



# Mechanical Properties of Concrete with Replacement of Steel Slag as Coarse Aggregate

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## ABSTRACT

Steel slag is a byproduct of the steelmaking and steel refining processes Presently in India, due to limited modes of practices of utilization, huge amount of iron and steel slag dumped in yards of each production unit and engaging of important agricultural land and grave pollution to whole environment. This review presents utilization trends of steel slag and possible potentials for large-scale employment of steel slag in Indian context.

This project aim is to study experimental investigation about the effect of partial replacement of coarse aggregates by steel slag (SS), on the various strength and durability properties of concrete, by using the mix design of M30 grade. The optimum percentage of replacement of coarse aggregate by steel slag is found

This study is carried out to determine the feasibility of using steel slag as partial replacement for coarse aggregates of M30 grade with different replacement percentages i.e. (0%, 25%, 50%, 75%&100%).

In this present study, physical and chemical characteristics of steel slag are to be analyzed and then the research progress of steel slag with natural aggregate concrete cubes, cylinders and beams are to be casted by using mix design M30 and are cured for 7, 28 & 56 days. The mechanical, durability properties of hardened concrete is to be carried out according to IS codes. For mechanical properties of concrete (i.e. compressive strength, Split tensile strength & Flexural strength) are to be determined and durability properties like acid attack, drying shrinkage, indirect carbonation, also need to be investigated. And after that will addition with fibers for maximum strength attained mixes of steel aggregate replacement mixes. By comparing the test results it may be concluded that steel slag may be used as replacement of natural coarse aggregate in concrete.

## INTRODUCTION

Current total productions of steel slag in India, are around 12 million tonnes per annum (Indian Minerals Yearbook, May 2016). 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 slags 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. Presently in India, due to limited modes of practices of utilization, huge amount of iron and steel slag dumped in yards of each production unit and engaging of important agricultural land and grave pollution leading to the serious pollution to the environment.

Concrete is amongst one of the most widely used construction materials in the world. Nowadays, the major problem in the construction industry is the non-availability of coarse aggregate and it has compelled the researchers to think about some alternate option. Utilization of industrial by-product has become an attractive alternative to disposal. An efficient approach to overcome these problems is the slag utilization. It is an environmental application since the reuse or recovery of this material provides environmentally related benefits.

The scope of this project is to determine the feasibility of using steel slag as partial replacement for coarse aggregates of M30 grade with different replacement percentages of aggregates. The main objective of present study is to achieve the target strength in M30 grade with different replacement percentages i.e. (0%, 25%, 50%, 75% & 100%) and study their compositions.

1. Characterization of materials i.e. cement, coarse aggregate and steel slag.
2. Design M30 grade of concrete with Steel Slag as Partial or complete replacement of Coarse Aggregates.
3. To study the mechanical properties of concrete with coarse aggregate replaced with steel slag at percentage of 0%, 25%, 50%, 75%, and 100% and to find out the optimum percentage replacement.

## REVIEW OF LITERATURE

**Liwu Mo et.al [1]** studied 60% of steel slag powders containing high free-CaO content, 20% of Portland cement and up to 20% of reactive magnesia and lime were mixed to prepare the binding blends. The binding blends were then used to cast concrete, in which up to 100% of natural aggregates (limestone and river sands) were replaced with steel slag aggregates. The concrete was exposed to carbonation curing with a concentration of 99.9% CO<sub>2</sub> and a pressure of 0.10 MPa for different durations (1d, 3d, and 14d). The carbonation front, carbonate products, compressive strength, microstructure, and volume stability of the concrete

were investigated. Results show that the compressive strength of the steel slag concrete after CO<sub>2</sub> curing was significantly increased. The compressive strengths of concrete subjected to CO<sub>2</sub> curing for 14d were up to five-fold greater than that of the corresponding concrete under conventional moist curing for 28d. By replacement of limestone and sand aggregates with steel slag aggregates also increased the compressive strengths of the concrete subjected to CO<sub>2</sub> curing. The author study provides a potential approach to prepare concrete with low-carbon emissions via the accelerated carbonation of steel slag.

**Liu Chunlin et.al [2]** investigate the possibility of replacing the traditional aggregates for concrete production. Compressive and flexural strength, volume deformation of concrete containing EAF slag as aggregate were experimentally investigated by strength test according to the specification of GB/T 50081-2002 and unrestrained specimens volume deformation test. The test results indicate that the mechanical strength of steel slag concrete is acceptable, though slightly lower flexural strength than that of conventional concrete and the expansion induced from steel slag using as both coarse and fine aggregates in concrete may lower the shrinkage and expansion to a certain extent. In accordance with the experimental phase the author preliminary study conclusions are the strength performance of EAF slag concretes is similar to that of a more traditional concrete, with a higher compressive strength and a slightly less flexural strength and the volume deformation of SSAC shows dilatometric effect (less shrinkage) comparing with the conventional concrete. However, further researches must be investigated thoroughly for the theory and application of scrap tire particle modified steel slag aggregates concrete.

**Ivanka Netinger et.al [3]** experimental study of the residual properties of the mixtures prepared with slags available from the Croatian steel plants after their exposure to high temperatures was performed and the results were compared with the same properties of the reference concrete made of dolomite. Electric arc furnace (EAF) steel slag as by-products from the steel production industry is considered as an aggregate which could improve post-fire properties of concrete due to the fact that it is the material that is made at the temperatures of up to 1650 °C. At the age of 56 days

concrete specimens have been exposed to high temperatures up to 800 °C. Upon cooling of the specimens their residual properties (compressive strength, modulus of elasticity, weight loss and ultrasonic pulse velocity) were tested and compared with the same properties of the reference concrete. Microstructural analysis based on SEM observations was also done. The obtained results showed that slag could improve fire performance of concrete in the temperature range up to 400 °C. The improvement was especially prominent in the case of the mixtures prepared with previously thermally treated slag where relative residual compressive strength was increased up to 16% at the temperature of 400 °C.

**V. Subathra Devia et.al [4]** study experimentally, the effect of partial replacement of coarse and fine aggregates by steel slag (SS), on the various strength and durability properties of concrete, by using the mix design of M20 grade. The optimum percentage of replacement of fine and coarse aggregate by steel slag is found. Workability of concrete gradually decreases, as the percentage of replacement increases, which is found using slump test. The author investigate the possibility of replacing the conventional aggregates by steel slag, the strength and durability properties were studied. Compressive strength, tensile strength, flexural strength and durability tests such as acid resistance, using Hcl, H2SO4, and Rapid chloride penetration, are experimentally investigated. The test results indicate that for conventional concrete, the partial replacement of fine and coarse aggregates by steel slag improves the compressive, tensile and flexural strength. The preliminary study conclusions obtained from author study are the optimum percentage of replacement for fine aggregate is 40% and for coarse aggregate is 30%, beyond which the compressive strength decreases on further replacement. Improvement in strength property

#### EXPERIMENTAL WORK

##### Physical properties of cement.

SNO	Description of test	IS code
1	Specific Gravity	IS 4031-1988(part-11)
2	Fineness	IS 4031-1996(part-1)
3	Standard consistency	IS 4031-1988 (part-4)
4	Initial Setting time	IS 4031-1988 (part-5)
5	Final setting time	IS 4031-1988 (part-5)

was slightly lower for CA replacement when compared with FA replacement. But the flexural strength has slightly decreased for combined replacement. So, the concrete with partial replacement of CA and FA by steel slag shows better resistance to Hcl than to H2SO4 and Deflection in RCC beams gradually increases as the load on the beam increases for both the partial replacement. By adding steel slag to the aggregates, the resistance to deflection and vertical strain will increase. Further researches can be carried out to improve the strength and acid resistance by the addition of some admixtures. **Ivana Barisic et.al [5]** investigated about the new type of low-strength concrete made with steel slag and gravel. The aim of the author study was to identify possible applications of slag as aggregates in cement-stabilized base courses to reduce the consumption of natural materials and cement, as well as to introduce the new aggregate into Croatian road-construction practices. For these purposes, the following basic engineering properties of these layers were determined for fifteen different mixtures: optimum water content, density, compressive strength and indirect tensile strength. Three different amounts of binder (2%, 4%, and 6%) and two types of aggregates (steel slag and gravel) were used. Additionally, the compressive and indirect tensile strength of the concrete increased with curing age. The strength of mixes with low cement contents increased with the slag content, while that of mixes with higher cement contents decreased with slag content. Finally, the average indirect tensile strength for all mixes as a percentage of compressive strength was 14%. The results of the author study could greatly influence the use of this non-traditional aggregate, which can now be technically and economically justified as components in stabilized base courses and used as coarse aggregate.

### Physical properties of fine aggregate

SNO	Description of test	IS code
1	Specific Gravity	IS 2386-1963 (part-3)
2	Fineness Modulus	IS 2386-1963 (part-3)
3	Bulk density	IS 2386-1963 (part-3)
4	Water absorption	IS 2386-1963 (part-3)

### Physical properties of coarse aggregate

S.No	Description of test	IS code
1	Specific Gravity	IS 2386-1963 (part-3)
2	Water absorption	IS 2386-1963 (part-3)
3	Bulk density	IS 2386-1963 (part-3)
4	Flakiness Index	IS 2386-1963 (part-1)
5	Elongation Index	IS 2386-1963 (part-1)
6	Aggregate Impact value	IS 2386-1963 (part-4)
7	Aggregate Crushing Value	IS 2386-1963 (part-4)

### Physical properties of steel slag

SNO	Description of test	Values Obtained
1	Specific Gravity	2.63
2	Water absorption	2.27%
3	Flakiness Index	16.8 %
4	Elongation Index	17.3 %
5	Aggregate Impact value	28.26%
6	Aggregate Crushing Value	39.28%
7	Fineness Modulus	7.17

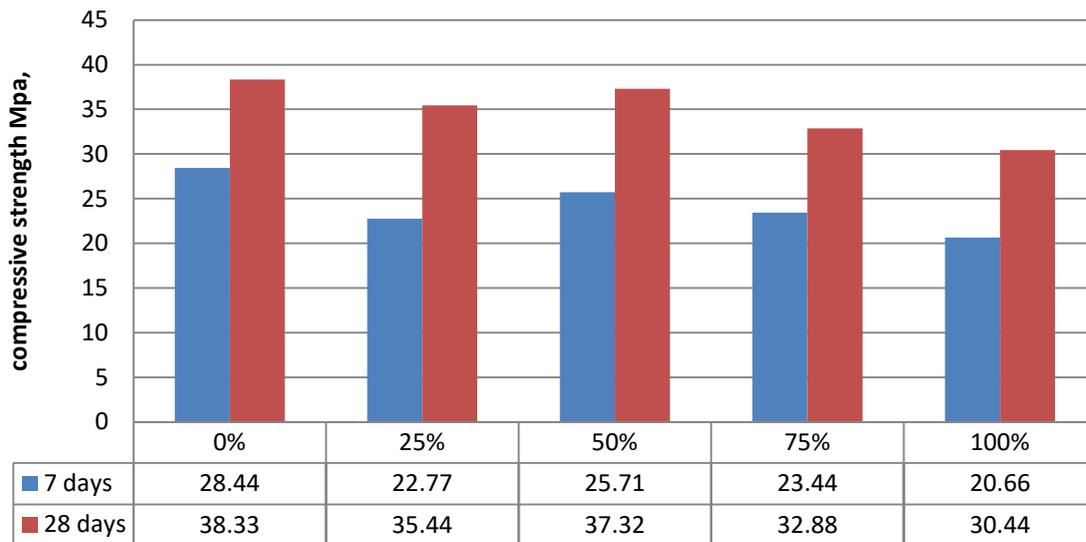
Mix designation	MIX S	MIX 1	MIX 2	MIX 3	MIX 4	Units	
Cement	100	100	100	100	100	%	
Fine aggregate	100	100	100	100	100	%	
Coarse aggregate	20 mm (70%)	100	75	50	25	0	%
	10 mm (30%)	100	100	100	100	100	%
Steel slag	0	25	50	75	100	%	
Normal water	100	100	100	100	100	%	
Sp	100	100	100	100	100	%	

## RESULTS AND DISCUSSIONS

### Average Compressive strength of concrete cubes replacement with steel slag

S.No	Mix designation	Compressive strength (MPa)	
		7 days	28 days
1	MIX S	28.44	38.33
2	MIX 1	22.77	35.44
3	MIX 2	25.71	37.32
4	MIX 3	23.44	32.88
5	MIX 4	20.66	30.44

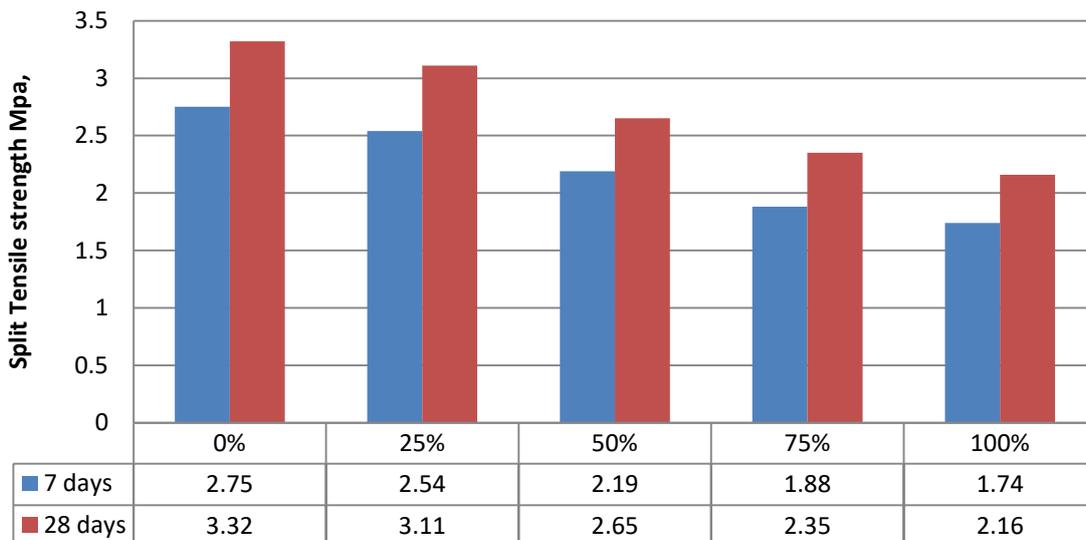
**Average Compressive strength of concrete cubes replacement with steel slag**



**Average Split tensile strength of specimen's replacement with steel slag**

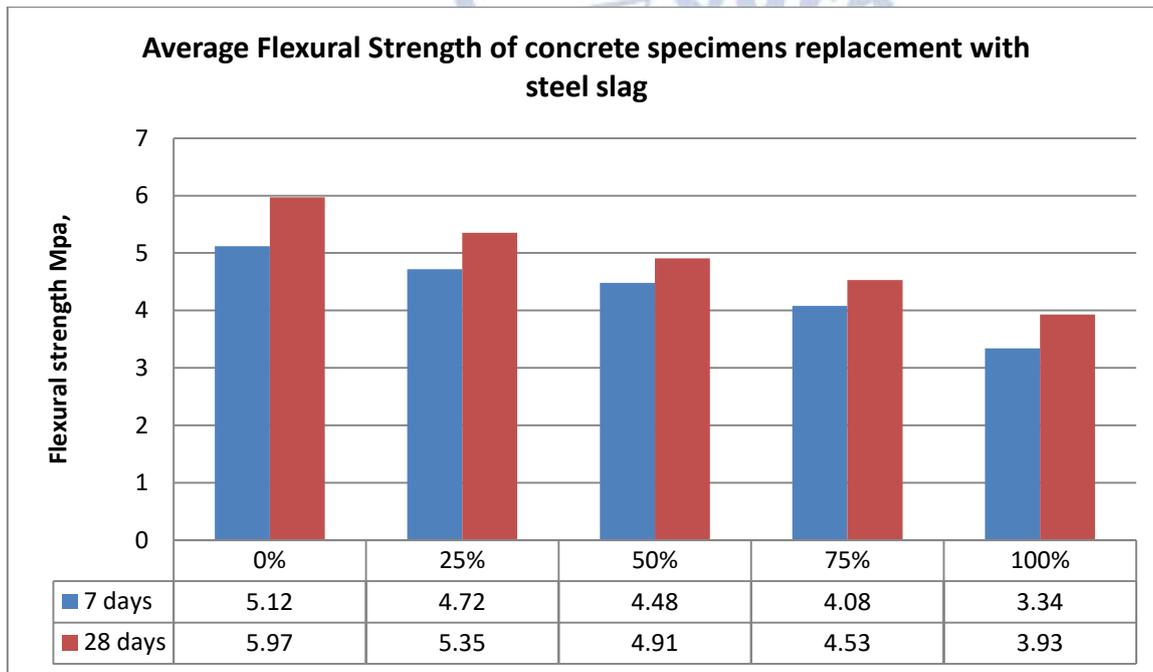
S.No	Mix designation	Split Tensile strength (MPa)	
		7 days	28 days
1	MIX S	2.75	3.32
2	MIX 1	2.54	3.11
3	MIX 2	2.19	2.65
4	MIX 3	1.88	2.35
5	MIX 4	1.74	2.16

**Average Split Tensile strength of concrete specimens replacement with steel slag**



### Average Flexural Strength of concrete specimen's replacement with steel slag

S.No	Mix designation	Flexural strength (MPa)	
		7 days	28 days
1	MIX S	5.12	5.97
2	MIX 1	4.72	5.35
3	MIX 2	4.48	4.91
4	MIX 3	4.08	4.53
5	MIX 4	3.34	3.93



### CONCLUSIONS

From the experimental works carried out, the following conclusions are made.

- This experimental study has proved to be better way to disposal of steel slag.
- The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete and has no negative effects on the properties of hardened concrete.
- The optimum percentage of steel slag was found to be 50%.
- The Compressive strength, flexural strength and splitting tensile strength for steel slag aggregates concrete were similar to conventional concrete. The strength may be affected with time and so long term effects on hardened properties of concrete require further investigation.

When this optimized value will be used, it will give better strength and more durable concrete when compared to control concrete and saves material cost.

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