

Partial Replacement of Fine Aggregate with Iron Slag

Kr.Ramsundar¹, R.Jayanthi²

Assistant Professor, Department of Civil Engineering, Misrimal Navajee Munoth Jain Engineering College,
Thuraipakkam, Chennai, India¹

Assistant Professor, Department of Civil Engineering, SriramEngineering College, Veppampattu, Thiruvallur district,
Chennai, India²

ABSTRACT:The environmental problems are very common due to generation of industrial byproducts. The industrial produce and utilization of these byproducts is the main challenge faced in India. Iron slag is one of the industrial byproducts from iron and steel making industries. The partial replacements of fine aggregate waste iron slag were reused to partially replace of 0%, 10%, 20% and 30% of sand weight. The test performed to evaluate waste iron slag concrete quality include slump cone test, compressive strength test, split tensile test and flexural strength test. Cubes and cylinders are casted and tested for 7 and 28 days.

KEYWORDS: Compressive strength, Iron Slag.

I.INTRODUCTION

Partial replacement of fine aggregate with iron slag helps to increase strength of the concrete. The cost of the sand is more, so waste iron slag as a replacement material is adopted. Iron slag is more economical and it has capacity to increase the strength of concrete up to 30% of replacement of slag. The use of iron slag overcomes the pollution problems in environment. Iron slag is easily available in the iron industries from iron ore. Iron slag has advantages of better performance, durability, production, cost less and eco-friendly.

As slag is an industrial by-product, its productive use grant an chance to relocate the utilize of limited natural resources on a large scale. Iron slag is a byproduct obtained in the manufacture of pig iron in the blast furnace and is produced by the blend of down-to-earth constituents of iron ore with limestone flux. Iron and steel slags can be differentiating by the cooling processing when removed from the furnace in the industry. Mostly, the slag consists of, magnesium, aluminum silicates calcium and manganese in various arrangements. Even though the chemical composition of slag same but the physical properties of the slag vary with the varying method of cooling. The slags can be used as cement major constituents as they have greater pozzolanic properties.

Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminium silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slag required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling.

The blast furnace (BF) is charged with iron ore, fluxing agents (usually limestone and dolomite) and coke as fuel and the reducing agent in the production of iron. The iron ore is a mixture of iron oxides, silica, and alumin. From this and the added fluxing agents, alkaline earth carbonates, molten slag, and iron are formed. It contains important amounts of free iron, giving it its high density and hardness, which make it particularly suitable as a road construction aggregate. Slag is transported to processing plants, where it undergoes crushing, grinding, and screening operations to meet various use specifications. Processed slag is either shipped to its buyer for immediate use or, in slack seasons, stored.

II. MATERIAL PROPERTIES

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, fine aggregates, in addition to iron slag. The aim of studying of various properties of material is used to check the appearance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

2.1 Portland Cement

Ordinary Portland Cement (OPC) of 53 Grade (Kcp cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps.

The physical properties of the cement as determined from various tests conforming to Indian Standard IS 12269: 2013 are listed in Table 2.1. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture. The various tests conducted on cement are initial and final setting time, specific gravity, fineness and compressive strength. The results of above said tests are given below in Table 2.1.

Table 2.1 Properties of OPC 53 Grade Concrete

S. No	Characteristics	Values Obtained	Values Specified By IS 12269:2013
1	Specific gravity	3.12	
2	Standard Consistency, percent	29	
3	Initial setting time, minutes	147	30(minimum)
4	Final setting time, minutes	305	600(maximum)
5	Compressive strength 7 days 28 days	41.5 N/mm ² 57.6 N/mm ²	37 N/mm ² (minimum) 53 N/mm ² (minimum)

2.2 Aggregates

Coarse Aggregates: The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. Coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383- 1970. Specific gravity and other properties of coarse aggregates are given in Table 2.2.

Table 2.2 Properties of Coarse Aggregates

Characteristics	Value
Colour	Grey
Shape	Angular
Maximum size	20 mm
Specific gravity	2.69

Fine Aggregates: The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. In this experimental program, fine aggregate was locally procured and conformed to Indian Standard Specifications IS: 383-

1970. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and conforming to grading zone II. It was coarse sand light brown in colour.

Table 2.3 Physical Properties of fine aggregates

Characteristics	Value
Specific gravity	2.59
Fineness modulus	2.62
Water absorption, %	0.89

2.3 Iron Slag

In this work, the Iron Slag is taken from the Iron and Steel industry located at gummidipoondi, Tamil Nadu. It is black in colour as shown in Figure 2.1 and physical properties as shown in Table 2.4.

Table 2.4 Physical Properties of Iron slag

Characteristic	Value
Colour	Black
Specific gravity	2.55
Fineness modulus	2.10



Fig. 2.1 Concrete mix with iron slag

The shape and physical characteristics of iron slag are similar to ordinary crushed stone and sand, however due to differences such as the chemical components and cooling processes, it is possible to provide different types of slag with a wide variety of unique properties.

III. MIX DESIGN

3.1 MIX PROPORTIONS

The table 3.1 shows the mix proportion of concrete.

Table 3.1 Mix Design Ratio

Ratio	cement	Fine aggregate	Iron slag	Coarse aggregate	Ratio(design mix) w/c:c:FA:IS:CA
0%	2.18kg	3.27kg	0	6.55kg	0.5:1:1.5:0:3
10%	2.18kg	2.943kg	0.327kg	6.55kg	0.5:1:1.4:0.1:3
20%	2.18kg	2.616kg	0.654kg	6.55kg	0.5:1:1.3:0.2:3
30%	2.18kg	2.289kg	.981kg	6.55kg	0.5:1:1.2:0.3:3

IV. EXPERIMENTAL PROGRAM AND RESULT

4.1 FRESH AND MECHANICAL PROPERTIES

4.1.1 Slump test

The workability of fresh concrete is measured using slump test. The figure 4.1 shows the variation of slump with different percentage replacement of fine aggregate using induction furnace slag. It was found that the value of slump increases with the incremental percentage of induction furnace slag of 10%, 20%, and 30% replacement of fine aggregate. The increment in workability of concrete with the increase in induction furnace slag is attributed to the low water absorption characteristics of induction furnace slag.

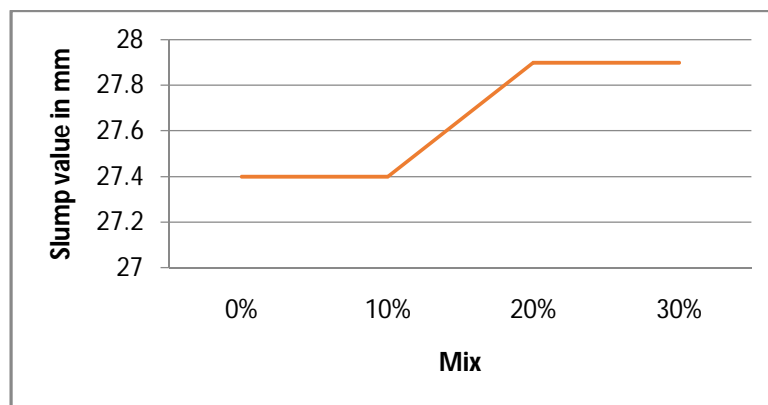


Fig.4.1 Slump Value

4.3 COMPRESSIVE STRENGTH

Test specimens of size 150x 150x 150 mm were prepared for testing the compressive strength concrete. The concrete mixes with varying percentages (0%, 10%, 20%,30%) of iron slag as partial replacement of fine aggregate (sand) were cast into cubes and cylinders for subsequent testing. In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water. The specimens so cast were tested after 7 and 28 days of curing measured from the time water is

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization

Volume 7, Special Issue 5, April 2018

1st International Conference on Recent Innovation in Civil Engineering and Management (ICRICEM '18)

22nd March 2018

Organized by

Department of Civil Engineering & MBA, Loyola Institute of Technology, Chennai, Tamilnadu, India

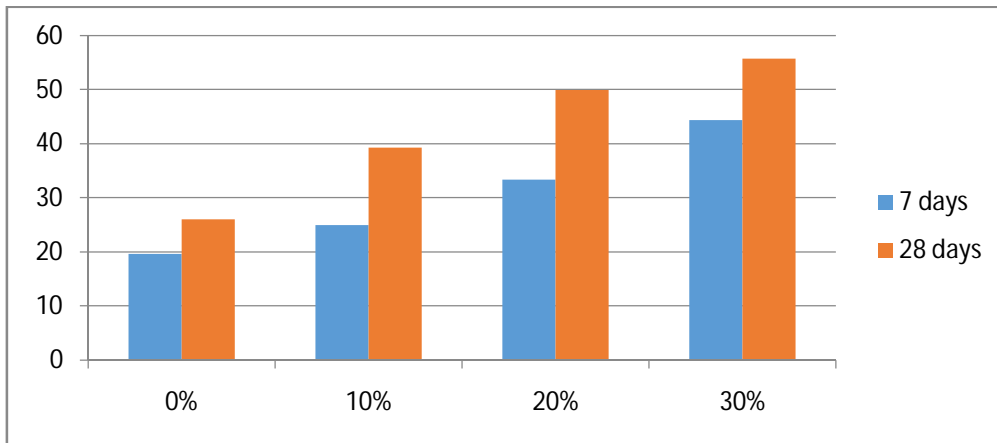
added to the dry mix. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with varying proportions of iron slag replacement at the age of 7 and 28 days are given in the Table 4.1

Table 4.1 Compressive strength of concrete mixes of specimen size 150 × 150 × 150 with iron slag

Mix	Compressive Strength (N/mm ²)		Average Compressive Strength (N/mm ²)	
	7 days	28 days	7 days	28 days
0%	20.50	25.80	19.70	26.08
	20.52	26.10		
	18.10	26.36		
10%	27.6	37.80	24.97	39.31
	24.2	39.70		
	23.13	40.44		
20%	35.20	51.86	33.37	49.89
	31.60	49.50		
	33.30	48.31		
30%	45.15	56.40	44.43	55.73
	41.80	57.30		
	46.35	53.50		

The cube strength results of concrete mix are also shown graphically in Figure 4.2. The compressive strength increases as compared to control mix as the percentage of iron slag is increased. After adding 10% iron slag in the mix, there is an increase of 26% after 7 days and 50% increase after 28 days as compared to the control mix. By adding 20% and 30% iron slag, there is large amount of increase in percentage i.e. 68%, 91% and 125%, 113% after 7 and 28 days respectively. The results also indicate that early age strength gain i.e. at 7 and 28 days, is higher when compared to the control mix if 30% of fine aggregate is replaced by iron slag. Beyond addition of slag result in decrease in compressive strength.

Fig 4.2 Compressive strength in N/mm²



4.4 SPLIT TENSILE STRENGTH TEST

Split tensile strength studies were carried out at the age of 7, 14 and 28 days. Test results are given below

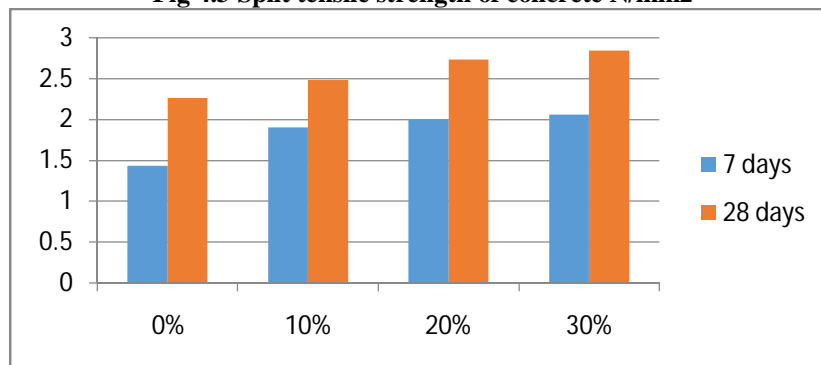
Table 4.2: Split tensile strength of concrete mixes with irons slag

Mix	Compressive Strength (N/mm ²)		Average Compressive Strength (N/mm ²)	
	7 days	28 days	7 days	28 days
0%	1.20	2.38	1.43	2.26
	1.40	2.10		
	1.70	2.30		
10%	1.90	2.50	1.90	2.48
	1.85	2.46		
	1.95	2.48		
20%	1.96	2.70	2.00	2.73
	2.04	2.75		
	2.02	2.73		
30%	2.02	2.82	2.06	2.84
	2.10	2.84		
	2.06	2.86		

The split tensile strength results of concrete mix are also shown graphically. The split tensile results follow a pattern similar to compressive strength i.e. increase in the value with increase in percentage of slag replacement. However, the

percentage increase in split tensile strength is smaller as compared to compressive strength. The split tensile strength increases with the percentage increase of iron slag as compared to control mix. After adding 10% iron slag in the mix, there is an increase of 24% after 7days and 9% increase after 28 days. By adding 20% ,30% iron slag , there is large amount of increase in percentage i.e. 37%,40%, 42% and 40%, 25%, 26%after 7and 28 days, respectively. The strength gain at early age of 7 days is highest for 30% slag replacement, whereas, the strength gain at 28 days is highest if 30% of sand in concrete is replaced by iron slag .From the strength point of view, it can be concluded that at early age presence of more amount of iron slag as sand replacement in concrete is beneficial for improving the strength characteristics.

Fig 4.3 Split tensile strength of concrete N/mm2



4.5 Flexural strength

The flexural strength test for beam specimen having the size of 100 x 100 x 500 mm was casted and cured at 28 days. It was kept horizontally between the loading surfaces of a universal testing machine and the load was applied until failure of the beam. The failure load was noted and shorter length from crack to support strength was measured Fig.4 shows the flexural strength of concrete using steel slag at 28th day. It is observed that flexural strength of concrete increases with the increase in the quantity of steel slag as replacement of coarse aggregate. The maximum increase in the flexural strength obtained at 30% and 35% replacement and the flexural strength of concrete increases 57.14% compared with control concrete.

Table 4.3: Flexural strength of concrete mixes with iron slag

MIX	Flexural strength N/mm ²	Average flexural strength N/mm ²
0%	3.5	3.5
	3.5	
10%	4	4
	4	
20%	4.5	4.5
	4.5	
30%	5.4	5.5
	5.6	

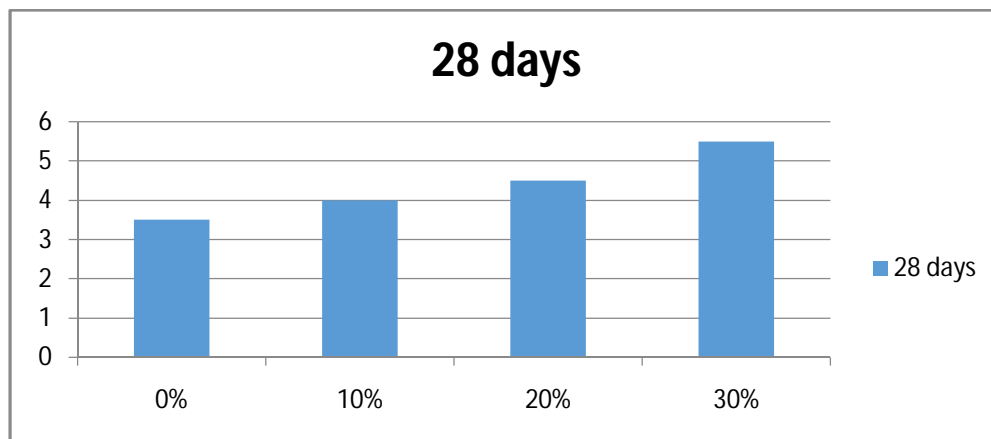


Fig.4.4 Flexural strength of concrete using steel slag at 28th day

V. CONCLUSION

5.1 GENERAL

This experimental study has proved to be better way to disposal of steel slag and also reduces impact of wasteslag on environment and human health. The strength and durability characteristics of concrete mixtures have been computed in the present work by replacing 10%, 20%, 30% ironslag with the sand. On the basis of present study, following conclusions are drawn.

- **COMPRESSIVE STRENGTH**

After adding 10% iron slag in the mix, there is an increase of 26% after 7 days and 50% increase after 28 days as compared to the control mix. By adding 20% and 30% iron slag, there is large amount of increase in percentage i.e. 68%, 91%, and 125%, 113% after 7 and 28 days respectively. The Compressive strength tends to increase with increase percentages of iron slag in the mix. The early age strength gain is higher as compared to later ages if 30% of fine aggregate is replaced by iron slag.

- **SPLIT TENSILE STRENGTH**

The Split tensile strength also tends to increase with increase percentages of iron slag in the mix. After adding 10% iron slag in the mix, there is an increase of 24% after 7 days and 9% increase after 28 days. By adding 20% , 30% iron slag , there is large amount of increase in percentage i.e. 37%, 40%,42% and 40%, 25%, 26% after 7 and 28 days, respectively. At early age presence of more amount of iron slag as sand replacement in concrete is beneficial for improving the strength characteristics.

- **FLEXURAL STRENGTH**

The flexural strength tends to increase with increase percentages of iron slag in the mix. After adding 10% iron slag in the mix, there is an 14% increase after 28 days as compared to the control mix. By adding 20%,30% iron slag , there is large amount of increase in percentage i.e. 28%, 57%, 57% after 28days respectively.

- **SLUMP TEST**

It was found that the value of slump increases with the incremental percentage of induction furnace slag of 10%, 20%,30% percent replacement of fine aggregate. The increment in workability of concrete with the increase in induction furnace slag is attributed to the low water absorption characteristics of induction furnace slag.

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization

Volume 7, Special Issue 5, April 2018

1st International Conference on Recent Innovation in Civil Engineering and Management (ICRICEM '18)

22nd March 2018

Organized by

Department of Civil Engineering & MBA, Loyola Institute of Technology, Chennai, Tamilnadu, India

VI. CONCLUSION

- This experimental study has proved to be better way to disposal of steel slag.
 - The replacement of fine aggregate with induction furnace slag has shown increase in the compressive strength, split tensile strength and flexural strength of concrete when compared to conventional concrete.
 - The optimum percentage of steel slag was found to be 30%.

REFERENCES

- [1] ALDEA C. M., YOUNG F., WANG K., SHAH S. P. (2000). "Effects OfCuring Conditions On Properties Of Concrete Using Slag Replacement." Cementand Concrete Vol. 30 pp 465-472.
- [2] AMERI M., KAZEMZADEHAZAD.S. (2012) "EvaluationOf The Use Of Steel Slag In Concrete". 25th ARRB Conference – Shaping the future: Linking policy, research and outcomes, Perth, Australia.
- [3] ASTM C1012/C1012M. (2011). Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution. Annual Book of ASTM Standards, American Society for Testing and Materials.
- [4] Indian minerals year book 2011, part II "Government of India Ministry of Mines Indian Bureau of Mines Indira Bhavan". Civil lines, Nagpur–440 102.
- [5] **IS: 10262-1982** (Reaffirmed 2004): Recommended guidelines for concrete mix design, Bureau of Indian Standard, New Delhi-2004.
- [6] **IS: 383-1970**: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, Bureau of Indian Standard, New Delhi-1970.
- [7] **IS: 2386 (Part I, III)-1963**: Methods of Test for Aggregates for Concrete, Bureau of Indian Standard, New Delhi-1963.
- [8] **IS: 4031 (Part 4, 5&6)-1988**: Methods of Physical Tests for Hydraulic Cement, Bureau of Indian Standard, New Delhi-1988.
- [9] **IS: 5816-1999**: Methods of test for Splitting Tensile Strength of Concrete, Bureau of Indian Standard, New Delhi-1999.
- [10] **IS: 8112-1989** (Reaffirmed 2005): Specification for 43 Grade Ordinary Portland Cement, Bureau of Indian Standard, New Delhi-2005.
- [11] ISMAIL Z.Z., AL-HASHMI E.A. (2012). "Reuse of waste iron as a partial replacement of sand in concrete." Waste Management Vol. 28 pp 2048-2053.
- [12] MASLEHUDDIN M., SHARIF M. AIFARABI., SHAMEEM M., IBRAHIM M., BARRY M.S. (2002). "Comparison of properties of steel slag and crushed limestone aggregate concretes." Construction and Building Material Vol. 17 pp 105-112.
- [13] NADEEM M., POFALE A.D. (2008). "Replacement Of Natural Fine Aggregate With Granular Slag - A Waste Industrial By-Product In Cement Mortar Applications As An Alternative Construction Materials." International Journal of Engineering Research and Applications Vol. 2 pp 1258 - 1264.
- [14] PELLEGRINO C., GADDO V. (2009). "Mechanical and durability characteristics of concrete containing EAF slag as aggregate." Cement & Concrete Composites Vol. 31 pp 663-671.
- [15] YIGITER H.S., YAZICI H., AYDM S. (2006). "Effects of cement type, water/cement ratio and cement content on sea water resistance of concrete." Building and Environment Vol. 42 pp 1770-1776.