Steel Slag as a Substitute for Fine Aggregate in High Strength Concrete

Krishna Prasanna P
Department of Civil Engineering
V R Siddhartha Engineering College
Vijayawada, India

Venkata Kiranmayi K
Department of Civil Engineering
V R Siddhartha Engineering College
Vijayawada, India

***Abstract*: Waste management is one of the most common and challenging problems in the world. The steel making industry has generated substantial solid waste. Steel slag is a residue obtained in steel making operation. This paper deals with the implementation of Steel slag as an effective replacement for sand. Steel slag, which is considered as the solid waste pollutant, can be used for road construction, clinker raw materials, filling materials, etc. In this work, Steel slag is used as replacement for sand, which is also a major component in concrete mixture. This method can be implemented for producing hollow blocks, solid blocks, paver blocks, concrete structures, etc. Accordingly, advantages can be achieved by using Steel slag instead of natural aggregates. This will also encourage other researchers to find another field of using Steel slag.**

Keywords –Steel Slag, Fine Aggregate, Compressive strength, Water absorption testing

I. INTRODUCTION

Steel slag exist as by-product during melting of steel scrapfrom the impurities and fluxing agents, which form the liquidslag floating over the liquid steel in arc or induction furnaces,or other melting units. The ferroalloys industry has generatedhistorically substantial solid waste. Great amount of wastedmaterials is generated by industries and has causedtremendous harm to both the environment and ecology. Thewaste removed from the furnace separately in a rate of about(10-15%) of the produced steel. Reuse of waste materialhas become very important during the past decade because ofthe reinforcement of environmental regulations that requireminimizing waste disposal. The main aim of the environmentprotection agencies and the government are to seek ways andminimize the problems of disposal and health hazards of byproducts.Steel making operations are specifically concernedby this problem because of generation of a huge quantity ofby-products. However, the development of science andtechnology has made it possible to transform the waste intonew resource to benefit human beings.

In fact, zero discharge of waste materials in many industriesbecomes true. Consequently, the construction of plants that is“environment-friendly” and that accommodate “recycling” hasbecome the target of most ferroalloy producers in the world toensure sustainable development.
In India, there is a greatdemand of aggregates mainly from civil engineering industryfor road and concrete constructions. The construction ofhighways and development of several expressways for high-speed corridors exert tremendous pressure on naturalresources. Mainly highway agencies, private organizationsand individuals are in the process of completing a wide varietyof studies and research projects concerning the feasibility,environmental suitability, and performance of using wasteindustrial products in highway construction. These studiestry to match society’s need for safe and economic disposal ofwaste materials with the highway industries need for betterand more cost-effective construction materials.
In the past 20thcentury, steel slag was found to be excellent aggregate for roadpaving. Chemical composition of typical steel slag consistmainly SiO_2, Al_2O_3, CaO, MnO, MgO, TiO_2, P_2O_5andFe_2O_3. The steel slag is considered as the waste material, which would have a promising future in the construction field.Concrete is a widely used construction material for varioustypes of structures due to its durability. For a long time it wasconsidered as the durable material requiring a little or nomaintenance. In recent times it was found that, whenreinforced concrete structures are exposed to harshenvironments, deterioration of concrete will occur due tomany reasons like chloride and sulphate attack, acid attack,corrosion failure etc. On the contrary the aggregates used forthe concrete are facing the greater demand. Utilization ofindustrial soil waste or secondary materials has beenencouraged in the construction field for the production ofcement and concretes. There are very less investigators on theuse of Steel slag in cement concrete.

Not much researchhas been carried out in India and other countries concerningthe incorporation of Steel slag inconcrete. Therefore, to generate specific experimental data onstrength and other characteristics of Steel slag as anaggregate, this work is performed.

Fig 1 Steel slag stocked in piles

II. MATERIALS

Cement

Ordinary Portland cement of grade 53 was used. The initial setting time of cement is 30 minutes and the specific gravity of cement is 3.15.

Fine Aggregate

Fine aggregate used was clear sand passing through 4.75mm sieve with a specific gravity of 2.64. The grading zone of aggregate was zone III.

Coarse Aggregate

Coarse aggregate used was angular crushed aggregate with a specific gravity of 2.8.

Concrete Mix Design

Design concrete mix of 1:1.05:1.71is adopted to attain 80N/mm^2. The water cement ratio of 0.3 is used. After several trails this mix design was finalised. Six cube specimens were casted and tested after curing for 28 days. The average compressive strength of 84 N/mm^2 is achieved.

Steel Slag

Steel slag has been sourced from Vizag Steel plant and has been under weathering process for a certain period(because better properties will be attained to steel slag when exposed to air for more period)

III. METHODOLOGY

The experimental investigation has been carried out on the test specimens (Cubes, Cylinders, Beams) to study the strength properties as a result of replacing fine aggregate by Steel slag in various percentages namely 5%, 10%,15%, 20%, 25%, 30% and 35%. The slump test was conducted on the fresh concrete and compressive strength, Split tensile test and Flexural Strength test were conducted on the hardened concrete.

IV. TESTING

The cubes, cylinders and beamswere casted and after completion of 28 days curing the following tests have been conducted,

Test	Stage of Concrete
Slump test	Fresh (Immediately)
Compressive strength	Hardened (After curing of 28 days)
Flexural Strength	
Split Tensile strength	

V. RESULT

a) SLUMP TEST

The slump test was done on the fresh concrete at various percentages of Steel slag,

Table 1. Slump values for various % of Steel slag

% of Slag	0	25	50	75	100
Slump	60	56	35	20	15

Fig 2. Slump test at 0% of Steel slag


Fig 3. Slump test at 100% of Steel slag

b) COMPRESSIVESTRENGTH

For every percentage of replacement 6 cubes have been casted. Among them, 3 cubes were tested on the 7th and the other 3 cubes were tested on the 28th day. Totally 48 cubes were casted and tested.

Table 2. Compression testing for Cubes

Percentage of Steel slag	Compressive Strength (N/mm^2)	
	7 days	28 days
0	53	83
5	55	84
10	54	85
15	55	87
20	56	88
25	58	90
30	57	87
35	58	83

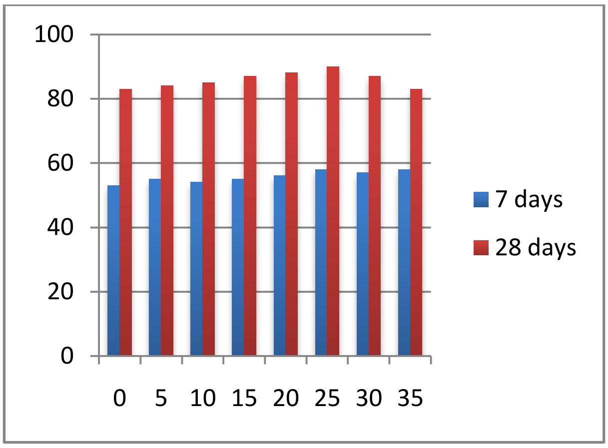

Fig 4. Compressive strength vs % of Steel Slag


Fig 5. Cube with 0 % of steel slag after testing


Fig 6. Cube with 100 % of steel slag after testing

c) FLEXURAL STRENGTH

For every percentage of replacement 6 beams have been casted. Among them, 3 beams were tested on the 7th and the other 3 beams were tested on the 28th day. Totally 48 beams were casted and tested.

Table 3. Flexural strength testing for Beams

Percentage of steel slag	Flexural strength	
	7 days	28 days
0	4.8	7.4
5	5.11	7.6
10	5.1	7.8
15	5.2	8.0
20	5.4	8.0
25	5.2	7.8
30	5.3	8.0
35	5.1	7.9

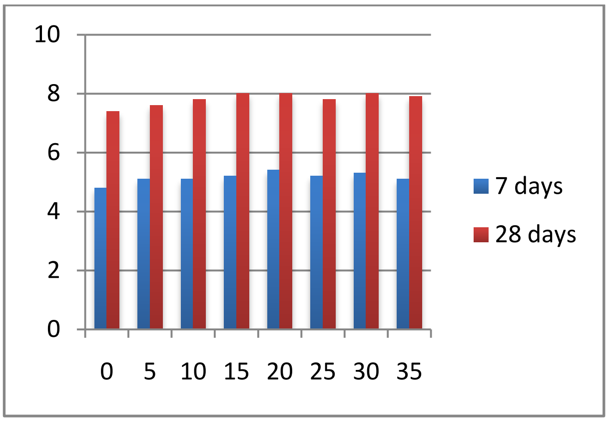

Fig7. Flexural strength vs % of Steel Slag

Fig 8. Flexural strength test for beam

d) SPLIT TENSILE STRENGTH

For every percentage of replacement 6 cylinders have been casted. Among them, 3 cylinders were tested on the 7th and the other 3 cylinders were tested on the 28th day. Totally 48 cylinders were casted and tested.

Table 4. Split Tensile strength testing for Cylinders

Percentage of steel slag	Split Tensile Strength	
	7 days	28 days
0	3.58	5.5
5	3.59	5.5
10	3.64	5.6
15	3.66	5.6
20	3.7	5.7
25	3.83	5.8
30	3.77	5.9
35	3.76	5.7

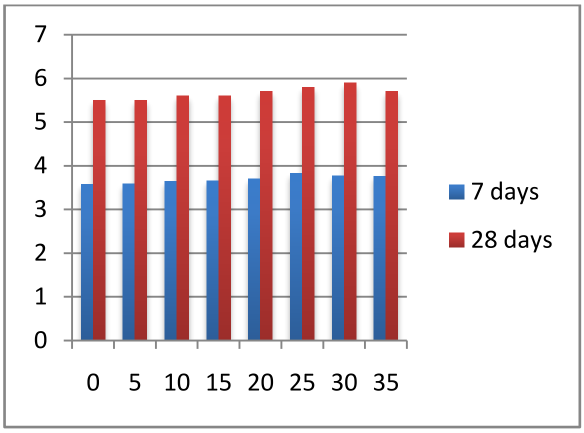

Fig 9. Split Tensile strength vs % of Steel Slag

Fig 10. Split Tensile strength for cylinder

VI. CONCLUSIONS

Results achieved could be considered in different aspects,

- The maximum compressive strength value occurs at 25% slag ratio and declines beyond the 25% replacement ratio.
- The slight improvement in strength may be due to shape, size and surface textureof steel slag aggregates, which provide better adhesion between the particles and cement matrix.
- In almost all replacement ratios the flexural strength increased by the increase in slag ratio; which support the notion that in the case of slag utilization, the compressive and flexural strength do not correspond to each other.
- The results of this research were encouraging, since they show that using steel slag as fine aggregate in concrete has no negative effects on the short term properties of hardened concrete.
- So Steel slag meets the requirements to be used in concrete mixes.
- Compressive strength, flexural strength and splitting tensile strength for steel slagaggregates concrete were similar to conventional concrete. The strength may beaffected with time and so long term effects on hardened properties of concreterequire further investigation.

VII. REFERENCES

- Mohammed. J and Abbas. O, "Using of Steel Slag in Modification of Concrete Properties", Eng.& Tech. Journal,Vol 37,No 9, 2009.
- Paul Bosela, Norbert Delatte, "Fresh and hardened Properties of Paving Concrete with steel slag aggregate", 9th international conference on Concrete Pavements, 2008, pp. 836 – 853.
- Mahmoud Ameri, Iran University of Science and Technology, School of Civil Engineering, Iran "EVALUATION OF THE USE OF STEEL SLAG IN CONCRETE"
- JIGAR P. PATEL "BROADER USE OF STEEL SLAG AGGREGATES IN CONCRETE" At the CLEVELAND STATE UNIVERSITY
- Alizadeh, R., Chini, M., Ghods, P., Hoseini, M., Montazer, Sh. and Shekarchi, M. (1996),"Utilization of electric arc furnace slag as aggregates in concrete" – Environmental Issue, CMIreport, Tehran
- Geopave (1993), Technical note on Steel Slag Aggregate, Vol. 9, pp.1