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AN EXPERIMENTAL STUDY ON CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE WITH COPPER SLAG AND CEMENT WITH FLY ASH

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Abstract - ***Concrete has been the most preferred construction material for over five decades.The problem of how to meet the increasing demand and cost of concrete in sustainable manner is a challenge in the field of civil engineering and environmental studies. Alternative materials generally used are mainly the industrial wastes which are facing the problems of safe disposal and cause environment hazards. Copper Slag and Fly Ash are such industrial wastes in huge quantity facing the safe disposal.In view of the above, An Experimental study carried on concrete by partial replacement of fine aggregate with copper slag and cement with fly ash in concrete production.This experimental study mainly consists of two parts. In first part optimum percentage of Copper Slag and Fly Ash were determined individually by testing the compressive strength of cement mortar cubes with various percentage replacement of fine aggregate with Copper slag and various percentage replacement of cement with Fly Ash. In second part optimum percentage of Copper Slag and Fly Ash together added to the concrete and various strength parameters were determined for M20 and M25 grade concretes. The obtained results were compared with those of control concrete made with ordinary Portland cement and fine aggregate. The results indicate that there is gain in strength and better resistant for durability tests.***

Keywords-Copper Slag, Fly Ash, Fine aggregate, Coarse aggregate, Cement, Partial replacement, Compressive Strength, Control concrete.

1. INTRODUCTION

Solid waste management is one of the most important environmental concerns in the world. Waste utilization hasbecome an alternative to disposal because of the lack of space for land filling. River Sand is common form of fine aggregate used in the production of concrete, but has become very expensive due to rapid depletion of river bed, high transportation cost etc. Cement acts as a binder material for Concrete. During the production of Cement, CO_2 is released into the atmosphere, which is harmful to the environment. Many researches have worked out on the ways of reducing the Cement Content which tends to the reduction in CO_2 emissions.The sustainable development for construction involves the use of non-conventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Using alternative materials in place of natural aggregate and cement in concrete production makes concrete as sustainable and environmentally friendly construction material.

Copper slag is an industrial by- product material produced from the process of manufacturing copper. To produce every ton of copper, approximately 2.2 tons copper slag is generated as a by-product material. In India copper slag is produced by many industries, one of them is Sterlite Industries Ltd (SIL), Tuticorin, Tamilanadu. It produces copper slag during the manufacture of copper metal. Currently, about 2600 tons of copper slag is produced per day and a total accumulation of around 1.5 million tons. It is a glassygranular material with high specific gravity and its Particle sizes are of the order of sand and can be used as fine aggregate in concrete. It has similar physical &chemical properties of Sand. It is considered as a waste material which could be used in the construction industry as full or partial substitute of fine aggregates. The use of copper slag in concrete provides potential environmental as well as economic benefits to the construction industry.

Fly Ash is a pozzolanic material which is defined as siliceous and aluminous material which in itself possesses little or no cementitious value, chemically react with Calcium Hydroxide (lime) in presence of water at ordinary temperature and form soluble compound comprises cementitious property similar to cement.Concrete containing fly ash becomes stronger, more durable, and more resistant to chemical attack. Because fly ash particles are small, they effectively fill voids.Mechanically fly ash particles are hard and round, they have a "ball bearing" effect that allows concrete to be produced using less water. This characteristics of Fly Ash contribute to enhanced concrete workability and durability. Finally, using Fly Ash creates significant benefits for our environment like conserving natural resources and avoids landfill disposal of ash products. By making concrete more durable, life cycle costs of roads and structures are reduced. Furthermore, fly ash use partially displaces production of other concrete ingredients, resulting in significant energy savings and reductions in greenhouse gas emissions.

2. OBJECTIVE

The main aim of the present work is to determine the strength and durability characteristics of concrete by partial replacement of Fine Aggregate with Copper Slag(CS) and Cement with Fly Ash(FA) for application in structural concrete, which will give better understanding on the properties of concrete.

3. MATERIALS

3.1 Cement

The cement which is used in the present study is Zuari Ordinary Portland Cement(OPC) of 53 grade. The properties of Cement are confirming to IS 12269-1987 Specifications.The properties are shown in Table No.3.1

Table 3.1 Physical properties of Cement

S.No	Property	values
1	Specific Gravity	3.12
2	Normal Consistency	33%
3	Setting Time 1.Initial setting time 2.Final setting time	 120mins 335mins
4	Fineness	4%

3.2 Fine Aggregate

Fine Aggregate which is used in the study is locally available and it conforming to IS 383:1970 Specifications. The properties are shown in Table No.3.2

Table 3.2 Physical properties of Fine Aggregate

S.No	Property	Result
1	Specific Gravity	2.57
2	Fineness Modulus	2.6
3	Zone	Zone – II

3.3 Coarse Aggregate

Coarse aggregate of nominal size 20 mm and 12 mm, obtained from the local quarry confirming to IS 383:1970 specifications were used. The properties of Coarse aggregate are shown in Table No.3.3.

Table 3.3 Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.67
2	Water Absorption	0.4 % (for 20mm) 0.9% (for 12mm)
3	Fineness modulus	6.53

3.4 Copper Slag(CS)

Copper Slag used in this work is obtained from Sterlite Industries Ltd ,Tuticorine,Tamilnadu. Copper Slag material is shown in Fig 3.1. Properties of Copper Slag are presented in Table No.3.4 and Table No.3.5.

Fig.3.1 Copper Slag

Table 3.4Chemical properties of Copper Slag

S.No.	Chemical composition	Results
1	Silica (SiO_2)	33.52
2	Ferric Oxide (Fe_2O_3)	55.8
3	Alumina (Al_2O_3)	3.8
4	Calcium Oxide (CaO)	3.14

5	Magnesium Oxide (MgO)	0.72
6	Sodium Oxide (Na_2O)	0.4
7	Pottassium Oxide (K_2O)	0.76
8	Titanium Oxide (TiO_2)	0.5
9	Copper(Cu)	0.99

Table 3.5 Physical properties of Copper Slag

S.NO	Property	Value
1	Specific Gravity	3.476
2	Fineness modulus	3.3
4	Water absorption	0.3%
5	Particle shape	Irregular
6	Colour	Glassy Black
7	Grading	Zone-11

3.5 FLY ASH:

Fly Ash used in this present experimental study is obtained from Rayalaseema Thermal Power plant, Proddatur. Fly material is shown in Fig 3.2**.** Specifications of Fly Ash given by the supplier shown in the Table 3.6 and Table 3.7.

Fig 3.2 Fly Ash

Table 3.6 Physical Properties of Fly Ash

S.No.	Physical Properties	Results
1	Physical State	Powder
2	Colour	Grey
3	Odour	Odourless
4	Specific Gravity	2.4
5	Moisture	3.14%

Table 3.7 Chemical Properties of Fly Ash

S.No.	Chemical composition	Results
1	Silica (SiO_2)	56.6
2	Alumina (Al_2O_3)	22.6
3	Ferric Oxide (Fe_2O_3)	8.14
4	Magnesium Oxide (MgO)	1.17
5	Calcium Oxide (CaO)	12.14

3.6 Water:

The water used for casting and curing of concrete test specimens was free of acids, organic matter, suspended solids and impurities which when present can adversely affect the strength of concrete.

4. CONCRETE MIX PROPORTION

M20 and M25grade of concrete were used in the present investigation. The mix design was done as per Indian Standard Code of Practice.

Grade		Cement	Fine aggregate	Coarse aggregate (60%-20mm+40%-12mm)	Water
M20	Proportion	1	2.02	3.74	0.52
	Quantity(kg)	320	648.56	1197.8	177
M25	Proportion	1	1.95	3.59	0.46
	Quantity(kg)	340	661.52	1221.79	156.4

5. RESULTS AND DISCUSSIONS

5.1 COMPRESSIVE STRENGTH OF CEMENT

5.1.1 Compressive strength of cement with copper slag replacement

The results of compressive strength of cement with various combinations of copper slag for different curing periods were obtained. Cement mortar Cubes of size 70.6 mm × 70.6 mm × 70.6 mm which are casted to test the compressive strength at the age of 3, 7 and 28days.The variation inCompressive strength of Cement with percentages of Copper Slag replacement were shown in fig 5.1.

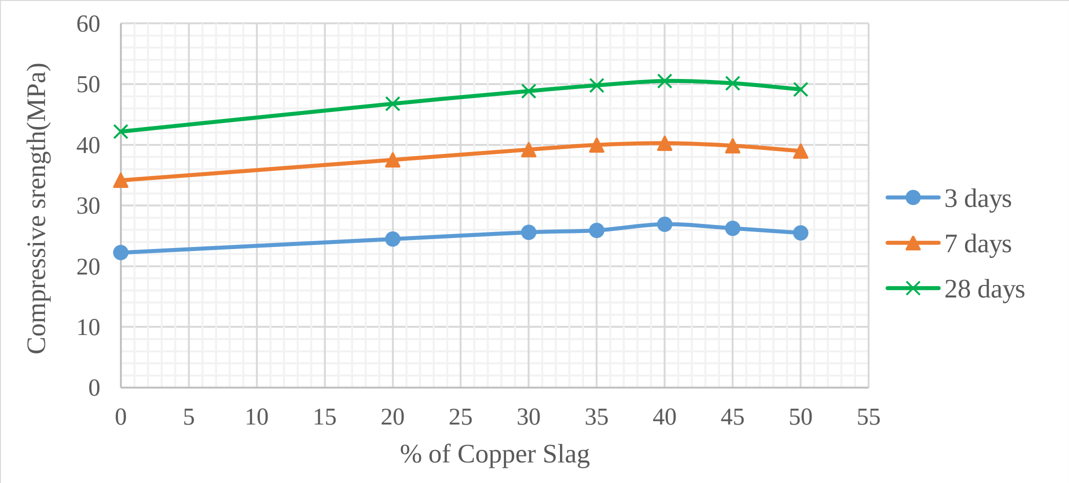

Fig 5.1 Variation inCompressive strength of cement with percentage of Copper Slag replacement

At 28 days of curing, upto 40% replacement of Fine aggregate with Copper Slag, the compressive strength of cement increases, further increase in replacement causes decrease in strength. At 40% replacement of Fine aggregate with Copper Slag gives a maximum Compressive strength of cement, which is 19.2 % more compared with Compressive strength of ordinary Portland cement. 50% replacement of Copper Slag also gives higher compressive strength compared with compressive strength of OPC.

5.1.2 Compressive strength of cement with Fly Ash replacement

The results of compressive strength with cement for various combinations of fly ash for different curing periods were obtained. Cement mortar cubes of size 70.6 mm × 70.6 mm × 70.6 mm which are casted to test the compressive strength at the age of 3,7and 28days. The variations in compressive strength of cement with percentages of Fly Ash replacement were shown in fig 5.2

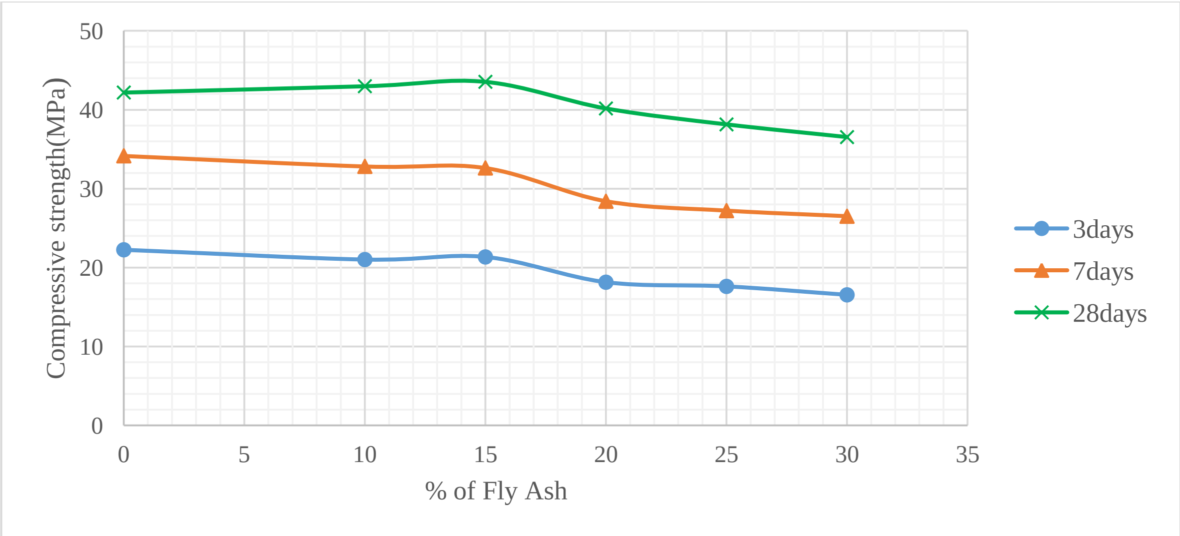

Fig 5.2 Variation of Compressive strength of cement and percentage of Fly Ash replacement

At 28 days of curing, upto 15% replacement of Cement with Fly Ash, compressive strength of cement increased, further increase in replacement, causes decrease in strength. At 15% replacement of Cement with Fly Ash gives maximum Compressive strength of cement, which is 3.22 % more compared with Compressive strength of ordinary Portland Cement.

5.2 OPTIMUM PERCENTAGE OF COPPER SLAG AND FLY ASH

From the above experimental result of Compressive strength of cement by partial replacement of Fine aggregate with Copper Slag and Cement with Fly Ash, optimum percentage of Copper Slag is obtained as 40% and optimum percentage of Fly Ash is 15%. This optimum percentage of Copper Slag and Fly Ash together added to the concrete and further studies have been conducted on the concrete and results were compared with control concrete.

5.3 COMPRESSIVE STRENGTH OF CONCRETE

5.3.1 Compressive Strength of M20 Grade concrete

The test results of compressive strength of M20 grade concrete with optimum percentages of Copper Slag and Fly Ash were shown in fig 5.3

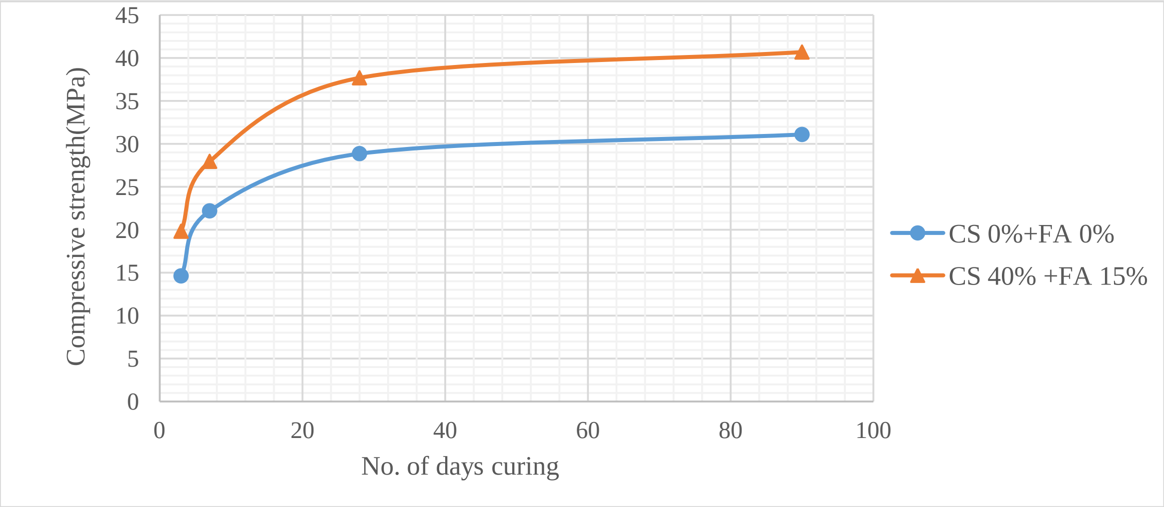

Fig 5.3. Variation in Compressive Strength of Concrete(M20 grade) with optimum Percentages of Copper Slag and Fly Ash replacement

Compressive strength of CS 40% + FA 15% concrete at 28 days of curing was 37.7 MPa, which is 30.59% more compared with compressive strength of control concrete and Compressive strength of CS 40% + FA 15% concrete at 90 days of curing was 40.7 MPa, which is 30.87% more compared with compressive strength of control concrete.

5.3.2 Compressive Strength of M25 Grade concrete

The test results of compressive strength of M25 grade concrete with optimum percentages of Copper Slag and Fly Ash were shown in fig 5.4

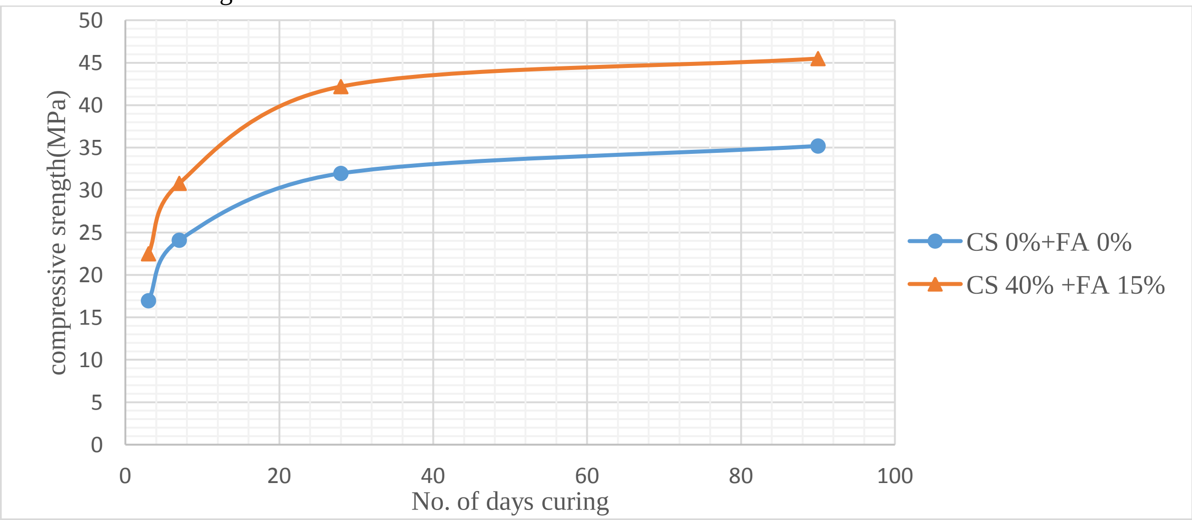

Fig 5.4. Variation inCompressive Strength of Concrete(M25 grade) with optimum Percentages of Copper Slag and Fly Ash replacement

Compressive strength of CS 40% + FA 15% concrete at 28 days of curing was 42.2 MPa, which is 32% more compared with compressive strength of control concrete and Compressive strength of CS 40% + FA 15% concrete at 90 days of curing was 45.5 MPa, which is 29.26% more compared with compressive strength of control concrete.

5.4 SPLIT TENSILE STRENGTH

The test results of split tensile strength of M20 and M25 grade concretes with optimum percentages of Copper Slag and Fly Ash wereshown graphically in Fig 5.5.The split tensile strength test was conducted at 28 days of curing.

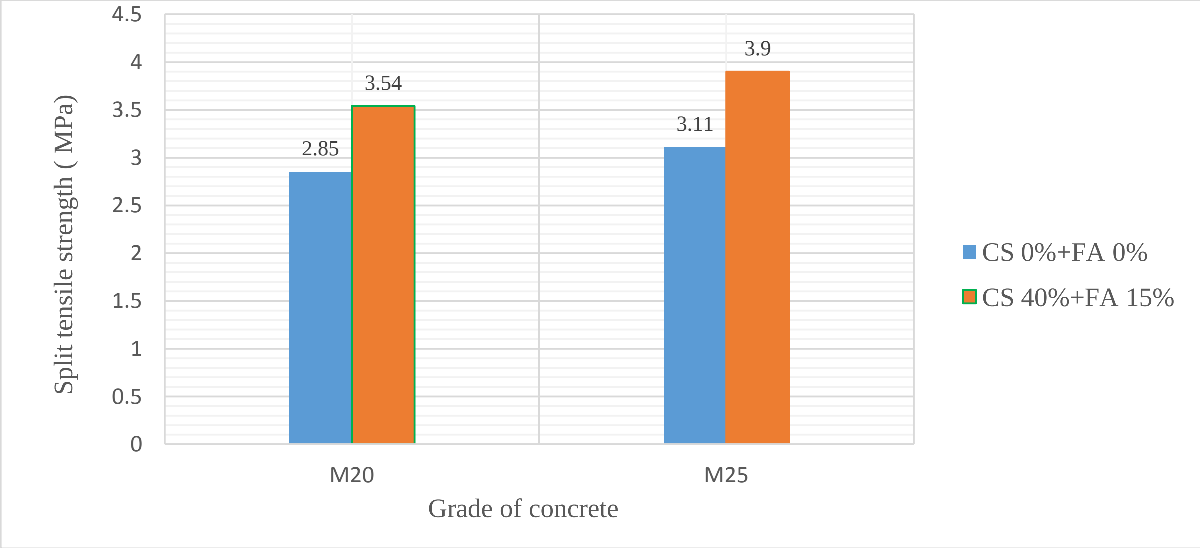

Fig 5.5.Variation in Split Tensile Strength of Concrete with optimum percentages of Copper Slag and Fly Ash replacement

For M20 Grade concrete , Split tensile strength of CS 40% + FA 15% concrete was 3.54 MPa, which is 24.21% more compared with Split tensile strength of control concrete and For M25 Grade concrete, Split tensile strength of CS 40% + FA 15% concrete was 3.9 MPa, which is 25.4% more compared with Split tensile strength of control concrete.

5.5 FLEXURAL STRENGTH

The test results of Flexural strength of M20 and M25 grade concretes with optimum percentage of Copper Slag and Fly Ash wereshown graphically in Fig 5.6.The Flexural strength test was conducted at 28 days of curing.

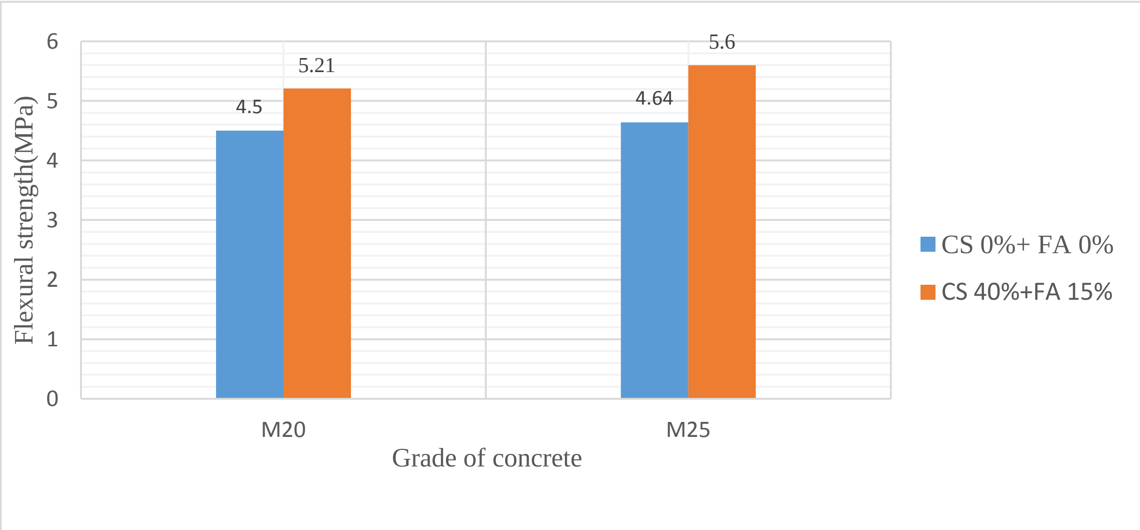

Fig 5.6 Variation in Flexural Strength of Concrete with optimum Percentages of Copper Slag and Fly Ash replacement

For M20 Grade, concrete Flexural strength of CS 40% + FA 15% concrete was 5.21 MPa, which is 15.78% more compared with Flexural strength of control concrete and For M25 Grade concrete, Flexural strength of CS 40% + FA 15% concrete was 5.6 MPa, which is 20.69% more compared with Flexural strength of control concrete.

5.6 MODULUS OF ELASTICITY

The test results of Modulus of elasticity of M20 and M25 grade concretes with optimum percentages of Copper Slag and Fly Ash were shown graphically in Fig 5.7.Modulus of elasticity test was conducted at 28 day of curing.

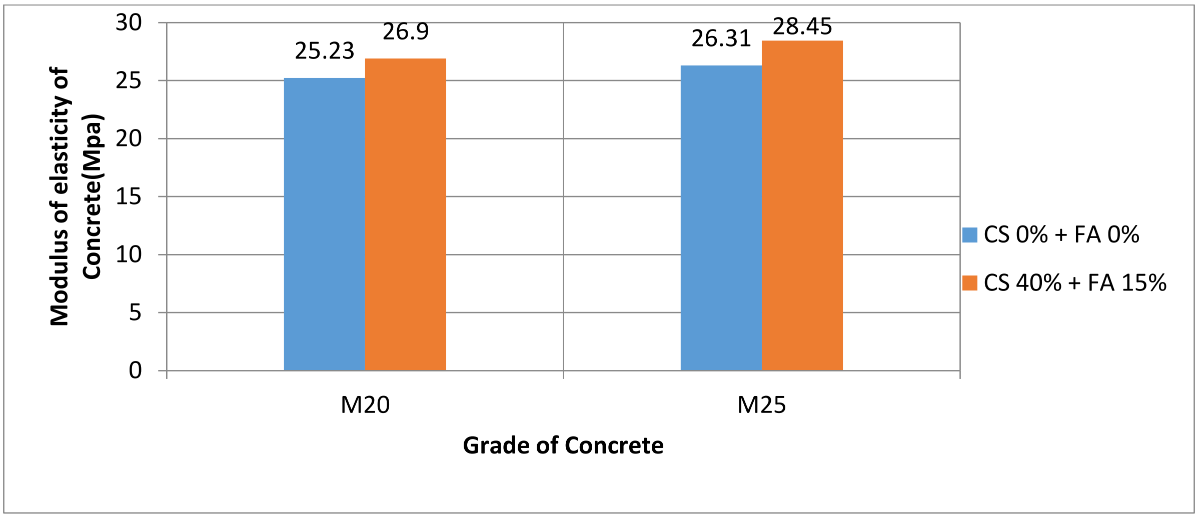

Fig. 5.7.Variation in Modulus of Elasticity of Concrete With optimum Percentages of Copper Slag and Fly Ash replacement

For M20 Grade concrete, Modulus of elasticity of CS 40% + FA 15% concrete was 26.9 GPa, which is 6.6% more compared with Modulus of elasticity of control concrete and For M25 Grade concrete, Modulus of elasticity of CS 40% + FA 15% concrete was 28.45 GPa, which is 8.13% more compared with Modulus of elasticity of control concrete.

5.7 DURABILITY TEST

5.7.1 Acid resistance of concrete

The concrete cube specimens of size 150 mm x150 mm x150 mm were cast. After 28 days of water curing, the specimens were removed from curing tank and allowed to dry for one day. The weights of concrete cube specimens were taken. The acid resistance test on concrete cubes were conducted by immersing those in the acid water for 28 days and 56 days, after 28 days of normal curing. Sulphuric acid (H_2SO_4) with pH of '1'at 5% weight of water was added to water in which the concrete cubes were stored. After 28 days and 56 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the % loss in weight of specimen and the % loss in compressive strength by immersing concrete cubes in acid water.
The percentage loss in weight of concrete cubes prepared with optimum percentages of Copper Slag and Fly Ash by immersing in 5% H_2SO_4 acid at 28 days and 56 days were represented in Table 5.1.
The percentage loss in compressive strength of concrete cubes prepared with optimum percentages of Copper Slag and Fly Ash by immersing in 5% H_2SO_4 acid at 28 days and 56 days were represented in Table 5.2.

Table 5.1 Percentage loss in weight of concrete in 5% H_2SO_4 Solution

Mix	Wt. before immersion (kg)	Wt. after immersion at 28 days (kg)	% Wt. loss at 28 days	Wt. after Immersion At 56 days (kg)	% Wt. loss at 56 days
CS 0%+FA 0%	8.302	7.928	4.5	7.561	9
CS 40%+FA 15%	8.700	8.452	2.85	8.193	5.8

At 28 days of Acid curing , percentage loss in weight of control concrete was 4.5% and percentage loss in weight of CS 40%+ FA 15% concrete was 2.85%. At 90 days of Acid curing , percentage loss in weight of control concrete was 9% and percentage loss in weight of CS 40%+ FA 15% concrete was 5.8%. Hence CS 40%+ FA 15% concrete possessed good resistance to acid attack compared with control concrete.

Table 5.2 Percentage loss in Compressive Strength of Concrete in 5% H_2SO_4 Solution

Mix	Initial Compressive Strength(MPa)	Compressive strength at 28 days(MPa)	% Comp. strength loss at 28 days	Compressive strength at 56 days(MPa)	% Comp. Strength loss at 56 days
CS 0%+FA 0%	28.87	25.65	11.5	24	16.9
CS 40%+FA 15%	37.7	35.05	7	33.51	11.15

At 28 days of Acid curing , percentage loss in Compressive strength of control concrete was 11.5% and percentage loss in compressive strength of CS 40%+ FA 15% concrete was 7%. At 90 days of Acid curing , percentage loss in compressive strength of control concrete was 16.9% and percentage loss in compressive strength of CS 40%+ FA 15% concrete was 11.5%. Hence CS 40%+ FA 15% concrete possessed good resistance to Acid attack compared with control concrete.

5.7.1 Alkaline resistance of concrete

The concrete cube specimens of size 150 mm x 150 mm x150 mm were cast. After 28 days of water curing, the specimens were removed from curing tank and allowed to dry for one day. The weights of concrete cube specimens were taken. The alkaline resistance test on concrete cubes was conducted by immersing those in alkaline water for 28 days and 56 days, after 28 days of normal curing. Sodium hydroxide (NaOH) with pH of '13' at 5% weight of water was added to water in which the concrete cubes were stored. After 28 days and 56 days of immersion, the concrete cubes were taken out from alkaline water. Then, the specimens were tested for compressive strength. The resistance of concrete to alkaline attack was found by the % loss in weight of specimen and the % loss in compressive strength by immersing concrete cubes in alkaline water.

The percentage loss in weight of concrete cubes prepared with optimum percentages of Copper Slag and Fly Ash by immersing in 5% NaOH alkaline at 28 days and 56 days were represented in Table 5.3.

The percentage loss in compressive strength of concrete cubes prepared with various concentrations of Copper Slag and Fly Ash by immersing in 5% NaOH alkaline at 28 days and 56 days were represented in Table5.4.

Table 5.3 Percentage loss in Weight of concrete in 5% NaOH Solution

Mix	Wt. before immersion (Kg)	Wt. after immersion at 28 days(Kg)	% Wt. loss at 28 days	Wt. after immersion at 56 days(Kg)	% Wt. loss at 56 days
CS 0%+FA 0%	8.284	8.058	2.7	7.94	4.15
CS40%+FA15%	8.536	8.417	1.4	8.312	2.62

At 28 days of Alkaline curing , percentage loss in weight of control concrete was 2.7% and percentage loss in weight of CS 40%+ FA 15% concrete was 1.4%. At 90 days of Alkaline curing , percentage loss in weight of control concrete was 4.15% and percentage loss in weight of CS 40%+ FA 15% concrete was 2.67%. Hence CS 40%+ FA 15% concrete possessed good resistance to Alkaline attack compared with control concrete.

Table 5.4 Percentage loss in Compressive Strength of Concrete in 5% NaOH Solution

Mix	Initial Compressive Strength (MPa)	Compressive strength at 28 days	% Comp. strength loss at 28 days	Compressive strength at 56 days(MPa)	% Comp. Strength loss at 56 days
CS 0%+FA 0%	28.87	27.55	4.6	26.12	9.53
CS 40%+FA 15%	37.7	36.5	3.2	35.5	5.83

At 28 days of Alkaline curing , percentage loss in Compressive strength of control concrete was 4.6% and percentage loss in compressive strength of CS 40%+ FA 15% concrete was 3.2%. At 90 days of Alkaline curing, percentage loss in compressive strength of control concrete was 9.53% and percentage loss in compressive strength of CS 40%+ FA 15% concrete was 5.83%. Hence CS 40%+ FA 15% concrete possessed good resistance to Alkaline attack compared with control concrete.

6. CONCLUSIONS

The results of the experimental investigation indicate that Copper Slag can be used as partial replacement of fine aggregate and Fly Ash can be used as partial replacement of Ordinary Portland cement for cement mortar and concrete preparation.

1. At 28 days of curing, up to 40% replacement of fine aggregate with copper Slag, the Compressive strength of cement was increased. Beyond 40% replacement of copper slag, causes decrease in Compressive strength was observed. At 40% replacement of fine aggregate with copper Slag, the Compressive strength of cement was increased by 19.7%, which is maximum one. But 50% of Fine Aggregate replacement with Copper Slag also gives 16.14% more compressive strength compared with control mix.
2. At 28 days of curing, up to 15% replacement of Cement with Fly Ash, the Compressive strength of cement was increased. Beyond 15% replacement of Fly ash, causes decrease in Compressive strength was observed. At 15% replacement of Cement with Fly ash, the Compressive strength of cement was increased by 3.2%, which is maximum.
3. From the experimental result of Compressive strength of cement, optimum percentage of Copper Slag is 40% and optimum percentage of Fly Ash is 15%.
4. Compressive strength of M20 and M25 Grades Concrete with optimum percentages of Copper Slag and Fly Ash replacement were increased by 30.9% and 32% respectively compared with control concrete at 28 days of curing.
5. Split tensile strength of concrete with optimum percentages replacement of Copper Slag and Fly Ash was increased averagely about 25% compared with control concrete for both M20 and M25 grade concrete at 28 days of curing.
6. Flexural strength of concrete with optimum percentages of Copper slag and Fly Ash were increased by 15.78% and 20.69% compared with control concrete for M20 and M25grade concrete respectively at 28 days of curing.
7. Modulus of elasticity of concrete with optimum percentages of Copper Slag and Fly Ash were increased by 6.6% and 8.13% compared with control concrete for M20 and M25 grade concrete respectively at 28 days of curing.
8. The increase in various strength properties of concrete was observed because of good mechanical and chemical properties of Copper Slag and pozzolanic action of Fly Ash. If fly ash is available in the mix, the surplus lime

becomes the source for pozzolanic reaction with fly ash and forms additional C-S-H gel having similar binding properties in the concrete as those produced by hydration of cement paste. The availability of additional binder leads to increase in the paste-aggregate bond, which results in improved strength properties of the concrete prepared with Fly Ash.

9. Under exposure to Acid H_2SO_4 and AlkalineNaOH, Copper Slag & Fly Ash Concrete has better resistance to weight loss & strength loss compared with control concrete.
10. Increase in Acid and Alkaline resistance of fly ash concrete is because of continuous reactions between fly ash and leached out lime, which continues to form additional C-S-H gel. This additional C-S-H gel fills in capillary pores in the cement paste, reducing permeability and ingress of chemical ions.

7. SCOPE OF FUTURE WORK:

1. The present experimental work can be extended to different Grades of Concrete with use of chemical Admixtures.
2. Strength and durability properties of Copper Slag concrete by adding non-metallic and organic fibres can be studied.
3. This work can be extended further by adding some other materials in addition to the Copper Slag and Fly Ash.
4. Utilization of Copper Slag on high strength Concrete beams for shear and torsion can be carried out.

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