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Effect of Addition of LD Slag Aggregate on Fresh and Hardened Properties of Cement Concrete

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Cement concrete lends itself to a multitude of unique designs because of its many beneficial characteristics. Because of its inexpensive cost and desirable physical qualities, concrete is one of the most extensively utilised civil engineering materials. In this article, LD (Linz and Donawitz) slag is used to partially replace fine aggregate. This research mainly concentrates on partial replacement of natural fine aggregate with LD slag fine aggregate. Since the construction industry activity in India is gaining its momentum there is a scarcity of natural resources to overcome this problem substitute materials should be used to make the concrete and studies have to be conducted. In this study such an attempt is made where natural fine aggregate is partially replaced with LD slag fine aggregate. The purpose of this work is to investigate the fresh and hardened qualities of M-30 grade concrete in which LD slag has been partially replaced by the weight of natural fine aggregate in the ratios of 0%, 10%, 20%, 30%, 40%, and 50%. The slump test is used to investigate the features of workability. Compressive and split tensile strength tests are used to investigate the hardened characteristics of concrete. After 28 days of curing, the test is performed, and a mathematical regression model is constructed for the same.

Keywords: LD Slag; Compressive strength; Split Tensile; Slump test; Regression Model

I. INTRODUCTION

Concrete is a composite product made by combining cement, aggregates, water, and if necessary, an admixture, and it go through a variety of processes including handling, placement and curing. The homogeneity of concrete is enhanced through inspection and control at all stages of the manufacturing process, from the purchase of raw materials to the creation of the finished product. Concrete is made up of four elements that are divided into two groups. There are two groups: active and inactive. Water and cement make up the active group. Fine and coarse particles make up the inactive group.

The transformation of pig iron into liquid steel generates LD slag in the steel-making process. The initials LD refer to the fact that the steel is made in an oxygen converter of the LD type (Subathra & Gnanavel, 2014). The letters LD stand for Linz and Donawitz, two Austrian locations where the technique was created. Basic Oxygen Process is another name for this procedure. In Indian steel factories, around 200 kg of LD slag is produced each tonne of hot metal produced. Only around a quarter of this is repurposed in India, compared to 70-100 percent in other nations (Padmapriya *et al.,* 2015)

To make concrete elements such as cement, water, aggregates and occasionally admixtures are combined in the proper amounts. When this mixture is poured into moulds and left to cure, it hardens into a rock-like mass known as concrete. Cement is the most expensive and energy-intensive component of concrete. The cost of concrete can be decreased by partially replacing cement and by replacing natural aggregates and other substitute materials (Rafat Siddique, 2004).

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II. EXPERIMENTAL WORK

A. Materials

In this Experiment, the following materials are used: for testing program, 43 grade Ordinary Portland Cement (OPC) with a specific gravity of 3.15 and adhering to IS: 8112-2013 was employed. Fine aggregate: This experimentation programme employed locally accessible river sand with a specific gravity of 2.63 and a zone II confirming to IS: 383-2016. Water For the preparation and curing of specimens, potable tap water is utilised. JSW, Toranagallu, Hosapete, LD slag fine aggregate is procured.

B. Mix Design

In this combination, fine aggregate is largely replaced with LD slag fine aggregate, while cement and coarse aggregate are kept unchanged.

a. M0 refers to control concrete that hasn't had any LD slag aggregate added to it.
b. M1 refers to the inclusion of 90% fine aggregate and 10% LD slag fine aggregate to the mix.
c. M2 refers to the inclusion of 80 percent fine aggregate and 20% LD slag fine aggregate to the mix.
d. M3 refers to the inclusion of 70% fine aggregate and 30% LD slag fine aggregate to the mix.
e. M4 refers to the inclusion of 60% fine aggregate and 40% LD slag fine aggregate to the mix.
f. M5 refers to the inclusion of 50% fine aggregate and 50% LD slag fine aggregate to the mix.

C. Methods

The proportions of cement, fine aggregate and coarse aggregate were 1:1.63:2.83 matching to M-30 grade concrete and the mix design was done according to IS 10262: 2019. The concrete was made by homogeneously combining all of the elements. The needed amount of water was added to this dry mix (w/c=0.44) and the entire mass was homogeneously mixed once again. The specimens were smoothed after the wet concrete was put into the moulds which were compacted in three layers by manual compaction. The specimens were de-moulded and moved to curing tanks after 24 hours, where they cured for the requisite number of days. Compressive strength was measured using specimens with dimensions of 150x150x150 mm. They were put through their faces on a 3000 kN compressive strength testing equipment in accordance with IS: 516-1959. The following equation is used to compute compressive strength:

$$F=P/A$$

Where, F= Compressive strength of specimen (in MPa), P= Maximum load applied to the specimen (in N) and A= Cross sectional area of the specimen (in mm^2).

Table 1. Findings of slump test

Sl. No.	Mix Designation	Slump in mm
1	M0	100
2	M1	105
3	M2	110
4	M3	110
5	M4	115
6	M5	120

A cylindrical specimen with a diameter of 150 mm and a length of 300 mm was produced to test the Split tensile strength. On a 3000 kN capacity Compression testing machine, a split tensile strength test was performed in accordance with IS: 5816-1999. The following equation is used to compute the Split Tensile Strength:

$$F=2P/(\pi DL)$$

Where, F= Split Tensile strength of specimen (in MPa), P= Load at failure (in N),L= Length of cylindrical specimen (in mm) and D= Diameter of the cylindrical specimen (in mm).

III. RESULTS AND ANALYSIS

A. Slump Test for Concrete

The Concrete Slump test is used to determine the consistency of new concrete before it hardens. It is used to test the workability of freshly mixed concrete and as a result the ease with which it flows. It can also be used to detect a batch that has been poorly mixed. The slump cone test consists of a steel mould in the shape of a cone with an interior top diameter of 10cm, a base diameter of 20cm, and a height of 30cm, as illustrated in Figure 1.

Figure 1. Slump test

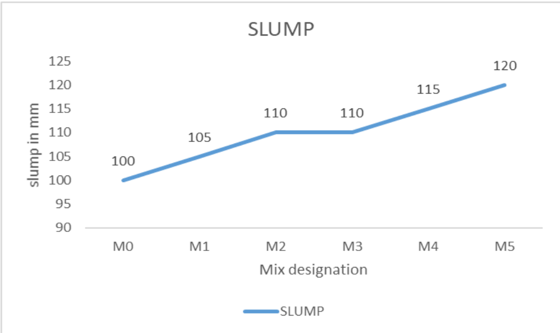

Figure 2. Findings of slump test

B. Compressive Strength Test

The capacity of a material or constitution to endure axial masses tends to lower the scale's compression strength. Compression testing machine [CTM] is used to measure it. Concrete may be produced to have an Extremely high compressive strength. In concrete specimens, natural fine aggregate is partially substituted by LD slag fine aggregate at different percentages, while cement and natural coarse aggregate remain constant. Compressive force for assessing, mould dimension (150x150x150) mm, as indicated in Figure 3. According to Indian standard 516-1959, the compression testing equipment has a capacity of 3000 kN.

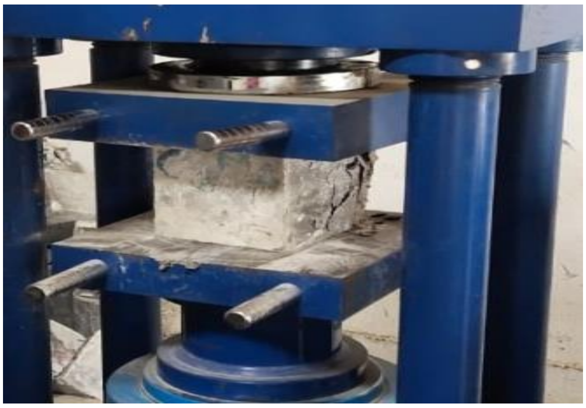

Figure 3. Compressive strength test

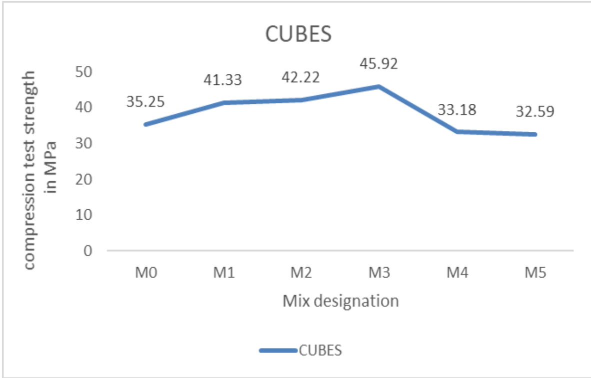

Figure 4. Compressive strength of concrete for 28 days

Table 2. Compressive strength of concrete for 28 days

Sl.No.	Mix Designation	Compressive strength (MPa) for 28 days
1	M0	35.25
2	M1	41.33
3	M2	42.22
4	M3	45.92
5	M4	33.18
6	M5	32.59

C. Split Tensile Strength Test

A cylinder specimen with a diameter of 150mm and a height of 300mm was cast to conduct the Split Tensile Strength test. The Spilt Tensile test was performed according to Indian Standard 5816-1999 on a Compression Testing Machine with a capacity of 3000 kN (Figure 5).

Figure 5. Split tensile strength test

Table 3. Split Tensile Strength of Concrete for 28 Days

Sl. No.	Mix Designation	Split Tensile strength (MPa) for 28 days
1	M0	2.33
2	M1	3.01
3	M2	3.06
4	M3	3.41
5	M4	3.18
6	M5	3.15

IV. REGRESSION MODEL

A. Compressive Strength

The multidimensional regression model to predict the compressive strength of concrete is done by considering two variables natural fine aggregate and LD slag fine aggregate. the standard mathematical format Equation (1) is used to obtain the required regression model with two variables.

$$FC' = b1x1 + b2x2 + a \quad (1)$$

Where

x1= Sum of the all the fine aggregate variant starting from the 0.00, 0.90, 0.80, 0.70, 0.60, 0.50.

x2 = Sum of the all the LD Slag variant ranging from 0.00, 0.10, 0.20, 0.30, 0.40, 0.50.

y = Experimental compressive strength obtain from the above Table 2.

Here B1 can be calculated by using the following formula:

$$B1 = (((\sum x_1 y \ X \sum x_2^2) - \left(\sum x_1 x_2 \ X \ \sum x_2 y\right)) / \ ((\sum x_1^2 \ X \ \sum x_2^2) - (\sum x_1 x_2 \ X \sum x_1 x_2)\big))$$

$$B2 = (((\sum x_2 y \ X \sum x_1^2) - \left(\sum x_1 x_2 \ X \ \sum x_1 y\right)) / ((\sum x_1^2 \ X \ \sum x_2^2) - (\sum x_1 x_2 \ X \sum x_1 x_2)\big))$$

a=Mean of(y) – b1X mean of(x1) – b2X mean of(x2).

From the above steps the regression model is obtained as follows:

Fc=11.754 X x1- 14.766 X x2 + 35.25

Table 4. Experimental and regression model compression test values

Sl.no	Mix Designation	Compressive strength Experimental values (MPa)	RM Values (MPa)	EXP/ RM
1.	M0	35.25	35.25	1.00
2.	M1	41.33	44.35	0.93
3.	M2	42.22	41.70	1.01
4.	M3	45.92	39.04	1.17
5.	M4	33.18	36.40	0.90
6.	M5	32.59	33.74	0.96

The regression model (RM) and experimental (EXP) values. According to the given data, the EXP/RM ratio is in the range of 0.93 to 1.17. This demonstrates how well the suggested regression model fits experimental data.

B. Tensile Strength

By considering the values obtained from experimental compression test and experimental tensile test linear regression model is developed as shown the general equation below:

$$Ft' = bx + a \quad (2)$$

Where

x= sum of square root of Experimental compression test values ranging from 5.93, 6.42, 6.49, 6.77, 5.76 and 5.70.

b= $\frac{\sum x^2}{\sum \sqrt{x}}$

a =mean (y) – b X Mean(x)

From the above steps the regression model is obtained as follows:

Ft= 0.28735 X x + 1.24561

Table 5. Experimental and regression model split tensile test values

Sl.no	Mix Designation	Split tensile Experimental values (MPa)	RM Values (MPa)	EXP/ RM
1.	M0	2.33	2.95	0.79
2.	M1	3.01	3.09	0.97
3.	M2	3.06	3.11	0.98
4.	M3	3.41	3.19	1.07
5.	M4	3.18	2.90	1.10
6.	M5	3.15	2.89	1.09

The regression model (RM) and experimental (EXP) values. According to the given data, the EXP/RM ratio is in the range of 0.79 to 1.10. This demonstrates how well the suggested regression model fits experimental data.

V. OBSERVATIONS AND DISCUSSIONS

In the present work, the effect of addition of LD slag aggregate on fresh and hardened properties of cement concrete is investigated and following observations were made from the experiments conducted. The test result show that the workability increased with addition of LD slag fine aggregate.

At 28 days of curing period, the compressive strength increased as the replacement level of LD slag fine aggregate increased. The cement and natural coarse aggregate in all mixes were kept constant. The compressive strength of Mix M1, M2, M3 is having higher compressive strength by 17.24%, 19.77%, 30.26%, respectively, and for mix M4 and M5 indicating negative value of 5.87% & 7.54% compared to control concrete. Mix M3 was showing highest compressive strength compared to all other mixes. At 28 days of curing period, the split tensile strength of Mix M1, M2, M3, M4, M5 has higher split tensile strength by 29.18%, 31.33%, 46.35%, 36.48%, 35.19%, respectively, compared to control concrete. Mix M3 was showing the highest split tensile strength compared to all other mixes.

From the experimental results of compressive strength and split tensile strength of control concrete and concrete made with LD slag fine aggregate is performing better than control concrete.

VI. CONCLUSION

The following conclusion can be formed based on the qualities of fresh concrete and limited strength tests.

1. The use of LD slag fine aggregate to concrete increases its workability.
2. Workability increases as the percentage of LD slag fine aggregate increases.
3. Outcomes of compressive strength reveal that till M3 mixes, they have better results than control concrete. However, the M3 mix yields the best outcomes.
4. The split tensile strength findings reveal that all of the mixes outperform the control concrete. However, the M3 mix yields the best outcomes.
5. A portion of the LD slag fine aggregate can be substituted with natural fine aggregate. When compared to control concrete, this material will produce the best results.

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