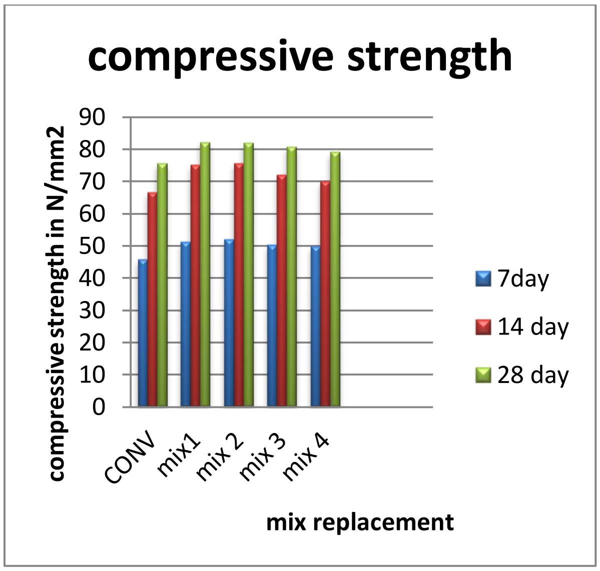

Fig 1show compressive strength of concrete

7.2.2 Split Tensile Strength Test

For testing 150mm X 300 mm cylinder mould casted and 7,14 and 28 days value found

Table 13 split tensile strength value

S. No	Mix proportion	Compressive strength in N/mm^2		
		7day	14 day	28 day
1	M_0	2.82	3.8	4.58
2	M_1	3.89	4.81	5.44
3	M_2	3.67	4.80	5.37
4	M_3	3.66	4.59	5.25
5	M_4	3.9	4.24	4.75

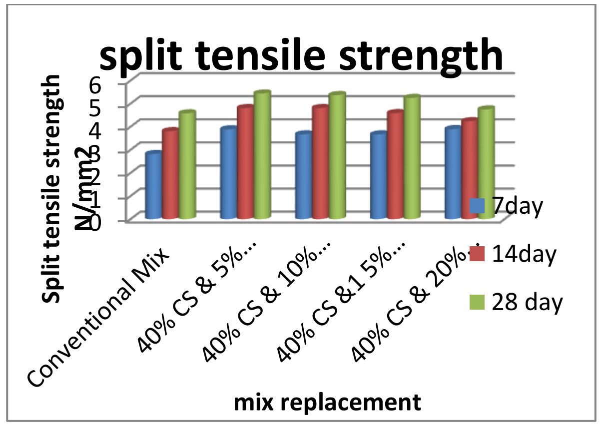

Fig 2 split tensile strength of concrete

6.2.3 Flexural Strength Test

For flexural quality, solid light emission 500 × 100 × 100 mm, were cast with various level of mineral admixtures extend from 0 to 20% &copper slag 40%. At that point, the shafts are continued restoring for 28 days. Three examples were tried at each restoring age[5].

Table 14 flexural strength value

S.No	Mix proportion	Compressive strength in N/mm^2
		28 day
1	M_0	6.75
2	M_1	8.55
3	M_2	8.1
4	M_3	7.65
5	M_4	7.2

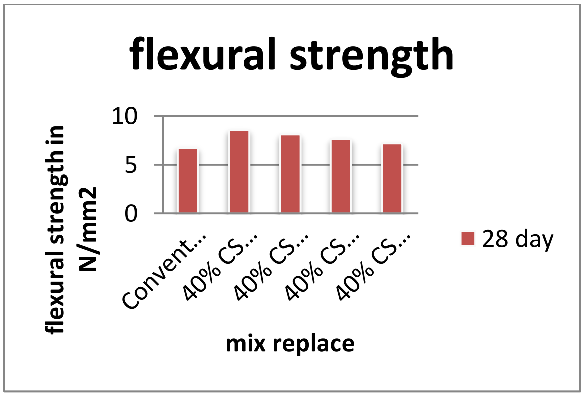

Fig 3 show the split tensile strength of concrete

VII. DURABILITY TEST

7.1 RCPT (RAPID CHLORIDE PERMEABILITY TEST)

The test procedure follows as per ASTM C 1202-97. The cylinder specimen prepared by 100X200mm.

Table 15 RCPT Result Value

Mix	Charges Passed in Coulombs	Permeability Class
M1	98	Negligible
M2	128	Very low

7.2 WATER ABSORPTION TEST

Water Absorption Test is directed on 100mm x100mm x 100mm solid example. The 28 days restored blocks are taken out from the relieving yard and permitted to dry at climatic temperature. These examples are painstakingly gauged and the underlying weight is noted { Wi }. Following 24 hours the dried examples are removed from the stove and permitted to cool at typical room temperature. These examples are again weighed cautiously and the loads are noted {Wf }. The qualities got are plotted as appeared in diagram 3. These are gotten from the recipe.

Table16 Water absorption Result Value

Mix replacement	Water absorption value in %
M1	1.56
M2	1.05
M3	1.13

7.3 SULPHATE ATTACK TEST

The test was carried out to study the effect of silica fume and GGBS as cement replacement and Copper slag as a fine aggregate replacement on the resistance against chemical attack. The 10 × 10 × 10 cm concrete cube specimens were cast and cured in water for 28 days. $MgSO_4$ solutions with initial concentrated an amount of 5% by volume were prepared in acid-resistant. The initial weight was determined and then the specimens were immersed into sulphate solution for 4 weeks. After 4 weeks the specimen was taken out and weight is measured.

Table 17 Weight Loss Due to Sulfate Attack

Mix	Weight Loss %
M1	0.328
M2	0.207

7.4 AC IMPEDANCE TECHNIQUE.

Air conditioning impedance spectroscopy is being utilized as non-destructive systems for evaluating consumption of steel rebar implanted in concrete. Round and hollow solid examples of size 75mm dia and 150mm tallness were thrown with midway put steel bar of 12mm breadth. The capability of the rebar was estimated occasionally utilizing high info impedance multimeter. Impedance estimation was made utilizing three anode course of action. Treated steel cathode of size 10mm x80mm was utilized as a helper anode and immersed calomel terminal was utilized as a kind of perspective anode. Rebar implanted in concrete went about as working anode.

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Table18 AC Impedance – 12mm

days	Specimen	R_{ct}	f_{max}	C_{dl}	Efficiency
0	M1	4.687	1.470	0.019	15.34
	M2	3.687	1.470	0.019	25.12
20	M1	4.096	1.777	0.015	23.36
	M2	3.403	1.777	0.026	32.1

8.0 MICROSTRUCTURAL ANALYSIS

8.1 SCANNING ELECTRON MICROSCOPE (SEM) AND ENERGY DISPERSIVE X-RAY ANALYSIS (EDAX)

- Degree of hydration of cement
- In relation to forensic investigations on deteriorated concrete scanning electron microscopy may add valuable data about the cause of deterioration. SEM-EDX analysis typical supplies information on:
- Chemical composition of mineral phases

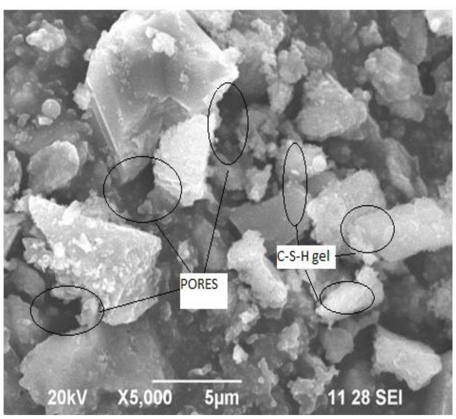

Fig 4 show SEM Analysis of conventional concrete

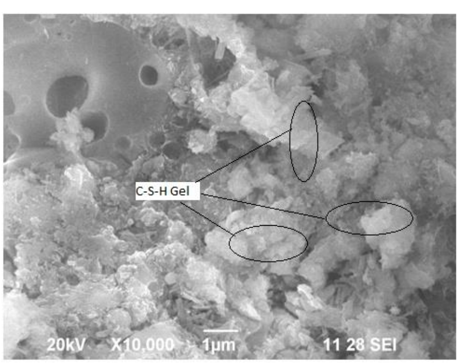

Fig 5 show SEM Analysis of an optimum mix

8.2 ENERGY DISPERSIVE X-RAY ANALYSIS (EDAX)

To find the chemical composition of silica fume GGBS and Copper slag Energy Dispersive Analysis X-Ray Spectroscopy analysis was done.

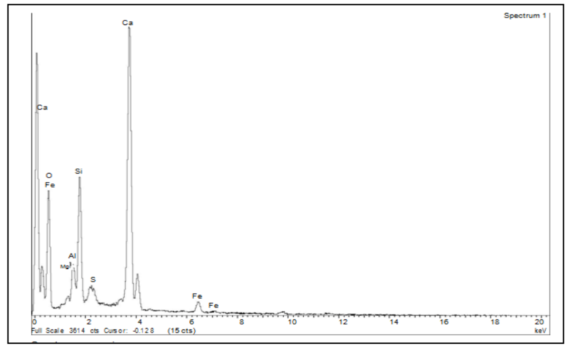

Table 19 EDAX for Conventional

ELEMENT	WEIGHT %
O K	58.85
Mg K	0.69
Al K	2.83
Si K	9.00
S K	0.30
Ca K	26.05
Fe K	2.29

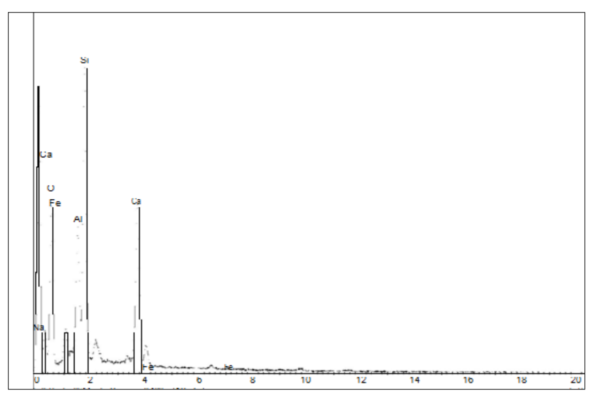

Table 20 EDAX for Optimum mix

ELEMENT	WEIGHT %
O K	54.68
Na K	3.47
Al K	7.97
Si K	19.23
Ca K	14.06
Fe K	0.59

X. CONCLUSION

Based on the investigations carried out on the use of silica fume and GGBS in concrete as a mineral admixture for cement and copper slag as a fine aggregate replacement, the following results are concluded :

- Using mineral admixture as silica fume and GGBS it improves the compressive strength, bond strength, abrasion resistance, reduces the permeability of concrete to chloride ions and also protects reinforcement from corrosion.
- Slump values decrease with increasing the amount of silica fume and GGBS.
- The mix having 5% silica fume replacement and 5% of GGBS and 40% of copper slag showed an increase in strength of the reference mix at the age of 28
- The mix having 5% silica fume replacement and 5% of GGBS and 40% of copper slag shows the highest value for compressive strength, split tensile strength and flexural strength.
- The mix with 5% replacement of silica fume and GGBS offered greater resistance to sulfate and chloride attack.
- The mix having 5% silica fume replacement and GGBS and 40% of copper slag is considered as the optimum mix.
- From the SEM analysis result, the availability of pores between the Control mix and optimum mix is reduced.
- Formation of needle-like secondary CSH gel modified the microstructure of the optimum mix.
- From the EDAX result, the formation of secondary C-S-H gel is reduced of calcium hydroxide content.
- The pores between the materials get reduce and thus the development of cracks in the material also decreases.

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