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Utilization of Steel Slag as Partial Replacement of Cement in Concrete Pavement

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***Abstract:** This experimental work attempts to identify the behaviour of M35 grade of concrete by partial replacement of cement (OPC 43) by STEEL SLAG. In this work steel slag is used as a replacing agent to reduce the usage of cement. With this the CO_2 emitted during the manufacturing of cement can be reduced to a certain level. This will be advantageous to the environment as there will be reduction of green house gases. This experimental work is carried out in 5 phases in which M35 grade of concrete is prepared. 1st phase (0% steel slag + 100% cement), 2nd phase (10% steel slag + 90% cement), 3rd phase (20% steel slag + 80% cement), 4th phase (30% steel slag + 70% cement), 5th phase (40% steel slag + 60% cement). The cube mould of size 150mm X 150mm X 150mm is used for testing of compressive strength of concrete and the beam mould of size 150mm X 150mm X 700mm is used for testing of flexural strength of concrete.*

***Keywords:** Cement, Steel Slag, Compressive Strength, Flexural Strength*

I. INTRODUCTION

The steel slag is a by-product of steel industry. It is produced during the production of steel. Electric arc furnace process is the process during which steel slag is obtained. In this process high power electric arc are used in the furnace to produce the heat which is required to melt the steel scrap and to convert it into high quality steel. The graphite electrode with the spout are provided in the electric arc furnace. The electric arc resists the electric flow which generates the heat at a very high temperature but the scrap metal could not resists the electricity and the scrap starts melting and in some time all the scrap changes into the molten state. This process can take up to 3 hours to complete. The temperature of electric arc furnace can reach up to 1800°C.

TABLE-I
PHYSICAL PROPERTIES OF STEEL SLAG

Test	Results
Specific gravity	3.4
Unit weight	1782 kg/m^3
Water absorption	1.6 %

TABLE-II
CHEMICAL PROPERTIES OF STEEL SLAG

Chemical	Percentage (%) by mass
Silica	32.48
Alumina	9.83
Lime	39.42
Iron oxide	0.93
Magnesia	11.67
Sodium oxide	0.13
Potassium oxide	0.28
Sulphate	1.79
Loss of ignition	2.18

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II. METHODOLOGY

A. Collection of Materials

1) Cement
2) Sand
3) Coarse aggregate
4) Water
5) Steel Slag
6) Admixture

The above materials were collected from the nearest material supplier except steel slag which was collected from Shree Durga Steel Industries Pvt. Ltd. Situated in village-Bhalgarh, district-Sonipat, Haryana

Shree cement OPC 43 grade was used

Admixture – FORSOC Conplast SP430 ES2 was used.

B. Testing of Materials

TABLE-III
TEST RESULTS FOR CEMENT OPC 43 GRADE

Specific gravity	3.17
Consistency of cement	32
Initial setting time	46 minutes
Final setting time	244 minutes
Compressive strength 3 days	24.10 N/mm^2
Compressive strength 7 days	36 N/mm^2
Compressive strength 14 days	44.60 N/mm^2

TABLE-IV
TEST RESULTS FOR SAND

Specific gravity	2.69
Water absorption	0.8%
Sieve analysis	Zone II

TABLE-V
TEST RESULTS FOR COARSE AGGREGATE (10mm & 20mm)

Tests	10 mm	20 mm
Specific gravity	2.615	2.648
Water absorption	0.5%	1.2%

C. Mix design

Test data
Grade designation – M35
Type of cement – OPC 43 grade
Minimum cement content – 325 kg/ m^3
Maximum W/C ratio – 0.45
Workability (slump) – 25 to 50mm
Specific gravity of cement – 3.17
Specific gravity of 20mm aggregate – 2.648
Specific gravity of 10mm aggregate – 2.615
Specific gravity of fine aggregate – 2.69
Admixture –FORSOC Conplast SP430 ES2

Admixture ratio – 0.7% of cement content by weight
Sieve analysis of fine aggregate – conforming to Zone II (IS 383-1970)

1) Design Mix Calculations

Target strength f 'ck = fck+ 1.65 x s
= 35+1.65 x 5
= 43.25N/mm^2

W/C ratio = 0.42 (for workability of 25- 50 mm)

Maximum Water content for 20 mm aggregates = 186 Kg/ m^3

Cement Content = 186/ 0.42
= 443 Kg/ m^3

Volume of Coarse aggregates 20mm = 0.619
Volume of Fine aggregates = 1 - 0.619= 0.381

Mix Calculations:-

Volume of Concrete = 1 m^3
Volume of cement = (443/3.16) x (1/1000)
= 0.140 m^3
Volume of water = (186/1) x (1/1000)
= 0.186 m^3
Volume of all in aggregates = (a – (b + c)
= [1- (0.140 + 0.186)]
= 1 – 0.326
= 0.674m^3
Mass of Coarse aggregate = 0.674 x 0.619x 2.64 x 1000
=1102kg/m^3
Mass of the Fine aggregates = 0.674x0.381x2.69x1000
= 691kg/m^3

So,	W/C ratio	= 0.42		
	Cement	= 443 Kg/m^3	= 443/443	= 1
	Fine aggregates	= 691 kg/m^3	= 691/443	=1.55
	Coarse aggregates	= 1102 kg/m^3	= 1102/443	=2.487
	Water	= 186 kg/m^3		
	Admixture	= 0.7% of cement content by weight		

RATIO = 1 : 1.55 : 2.487

D. Mixing Process

The weight of all the material are measured sapeeratly using weighing machine and the mixing machine is used for the mixing process

E. Moulding and Demoulding Process

The prepared concrete is filled into the cube moulds of size 150mm x 150mm x150mm and the beam mould of size 150mm x 150mm x 700mm. Proper compaction of the concrete is ensured by using vibration machine for the removal of air voids in the concrete mix, the vibration machine is used for the time of two minutes.

The cube moulds are demoulded after 24 hour and the beam moulds are demoulded after 48 hours.

F. Curing Process

After removing of the moulds the cubes and the beams specimens are placed in the tank filled with water in the laboratory till the date of testing.

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G. *Testing Process*

The cube moulds for compressive strength are tested for 7 days, 14 days and 28 days and the beam moulds for flexural strength are tested for 7 days and 28 days.

H. *Test Results*

TABLE-VI
Test Results For Compressive Strength Of Cubes

Mix proportion	7 days (mpa)	14 days (mpa)	28 days (mpa)
0% steel slag	16.07	29.92	44.65
10% steel slag	16.57	29.55	44.45
20% steel slag	16.26	31.12	46.45
30% steel slag	19.14	33.02	47.85
40% steel slag	14.82	28.37	42.37

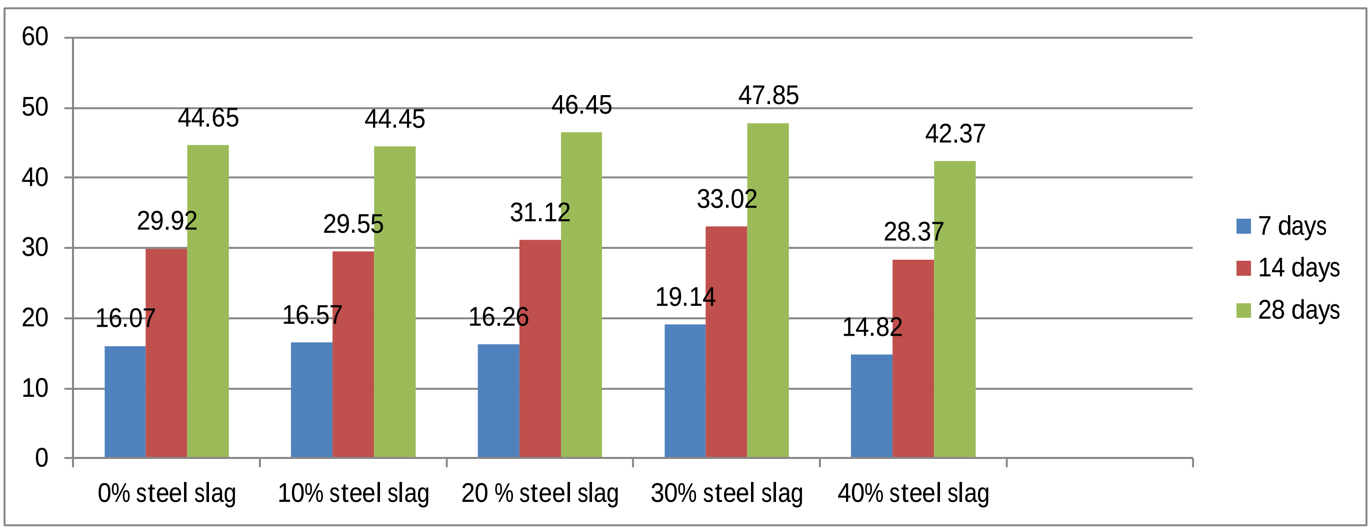

Figure 1-Compressive Strength values of cubes

TABLE-VII
Test Results for Flexural Strength Of Cubes

Mix %	7 days	28 Days
0% steel slag	3.13	4.82
10% steel slag	3.26	5.03
20% steel slag	3.65	5.63
30% steel slag	2.89	4.45
40% steel slag	2.85	4.39

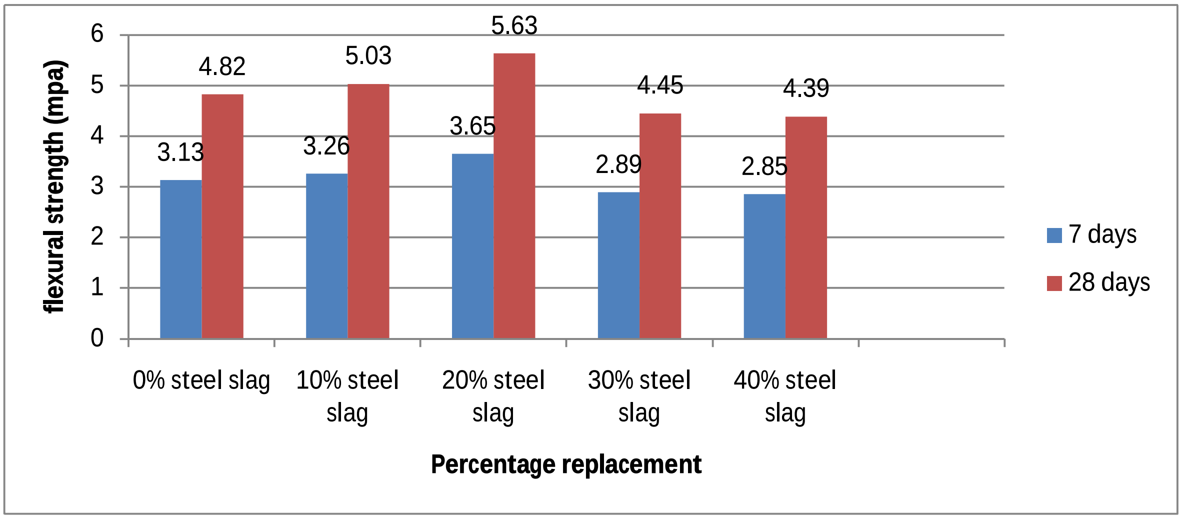

Figure 2 - Flexural Strength values of beams

III. CONCLUSION

1) The workability of concrete decreases with the increase in steel slag, the particles of steel slag reduces the amount of water required to produce a given slump.
2) The compressive strength and flexural strength increases with the increase of steel slag in concrete up to 30%. Replacement with cement in conventional mix, however the compressive strength increases more as compared to flexural strength, the values are acceptable as per IRC.
3) As per results optimum percentage of steel slag for compressive strength is 30%. At 30% replacement of steel slag with cement for M35 grade concrete compressive strength is maximum. For flexural strength optimum percentage for replacement of cement with steel slag is 20%.
4) Mixing of steel slag in concrete conventional mix has resulted in considerable variation in the properties of fresh concrete. Integration of fly ash in concrete increased the cohesiveness of the mix, prohibited segregation and resulted in reduced bleeding. Higher percentages of steel slag can cause a change in color of the mix.

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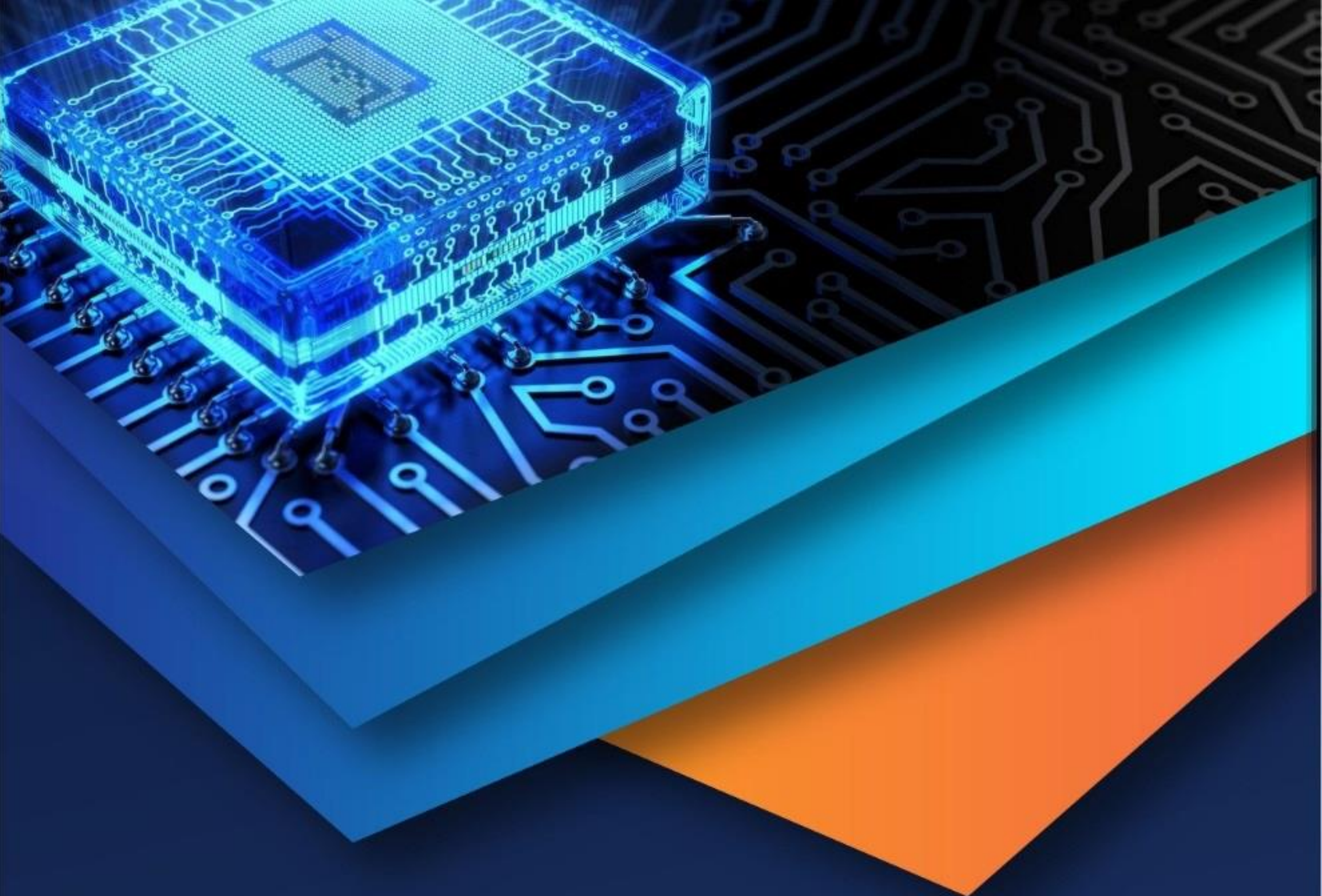

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