STUDY ON STRENGTH AND DURABILITY PROPERTIES OF CONCRETE USING STEEL SLAG AS COARSE AGGREGATE IN CONCRETE

A. Poonkodi[1], R. Vinodkumar[2]

[1]Assistant Professor, Department of Civil Engineering, (Roever engineering college, Elambalur-621220)
[2]sobha developers in Bangalore (senior site engineer),

Abstract - *In this study presents an strength and durability properties of concrete using steel slag as coarse aggregate in concrete is compared with the crushed stone coarse aggregate in concrete. Steel slag is a byproduct of steel manufacturing industry.Using the waste materials to reduce the natural sources and clean environment. In this study concrete of M50 grade for W/C ratio of 0.35.The total number of 81 cubes, cylinders and prism were casted with steel slag as coarse aggregate for the replacement of 25%, 50%, 75%. The 100 % (with and without silica fume) replacement of steel slag as coarse aggregate is M50 grade for W/C ratio of 0.33 and 0.36. Test for mechanical properties such as compressive strength, modulus of elasticity of concrete and flexural strength and durability test such as Acid attack test and RCPT.*

Key Words: **High strength concrete, steel slag, Mechanical properties, Durability.**

1. INTRODUCTION

Steel slag is a byproduct of steel manufacturing industry. In large area of land is utilized for the disposal of solid wastes, producing by industries. The best management option for this by product is recycling its leads to reduction of landfills reserved for its disposal, saving the natural resources and attaining a clean environment. As the aggregates can significantly control the properties of concrete, the properties of the aggregates have a great importance (Beshr et al., 2003). Maslehuddin et al. (2002) have indicated that the durability of steel slag cement concrete is better than the same for crushed limestone aggregate. Therefore, a thorough evaluation is necessary before using any waste material as aggregate in concrete. The use of steel slag as coarse aggregate to reduces the need of conventional coarse aggregate in concrete. Environmental and Economic reasons have led to rapid development of slag utilization. Using steel slag as coarse aggregate to reduce the cost of the concrete production.

2. MATERIAL USED

2.1 Cement

OPC 53 grade zurai cement was used in this investigation conforming to IS 12269:2013. The properties of this cement are under,

- Specific gravity :3.14
- Fineness :8%
- Normal consistency :26%

2.2 Fine aggregate

River sand was used. The properties of fine aggregate are,

- Specific gravity : 2.65
- Fineness modulus : 3.21(zone III)
- Water absorption : 0.8%

2.3 Coarse aggregate:

Locally available, maximum size 12.5mm and 20mm

- Specific gravity : 2.73
- Crushing value : 23.9%
- Impact value : 15.74%
- Water absorption: 0.3%

2.4 Steel slag

Steel slag was obtained from local steel industry in pudhucherry(pullkit metal private limited).using jaw crusher to crush the steel slag for 12 to 20 mm size of coarse aggregate.

- Specific gravity : 3.17
- Crushing value : 29.3%
- Impact value : 19.41%
- Water absorption: 0.6%

Fig-1: Steel slag

2.5 Water

Portable water was used in mixing and curing of all the mixes.

2.6 Chemical Admixture type

Super plasticizer (con plast SP 430 DIS and TECH MIX 550) 0.9% and 0.7% weight of cement was used.

2.7 Silica fume

In this experimentation, Silica fume added with 8% weight of cement was used

3. MIX PROPORTION:

As per IS 10262:2009 designed by M50 grade of concrete.

Table-1: Concrete mix proportions

MIXES	C	SF	FA	CA	SS
Cc	437	0	618	1293	0
25%	437	0	618	969	323
50%	437	0	618	646	646
75%	437	0	618	323	969
100% (without SF)	436	0	626	0	146
100% (with SF)	427	37.1	615	0	145

F.A - fine aggregate, Kg/m^3
SF - silica fume, Kg/m^3
C.A - coarse aggregate, Kg/m^3
S.S - steel slag, Kg/m^3
W/C -water cement ratio, Kg/m^3
c - cement, Kg/m^3

4. EXPERIMENTAL PROGRAMME AND DISCUSSION OF RESULT

4.1 Workability test:

Slump test results are shown in Fig-2 The workability of concrete mixes containing steel slag aggregate (SSA) decreased with an increase in the aging period of SSA. As the aging period increased, the hardness and surface roughness of SSA also increased due to weathering, which resulted in harsh mix with a reduced workability. The proportion of the super plasticizer may be increased so as to increase the workability. However, it was kept constant in this research to enable a more accurate comparison. The 100 percentage replacement of steel slag as coarse aggregate the workability will be nearer to the conventional concrete, because of an addition of silica fume and superplastizier to be used.

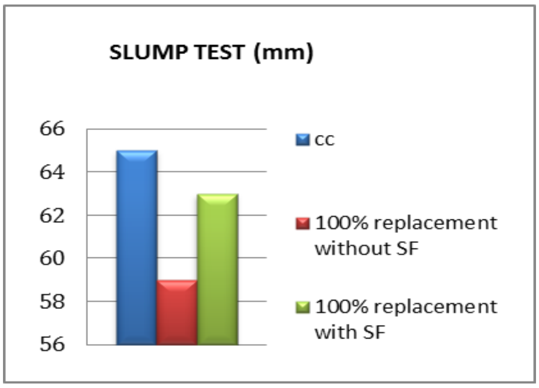

Fig.2:slump test results

3.2 Compressive strength test result:

Compressive strength results are presented in Table-2 and Fig-4 shows the comparison compressive strength in cubes. It was expected that the increase in the aging period of steel slag aggregate will bring about an increase in compressive strength. The size of the test specimen is 150 mm x 150 mm x 150 mm. The specimens kept for curing process for 7 and 28 days period were taken out of the curing tank, wiped out with cloth and weighed on digital weighing machine. The compressive strength was calculated by using this formula

$$f_c = \frac{P}{A} \text{ N/mm}^2$$

Where,

P = Load at which the specimen fails in Newton
A = Area over which the load is applied in mm^2
f_c= Compressive stress in N/mm^2

Table-2: Results of compressive strength of concrete

Age Type of Concrete	7 days N/mm^2	28days N/mm^2
CC	45.06	57.78
25%	42.51	54.5
50%	43.49	55.32
75%	41.15	52.76
100%(without SF)	42.042	53.9
100%(with SF)	46.371	59.45

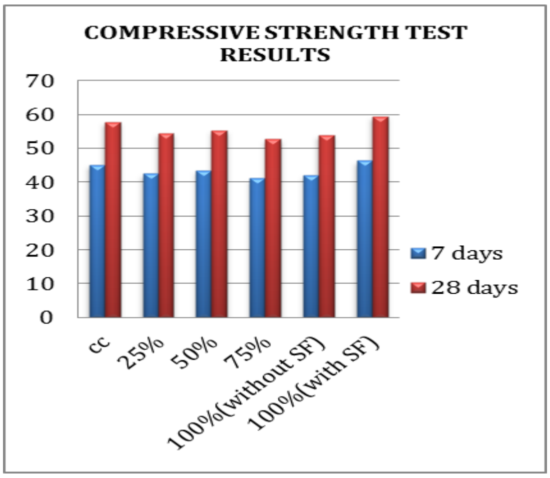

Fig-3:comparisons of compressive strength

3.3 Modulus of elasticity test:

Modulus of elasticity test results is presented in Table 3 and Fig.5 shows the testing of specimens in compressing testing machine. Size of the test specimen is 150 mm x 150 mm x 300 mm. The test was carried out with cylindrical specimens. Compressometer with gauge length of 200 mm was fitted to the specimen. The specimen is then loaded in compression testing machine and the compressive load was gradually applied. A dial gauge attached with the compressometer reads the change in the gauge length. For each increment in compressive load, the change in gauge length was noted.

Table-3: Result of Modulus of elasticity of concrete

Age Type of Concrete	7 days strength X 10^4 N/mm²	28days strength X 10^4 N/mm²
CC	2.808	3.60
25%	2.71	3.48
50%	2.77	3.56
75%	2.55	3.27
100% (without SF)	2.62	3.37
100%(with SF)	2.86	3.67

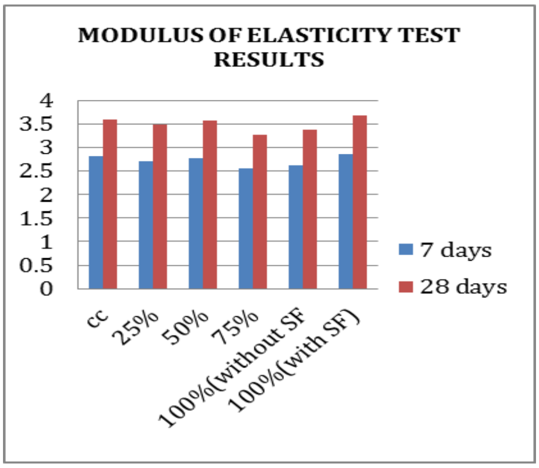

Fig-5:comparison of modulus of elasticity test

3.4 Flexural strength test

A flexural strength test result is presented in Table 4 and Fig.6 shows the testing of specimens It is measured by loading un-reinforced beam or prism of size 100 × 100 × 500 mm. The prism is casted and after 24 hours it was de-molded and kept in a curing tank for 7 and 28 days and then it was taken out dried in atmosphere for few hours after that the specimens were tested for its flexural strength as per IS: 516-1959 using a calibrated flexural testing machine. The bed of testing machine should be supported, and these rollers should be mounded that the distance from center is 50 mm for 100 mm specimen. The Flexural Strength is expressed as Modulus of Rupture in N/mm². The Flexural Strength of the specimen was calculated by using the formula

$f_b = \frac{pl}{bd^2}$ N/mm²

Where,
P = Load at which specimen fails in N
l = Effective span in mm
b = Breadth of the specimen in mm
d = Depth of specimen in mm

Table-3: Result of Flexural strength test of concrete

Age Type of Concrete	7 days N/mm²	28days N/mm²
CC	3.99	5.12
25%	3.728	4.78
50%	3.861	4.95
75%	3.5802	4.59
100%(without SF)	3.6582	4.69
100%(with SF)	4.1652	5.34

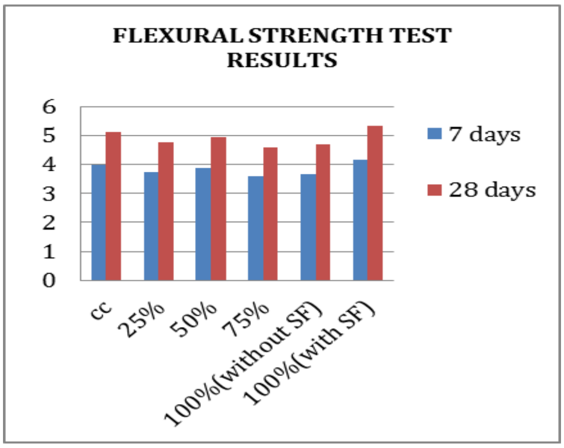

Fig-6: comparisons of flexural strength

3.5 Acid test

In order to assess the weight loss, concrete cubes is exposed to chemical media. For acid test, hydrochloric acid (HCL) solution was prepared by mixing 5% of Conc. Hcl with one litre of distilled water as per ASTM G20-8 or make an Acidic solution with 1N (Normality) as per laboratory standards. The concrete cube specimens of various concrete mixtures of size 150 mm x150 mm x150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for five days. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 56 days after 28 days of curing. Hydrochloric acid (HCl) with pH of about 3.5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 56 days. After 56 days of immersion, the concrete cubes were taken out of acid water. Then, the weight of specimens were taken and tested for compressive strength. The resistance of concrete to acid attack was found by the percent loss of weight of specimen and the percent loss of compressive strength on immersing concrete cubes in acid water.

Weight loss = Weight of cube after Normal Curing –Weight of cube after taking from acid solution

Fig-7: Acid attack test

Table-5: Results of acid test

Mixes	Percentage in weight loss	Percentage in strength loss
CC	1.26	2.83
50%	2.15	3.89

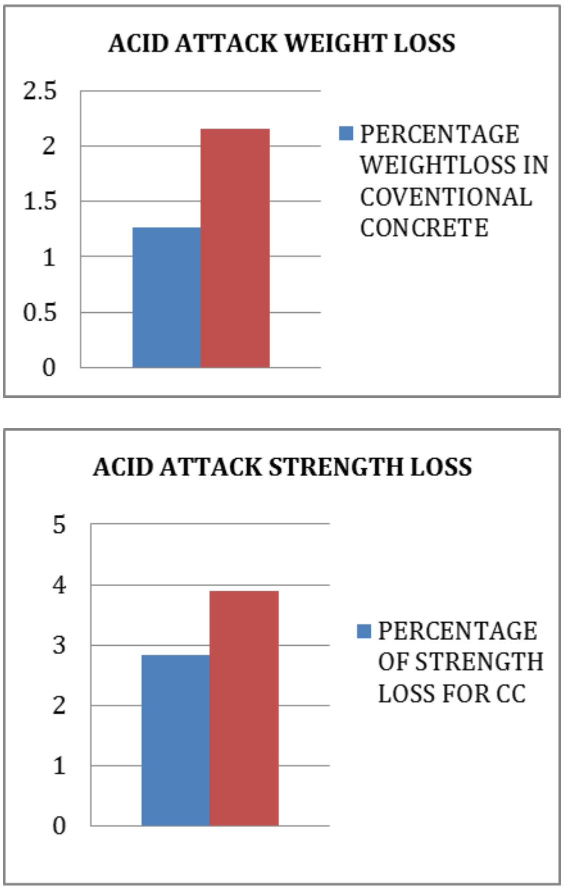

Fig-8: comparisons of acid attack test

4.6 Rapid Chloride Penetration Test (RCPT)

The test specimen consisted 50mm thick slices of 100mm nominal diameter cylinders of cores obtained by cutting the reference concrete cube specimens cast in an ambient humidity and temperature conditions for each grade.

Table-5: Chloride ion penetrability based on charge Passed

Chloride ion penetrability	Charge passed (coulombs)
High	> 4000
Moderate	2000 – 4000
Low	1000 –2000
Very Low	100 – 1000
Negligible	<100

Fig-9: Cutting the 50 mm slices

Fig-10: RCPT Setup

$$Q=900[I0+2\,I(30)+2\,I(60)+\ldots\ldots\ldots+2\,I(360)]$$

$$QS = Q \times (95 \div x)^2$$

Where,

Q = charge passed (coulombs)

Q_S =current (amperes) at t mints after voltage is applied

I =charge passed (coulombs) through a 100 mm diameter specimen

X = diameter of the specimen

Table-6: RCPT test results

Mixes	Charge passed (coulombs)	Chloride ion penetrability
CC	1035.21	Low
50%	2049.80	Moderate

5. CONCLUSION

- ✓ The 100% replacement of steel slag as coarse aggregate in concrete was less workability when compare to crushed stone coarse aggregate concrete. Super plasticizer is used as an admixture in concrete and it could be save 20 to 30% of water.

- ✓ In the physical properties test results the Specific gravity of steel slag is 13.24% higher than that of crushed stone coarse aggregate.
- ✓ Crushing value and impact value test results of steel slag aggregate have 18.23 % & 18.90 % higher than that of crushed stone coarse aggregate.
- ✓ In the mechanical property test results the 50% replacement of steel slag as coarse aggregate in concrete is very nearer to crushed stone aggregate in concrete.

REFERENCES

[1] Akin Altun.I and Ismail Yilmaz (2002). Study on steel furnace slags with high Mgo as additive in Portland cement, Journal of Cement and concrete research, Vol.32, pp 1247-1249.

[2]Beshr.H,Almusallam.A.Aand Maslehuddin.M (2002). Effect of coarse aggregate quality on the mechanical properties oh high strength concrete, Journal of Construction and building materials, Vol.17, pp 97-103.

[3]Dr.Chinnaraju.K and Ramkumar (2013). Study on Concrete Using Steel Slag as Coarse Aggregate Replacement and Eco sand As Fine Aggregate Replacement, International Journal of Research in Engineering & Advanced Technology, Vol.1, pp 1-6.

[4] IS 10262:2009 - Concrete mix proportioning-Guideline, Bureau of Indian Standard, New Delhi, India.

[5] IS 456:2000 - Plain and Reinforced Concrete Code of Practice, Bureau of Indian Standard, New Delhi, India.

[6] IS 383:1996 - Specification for coarse and fine aggregate from natural sources for concrete, Bureau of Indian Standard, New Delhi, India.

[7] Jafari Ani.O, Shafabakhsh.G.H and Talebsafa.M (2015). Artificial neural network modeling (ANN) for predicting rutting performance of nano-modified asphalt mixtures containing steel slag, Journal of Construction and building materials, pp 136-143.

[8] Khalid Raza, Sharda Sharma, Ritesh Mall and Patel (2014). Comparative Strength Analysis Of Concrete By Using Steel Slag As An Alternative To Normal Aggregates (Coarse) In Concrete, International Journal of Civil Engineering, Vol.3, pp 53-57.

[9] Kothai and Dr.R.Malathy (2014). Utilization Of Steel Slag In Concrete As A Partial Replacement Material for Fine Aggregates, International Journal of Innovative Research in Science, Engineering and Technology, Vol.3, pp 11585-11592.

[10] Maslehuddin.M, AlfarabiM.Sharif, Shameem, Ibrahim and Barry (2002). Comparison of properties of steel slag and crushed limestone aggregate concretes, Journal of Construction and Building Materials, Vol.17, pp 105-112.