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Effect of Steel Slag as Partial Replacement of Coarse Aggregate in M35 Grade of Concrete

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Abstract:

Aggregates are the important constituents in concrete. In India, annual outcome of Steel Slag is about 10 Million Tone . The utilization of waste materials from the industries has been continuously emphasized in the research work. The present work is to use steel Slag as partial replacement for coarse aggregate. The M35 concrete with steel slag partial replacement for coarse aggregate are examined in the present study. According to material properties studied are 7days and 28days compressive strength, flexural strength and split tensile strength were found experimentally. The results were compared with conventional concrete property. The results showed that partially replacing about 0%, 15 % , 30 %, 45%, and 60% of steel slag aggregates by weight for natural aggregates From these results of the study we can say that as the percentage of steel slag as replacement is increased (0% to 45%) the strength of concrete increases. After 45% replacement of Coarse aggregate as steel slag slight decrease in strength is observe, but still it is higher than 0% replacement without any adverse effect on the strength of concrete.

Keywords - Steel Slag, Compressive Strength, Flexural Strength, Spilt Tensile Strength.

1.INTRODUCTION

Global warming and environmental destruction has come forward as a major issue in the recent years. Started alarming in engineers mind, especially in civil engineers mind. Looking forward for finding out the solution of these issues and also the use of more and more environmental- friendly materials in every Industry particularly construction industry is a paramount importance. Civil engineers start thinking about concrete, which is more dominant product to be used by civil engineers to make it environmental friendly. These materials are majority byproducts from other processes, out of all these materials one of the useful byproduct material is Steel slag. Steel slag is previously used as aggregate in hot mix asphalt surface applications, but needs to update for additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. From these results of the study we can say that as the percentage of steel slag as replacement is increased (0% to 45%) the strength of concrete increases. After 45% replacement of Coarse aggregate as steel slag slight decrease in strength is observe, but still it is higher than 0% replacement without any adverse effect on the strength of concrete.I 1 producing 3-7 tonnes of waste which includes the solid, liquid and gas are generated for every ton of steel produced.

II. MATERIALS AND PROPERTIES

CEMENT PROPERTIES

Cement Brand : Ultratech Cement

Cement Type : Ordinary Portland

Specific Gravity of Cement,G =3.13

Standard Consistency of cement:

Quantity of Cement: W_1=400gms

Quantity of Water: W_2= 33%=132ml

Penetration of Plunger from Top = 33 mm

(Desirable is 33 to 35 mm)

Initial Setting Time: Quantity of Cement: W_1=400gms

Weight of Water as per Standard Consistency: P = 33 %= 132 ml

Initial Setting Time of the Cement : 28mins. Final Setting Time of the Cement : 560 mins. Fineness of Cement,W = 225m^2/kg Compressive strength of Cement

3days : 23

7days : 37

28days : 43

SAND (Fine Aggregate)

The sand used for the work was locally procured and conformed to Indian Standard Specifications IS: 383-2016. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm. The various other tests conducted are specific density, bulk density, fineness modulus, water absorption and sieve analysis. The fine aggregated belonged to grading zone II. This Aggregate hasabsorptionof1.23%.TheBulkSpecificGravityofthe fine aggregate was 2.60 while its Fineness modulus was2.63.

AGGREGATE (COARSE AGGREGATE)

The material which is retained on IS sieve no. 4.75 is termed as a coarse aggregate. The crushed stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used int his work.

Physical Properties of coarse aggregates.

Characteristics	Value
Type	Crushed
Specific Gravity	2.884
Total Water Absorption	0.97%
Fineness Modulus	6.96

Mechanical Properties of Aggragate

Property	Value
Elongation Index	13 % (should not be more than 15 %)
Flakiness Index	12 % (should not be more than 15 %)
Specific Gravity of Aggregate Slag Aggregate	G = 2.98
Aggregate impact value	4.5 % (should not be more than 30 %)
Crushing value	19.11 % (should not be more than 45 %)
Dry Loose Bulk Density	1.52 Kg/lt
Water Absorption	1.0 % (should not be more than 2 %)
Abrasion Value	14 % (should not be more than 30 %)

Steel Slag

Steel Slag is the main component of this study, which is locally available material. Steel Slag used in is work is collected from Jai Jawala Steel industry Baddi. Steel slag is a byproduct obtained either from conversion of iron to steel in a Basic Oxygen Furnace (BOF), or by the melting of scrap to make steel in the Electric Arc Furnace (EAF). The molten liquid is a complex solution of silicates and oxides that solidifies on cooling and forms steel slag.Steel slag is defined by the American Society for Testing and Materials (ASTM) as a non-metallic product, consisting essentially of calcium silicate sand ferrites combined with fused oxides of iron, aluminum, manganese, calcium and magnesium that are developed simultaneously with steel in basic oxygen, electric arc, or open hearth furnaces. (Kalyoncu, 2001). Steel furnace slag is produced in a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF) as a byproduct of the production of steel. In the Basic Oxygen Furnace (BOF), the hot liquid metal from the blast furnace, scrap and fluxes, which contain lime (CaO) and dolomitic lime, are charged to a furnace (Shi, 2004). A lance is lowered into the converter and then oxygen in injected with high pressure. This slag is in molten state and is then processed to remove all free metallic impurities with help of magnetic separation and then sized into construction aggregates .Unlike the Basic Oxygen Furnace (BOF) process, the Electric Arc Furnace (EAF) does not use hot metal, but uses cold steel scraps. This slag which floats on the surface of molten steel is then poured off. Minor elements included are manganese, iron, sulfur compounds and traces of several other elements .Physical characteristics such as porosity, density, particle gradation, are affected by the cooling rate of the slag and its chemical composition.

Constituents	**Composition provided By Steel Industry (%)**	**Composition provided by NSA(%)**
Aluminum oxide (Al_2O_3)	4.84	1-5
Calcium oxide (CaO)	30.7	40-52
Chromium oxide (Cr_2O_3)	0.28	---
Iron oxide (FeO)	35.6	10 – 40 (70 -80% FeO, 20-30% Fe_2O_3)
Magnesium oxide (MgO)	9.95	5-10
Manganese oxide (MnO)	3.99	5-8
Phosphorus oxide (P_2O_5)	0.61	0.5-1
Potassium oxide (K_2O)	0.05	--
Silicon oxide (SiO_2)	12.0	10-19
Sodium oxide (Na_2O)	0.09	--
Titanium oxide (TiO_2)	0.65	--
Vanadium oxide (V_2O_5)	0.21	--
Water Absorption	3.37	--
SSD Specific Gravity	3.09	--

The physical mechanical and chemical properties of steel slag are shown below.

1.Physical Properties of Steel Slag

Property	Value
Specific Gravity	> 3.2 - 3.6
Unit Weight, kg/m3	1600 – 1920
Water Absorption	up to 3%

2 Mechanical Properties of Steel Slag as Aggregate

Property	Value
Elongation Index	1.01 % (should not be more than 15 %)
Flakiness Index	4.48 % (should not be more than 15 %)
Specific Gravity of Steel Slag Aggregate	G = 2.91
Aggregate impact value	23.21 % (should not be more than 30 %)
Crushing value	36.55 % (should not be more than 45 %)
Dry Loose Bulk Density	1.12 Kg/lt
Water Absorption	2.5 % (should not be more than 2 %)
Abrasion Value	27 % (should not be more than 30 %)

Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life also usually is suitable. When water is obtained from sources mentioned above, no sampling is necessary. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided since the quality of the water could change due to low water or by intermittent tap water is used for casting.

3.DESGIN MIX AS PER IS 10262:2009

Mass of Cement in kg/m^3 -400

Mass of Water in kg/m^3 - 160

Mass of Fine Aggregate in kg/m^3 - 704 Mass of Coarse Aggregate in kg/m^3 - 1271

Mass of 20 mm in kg/m^3 - 915

Mass of 10 mm in kg/m^3 - 356

Mass of Admixture in kg/m3 - 2.00

Water Cement Ratio - 0.40

4.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.

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.

Mixture	Measured slump (mm)
Steel Slag 0%	50
Steel Slag 15%	48
Steel Slag 30%	42
Steel Slag 45%	37
Steel Slag 60%	35

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.

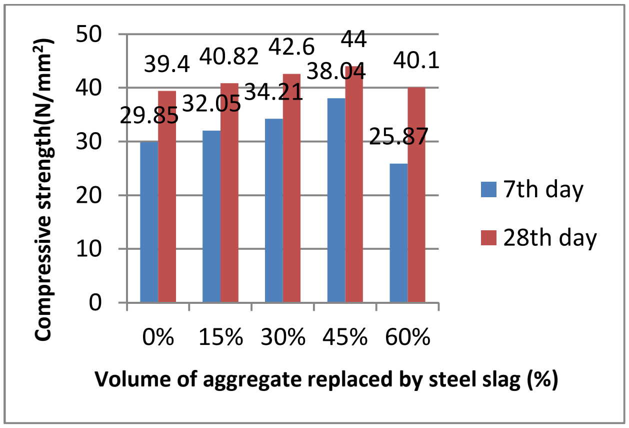


Fig4.1 Compressive strength of concrete using steel slag at 7th& 28th day

Fig.1 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.

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.

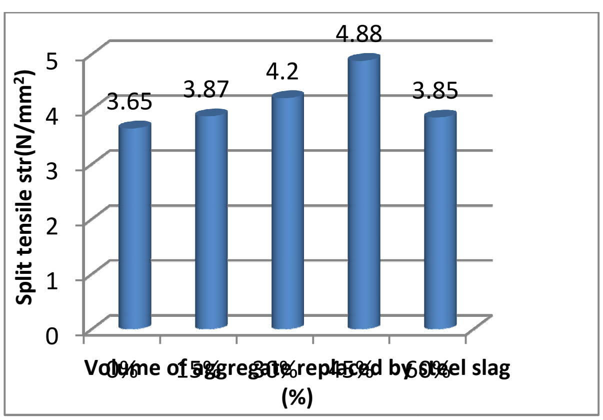
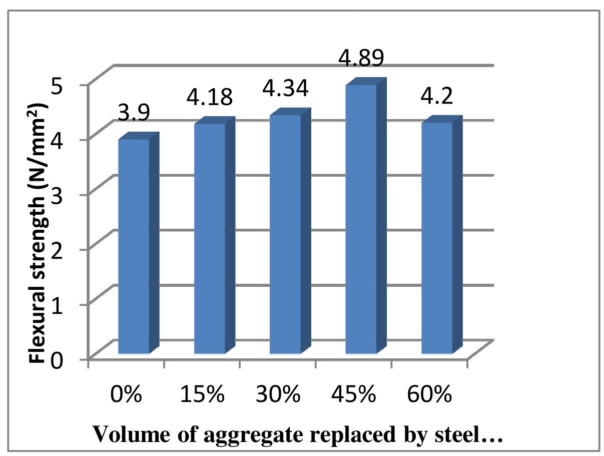


Fig4.2 Split tensile strength of concrete using steel slag at 28th day

Fig.2 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 45% 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.

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.

Fig4.3 Flexural strength of concrete using steel slag at 28th day

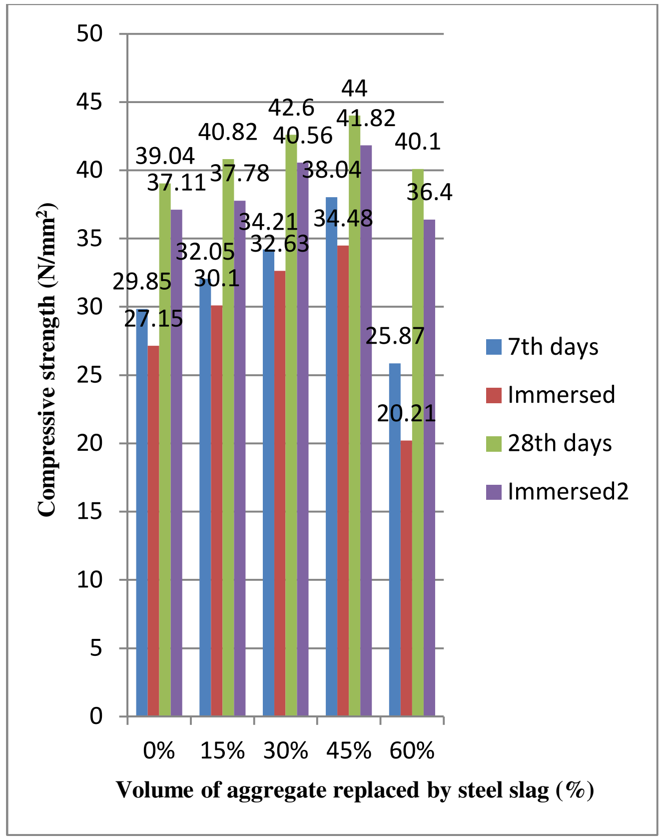
Fig.3 shows the flexural strength of concrete using steel slag at 28th day. It is observed that flexural strength of concrete increases with the increase in the quantity of steel slag as replacement of coarse aggregate. Upto 45% of replacement by steel slag, the flexural strength of concrete increases but beyond 45% decrease in the strength was observed. The maximum increase in the flexural strength obtained at 45% replacement and the flexural strength of concrete increases 18.20% compared with control concrete.

Resistance to Sulphate attack of concrete

This test was conducted on 150 x 150 x 150mm cube specimens. The cubes were casted and cured in water for 28 days. Sodium sulphate($NaSo_4$) solution of 50g/l is used to evaluate sulphate resistance of concrete. Cubes are immersed in solution after 28 days curing, and are tested for compressive strength at 7&28 days. When this compressive strength is compare with the compressive strength of specimen cured in water at same ages also there is increase of steel slag aggregate with natural aggregate at 15%, 30%, 45%and 60% were also checked. When the replacement of natural aggregate with steel slag increase in the mix.

Compressive strength of concrete mixes after immersion in $NaSo_4$solution

From observation we conclude that the Resistance to sulphate attack of concrete increases as the quantity of steel slag is increases on replacement of coarse aggregate .Only upto 45% replacement of steel slag the Resistance of sulphate attack of concrete shows increment beyond it will show decrement in the strength is observed.



The Resistance to sulphate attack of concrete mix increases upto 16% if 45% of aggregate is replaced by steel slag at 28 days.

5.CONCLUSION

- The optimum value of compressive strength , flexural strength, split tensile strength can be achieved by 45% replacement of steel slag.
- Strength of M35 grade of concrete increases with increases in steel slag quantity. The improvement in strength may be due to shape, size and surface texture of steel slag aggregate, which provide better adhesion between the particles and cement paste.
- This experimental study has proved to be better way to disposal of steel slag
- The cost of slag is almost 50% of that of natural aggregate also it is economical to use the Steel Industrial waste product. Also it could be easily used as coarse and fine aggregate in all plain concrete applications.

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