ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 2, Issue 7, July 2015

Strength and Durability of Concrete Using Steel Slag as a Partial Replacement of Coarse Aggregate in Concrete

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Abstract: Global warming and environment destruction have become the major issue in recent years. Emission of green house gases from industries has impact on climate change. Preventing the depletion of natural resources and enhancing the usage of waste materials has become a challenge to the scientist and engineers. A number of studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using this waste material. The major byproducts of industry are slag. To solve the problem in effective manner slag is use in concrete by replacing natural coarse aggregate. In this study, the replacement was done with coarse aggregate by steel slag for different proportions of 0%, 20%, 40%, 60%, 80% and for a M40 grade of concrete is used for a water cement ratio of 0.40.Tests on compressive strength, split tensile strength, flexural strength at 7 days and 28 days are conducted on specimens. The optimum strength is obtained on 60% replacement of coarse aggregate bysteel slag.

Keywords: Cement, Steel Slag, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Concrete is one of the prime materials for structures and it is widely used for various applications all over the world. Aggregates and cement play a major role in concrete. In India there is a great shortage of natural aggregates. Recently Tamil Nadu Government has imposed restrictions on removal of sand from the river beds due to its threatening effects. Production of cement liberates same amount of carbon dioxide which is the great cause of ozone depletion(Kanmalai, 2008). This effect creates a question on the sustainability of concrete. In order to make concrete a sustainable material, suitable engineering approaches can be done. Apart from this waste generation has increased considerably and find no way for disposal. In order to overcome this, industrial slags can be used as alternate building materials. In this present study, an attempt is made by utilizing steel slag as suitable substitutes for aggregates in concrete. Steel slag is an industrial by-product obtained from the steel manufacturing industry. It is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic nonmetallic components present in the steel scrap(Chinnaraju, 2013). Steel slag are being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity. Steel slag generally exhibits the potential to expand due to the presence of un-hydrated free lime and magnesium oxides which hydrate in humid environments. If such a product is used in the concrete, it influences both the mechanical and physical properties of concrete along with its durability. The steel slag which obtained from Steel Plant at GummudiPoondy.

II. REVIEW ON LITERATURES

Brindha et al. (2010) studied the presence of silica in slag is about 26% which isdesirable since it is one of the constituents of the natural fine aggregate used in normal concreting operations. From the experiments, the results of compressive and split tensile strength test indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions and 15% of cement. Water absorption of S40 copper slag concrete specimens is about 22% lower than the controlled specimens. Water permeability in concrete reduced up to 40% replacement of fine aggregate using copper slag.

Mahmoud Ameri et al. (2012) studied the effect of

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utilizing air-cooled steel slagfrom Zob-Ahan steel production factory in concrete. General observations were carried out according to ASTM D 5106 in order to consider suitability of SS for replacement of natural aggregates in concrete. Compressive strength tests were performed on samples containing slag ratios of 0, 25, 50, 75 and 100 % and cement contents of concrete 200, 300 and 350 kg/m^3. According to the results, compressive strength improved with the increase in steel slag ratio up to 25% and further decreases the compressive strength when increasing the steel slag ratio above 25%. Concrete mixes with higher slag ratios meeting the ACI 325.10R-99 standard with different cement contents were tested for flexural strength and the results indicated that the slag ratio increases in concrete, the flexural strength increases.

Suresh Reddy et al. (2013) studied the concrete made of copper slag replacingsand up to 50% are used to study the strength parameters, compressive strength, split tensile strength and flexural strength of both M30 and M40 grade of concrete mixes. Sand was replaced with copper slag in proportions of 0%, 10%, 20%, 30%, 40% and 50%. From the results, it was concluded that the compressive strength, split tensile strength and flexural strength of concrete mix increased marginally up to 40% replacement of sand by copper slag at the age of both 28 and 56 days.

III. Materials & Properties

Ordinary Portland cement from Chettinad Cement Company of grade 53 was used for this studywhich has the fineness 3%, Specific gravity 3.15, Consistency 30%, Initial setting time 36min and Final setting time 270 min.The physical properties of materials are tabulated in table1.

Table 1 Physical properties of materials

Material	Fine aggregate	Coarse aggregate	Steel slag
Specific gravity	2.6	2.85	2.61
Water absorption (%)	0.9	0.4	0.9
Bulk density (kg/m^3)	1589.30	1452	1382
Moisture content (%)	2.5	0.26	0.3
Fineness modulus	3.10	3.06	2.92

IV. Methodology

The basic tests are conducted on various materials like OPC53 grade cement, fine aggregate, coarse aggregate and steel slag to check their suitability for making concrete. The mix proportions of concrete are modified for using steel slag as a partial replacement of coarse aggregate. The cubes were cast by replacing coarse aggregate with 0%, 20%, 40%, 60% and 80% of steel slag. Specimens are cast as per mix design and the tests are conducted after proper curing, the tests are compressive strength of cubes (150mm x 150mm x 150mm), split tensile strength of cylinders (150mm x 300mm) and flexural strength of prisms (100mm x 100mm x 500mm). From the studies, optimum results are found out and compared with the control concrete.

V. Mix Proportion

Concrete mix design is a process by which the proportions of the various raw materials of concrete are determined with an aim to achieve a certain minimum strength, as economically as possible. Based on the simplified mix design procedure as per IS 10262:2009, a concrete mix proportions with characteristic compressive strength of 40Mpa was designed without any admixtures. The mix adopted for the study is given in Table 2.

Table 2 Mix proportion

	Cement	**Water**	**Fine Aggregate**	**Coarse Aggregate**
kg/m^3	493	197.2	639.038	1198.197
Ratio	1	0.4	1.296	2.430

VI. Test Results And Discussion

The test results of slump, compressive strength, split tensile strength and flexural strength obtained from the experimental study are given in the form of graph and made discussion also.

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A. Slump test

Slump test is conducted on fresh concrete of different mix proportions. The obtained slump value for normal concrete is 50 mm. This indicates medium workability.

Fig.1 shows the variation of slump value of concrete using steel slag. From the graph it is observed that in concrete, percentage of steel slag increases, it decreases the workability.

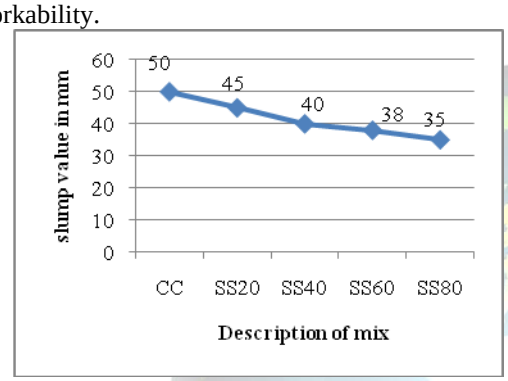

Fig.1 Variation of slump value of concrete using steel slag

B. Compressive strength

Concrete cubes of size 150 mm X 150 mm X 150 mm were prepared and the specimen is cured, it is tested for compressive strength. The maximum load at failure reading was taken.

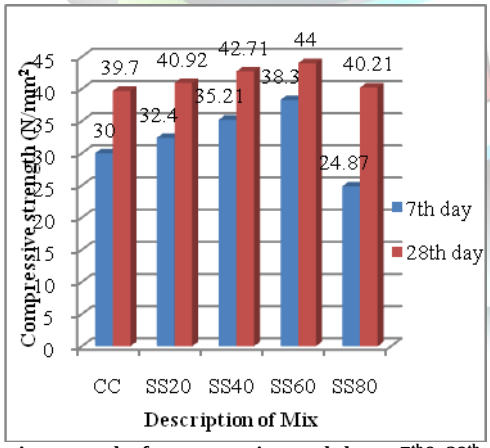

Fig.2 Compressive strength of concrete using steel slag at 7th& 28th day

Fig.2 shows the compressive strength of concrete using copper slag at 7th and 28th day. It was observed that the strength of concrete increases with the increase in the quantity of steel slag as replacement to natural aggregates. Upto 60% replacement of coarse aggregate by steelslag , the compressive strength of concrete of all concrete mix increases but beyond 60% decrease in the strength is observed. The compressive strength of concrete increases 9.70 % if 60% of coarse aggregate is replaced by steel slag. The improvement in strength may be due to shape, size and surface texture of steel slag aggregates, which provide better bonding between the particles and cement paste.

C.Split tensile strength

Concrete cylinders of diameter 150 mm and height 300mm were casted and the specimen is cured, it is tested for split tensile on 28th day. The maximumload at failure reading was taken.

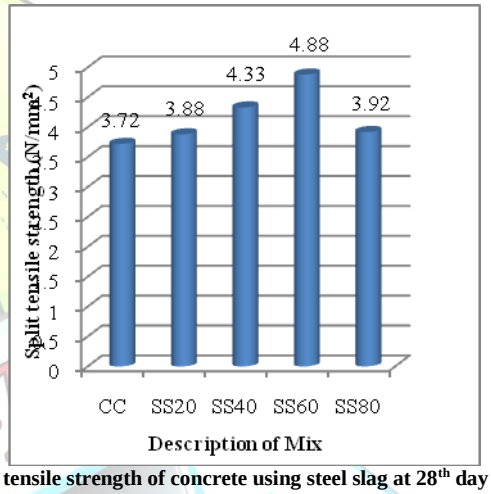

Fig.3 Split tensile strength of concrete using steel slag at 28th day

Fig.3 shows the split tensile strength of concrete using steel slag at 28th day. The split tensile strength of concrete showed similar behavior to the compressive strength. The results showed that the split tensile strength is increased upto 60% replacement of coarse aggregate using steel slag, beyond that the split tensile strength value reduced but it more than the split tensile strength of control mix. The results showed that the replacement of coarse aggregate using steel slag in concrete increases the tensile strength of about 23.70 % with that of control mixture.

D.Flexural strength

The flexural strength test for beam specimenhaving thesize of100 x 100 x 500 mmwas 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.

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ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 2, Issue 7, July 2015

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. Upto 60% of replacement by steel slag, the flexural strength of concrete increases but beyond 60% decrease in the strength was observed. The maximum increase in the flexural strength obtained at 60% replacement and the flexural strength of concrete increases 18.20% compared with control concrete.

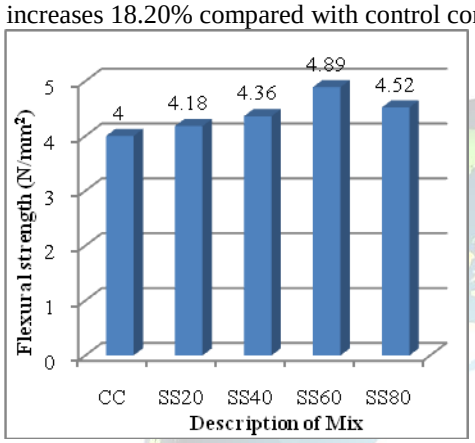

Fig.4 Flexural strength of concrete using steel slag at 28th day

VII. Durability Test Results

A. Sulphate attack test

The 150mm of cubes were immersed in the 5% of $MgSO_4$ solution for 28 days and found that the percentage loss in weight and compressive strength of concrete cubes. The result of the test showed that concrete containing steel slag has good resistance to sulphate attack. The loss in weight and compressive strength of concrete with 40% of copper slag and 60 % of steel slag was lower than control concrete. The percentage of loss of compressive strength of conventional concrete is 0.58% and percentage of loss in weight by 2.9% when compared with the concrete containing steel slag. The concrete cube containing steel slag resists the sulphate attack when compared to the control concrete. Table 3 shows the the percentage of weight loss and strength loss in sulphate resistance test.

Table 3Percentage of loss in weight and compressive strength due to Sulphate attack

Specimen	Loss in weight(%)	Loss in compressive strength(%)
Conventional cube	5.56	4.78
Cube contain60% of Steel Slag	2.66	4.2

B. Acid Resistance test

The acid resistance test was conducted in 150mm cubes by immersing in 5 % of Hydrochloric acid solution for 28 days. Then the weight loss and compressive strength were determined for the cubes. From the result, it was observed that the concrete having steel slag has good acid resistance when compared with control concrete. It could be in concrete, the use of steel slag prevents a growth of calcium hydroxide around the fine aggregate particles and prevents the formation of ettringite (sulfate calcium sulfoaluminate). Therefore, these mechanisms improve the concrete as resistance of concrete to acid attack. The obtained weight loss of control concrete is 3.44% and higher than the concrete with steel slag. The percentage of loss of compressive strength of control concrete is 1.98% and higher than the concrete containing steel slag. The concrete cube containing steel slag resist the acid attack when compared to the control concrete. Table 4shows the percentage of weight loss and strength loss in acid resistance test.

Table 4Percentage of loss in weight and compressive strength due to Acid attack

Specimen	Loss in weight (%)	Loss in compressive strength(%)
Conventional cube	7.32	10.7
Cube contain60% of Steel Slag	3.88	8.72

VIII. Conclusion

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

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- This experimental study has proved to be better way to disposal of steel slag.
- The replacement of coarse aggregate with steel slag has increased the compressive strength, split tensile strength and flexural strength of concrete.
- The optimum percentage of steel slag was found to be 60%.
- The increase in percentage of steel slag in concrete shows higher resistance to acid and sulphate attack.
- When this optimized valuewill beused,it will givegood strength more durable concrete when compared to conventional concrete and saves material cost upto 10%.

ACKNOWLEDGMENT

The authors are grateful to the Department of Civil Engineering, Dr.Sivanthi Aditanar College of Engineering, Tiruchendur, Tamilnadu for the project approval and support.

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ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 2, Issue 7, July 2015

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