STUDY OF STRENGTH AND DURABILITY OF STEEL MESH REINFORCED CONCRETE WITH STEEL SLAG AND COPPER SLAG AS VALUE ADDED MATERIAL IN CONCRETE

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Abstract - *In construction materials, concrete is the largest production of all other materials. Aggregates are the important constituents in concrete. The increase in demand for the ingredients of concrete is met by partial replacement of materials by the waste materials obtained by means of various industries. Steel slag is a waste product generated during the production of steel. These wastes are disposed in the form of landfills causes an enormous amount of land pollution. So, for the increasing demand to protect the environment, especially in build-up areas, the need to use these wastes are very important. Therefore, replacing all or some portion of natural aggregates with steel slag and copper slag would lead to considerable environmental benefits. The utilization of waste materials from the industries has been continuously emphasized in the research work. The present work is to use steel slag and copper slag as partial replacement for fine aggregate. The M25 concrete with steel and copper slag replacement for fine aggregate are examined. Durability tests were carried out, also compressive strength, flexural strength and split tensile strength were found experimentally. The results were compared with conventional concrete. The results showed that replacing about 30% steel slag and 20% copper slag aggregates by volume for natural aggregates will increase the strength and durability of concrete.*

Key Words: **Steel slag, Copper slag, Replacement, Durability, Strength, Convention, Utilization…**

1. INTRODUCTION

Concrete remains the most widely used man-made material in the world. In actual fact, our world is continuously being built up by concrete from ancient age to present time, from cities to communities and in every continent of the globe. There cannot be any sustainable development without the contribution of this composite material which has been known for many years and has metamorphosed from very crude to highly technical material through the ages.

A concrete structure may deteriorate because of deterioration of the concrete itself or because of corrosion of the steel reinforcing bars inside the concrete. Common causes of the deterioration of concrete include alkali-aggregate reaction, chemical attack, freezing and thawing action, abrasion and fire. There is often the misunderstanding that carbonation and chloride attack would cause deterioration of concrete. In actual fact, carbonation and chloride attack would not cause any harm to the concrete itself; they mainly cause de-passivation of the steel in concrete, which then leads to steel corrosion. Deterioration of concrete is not a common problem. In most cases, if there is any problem with the durability of a concrete structure, it is the corrosion of the steel reinforcing bars that is most likely to be the major use.

1.1 STEEL SLAG

The utilization of industrial by-products from the steel-making industry like blast furnace slag and steel slag has been established in a number of applications in the civil engineering industry.

Steel slag is a by-product of the conversion of iron to steel process and it presents differences depending on the raw materials and process. Fifty million tonnes per year of steel slag is produced as a residue in the world. In Europe every year nearly 12 million tons of steel slags is produced. Owing to the intensive research work during the last 30 years, today about 65% of the produced steel slag is used on qualified fields of application. But the remaining 35% of these slags is still dumped.

Figure 1: Steel slag

1.2 COPPER SLAG

Copper Slag is an industrial byproduct abundantly available near copper producing industries having similar physical &chemical properties of Sand can be considered as an alternative to the river sand. This will help in resolving a major concern of industrial waste disposal along with decreased cost of construction.

Copper slag's physical mechanical characteristics can be used to make products such as cement, abrasive, aggregate, roofing granules, etc. Copper slag has gained popularity for use as a fill material in construction industry. Because the copper slag has high strength /weight ratio it can be used as a best alternative to sand.

Figure 2: Copper slag

1.3 MESH REINFORCED CONCRETE

Mesh reinforced concrete can be defined as a composite material of cement concrete or mortar along with certain discontinuous discrete and uniformly dispersed Mesh. The basic reason why a reinforcing such material is needed in a concrete is because concrete has little resistance to tension. By adding fabric to the concrete, you add tensile strength, since steel is extremely strong in tension.

Advantages

- An increase in load bearing capacity due to the redistribution of stresses.
- Reinforcement throughout the full depth offers excellent crack - control.
- Optimal resistance against impact and dynamic loads.
- Joint spacings can considerably be increased.
- The floor thickness can be reduced by using steel fibers.

2. AIM

The aim of our project is, "To evaluate the strength and durability of concrete by replacing fine aggregate partially with 30% of steel slag and 20% of copper slag through strength tests such as compression test, spilt tensile test and flexural strength test and durability tests such as acid resistance test, sulphate and chloride exposure tests".

2.1 OBJECTIVES

- To study the effect of compressive, split tensile, flexural strength characteristic properties of steel slag waste as 30% replacement to fine aggregates in concrete.
- To study the effect of compressive, split tensile, flexural strength characteristic properties of copper slag waste as 20% replacement to fine aggregates in concrete.
- To study the effect of durability characteristic properties of steel slag waste as 30% replacement to fine aggregates in concrete.
- To study the effect of durability characteristic properties of copper slag waste as 20% replacement to fine aggregates in concrete.

3. MATERIALS

3.1 CEMENT

Cement is the most important constituent of concrete because it acts as an excellent binding material in concrete mix as well as offers good resistance to the moisture and possesses good plasticity.

Ordinary cement contains two basic ingredients called as argillaceous materials containing clayand calcareous materials containing calcium carbonate predominate. For general concrete constructions, IS: 456-2000 permits the use of types of cement.

3.2AGGREGATES

Aggregates are inert materials which when mixed with cement in the presence of water form concrete. They are used as filler materials in concrete. Aggregates constitute the major portion to the total volume of concrete and hence they influence the strength of concrete to a great extent.

Depending upon their size the aggregates are classified as:

(a) Fine Aggregate.

(b) Coarse Aggregate.

a) Fine Aggregate

The aggregates passing through I.S. sieve No 480 (4.75 mm. sizes) is termed as fine aggregate. The sum of percentage of all types of deleterious materials in fine aggregate should not exceed 5%. Natural sand or crushed stone dust is the fine aggregate mainly used in concrete mix.

b) Coarse Aggregates

The aggregates retained on I.S. sieve No 480 (4.75 mm size) is termed as coarse aggregate. The size of the coarse aggregate used, depends upon the nature and type of work required.

3.3 WATER

This is the least expensive but most important ingredient of concrete. The requirement of water is for proper hydration of cement, adequate workability in fresh concrete and for proper curing of hardened concrete. The water which is used for making concrete should be clean and free from harmful impurities such as oil, alkali, acid etc. In general, the water which is fit for drinking should be used for making concrete.

3.4 SQUARE WIRE MESH

Square wire mesh is readily available in Market and it is known to be the cheapest and easiest to handle. This mesh in either woven or welded construction, uses include railing infill panels and many other applications. Square wire meshes of 0.5 mm diameter is used.

Figure: Square wire mesh

4. DURABILITY TESTS

4.1 ACID RESISTANCE TEST

Acid resistance test is done by weighing the 28 days cured specimen and the same is immersed in sulphuric acid for 28 and 90 days. Weight difference is measured after the curing period. The effect of sulphuric acid on the normal concrete and concrete with steel slag are assessed by conducting tests based on ASTM C267 (2012).

Cube specimens of size 150 mm× 150 mm×150 mm is used in the study to measure the reduction in mass loss on exposure to 5% sulphuric acid solution. Cube specimens prepared are immersed in 5% sulphuric acid solution, each specimen is removed from the baths, brushed with a soft nylon brush, and rinsed in distilled water. This process removes the loose surface material from the specimen. The specimen is then dried and weighed. The specimens so prepared are compared with the normally cured specimens. The surface color change, surface deterioration, weight loss is studied.

$$\text{Weight loss (\%)} = \frac{W_I - W_F}{W_I}$$

where,

W_I = weight of the specimens before immersion,

W_F = weight of cleaned specimens after T-day of immersion (T = 28 and 90 days).

4.2 SULPHATE EXPOSURE TEST

The resistance to sulphate attack is determined as per ASTM C452 (2015) by immersing cubes of size 150 mm×150 mm×150 mm into sulphate solution prepared by adding 5% Sodium sulphate (Na_2SO_4) and 5% Magnesium sulphate ($MgSO_4$) by weight to water. Each specimen is then removed from the baths, brushed with a soft nylon brush, and rinsed in distilled water. This process removes the loose surface material from the specimen. The specimen is then dried and weighed. The specimens so prepared are compared with the normally cured specimens. The surface color change, surface deterioration, weight loss are studied.

4.3 CHLORIDE EXPOSURE TEST

The resistance to Chloride attack is determined as per ASTM C452 (2015) by immersing cubes of size 150 mm×150 mm ×150 mm into chloride solution prepared by adding 5% Sodium chloride (Nacl) by weight to water. Each specimen is then removed from the baths, brushed with a soft nylon brush, and rinsed in distilled water. This process removes the loose surface material from the specimen. The specimen is then dried and weighed. The specimens so prepared are compared with the normally cured specimens. The surface color change, surface deterioration, weight loss are studied.

5. STRENGTH TESTS

5.1 Compressive Test:

The compressive strength of concrete is the most common performance requirement used by the engineer in designing buildings and other structures. After 28 days of curing the cubes were removed from the curing tank, weighed and tested for compressive strength in a 2000 KN digital compression testing machine with the cast face parallel to the axis of loading at the rate of 3.2 KN/sec as per IS: 516-1959. The load at which the specimen fails is recorded.

$$\sigma = P/A$$

Where, P = Load applied [N],

A = Area [mm^2]

6. RESULTS AND DISCUSSION

6.1 ACID RESISTANCE TEST

6.1.1 SULPHURIC ACID

STEEL SLAG (28 days)

Table: 1 ACID RESISTANCE TEST (H_2SO_4)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	7.15	6.4	7.55	6.92	8.13	7.61
	W_B	7.11	6.87	7.35	7.1	8.11	7.8
	W_I	7.13	-	7.45	-	8.12	-
	W_F	-	6.63	-	7.01		7.705
Weight loss (%) in conventional concrete		6.94		5.87		5.1	
Weight of concrete with 30% steel slag in kg	W_A	7.55	7.2	8.23	7.98	8.5	8.24
	W_B	7.43	7.04	8.15	7.82	8.4	8.16
	W_I	7.49	-	8.19	-	8.45	-
	W_F	-	7.124	-	7.90	-	8.20
Weight loss (%) in concrete with 30% steel slag		4.85		3.45		2.92	
Reduction in weight loss (%)		28.67		41.22		42.87	
Compression strength (N/mm^2)of conventional concrete		25.04		27.32		28.73	
Compression strength (N/mm^2)of concrete with 30% steel slag		28.54		30.47		31.11	
% variation in strength		13.9		11.5		8.028	

Example for Calculation:

Weight loss in conventional concrete $= \frac{7.13-6.63}{7.13} \times 100 =$ 6.94%

Reduction in weight loss $= \frac{6.94-4.85}{6.94} \times 100 = 28.67$ %

% Variation in strength $= \frac{25.04-28.54}{25.04} \times 100 = 13.9\%$

- **copper slag (28 days)**

Table 2 ACID RESISTANCE TEST (H_2SO_4)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	7.15	6.4	7.55	6.92	8.13	7.61
	W_B	7.11	6.87	7.35	7.1	8.11	7.8
	W_I	7.13	-	7.45	-	8.12	-
	W_F	-	6.63	-	7.01		7.705
Weight loss (%) in conventional concrete		6.94		5.87		5.1	
Weight of concrete with 20% copper slag in kg	W_A	7.17	7.0	7.64	7.35	8.17	8.08
	W_B	7.31	6.92	7.7	7.5	8.25	7.92
	W_I	7.24	-	7.67	-	8.21	-
	W_F	-	6.96	-	7.429	-	8.0
Weight loss (%) in concrete with 20% copper slag		3.76		3.135		2.52	
Reduction in weight loss (%)		45.82		46.59		50.5	
Compression strength (N/mm^2)of conventional concrete		25.04		27.32		28.73	
Compression strength (N/mm^2) of concrete with 20% copper slag		30.25		32.02		32.97	
% variation in strength		20.8		17.20		14.7	

W_A = Weight of specimen-1 in kg

W_B = Weight of specimen -2 in kg

W_I = Initial Average weight of specimens 1 and 2 in kg

W_F = Final Average weight of specimens 1 and 2 in kg

6.1.2 HYDROCHLORIC ACID

Steel slag

Table 3: ACID RESISTANCE TEST (HCl)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	7.8	7.3	7.85	7.62	8.3	8.06
	W_B	7.2	7.22	7.67	7.46	8.18	8.0
	W_I	7.5	-	7.76	-	8.24	-
	W_F	-	7.26	-	7.54	-	8.03
Weight loss (%) in conventional concrete		3.09		2.74		2.48	
Weight of concrete with 30% steel slag in kg	W_A	7.7	7.44	7.8	7.78	8.6	8.20
	W_B	7.56	7.48	7.98	7.7	8.2	8.32
	W_I	7.63	-	7.89	-	8.4	-
	W_F	-	7.46	-	7.74	-	8.26
Weight loss (%) in concrete with 30% steel slag		2.15		1.88		1.6	
Reduction in weight loss (%)		30.42		31.38		35.48	
Compression strength (N/mm^2) of conventional concrete		31.16		31.99		33.45	
Compression strength (N/mm^2) of concrete with 30% steel slag		31.81		32.93		34.04	
% variation in strength		2.08		2.93		1.76	

Copper slag

Table 4: ACID RESISTANCE TEST (HCl)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	7.8	7.3	7.85	7.62	8.3	8.06
	W_B	7.2	7.22	7.67	7.46	8.18	8.0
	W_I	7.5	-	7.76	-	8.24	-
	W_F	-	7.26	-	7.54	-	8.03
Weight loss (%) in conventional concrete		3.09		2.74		2.48	
Weight of concrete with 20% copper slag in kg	W_A	7.8	7.55	7.95	7.77	8.7	8.38
	W_B	7.46	7.39	7.83	7.73	8.3	8.24
	W_I	7.63	-	7.89	-	8.5	-
	W_F	-	7.47	-	7.75	-	8.31
Weight loss (%) in concrete with 20% copper slag		2.07		1.69		1.47	
Reduction in weight loss (%)		33		38.32		40.72	
Compression strength (N/mm²) of conventional concrete		31.16		31.99		33.45	
Compression strength (N/mm²) of concrete with 20% copper slag		32.99		34.01		35.56	
% variation in strength		5.87		6.31		6.30	

6.2 SULPHATE EXPOSURE TEST

Table 5. SULPHATE EXPOSURE TEST (Na_2SO_4 & $MgSO_4$)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	7.1	7.0	8.18	7.8	8.6	8.5
	W_B	7.04	6.84	8.08	8.16	8.54	8.36
	W_I	7.07	-	8.13	-	8.57	-
	W_F	-	6.92	-	7.98	-	8.43
Weight loss (%) in conventional concrete		2.02		1.76		1.61	
Weight of concrete with 30% steel slag in kg	W_A	8.0	7.86	8.4	8.16	8.73	8.9
	W_B	7.96	7.9	8.28	8.34	8.85	8.52
	W_I	7.98	-	8.34	-	8.79	-
	W_F	-	7.88	-	8.25	-	8.71
Weight loss (%) in concrete with 30% steel slag		1.2		0.98		0.85	
Reduction in weight loss (%)		40.59		44.31		47.20	
Compression strength (N/mm²) of conventional concrete		33.25		35.11		35.97	
Compression strength (N/mm²) of concrete with 30% steel slag		36.21		36.82		38.63	
% variation in strength		8.9		4.87		7.39	

Copper Slag

Table 6. SULPHATE EXPOSURE TEST (Na_2SO_4 & $MgSO_4$)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	7.1	7.0	8.18	7.8	8.6	8.5
	W_B	7.04	6.84	8.08	8.16	8.54	8.36
	W_I	7.07	-	8.13	-	8.57	-
	W_F	-	6.92	-	7.98	-	8.43
Weight loss (%) in conventional concrete		2.02		1.76		1.61	
Weight of concrete with 20% copper slag in kg	W_A	7.06	6.99	8.48	8.23	8.63	8.54
	W_B	7.2	7.15	8.22	8.35	8.55	8.50
	W_I	7.13	-	8.35	-	8.59	-
	W_F	-	7.07	-	8.29	-	8.52
Weight loss (%) in concrete with 20% copper slag		0.86		0.79		0.74	
Reduction in weight loss (%)		57.4		55.1		54	
Compression strength (N/mm²) of conventional concrete		33.25		35.11		35.97	
Compression strength (N/mm²) of concrete with 20% copper slag		36.92		37.23		38.98	
% variation in strength		11.03		6.03		8.36	

6.3 CHLORIDE EXPOSURE TEST

Steel slag

Table 7: CHLORIDE EXPOSURE TEST (NaCl)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	8.1	7.92	8.04	8.0	8.07	8.09
	W_B	7.7	7.76	7.96	7.88	8.03	7.89
	W_I	7.9	-	8.0	-	8.05	-
	W_F	-	7.84	-	7.94	-	7.99
Weight loss (%) in conventional concrete		0.74		0.71		0.70	
Weight of concrete with 30% steel slag in kg	W_A	8.1	8.21	8.27	8.0	8.35	8.03
	W_B	8.0	7.77	8.05	8.22	8.13	8.35
	W_I	8.05	-	8.16	-	8.24	-
	W_F	-	7.99	-	8.11	-	8.19
Weight loss (%) in concrete with 30% steel slag		0.649		0.60		0.59	
Reduction in weight loss (%)		12.29		15.49		15.79	
Compression strength (N/mm²) of conventional concrete		37.14		37.56		38.09	
Compression strength (N/mm²) of concrete with 30% steel slag		38.41		33.98		39.54	
% variation in strength		3.41		3.78		3.80	

Copper slag

Table 8: CHLORIDE EXPOSURE TEST (NaCl)

		Conventional concrete		Concrete with 1 layer of mesh		Concrete with 2 layers of mesh	
Weight of conventional concrete in kg	W_A	8.1	7.92	8.04	8.0	8.07	8.09
	W_B	7.7	7.76	7.96	7.88	8.03	7.89
	W_I	7.9	-	8.0	-	8.05	-
	W_F	-	7.84	-	7.94	-	7.99
Weight loss (%) in conventional concrete		0.74		0.71		0.70	
Weight of concrete with 20% copper slag in kg	W_A	8.06	8.0	7.98	8.12	8.38	8.4
	W_B	8.0	7.96	8.44	8.2	8.6	8.48
	W_I	8.03	-	8.21	-	8.49	-
	W_F	-	7.98	-	8.16	-	8.44
Weight loss (%) in concrete with 20% copper slag		0.61		0.55		0.48	
Reduction in weight loss (%)		17.56		22.53		31.42	
Compression strength (N/mm²) of conventional concrete		37.14		37.56		38.09	
Compression strength (N/mm²) of concrete with 20% copper slag		38.76		39.02		39.97	
% variation in strength		4.36		3.88		4.93	

7. CONCLUSIONS

The conclusions listed below are based on the tests conducted.

- ✓ It is observed that the partial replacement of fine aggregate by steel or copper slag improves the acid resistance of concrete considerably. The weight loss in cubes after immersion in acids was very low.
- ✓ The reduction in weight loss of concrete specimens replaced by 30% of steel slag without mesh is 28% for 28 days,56% for 90 days, a with 1 layer of mesh is 41% for 28 days ,61% for 90 days and with 2 layers of mesh 42% for 28 days,65% for 90 days and strength variation is about 4.8% for 28 days,14% for 90 days ,4.2% for 28 days ,11.5% for 90 days and 8% for 28 days ,8.3% for 90 days respectively in case of sulphuric acid.
- ✓ The reduction in weight loss of concrete specimens replaced by 20% of copper slag without mesh is 45-57%, with 1 layer of mesh is 46-66% and with 2 layers of mesh 50-69% and strength variation is about 5.7-21% ,13-17% and 13-15% respectively in case of sulphuric acid.
- ✓ The reduction in weight loss of concrete specimens replaced by 30% of steel slag without mesh is 30%, with 1 layer of mesh is 31% and with 2 layers of mesh 35% and strength variation is about 2%, 3% and 2% respectively in case of Hydrochloric acid.
- ✓ The reduction in weight loss of concrete specimens replaced by 20% of copper slag without mesh is 33%, with 1 layer of mesh is 38% and with 2 layers of mesh 40% and strength variation is about 6%, 6.3% and 6.3% respectively in case of Hydrochloric acid.
- ✓ So, the concrete with partial replacement of fine aggregate by steel and copper slag shows better resistance to Hcl than to H_2SO_4.
- ✓ The reduction in weight loss of concrete specimens replaced by 30% of steel slag without mesh is 41%, with 1 layer of mesh is 45% and with 2 layers of mesh 47% and strength variation is about 9% ,5% and 8% respectively in case of sulphate exposure.
- ✓ The reduction in weight loss of concrete specimens replaced by 20% of copper slag without mesh is 57%, with 1 layer of mesh is 55% and with 2 layers of mesh 54% and strength variation is about 11%, 6% and 8% respectively in case of sulphate exposure.
- ✓ The reduction in weight loss of concrete specimens replaced by 30% of steel slag without mesh is 12%, with 1 layer of mesh is 15.5% and with 2 layers of mesh 16% and strength variation is about 3% ,4% and 4% respectively in case of chloride exposure.
- ✓ The reduction in weight loss of concrete specimens replaced by 20% of copper slag without mesh is 17.5%, with 1 layer of mesh is 22.5% and with 2 layers of mesh 31.5% and strength variation is about 4.3% ,4% and 5% respectively in case of chloride exposure.
- ✓ Based on the above test results it can be concluded that copper slag replaced and mesh reinforced concrete shows better durability characteristics than steel slag replaced and mesh reinforced concrete.
- ✓ Also from above test results it can concluded that resistance of concrete against H_2SO_4 , Hcl, Sulphate and Chloride ions increases as the reinforcement increases.

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