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Strength Enhancement of Concrete using steel slag

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Abstract — in construction materials, concrete is the largest production of all other materials. Aggregates are the important constituents in concrete. The increase in demand for the ingredients of concrete is met by partial replacement of materials by the waste materials which is obtained by means of various industries. Steel slag is a waste product generated during the production of steel. These wastes are disposed in the form of landfills causes an enormous amount of land pollution. In this study, the use of steel slag as fine aggregate in concrete is investigated. For this purpose, various concrete proportions with water/cement ratio of 0.4 are prepared. Compressive strength of concrete is examined by using steel slag as fine aggregate, eventually concrete mixtures containing steel slag as fine aggregate show better performance than normal concrete up to certain percentages of steel slag. In this study, the cubes casted in 0%, 10%, 20%, 30% and 40% of steel slag as fine aggregate.

Keywords— compressive strength, split tensile strength, flexural strength, steel slag

I. INTRODUCTION

The government of India has targeted the year 2020 for providing housing for all the people. Such large scale construction projects require huge amount of fine aggregates needed but now a day's huge scarcity of fine aggregates. The present need is to replace the scarce and costly conventional building materials by innovative, cost effective and environment friendly alternate building materials. For many years by-products such as fly ash, silica fume and slag were considered as waste materials which have been used in the construction for partially or fully replacing fine and coarse aggregates.

Human activities on earth produce in considerable quantities of wastes more than 2,500 million tons per year, including industrial and agricultural wastes from rural and urban societies. This creates serious problems to the environment, health and also the land filling. Now a day the concrete is most used manmade material in the world. The Indian construction industry alone consumes approximately 400 million tons of concrete every year and the relative amount of mortar too. Therefore the demand of the concrete and the required raw materials are very high. This causes the hike in the costs of cement, fine and coarse aggregates. Quite often the shortage of these materials is also occurred. Following a normal growth in population, the type and amount of waste materials have increased rapidly. Many of the non-decaying waste materials will remain in the environment for thousands of years. The non-decaying waste material causes a waste disposal predicament, thereby contributing to the environmental problems. However, the environmental impact can be reduced by making more sustainable use of this waste. This is known as the Waste Hierarchy and its aim is to reduce, reuse, or recycle waste, being the preferred option of waste disposal.

To avoid the problems like cost hike and cuts in supply of concrete and mortar, the alternate material or the partial replacements for the cement and aggregate should be developed by recycling of waste materials. This provides us the low cost, light-weight and eco-friendly construction products. Use of the waste materials also reduces the problem of land-filling, environmental and health concern. The use of various waste materials like rice husk ash (RHA), quarry dust (QD), crumb rubber, sewage sludge ash (SSA) as mineral additive, paper mill sludge ash (PA), fly-ash, fly-ash based geo-polymer, ground granulated blast furnace slag (GGBF), pumice fine aggregate especially in mortar and concrete. Rice husk ash contains silica with small amount of alkalis and other trace elements. Availability of natural aggregates is getting depleted and also it becoming costly, therefore the replacement of natural sand by the waste industries by-products has been continuously emphasized during recent years. Natural sand is replaced by steel slag sand in various percentages. In this study, therefore an attempt has been to study the effect of replacement of fine aggregate using steel slag and mechanical properties were conducted.

Material investigation

A. Cement

Cement is binding material which is used for making a concrete. Among various types of cement, we are using Ordinary Portland Cement of 43 grades in the project. The physical properties of cement which are found in references as per IS 4031 are given in Table1.

TABLE 1
PHYSICAL PROPERTIES OF CEMENT (OPC 43 GRADES)

Sl. No	Property	Value
1	Specific gravity	3.12
2	Standard consistency (%)	31
3	Initial setting time (min)	50
4	Final setting time (min)	450

B. Fine Aggregate

Good quality river sand free from silt and other impurities passing through 4.75 mm sieve is used in this study. The physical properties of fine aggregate determined in accordance with IS 2386 are shown in Table 2.

TABLE 2
PHYSICAL PROPERTIES OF FINE AGGREGATE

Sl. No	Description	Quantity
1	Specific gravity	2.6
2	Water absorption (%)	1.7
3	Bulk density(kg/m^3)	1680
4	Fineness modulus	2.97

C. Steel Slag

At present many steel plant are being set up across the world causes a huge production of solid waste material like slag. Presently, total steel production in India is about 72.20 million metric tons and the waste generated annually is around 19 million metric tons and 50 million metric tons worldwide. However, steel slag has not been used efficiently and thoroughly for long, which causes its great accumulation, waste of land and serious air and water pollution. Steel slag contains a certain amount of important minerals of cement clinker, such as C_2S and C_3S. So it can be used as cement and concrete admixtures.

TABLE 3
PHYSICAL PROPERTIES OF STEEL SLAG

Sl. No	Description	Quantity
1	Specific gravity	2.67
2	Water absorption (%)	2.9
3	Bulk density(kg/m^3)	1911.11
4	Fineness modulus	2.5

D. Coarse Aggregate

Crushed granite stone obtained from locally available crushers, passing through 20 mm and retaining on 16 mm and passing through 12.5mm and retaining on 4.75 mm sieves are used as coarse aggregate for experimental work. The physical properties of coarse aggregate determined in accordance with IS 2386 are given in Table 4.

TABLE 4
PHYSICAL PROPERTIES OF COARSE AGGREGATE

Sl. No	Description	Quantity
1	Specific gravity	2.75
2	Water absorption (%)	1.65
3	Bulk density(kg/m^3)	1518.5
4	Fineness Modulus	3.2

E. Super Plasticizer(SP)

The purpose of super plasticizer is to increase the flow with reduced water content. Various types of Super plasticizer are available in the market. In this project SP with higher specific gravity of 1.145, named Supa-flo is used for attaining the required flow characteristics.

F. Water

Potable drinking water with pH value ranging between 6 and 7 has been used for mix.

II. MIX PROPORTIONING

The mix proportion based on IS 10262 (2009) arrived for M30 grade of concrete using the above materials is given in the Table 5

TABLE 5
MIX PROPORTION FOR W/C 0.4

Sl. No	Materials	Quantity
1	Cement (kg/m³)	400
2	Sand (kg/m³)	718.224
4	Coarse aggregate (kg/m³)	1106.34
5	Water (l/m³)	180
6	Super plasticizer (%)	1

III. Experimental scheme

The experimental scheme is worked out, in order to produce concrete having 100 % SS to give strength and durability performance as that of normal concrete. Hence, the parameters chosen for the experimental study are (a) water cement ratio (b) quantity of SS. With these above parameters the experimental scheme is arrived at for testing for the mechanical and durability characteristics of concrete containing SS. Table shows the experimental matrix followed in the present study. Table 7 shows the test matrix of specimens tested for its mechanical properties along with the mix designation.

TABLE 7
THE TEST MATRIX OF SPECIMENS TESTED FOR ITS MECHANICAL PROPERTIES

Sl. No	Amount of SS (%)	Mix Designation	w/c
1	0	NC	0.4
2	10	SS 10	
3	20	SS 20	
4	30	SS 30	
5	40	SS 40	

IV. Testing of specimens

A. Compressive strength

The compressive strength test on concrete specimens incorporating steel slag was performed as per IS: 516-1959 on standard compression testing machine of 2000kN capacity. Totally 30 numbers of cubical specimen of size 100mm x 100mm x 100mm were cast and tested for the compressive strength at the age of 7days and 28days.

B. Tensile Strength

The Tensile strength test on concrete specimens incorporating steel slag was performed on standard compression testing machine of 2000KN capacity as per IS: 516-1959. Totally 15 numbers of cylindrical specimen of size 100mm x 200mm were casted and tested for the tensile strength at the age of 7days and 28days.

C. Flexural strength

The Flexural strength test on concrete specimens incorporating steel slag was performed on flexural testing machine as per IS: 516-1959. Totally 15 numbers of beams of size 500mm x 100mm x 100mm were casted and tested for the flexural strength at the age of 28 days.

V. Result and discussion

A. Compressive strength

The effect of partial replacement of steel slag with fine aggregate on compressive strength of concrete specimens is given in Table 8. The compressive strength results of concrete for various mix proportioning of steel slag to fine aggregate are found at 7, 28 days. The test results reveal that the compressive strength of concrete specimens is influenced by the amount of Steel slag. It is seen that a maximum compressive strength 44.48 MPa are obtained with water 0.4 respectively at the age of 28 days.

TABLE 8
COMPRESSIVE STRENGTH FOR VARIOUS CONCRETE MIXES (MPa)

Mix designation	w/c 0.4	
	7 days (MPa)	28 days (MPa)
Normal mix	21.86	29.55
SS 10	29.61	35.93
SS 20	31.94	38.24
SS 30	32.54	44.48
SS 40	30.05	37.44

The compressive strength for various proportion of steel slag for fine aggregate is shown in Figs 3 & 4. The test results of compressive strength shows that, there is no problem at all up to 30% replacement of steel slag more than that the compressive strength decreases

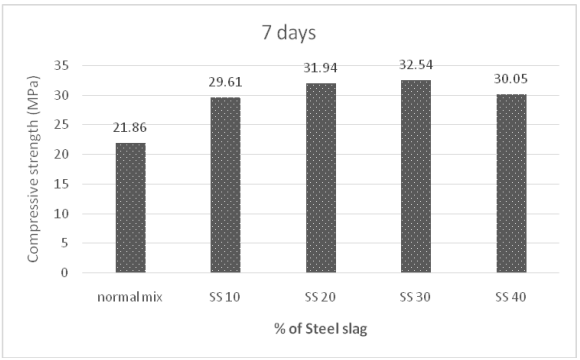

Fig 3 compressive strength at 7 days

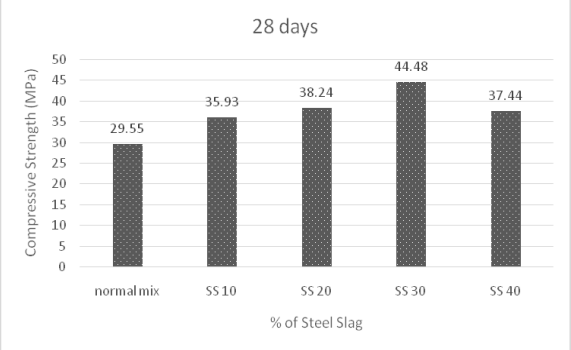

Fig 4 compressive strength for various concrete mixes at 28 days

B. Split Tensile Strength

The effect of partial replacement of fine aggregate with steel slag on tensile strength of concrete specimens is given in Table 9. The split tensile strength results of concrete for various mix proportioning of steel slag to fine aggregate are found at 7, 28 days. The test results reveal that the split tensile strength of concrete specimens is influenced by the amount of Steel slag. It is seen that a maximum compressive strength 3.89 MPa are obtained with water 0.4 respectively at the age of 28 days.

TABLE 9
SPLIT TENSILE STRENGTH FOR VARIOUS CONCRETE MIXES (MPa)

Mix designation	**w/c 0.4**	
	7 days	**28 days**
Normal mix	4.45	4.35
SS 10	3.85	3.81
SS 20	3.92	3.84
SS 30	3.94	3.87
SS 40	3.72	3.89

The split tensile strength for various proportion of steel slag for fine aggregate is shown in Figs 5 & 6. The test results of split tensile strength shows that, there is no problem at all up to 30% replacement of steel slag more than that the split tensile strength decreases.

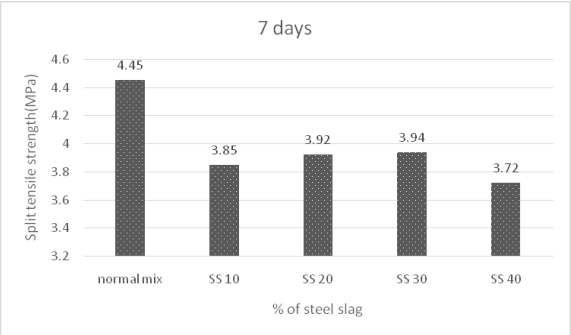

Fig 5 split tensile strength at 7 days

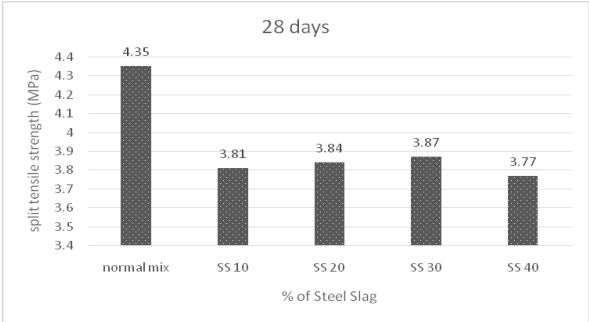

Fig 6 split tensile strength at 28 days

C. Flexural strength

The effect of partial replacement of fine aggregate with steel slag on flexural strength of concrete specimens is given in Table 10. The flexural strength results of concrete for various mix proportioning of steel slag to fine aggregate are found at 28 days. The test results reveal that the flexural strength of concrete specimens is influenced by the amount of Steel slag. It is seen that a maximum flexural strength 2.9 MPa are obtained with water 0.4 respectively at the age of 28 days.

TABLE 10
FLEXURAL STRENGTH FOR VARIOUS CONCRETE MIXES (MPa)

Mix designation	**w/c 0.4**
	28 days
Normal mix	3.9
SS 10	2.7
SS 20	2.9
SS 30	3.3
SS 40	2.42

The flexural strength for various proportion of steel slag for fine aggregate is shown in Fig 7. The test results of flexural strength shows that, there is no problem at all up to 30% replacement of steel slag more than that the flexural strength decreases

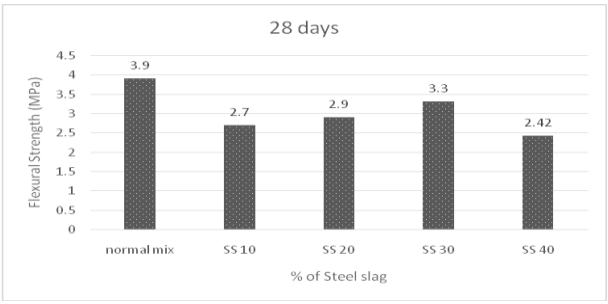

Fig 7 flexural strength for various concrete mixes at 28 days

VI. CONCLUSIONS

This study investigated the use of steel slag as partial replacement of fine aggregate in concrete production. The properties of the steel slag were equally examined. The study concluded as follows:

- The Compressive split tensile, flexural strength of Concrete increase Up to 30%.
- After 30% the Compressive, split tensile, flexural strength of Concrete Decrease at 40%.
- Eco-friendly and Mass utilization of waste material is possible in construction by using steel slag as partial replacement of fine aggregate in concrete.

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