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Effect of partial Replacement of fine aggregate with steel slag and complete replacement of natural coarse aggregate in cement concrete

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ABSTRACT:
This paper deals with partial replacement of fine aggregate with steel slag and complete replacement of course aggregate with recycled aggregate. The steel Industry generates enormous amount of solid waste every year. To utilize these waste products is one of the major problems in India causing various environmental hazard. This leads to the wastage of potential sources of steel. However, this can be utilized partially in cement concrete in place of fine aggregate. In addition, natural coarse aggregates are moving towards scarcity because of lack of resources; therefore, their production and shipment has become more difficult. At same time, now a days, there are large number of demolished concrete structure which leads to land pollution and space congestion mainly in urban areas. So, the coarse aggregate obtained from demolished structure can be utilized in the construction of new concrete structure. Thus, this would ensure the utilization of waste material in structures thereby reducing the land pollution. The addition of steel slag would provide some strain to the concrete thereby increasing its ductility. In addition, the use of recycled aggregate would facilitate good bond strength in case reinforced concrete structure. The research reports that the concrete having steel slag and recycled coarse aggregate had greater strength than the plain concrete.

KEYWORDS: Industrial steel slag, Recycled coarse aggregate, demolished structure, environmental hazard

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I. INTRODUCTION

This research deals with the effect in properties of concrete when coarse aggregate is completely replaced by recycled aggregate and partial replacement of fine aggregate with steel slag. Today steel industry is one of the major contributors in the Indian economy. Consequently, in steel industry enormous amount of steel slag is generated every day. This steel slag is mostly treated as waste product. To utilize these waste products is one of the major problems in India. However, it would be good idea to use this steel slag in concrete as partial replacement of fine aggregate. As concrete is very weak in tension, the addition of steel slag would provide some ductility. The same has been investigated in this paper. In addition, natural coarse aggregates are moving towards scarcity because of lack of resources; therefore, their production and shipment has become more difficult. At same time, now a days, there are large number of demolished concrete structure which leads to land pollution and space congestion mainly in urban areas. So, the coarse aggregate obtained from demolished structure can be utilized in the construction of new concrete structure. Thus, this would ensure the utilization of waste material in structures thereby reducing the land pollution. The difference between the properties of recycled aggregate and natural aggregate are caused due to the old mortar attached to the recycled aggregate. This would facilitate better interlocking between the constituent of concrete leading it to less prone to failure.

Various researchers have shown that the partial replacement of fine aggregate with fly ash, rice husk, coir fiber etc. in optimum proportion increases the strength of concrete. Qasrawi et al. (2009) have reported that concrete having fine aggregate partially replaced by steel slag had greater strength than plain concrete and the addition of steel slag reduces the workability. While Ali et al. (2012) used recycled glass content in self-compacting concrete. Fine aggregate in proportions of 0%, 10%, 20%, 30%, 40%, and 50% have been replaced. The experimental results showed that the slump flow increased with the increase of recycled glass content and decreasing the concrete strength making suitable for self-compacting concrete. Bai et al. (2020) reported about the content of old mortar attached to the recycled aggregate and its importance in concrete. There is research gap

between partial replacement of fine aggregate and natural coarse aggregate. From here itself the idea of using steel slag along with recycled aggregate is taken.

In this investigation, a mix design of M20 and M30 grade of concrete is performed as per the bureau of Indian standards, IS 10262- 1982. In the concrete mix, fine aggregate is partially replaced by steel slag in proportion 10%, 20%, 30% and 40% and the natural coarse aggregate is completely replaced by recycled coarse aggregate. The steel slag is taken from Bokaro steel plant while the recycled aggregate is taken from local demolished concrete structure. In the preliminary investigation, mix design of concrete having natural fine aggregate and coarse aggregate is performed for reference measure. Properties of concrete like compressive strength, split tensile strength and flexural strength is studied. To conduct these tests, cubes, cylinders and beams are casted. From the result, the change in these properties of concrete for different proportion of steel slag is reported.

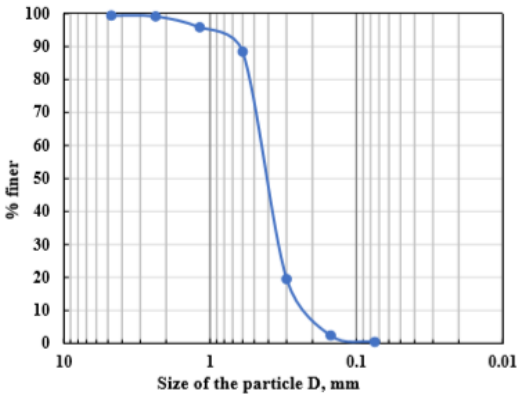
In the comparison of results, the concrete having steel slag content shows better result but to a certain limit. As the replacement level of sand with steel slag is increased, the strength tends to decrease due to less moisture absorption capacity of steel slag in comparison to sand. This deficiency is overcome by the use of recycled aggregate which have more moisture absorbing capacity. Therefore, there is optimum percentage of steel slag to obtain maximum strength of concrete. This makes the use of steel slag by replacing sand and the use of recycled aggregate a promising concept.

II. MATERIALS AND METHODOLOGY

In this study, Portland Cement of 53 grade confirming to IS 12269-1987 is used, fine aggregates, natural coarse aggregates, recycled coarse aggregate, steel slag is used. Fine aggregate was taken from the locally available river. Specific gravity was 2.61. To classify the type of sand as per unified classification system, gradation test of the sand was carried out. From the particle size distribution curve, D_{10}, D_{30} and D_{60} were 0.217, 0.346 and 0.476 mm respectively. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) were found to be 2.19 and 1.159 respectively. As per ASTM D2487-17, the sand is classified as poorly graded sand (SP) belonging Zone II.

The steel slag was taken from the Bokaro steel plant having specific gravity in the range 2.6 to 3.5 and size ranging from 2.36mm to 4.75mm. The particle size distribution curve for steel slag is plotted for the comparison with the fine aggregate.

The recycled aggregate was taken from the locally demolished concrete structure. The water absorption test is conducted. The water absorption for natural coarse aggregate comes out to be 0.8% while that for recycled aggregate is 1.6%. Recycled aggregate absorbs more water due to mortar attached to it.



III. EXPERIMENTAL SETUP AND RESULT

The main objective of this research was to determine the properties of concrete containing recycled coarse aggregate and various level of replacement of fine aggregate with steel slag. For that purpose, compressive strength test was performed using concrete cube of size 150mm x 150mm x150mm. For split tensile strength test cylinders of diameter 150mm and of length 300mm is prepared. Flexural strength is performed on beam of size 100mm x 100mm x 500 mm.

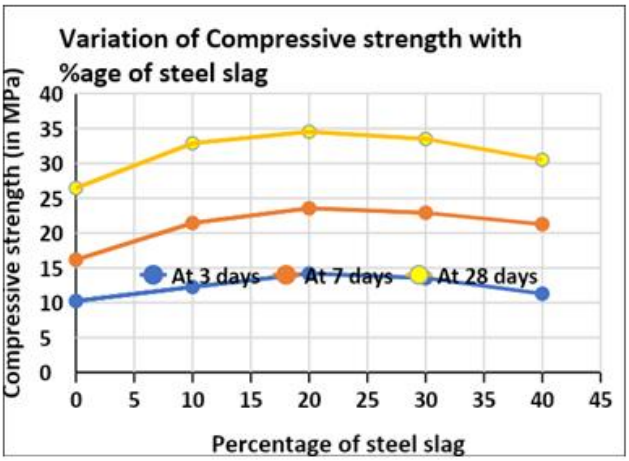
A. Compressive strength

Standard concrete cube having 0% replacement of fine aggregate and natural coarse aggregate is prepared for M20 and M30 grade of concrete as per IS 10262:2009. Cubes are prepared at different level of fine aggregate replacement

(10%, 20%, 30%, 40%) with steel slag and complete replacement of natural coarse aggregate by recycled coarse aggregate. Three cubes were tested at 3days, 7days, and 28days for each of the specifications in compression testing machine. The average value of compressive strength was reported in Table1.

Table 1 Average compressive strength of M20 grade concrete

Sl No.	Percentage of steel slag (%)	Average Compressive strength at 3 days (in MPa)	Average Compressive strength at 7 days (in MPa)	Average Compressive strength at 28 days (in MPa)
01	0	10.23	16.15	26.44
02	10	12.25	21.43	32.87
03	20	14.18	23.54	34.52
04	30	13.52	22.90	33.48
05	40	11.28	21.26	30.50

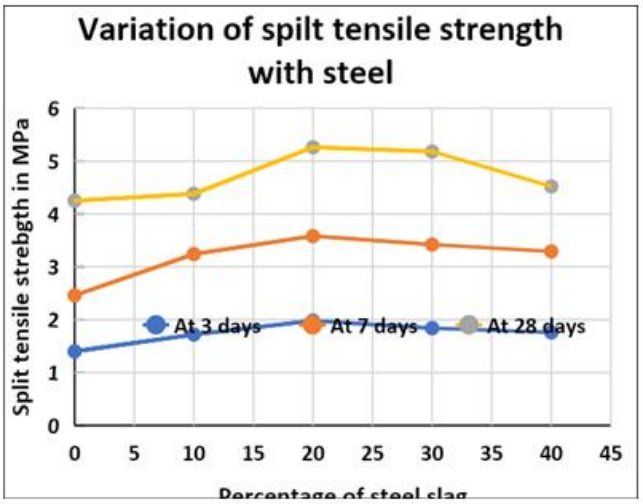


B. Split Tensile strength

Split tensile strength of concrete cylinders were performed. Average split strength was reported for every percentage of steel slag in Table 2.

Table 2 Average split tensile strength of m20 grade of concrete

Sl No.	Percentage of steel slag (%)	Average split tensile strength at 3 days (in MPa)	Average split tensile strength at 3 days (in MPa)	Average split tensile strength at 3 days (in MPa)
01	0	1.40	2.46	4.25
02	10	1.72	3.24	4.38
03	20	1.98	3.58	5.26
04	30	1.84	3.42	5.18
05	40	1.76	3.29	4.52

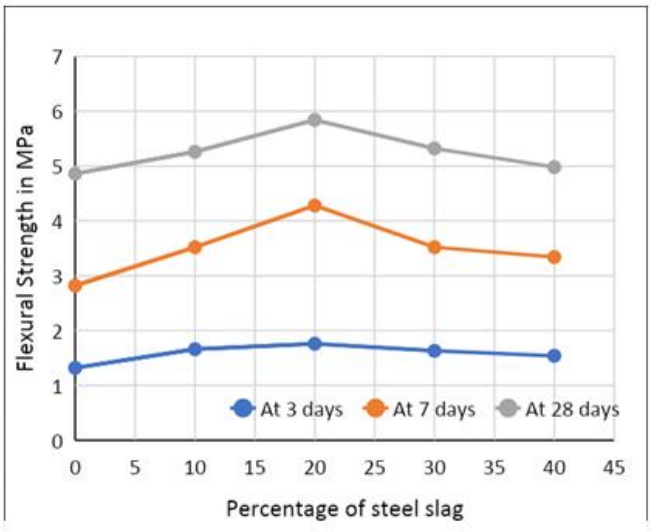


C. Flexural Strength Test

Flexural test was performed on concrete beam of cross section 150mm x 150mm. The beam was placed in UTM in such a manner that two-point loading test can be performed. The average flexural result at 3days, 7days and 28 days for each percentage of steel slag is reported in Table 3.

Table 3 Average flexural strength of M20 grade of concrete at different percentage of steel slag

Sl No.	Percentage of steel slag (%)	Average flexural strength at 3 days (in MPa)	Average flexural strength at 7 days (in MPa)	Average flexural strength at 28 days (in MPa)
01	0	1.32	2.82	4.86
02	10	1.66	3.52	5.26
03	20	1.76	4.28	5.84
04	30	1.63	3.52	5.32
05	40	1.54	3.34	4.98



IV. CONCLUSIONS

From the result of compressive strength test, split tensile strength test and flexural strength test, it is quite evident that with the addition of steel slag, the strength of concrete increases. Following conclusions can be drawn.

- From the graph it can be reported that as the percentage of steel slag increases, the strength

increases. After certain limit the strength decreases.

- From the investigation, the optimum percentage of steel slag is reported to be 20%.
- The use of recycled coarse aggregate provides concrete the ability to absorb more water and consequently, the structure would have less creep and shrinkage.
- The addition of steel slag in concrete also provides some ductility.
- From the study, it is investigated that improvement in strength also depends on shape, size and surface texture of steel slag aggregates, which provide better adhesion between the particles and cement matrix.
- This investigation recommends the use of steel slag, a waste cheap material used as fine aggregates and recycled coarse aggregate in M20 grade of concrete. This eliminates the disposal problem of demolished concrete structure which is need of the hour for environment.

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