Experimental Investigation on Use of Steel Slag as a Partial Replacement of Fine Aggregate in Concrete

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Abstract: **In India, currently around 15 million tons of steel slag for each annum is produced, which is a long way behind the created nations. In India, because of constrained methods of practices of utilization, tremendous quantity of iron and steel slag are dumped in yards of every generation unit and drawing in of significant farming area and grave contamination to entire system. An effective way to deal with beat these issues is the slag use. Physical and chemical properties of steel slag is an integral factor of steel slag reused as aggregate material, concrete and solid admixture, soil stabilizer and as a construction material and so forth. This survey presents use patterns of steel slag and potential possibilities for huge scale work of steel slag in Indian setting.**

The first extent of this study was to research the properties of cement with steel slag as a substitution to fine aggregates. For this research, the percentage of the volume of fine aggregates normally used in concrete was replaced by steel slag. The replacement was done for the natural aggregates with replacements of the steel slag by 10%,20%,30%,40%, and 50% increments. The fresh and hardened properties of concrete were tried with steel slag as an aggregate. In addition to this research several tests were also included such as compressive strength, split tensile strength and the flexural strength of concrete with steel slag aggregates. In this way, supplanting the regular fine aggregates in concrete applications with steel slag would prompt impressive ecological advantages and would be conservative.

Keywords: **Cement, Steel slag, Concrete, Compressive strength, Split tensile strength & Flexural strength.**

I. INTRODUCTION

Steel slag is an industrial by-product of the Steel industry. It has the issue of disposal as waste and is of ecological concern [2]. It has the most comparable properties of normally accessible sand, so it tends to be utilized in many of the situations ([4]-[6], [11]). In few cases it is even utilized as coarse aggregate too. Steelmaking slag explicitly slag produced from Electric Arc Furnace (EAFs) and Basic oxygen heater (BOFs), during the steel making process has numerous significant and earth safe employments [7]. In numerous applications because of its one kind physical structure, slag outflanks the characters for which it is utilized as a substitution [8]. Not only does the slag offers a better-quality material for many of the constructions, but also the use of slag promote the conservation of natural sources.

II. OBJECTIVES OF THE STUDY

- The main objective of this work was to efficiently utilize the steel slag in the construction methods.
- To test the strength parameters of concrete as per Indian Standard by conducting related tests like Compressive strength, Tensile strength and Flexural strength at replacement levels of 0%,10%,20%,30%, 40% and 50%.
- To compare the strength parameters considering the effect of replacements of fine aggregate and steel slag respectively.

III. MATERIALS & METHODOLOGY

A. Materials Used:

1) Ordinary portland cement

Ordinary Portland Cement is the most common type of cement generally used around the world. Cement is a binder material that sets in a few hours, and hardens over a period and can bind other materials together [1]. In this project work, Ordinary Portland Cement (OPC) of 43 Grade conforming to various specifications as per IS 269: 2015 is used. It is also tested for physical and chemical properties as per Indian standards.

2) Fine aggregate (M-Sand)

Manufactured sand (M-sand) is used as a fine Aggregate in this study. M-sand is produced from hard granite stone by crushing [10]. It must be well-graded throughout the work. It does not contain impurities such as clay and silt, being the reason in having increased quality, strength and durability of concrete. Particles should pass through 4.75 mm sieve. The fine aggregate used should be in accordance to IS 383: 2016.

3) Steel slag

Steel slag is a by-product obtained either from the 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). It does not contain impurities such as clay and silt, being the reason in having increased quality, strength and durability of concrete [9].

4) Coarse aggregate

Aggregates should be uniform with respect to shape and grading. Coarse aggregate of maximum size 20 mm is used throughout the concrete. The Coarse aggregates conforming to IS 383: 2016 are used.

5) Mixing Water

The quality of water must be checked on the same line like that for using a concrete mix. The water used for preparing concrete mix and used for curing should be clean and free from harmful impurities such as salts, acids, alkali, oil, and organic materials. The PH of the water used should be in the range of 6-8 to control the deleterious of concrete and reinforcement. The water used should be confirming to IS 456:2000.

Table I

Properties of the cement used

SL. No.	Important Property	Result	Values as per IS: 8112-1989	Standard Method
1	Colour	Greyish	--	--
2	Grade	53	--	--
3	Type	OPC	--	--
4	Specific Gravity	3.10	2.9 – 3.15	IS:2386 (PART-III) - 1963
5	Initial Setting Time, IST	30 min	30 min	IS: 4031-(PART-5)-1988
6	Final Setting Time, FST	11 hours	> 60 min	IS: 4031-(PART-5)-1988
7	Fineness (By Sieving)	0.5%	Max 10%	IS: 4031– (PART-1) - 1996

Table II

Properties of the used fine aggregate

Sl. No	Property	Results	Standard Method
1	Specific Gravity, (S.G.)	2.69	IS:2386(3)-1963
2	Fineness Modulus	2.75	IS: 383-1970
3	Zone of aggregate	Zone - 1	IS: 383-1970

Table III

Properties of the used coarse aggregate

Sl. No	Property	Results	Standard Method
1	Shape	Angular	IS: 383-1970
2	Specific Gravity	2.74	IS:2386(3)-1963
3	Fineness Modulus	4.336	IS: 383-1970

Table IV

Properties of Steel Slag

Sl. No	Property	Results	Standard Method
1	Specific Gravity	2.54	IS:2386(3)-1963
3	Fineness Modulus	2.68	IS: 383-1970

B. Methodology

1. Mix Proportions

The designation of the different mixtures and the mix ingredients calculations per cubic meter of concrete are presented in Table V and VI. The compressive strength, split tensile and flexure strength of the different cubes have been found using standard procedures. It has been observed in the laboratory test that for M30 grade. In this work, 6 different concrete mixtures (mix designations) were proportioned, with a replacement percent by weight.

Table V

Mix designations of the study

Mix Designation	Replacement of Fine Aggregate by Steel Slag (%)

Mix1	10
Mix2	20
Mix3	30
Mix4	40
Mix5	50

Table VI

Calculations per m^3 of concrete

Mix Title	Cement, kg	M-sand, kg	Steel Slag kg	Coarse aggregate, kg	Water (litres)
Control	413.33	629.77	--	1169.57	186
Mix1		598.32	31.45		
Mix2		566.79	62.98		
Mix3		535.30	94.47		
Mix4		503.81	125.96		
Mix5		472.32	157.45		

IV. RESULTS & DISCUSSION

A. Compressive Strength

compressive strength test is conducted to determine the mechanical properties of concrete specimens by using compression testing machine. Fig. 1 shows the variation of compressive strength test results of concrete specimens. From the results following observations are made, the results of hardened concrete mix show that Steel Slag as a partial replacement up to 40% in fine aggregate can be done. The cube compressive strength at 3, 7 and 28 days of moist curing obtained is higher than that of target mean compressive strength. The Compressive Strength of Cube is almost greater than 2/3rd of the target mean compressive strength.

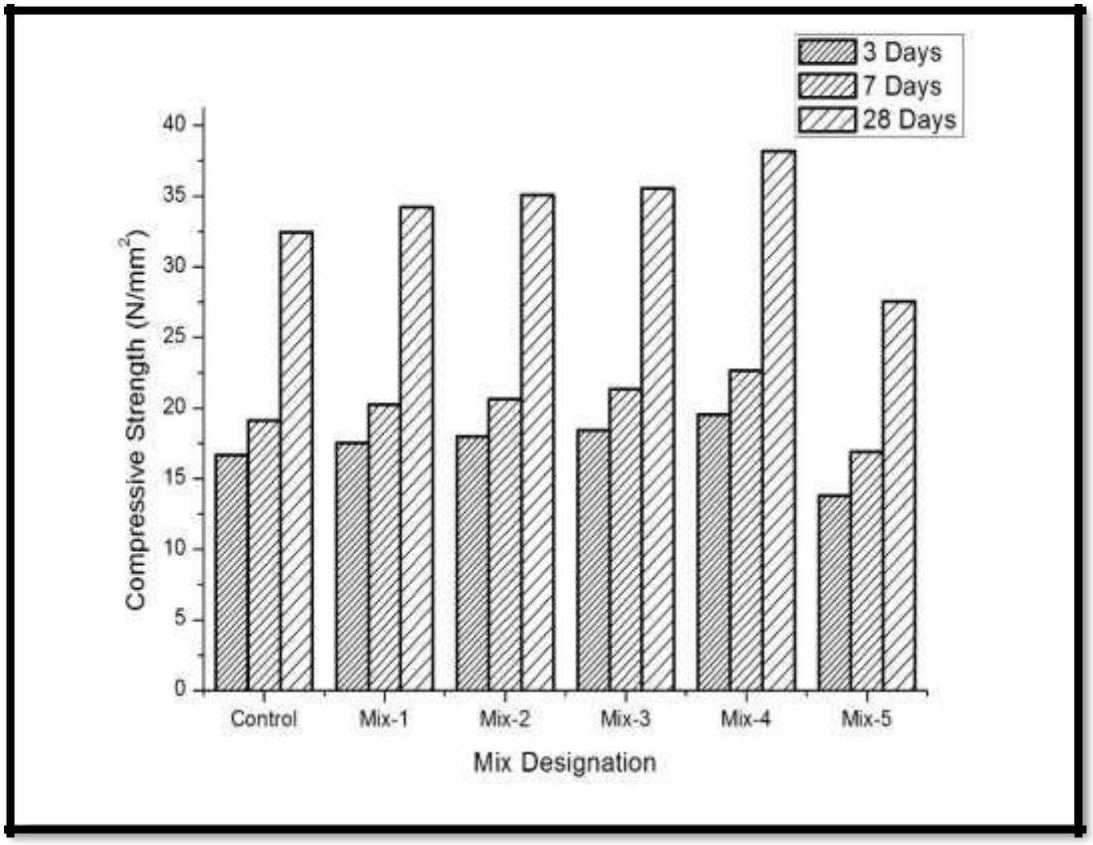

Fig. 1: Compressive strength test results of concrete test specimen at 3, 7 and 28 days of curing.

B. Split Tensile Strength

it is the basic and important test carried out for all the concrete cylinders depends on split tensile strength of the concrete grade of the concrete is known. If the split tensile strength of the concrete id more than the durability and strength of the concrete is more to calculate this strength of the concrete cylinders of standard size 150*300 mm is used. The prepared concrete cylinders are cured for an age of 3, 7, 28 days then concrete cylinders are tested under the compression testing machine. Fig. 2 shows the variation of split tensile strength test results of concrete specimens. From the results following observations are made, the obtained tensile strength values at 3,7 and 28 days of curing are in the range of 2MPa to 4.5MPa for M30 grade of concrete with various proportions respectively. It is observed that the results of split tensile strength showed lesser values compared to compression strength values. The sudden decrease is observed in split tensile strength

after a 40% replacement. The result shows that the optimum dosage of Steel Slag that can be replaced for fine aggregate is 40%.

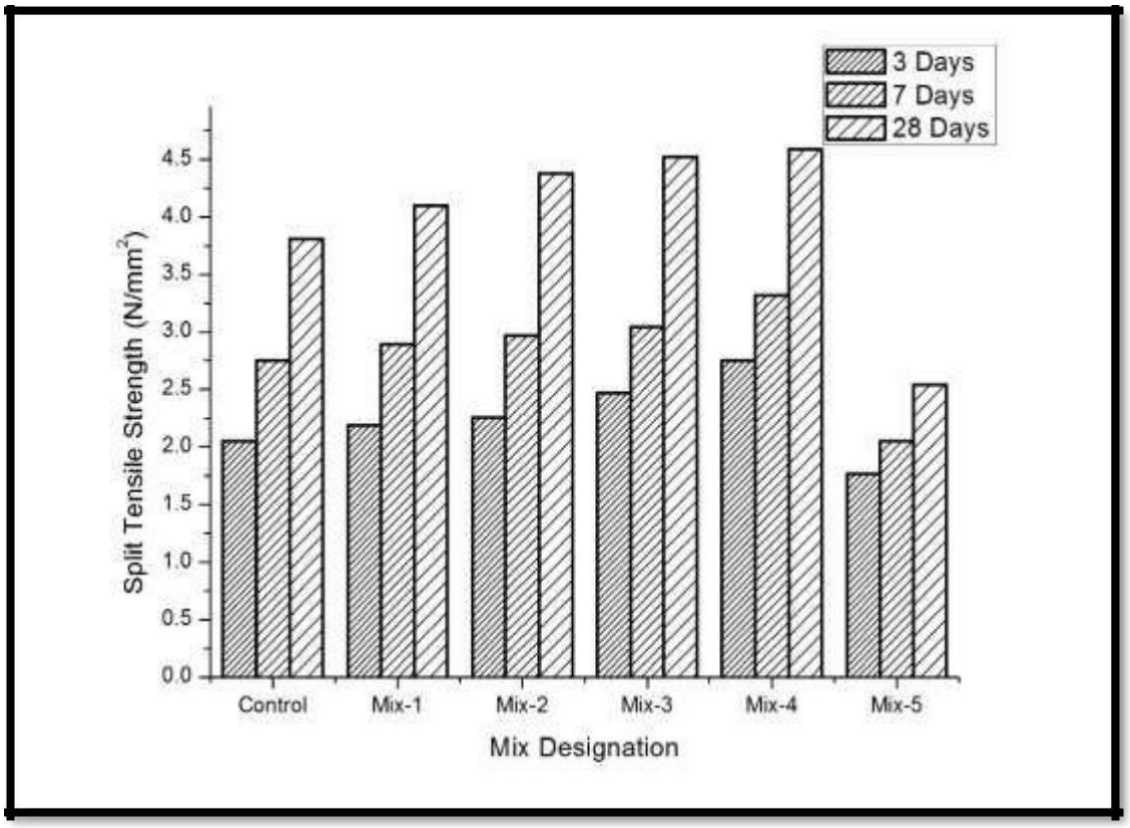

Fig. 2: Split tensile strength test results of concrete test specimen at 3, 7 and 28 days of curing.

V. CONCLUSION

- The characteristics of concrete with partial replacement is same as the concrete without partial replacement, hence the Steel Slag can be considered for construction.
- The compressive strength increases with increase in percentage of steel slag by 40% by weight of fine aggregate. The compressive strength decreases after 40% replacement of steel slag.
- The split tensile strength also increases with increase in percentage of steel slag by 40% by weight of fine aggregate and then reduces after that.
- From the results of compressive strength and split tensile strength conducted for 3 days, 7 days and 28 days curing, 40% replacement of steel slag in fine aggregate is the optimum percentage of replacement of M30 grade concrete and decreases considerably for further replacement of slag in concrete.
- Further increasing the percentages of partial replacement workability decreases because Steel Slag absorbs more amount of water and there are chances of corrosion to take place for reinforcement at higher percentage of Steel Slag replacement. Hence it can be concluded that we can use the Steel Slag as partial replacement up to 40% only for better achievement of strength parameters.

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