



IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY



VOLUME : 4 ISSUE : 03 Print / Issue Publication Date: 02-Sep-2019



ISSN : 2455-2143



DOI : 10.33564/IJEAST.2019.v04i03.060

Indexed In



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AN EXPERIMENTAL INVESTIGATION ON THE EFFECT OF INDUCTION FURNACE SLAG AS FULL REPLACEMENT OF FINE AGGREGATE AND PARTIAL REPLACEMENT OF COARSE AGGREGATE IN M25 GRADE CONCRETE

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Abstract -- The environmental problems are very common due to generation of industrial by-products. The industrial produce and utilization of these by-products is the main challenge faced in India. Induction Furnace Slag is one of the industrial by-product from steel and iron manufacturing industries. Hence, here an attempt has been made to assess the possibility of using an industrial furnace slag as a full replacement in fine aggregate and partial replacement in coarse aggregate. Induction furnace slag is used as replacement of fine and coarse aggregate on criteria of particle size after performing sieve analysis using Indian Standards and has been physically and chemically characterized. Induction furnace slag is replaced in coarse aggregate in the range of 0%, 5%, 10%, 15% and 20% by weight and 100% replacement in fine aggregate in concrete for M25 grade concrete is used for a W/C ratio 0.62. The test performed to evaluate induction furnace slag concrete quality include slump cone test, compressive strength test, split tensile strength test and flexural strength test. Cubes, cylinders and prisms are casted and tested for 3, 7, and 28 days. The results shows that as increment of induction furnace slag percentage improve the hardened properties progressively up to 15% of induction furnace slag is replaced in coarse aggregate and starts decreases after

15% of IFS is replaced in coarse aggregate for compressive strength, split tensile strength and flexural strength.

Keywords – Induction furnace slag (IFS), M25 grade concrete, Compressive strength, Split tensile strength, Flexural strength.

I. INTRODUCTION

Concrete is primarily comprised of Portland cement, aggregates, and water. Although the Portland cement typically comprises only 12% of the concrete mass, still it accounts for approximately 93% of the total embodied energy of concrete. Some remedial measures can be taken to minimize some better properties of concrete. In the process of cast iron and ductile iron production, secondary raw material and Industrial wastes are formed. The most abundant waste originating in the process is induction furnace slag. Slags are compounds of oxides of metal & nonmetallic elements which form chemical compounds and solutions with each other and also contain small volume of metals, sulfides of metal and gases. This slag is disposed of the factory floor due to which land contamination takes place which decrease fertility of soil. Induction furnace slag contain about 10-15% metal.



Fig 1 IFS at MAA MAHA MAYA INDUSTRIES

Concrete is a composite material, it is a mixture of cement, fine aggregate, coarse aggregate and water. In this investigation the Induction furnace slag was replaced in fine aggregate and coarse aggregate with different proportions. The present investigation has been done based on the following objectives.

- The target for the present work is to design a concrete mix which would reduce the cost of construction and cost of ingredients of concrete.
- To study the feasibility of attaining the strength with Ordinary Portland cement and induction furnace slag.
- To minimize the natural resources such as sand and crushed aggregates by replacing with Induction furnace slag.

II. LITERATURE REVIEW

Syed Istiaq Ahmad and Md. Shafiqur Rahman [2018] were studied the mechanical and durability properties of Induction-Furnace-Slag-Incorporated recycled aggregate concrete. The Recycled coarse aggregate was replaced with induction furnace slag by 0%, 25%, 50%, 75%, and 100% for each target strength. For up to 50% of induction furnace slag replacement, both compressive strength and split tensile strength increased in recycled aggregate concrete.

Kr. Ramsudar and R. Jayanthi [2018] in this experimental investigation the partial replacement of fine aggregate waste iron slag were reused to partially replacement of 0%, 10%, 20% and 30% of sand weight. The maximum strength of compressive strength and split tensile strength was found to be at 30% of steel slag.

U Mohammed et al. [2017] were conducted an experimental investigation was carried out to explore the suitability of utilizing induction furnace slag as coarse aggregate in concrete. The concrete specimens were tested at 7, 28 and 90 days. Based on results, the optimum replacement ratio of brick

aggregate by induction furnace slag aggregate with respect to compressive strength and tensile strength of concrete is found at 50%.

Anil et al. [2017] were conducted an experimental study on effect of steel slag as partial replacement of fine aggregate in M35 grade concrete. The fine aggregate was replaced with steel slag by 0%, 11%, 22%, 33%, and 44% (by weight) for each target strength. Based on results, the optimum value of compressive strength, flexural strength, split tensile strength can be achieved by 33% replacement of steel slag.

M. A. Qurishee et al. [2016] were conducted a study on use of slag as coarse aggregate and its effect on mechanical properties of concrete. The proportion of stone chips and slag used in this investigation as coarse aggregate are 0 to 100%. Concrete made by replacing coarse aggregate with BFS is observed to increase up to a replacement level of 40%.

III. EXPERIMENTAL INVESTIGATION

Experimental investigation were carried out on the various types of ingredients of concrete. Details of the material used, methodology of various tests conducted during investigation are as below.

A. Material used –

Cement

Ordinary Portland cement of 53 grade conforming to Indian standard IS: 12269-1987 was used for the present experimental investigation. Various properties of cement were determined as per IS4031 (1988) and the results are given in Table 1.

Table 1 Properties of Cement

Property	Result	Requirements of IS 12267-1987
Fineness of cement	5.8%	Not more than 10%
Normal consistency	31%	-
Specific gravity	3.07	-
Initial setting time	45 min	Should not be less than 30 min
Final setting time	480 min	Should not be more than 600 min
Compressive strength of motor cubes at the age of 28 days	53.6 MPa	Should be more than 53 MPa

Fine Aggregate

Natural River Sand conforming to IS: 383-1970 and IS 10262-2009 was used. The results of various tests on fine aggregate are given in Table 2.



Table 2 Properties of Fine Aggregate

S.No	Property	Result
1	Specific gravity	2.66
2	Fineness Modulus	2.72
3	Grading	Zone II

Coarse Aggregate

Crushed granite coarse aggregate conforming to IS: 383-1970 was used. The results of various tests on coarse aggregate are given in Table 3.

Table 3 Properties of Coarse Aggregate

S.No	Property	Result
1	Specific gravity	2.70
2	Fineness Modulus	7.72
3	Maximum Nominal Size	20 mm

Induction furnace slag as a fine aggregate

Induction furnace slag is an Industrial by-product of cast iron and ductile iron production. IFS used in experimental investigation from MAA MAHA MAYA INDUSTRIAL PVT LTD, Relligavaram Peta, Vizianagaram, Andhra Pradesh, India. The properties of Induction furnace slag as Fine aggregate is give in table 4.

Table 4 Induction furnace slag a Fine aggregate

S.No	Property	Result
1	Specific gravity	2.86
2	Fineness Modulus	2.55
3	Water absorption	20%
4	Bulk density	1478.33 Kg/cu.m

Induction furnace slag as a coarse aggregate

The properties of Induction furnace slag as Coarse aggregate is give in table 5.

Table 5 Induction furnace slag as Coarse aggregate

S.No	Property	Result
1	Specific gravity	1.5
2	Fineness Modulus	2.55
3	Water absorption	20%
4	Bulk density	701.33 Kg/cu.m

Potable Water

Ordinary potable tap water available in our laboratory was used for mixing and curing of reference concrete. It had a pH value of 7.2.

B. Mix Design –

M25 grade of concrete mix design was carried out as per IS: 10262-2009 and IS: 456-2000. Induction furnace slag is replaced in fine and coarse

aggregate with different ratios. The mix proportions of concrete mixture are given in Table 6.

Table 6 Mix Proportions

S.No	Material	M25 Grade concrete per m ³
1	Cement	381.29 Kg
2	Fine aggregate	0 Kg
3	Induction furnace as a Fine aggregate	698.815 Kg
4	Coarse aggregate	928.479 Kg
5	Induction furnace slag as a Coarse aggregate	89.698 Kg
6	Water	236.4 lt
7	Proportion	1 : 1.832 : 2.67
8	W/C ratio	0.62

IV. RESULTS AND DISCUSSION

A. Slump cone test –

Slump cone test measures the workability of concrete. Slump cone test is performed as per IS: 1199-1959. The results of various percentage of replacement of IFS in fine and coarse aggregate are given in Table 7.

Table 7 Slump values

W/C Ratio	Percentage of IFS in FA	Percentage of IFS in CA	Slump in mm
0.62	100	0	98
0.62	100	5	93
0.62	100	10	84
0.62	100	15	81
0.62	100	20	78

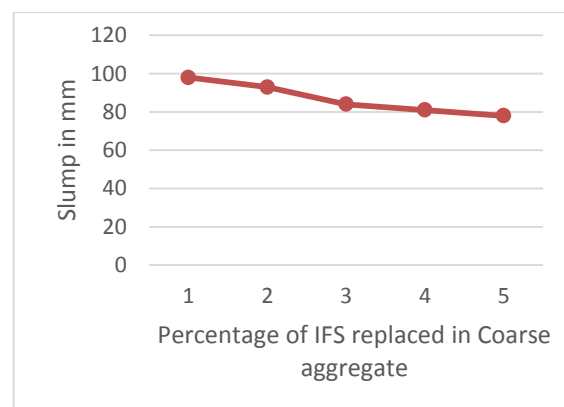


Fig 2 Slump in mm of different percentage of IFS replaced in coarse aggregate

From the above graph shows the comparison between the slump values of different percentage of induction furnace slag which is replaced in coarse aggregate. It is reported that if the percentage of



IFS is increase in coarse aggregate content and then the workability of concrete was decreases. The value of slump in above table is varies from 75 to 100 mm. So, the workability of above concrete is coming under medium workable.

B. Compressive Strength –

Concrete specimen cubes 150 mm X 150 mm X 150 mm are used to determine compressive strength of concrete were tested as per IS: 516-1959. The Induction furnace slag is full replaced in fine aggregate and partial replaced in coarse aggregate with different ratios. The below table shows the M25 Grade concrete mix compressive strength results with water cement ratio 0.62 W/C ratio.

Table 8 Compressive strength in MPa

Percentage of IFS replace in CA	Compressive Strength in MPa		
	3 days	7 days	28 days
0 %	15.36	18.47	31.55
5 %	17.63	22.72	37.19
10 %	19.43	23.85	39.24
15 %	20.28	25.28	42.09
20 %	13.83	22.45	36.19

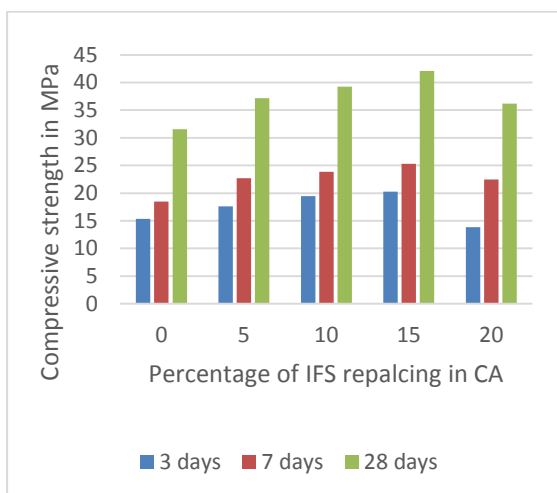


Fig 3 Compressive strength in MPa for different curing period

From the above graph shows the comparison between the compressive strength of M25 Grade concrete for various percentage of Induction furnace slag replacing in coarse aggregate at the ages of 3 days, 7 days and 28 days. It is reported that the maximum compressive strength occurs at 15 % of Induction furnace slag which is replaced in coarse aggregate i.e, 20.28 N/mm², 25.28 N/mm² and 42.09 N/mm² at the ages of 3 days, 7 days and 28 days respectively.

C. Split tensile strength –

The size of specimen 150 mm diameter and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cylinders are used to determine split tensile strength of concrete and were tested as per IS: 516-1959 and IS: 5816-1999. The below table shows the M25 Grade concrete mix Split tensile strength results with W/C ratio 0.62.

Table 9 Split tensile strength in MPa

Percentage of IFS replace in CA	Split tensile Strength in MPa		
	3 days	7 days	28 days
0 %	1.62	2.69	4.01
5 %	1.71	2.87	4.28
10 %	1.76	2.97	4.40
15 %	1.81	3.05	4.55
20 %	1.69	2.82	4.22

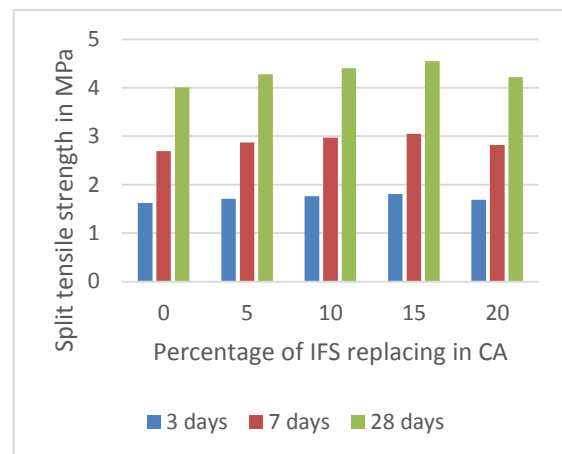


Fig 4 Split tensile strength in MPa for different curing period

From the above graph shows the comparison between the Split tensile strength of M25 Grade concrete for various percentage of Induction furnace slag replacing in coarse aggregate at the ages of 3 days, 7 days and 28 days. It is reported that at the maximum Split tensile strength occurs at 15 % of Induction furnace slag which is replaced in coarse aggregate i.e, 1.81 N/mm², 3.05 N/mm² and 4.55 N/mm² at the ages of 3 days, 7 days and 28 days respectively.

D. Flexural Strength –

Concrete specimen of size 100 mm X 100 mm X 500 mm is used to determine flexural strength of concrete and were tested as per IS: 516-1959. The flexural strength is usually obtained experimentally by means of two point load method. The below



table show the M25 Grade concrete mix flexural strength results with W/C ratio 0.62.

Table 10 Flexural strength in MPa

Percentage of IFS replace in CA	Split tensile Strength in MPa		
	3 days	7 days	28 days
0 %	1.69	2.83	4.22
5 %	1.75	2.98	4.41
10 %	1.86	3.11	4.63
15 %	1.89	3.19	4.76
20 %	1.76	2.97	4.43

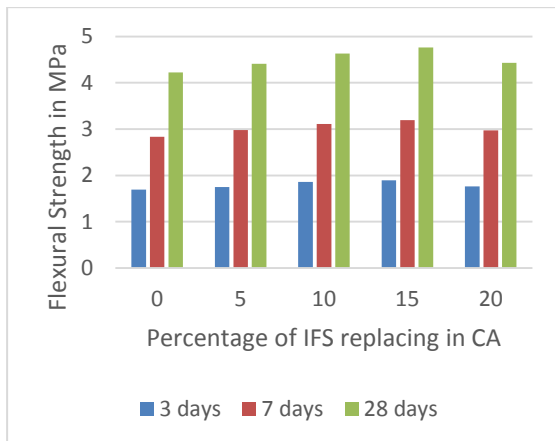


Fig 5 Flexural strength in MPa for different curing period

From the above graph shows the comparison between the flexural strength of M25 Grade concrete for various percentage of Induction furnace slag replacing in coarse aggregate at the ages of 3 days, 7 days and 28 days. It is reported that the maximum flexural strength occurs at 15 % of Induction furnace slag which is replaced in coarse aggregate at i.e, 1.89 N/mm², 3.19 N/mm² and 4.76 N/mm² at the ages of 3 days, 7 days and 28 days respectively.

V. CONCLUSIONS

Based on the experimental investigation the following conclusions are drawn

- The water absorption of Induction furnace slag as fine aggregate and as a coarse aggregate is 18.4% and 20% respectively. So, more W/C ration i.e, 0.62 is required to achieve medium workability.
- If the percentage of IFS increase in coarse aggregate content then it leads to decrease in workability. The value of slump is varies from 75 to 100 mm.
- The maximum compressive strength i.e, 20.28 N/mm², 25.28 N/mm², and 42.09 N/mm² at the ages of 3 days, 7 days and

28 days respectively for M25 Grade concrete mix occurs at 15% of IFS replaced in coarse aggregate and 100% of IFS is replaced in fine aggregate.

- The Compressive strength of concrete increases up to 15% of induction furnace slag replaced in coarse aggregate and then gradually decreases the compressive strength after 15% of induction furnace slag replaced in coarse aggregate.
- The maximum Split tensile strength i.e, 1.81 N/mm², 3.05 N/mm², and 4.55 N/mm² at the ages of 3 days, 7 days and 28 days respectively for M25 Grade concrete mix occurs at 15% of IFS replaced in CA and 100% of IFS is replaced in fine aggregate.
- The Split tensile strength of concrete increases up to 15% of induction furnace slag replaced in coarse aggregate and then gradually decreases the Split tensile strength after 15% of induction furnace slag replaced in coarse aggregate.
- The maximum Flexural strength i.e, 1.89 N/mm², 3.19 N/mm², and 4.76 N/mm² for M25 Grade concrete mix occurs at 15% of Induction furnace slag replaced in coarse aggregate and 100% of induction furnace slag is replaced in fine aggregate at the ages of 3 days, 7 days and 28 days respectively.
- The flexural strength of concrete increases up to 15% of induction furnace slag replaced in coarse aggregate in coarse aggregate and then gradually decreases the flexural strength after 15% of induction furnace slag replaced in coarse aggregate.
- The split tensile strength and flexural strength of induction furnace slag concrete mix gives good results compared to conventional concrete mix because of induction furnace slag contains about 10-15% of metals.

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