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# Strength Properties of Steel Slag in Concrete

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***Abstract:*** **Artful waste management is an essential aspect of viable steel industry. In this context, management of waste means diminishing waste where possible and reutilization of materials which might otherwise become waste. Management of solid waste practices has identified the reduction, recycling, and reuse of wastes as important for management of sustainable resources. Steel slag, a by-product obtained from steel formation during the separation of the molten steel from impurities in furnaces. A molten liquid melt obtained from slag is a complex silicates and oxides that solidify on cooling. A partial replacement of steel stag is referred in this study in terms of fine aggregate material. This study is carried out to understand the effects in terms of compressive, tensile and flexural strength. It will helpful for other researchers to know more about this field.**
**The aim of this experiment is to study the effect of Steel Slag as partial replacement of Fine Aggregate with 0%, 10%, 20%, 30%, and 40% are tested for M25& M30 grade of concrete after 7, 14, 28 and 50 days water curing. The result shows that variation in much strength for Fine aggregate replaced by Steel slag for 7, 14, 28 and 50 days water curing.**

***Keywords: Concrete, Steel slag, Fine Aggregates, Compressive Strength, Flexural Strength and Tensile Strength***

## I. INTRODUCTION

Aggregates are inert grainy materials such as sand, gravel or crushed stone that are an end product in their own right and are an essential ingredient in concrete. Aggregate, which contributes 60 to 75 percent of the total volume of concrete, are divided into two major categories--fine and coarse. Fine aggregates commonly comprises of natural sand or crushed stone with maximum particles passing through a sieve of 4.75mm. Fine aggregate(natural sand) which has been washed and sieved to remove larger particles i.e. more than 5 mm. IS specifications categorize the sand into four zones as per to its grading as fine aggregate of grading Zone-1 to grading Zone-4. The four grading zones which shows that it become finer from Zone-1 to Zone-4 progressively from 90% to 100% of the fine aggregate passes 4.75 mm IS sieve and 0 to 15% passes 150 micron IS sieve which depends on its grading zone. Steel slag, a by-product obtained from steel formation, is produced by the process of separation of the molten steel from impurities in steel-making furnaces. A molten liquid melt obtained from slag is a complex silicates and oxides that solidify on cooling. Essentially all steel is made in integrated steel plants using a sort of the basic oxygen process or in specialty steel plants (mini-mills) using an electric arc furnace process. Nowadays open hearth furnace process is of no use.

## II. LITERATURE REVIEW

Sultan A.Tarawneh, et.al .(2014) [10], in their study entitled "Effect of using Steel Slag aggregate on Mechanical Properties of Concrete".In this experiment their investigation is to evaluate the physical and mechanical properties and characteristics of steel slag aggregate concrete in comparison with the typical crushed limestone stone aggregate concrete. After proper investigation they founds that compressive strength at the stage of 7 days shows much more strength as compared to that of 28 days. They conclude that the added slag show good results at early age. Hence steel slag could be utilized as partial replacement.

P. Sateesh Kumar (2015) [7], in their paper entitled "Study on Behavior of Concrete Mix Replacing Fine Aggregate with Steel Slag at different Properties". The aim of this experiment is to study the effect of partial replacement of steel slag on various strength and durability properties of concrete by using mix design. The test is carried out at the replacement level of 10%, 20%, 30%, 40% at the ages of 7 and 28 days.They concludes that for conventional concrete, partial replacement of fine aggregate by steel slag improve the compressive, tensile, flexural strength. The viability of steel slag in concrete is found.

S.T.Borole, et.al.(2016) [9], in their paper entitled "Replacement of Fine Aggregate by Steel Slag". In this research paper M30 concrete with high volume steel slag replacement for fine aggregate is studied to examine the changes in properties of compressive strength, flexural strength and split tensile strength. After comparison with conventional concrete property results shows that replacing about 0%, 25 % and 50% of steel slag aggregates by that of fine aggregate will not show any harm and any adverse effect to the durability and strength. The test is carried out after 7 and 28 day of curing.

*OBJECTIVES*

To determine the optimum quantity of steel slag as a fine aggregate to enhance the strength of concrete by conducting related tests like Compressive strength, Tensile strength and Flexural strength at replacement level of 10%,20%,30% and 40%.

## III. MATERIALS USED

*A. Cement*: As per IS 8112-1989, ordinary Portland cement of grade 43 is used. The initial setting time of cement is 30 minutes and 3.15 is the specific gravity of cement.

*B. Fine Aggregate*: Natural river sand which is locally available obtained from the Narmada river of Hoshangabad City is used as fine aggregates. Natural sand passing through

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4.75mm sieve and retained on the 600 micron sieve with the specific gravity of 2.65 was used. Zone 2 was the grading of the aggregate.

*C. Coarse Aggregate*: Aggregates greater than 4.75mm are considered as Coarse aggregate. Crusted coarse aggregate of 20mm downsize were used with fineness modulus of 4.32 and a specific gravity of 2.84.

*D. Steel Slag*: In this experiment the steel slag collection is done from New Kabadkhana, Imamganj.Bhopal. Nowadays steel products are used everywhere. Steel is durable and strong. It is obtained either from conversion of iron to steel in a BOF (Basic Oxygen Furnace) or by the melting of scarp to make steel in the EAF (Electric Arc Furnace).

*E. Water*: As per the IS: 456-2000 specifications, clean and potable water was used.

*CHARACTERISTICS APPLICATION*: Steel slag is used in many fields of construction industry where its distinct characteristics can be put to effective use such as road base course material, course aggregate for concrete, calcium silicate fertilizer, blending material for Portland cement and soil improvement.

## IV. METHODOLOGY

In this study, M25, M30, mix proportion is designed as per the guidelines of Indian Standard recommended method IS 10262:2009. Cement of 43 grade is used; also zone 2 is taken into account from IS 383(1970). Steel slag is replaced by 10%, 20%, 30% and 40%.The coarse aggregate of size 20mm is selected which is retained on 10mm sieve. Fine aggregate passing through 4.75mm sieve and retained on 600micron sieve used.

## V. EXPERIMENTAL TESTS AND RESULTS

*A. SLUMP CONE TEST*

To study the Workability of fresh concrete, slump cone test is conducted. This test was carried out for M 25 & M 30 grade of concrete; the results are tabulated and plotted below.

Table 1.Slump test results for M25 and M30 grade of concrete

| Sr. No. | % Replacement of Fine Aggregate by Steel Slag | Slump Value In MM For M 25 | Slump Value In MM For M 30 |
|---|---|---|---|
| 1 | 0% | 75 | 75 |
| 2 | 10% | 73 | 69 |
| 3 | 20% | 66 | 61 |
| 4 | 30% | 55 | 52 |
| 5 | 40% | 52 | 48 |

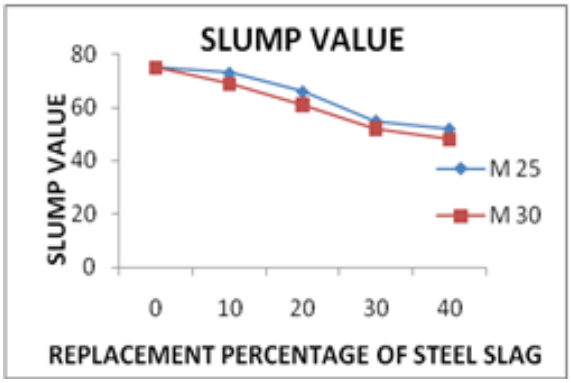


Figure 1: Slump Values of M 25 and M 30 grade of concrete

*COMPACTION FACTOR*

As per IS: 1199 – 1959, to find the workability of fresh concrete, compaction factor test is conducted by using Compacting factor apparatus. For the determination of workability of concrete this test is known for its accuracy. The test results are tabulated and plotted below.

Table 2.Compaction factor test results of M25 and M30 grade of concrete

| Sr. No. | % Replacement of Fine Aggregate by | Compaction factor Value in MM for M 25 | Compaction factor Value in MM for M 30 |
|---|---|---|---|
| 1. | 0% | 0.845 | 0.855 |
| 2. | 10% | 0.848 | 0.861 |
| 3. | 20% | 0.853 | 0.868 |
| 4. | 30% | 0.858 | 0.877 |
| 5. | 40% | 0.864 | 0.884 |

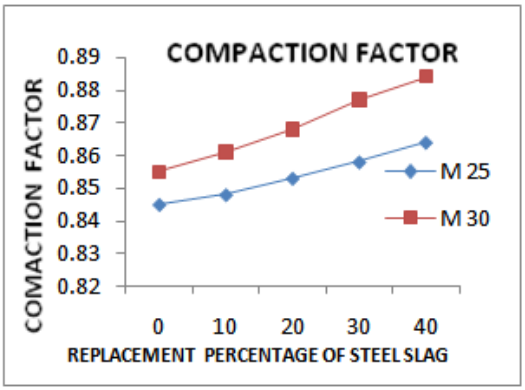


Figure 2: Compaction factor graph for M 25&M 30 grade of concrete

*B. COMPRESSIVE STRENGTH TEST*

(1). Concrete cubes (150mmx150mm) were casted for 0%, 10%, 20%, 30%, 40% replacement of steel. The compressive strength for M25 grade of concrete is tested for 7, 14, 28 and 50 days of curing and the results are tabulated and plotted below.

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Table3.Avg.Compressive strength test results for M25 grade of concrete

| Sr. No. | % Replacement of Fine Aggregate by Steel Slag | Average Com-Pressive Strength ($N/mm^2$) | Average Com-pressive Strength ($N/mm^2$) | Average Com-pressive Strength ($N/mm^2$) | Average Com-pressive Strength ($N/mm^2$) |
|---|---|---|---|---|---|
| | | 7 DAYS | 14 DAYS | 28 DAYS | 50 DAYS |
| **1.** | 0% | 18.30 | 23.23 | 32.54 | 37.19 |
| **2.** | 10% | 19.63 | 24.10 | 33.60 | 39.03 |
| **3.** | 20% | 22.32 | 26.44 | 36.33 | 40.26 |
| **4.** | 30% | 24.06 | 27.92 | 38.50 | 37.22 |
| **5.** | 40% | 23.08 | 27.14 | 37.22 | 41.26 |

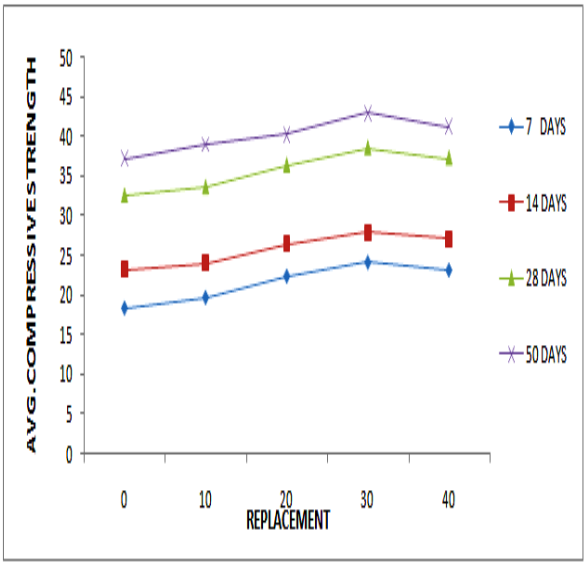


Figure 3: Compressive Strength Graph for M 25 grade of Concrete

(2). Concrete cubes (150mmx150mm) were casted for 0%, 10%, 20%, 30%, 40% steel slag replacement. The compressive strength for M30 grade of concrete is tested for 7, 14, 28 and 50 days of curing and the results are tabulated and plotted below.

Table 4.Avg.Compressive strength test results for M30 grade of concrete

| Sr. No. | % Replacement of Fine Aggregate by Steel Slag | Average Com-pressive Strength ($N/mm^2$) | Average Com-pressive Strength ($N/mm^2$) | Average Com-pressive Strength ($N/mm^2$) | Average Com-pressive Strength ($N/mm^2$) |
|---|---|---|---|---|---|
| | | 7 DAYS | 14 DAYS | 28 DAYS | 50 DAYS |
| 1. | 0% | 22.77 | 27.19 | 39.25 | 42.48 |
| 2. | 10% | 24.69 | 28.73 | 40.50 | 43.85 |
| 3. | 20% | 26.85 | 30.13 | 42.50 | 46.15 |
| 4. | 30% | 28.44 | 31.98 | 45.35 | 44.21 |
| 5. | 40% | 27.48 | 31.22 | 44.21 | 47.25 |

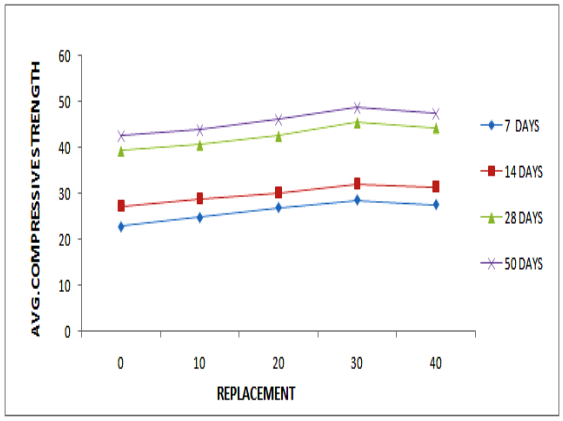


Figure 4: Compressive Strength Graph for M 30 grade of Concrete

- From both of the above graph i.e. M25 and M30, the compressive strength of concrete is increased gradually from 0% to 20% and achieved a maximum value at a replacement of 30% Steel slag in fine aggregate afterwards decreased for 40% replacement of steel slag.
- However compressive strength of concrete for the partial replacement of Fine aggregate with Steel slag of 40% does not show major decrement as compared to 30% and can be use by control mix.

*C. SPLIT TENSILE STRENGTH TEST*

Concrete cylinders (150mmx300mm) were casted for 0%, 10%, 20%, 30%, 40% replacement of steel slag. The split tensile strength for M25 and M30 grade of concrete is tested for 28 days of curing and the results are tabulated and plotted below.

Table 5.Avg.Tensile strength test results for M25 and M30 grade of concrete

| Sr. No | % Replacement of Fine Aggregate by Steel Slag | Average Tensile Strength for M25. ($N/mm^2$) | Average Tensile Strength for M30. ($N/mm^2$) |
|---|---|---|---|
| | | 28 DAYS | 28 DAYS |
| 1. | 0% | 2.533 | 3.376 |
| 2. | 10% | 2.663 | 3.496 |
| 3. | 20% | 2.75 | 3.666 |
| 4. | 30% | 2.956 | 3.906 |
| 5. | 40% | 2.866 | 3.793 |

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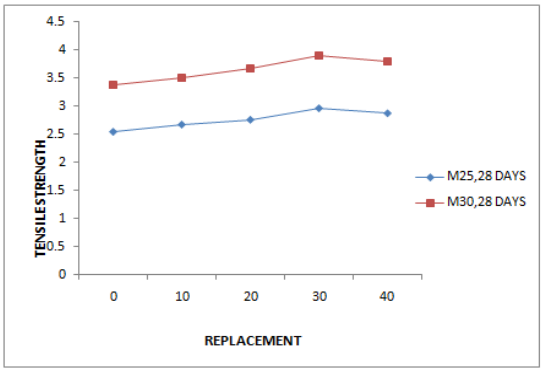


Figure 5: Tensile Strength Graph For M25 & M30 at 28 Days.

- From both of the above graph i.e. M25 & M30 grade of concrete, the Split tensile strength of concrete is increased gradually from 0% to 20% and attained a maximum value at a replacement of 30% Steel slag in fine aggregate afterwards decreased for 40% replacement of steel slag.
- However Split tensile strength of concrete for the partial replacement of Fine aggregate with Steel slag of 40% does not show major decrement as compared to 30% and can be use by control mix.

*D. FLEXURAL STRENGTH TEST*

Concrete beams (500mmx100mmx100mm) were casted for 0%, 10%, 20%, 30%, 40% replacement of steel slag. The Flexural strength for M25 & M30 grade of concrete is tested for 28 days of curing and the results are tabulated and plotted below.

Table 6 .Avg. flexural strength test results for M25 and M30 grade of concrete

| Sr. No | % Replacement of Fine Aggregate by Steel Slag | Average Flexural Strength for M25. ($N/mm^2$) | Average Flexural Strength for M30. ($N/mm^2$) |
|---|---|---|---|
| | | 28 DAYS | 28 DAYS |
| 1. | 0% | 2.730 | 3.352 |
| 2. | 10% | 2.972 | 3.457 |
| 3. | 20% | 3.491 | 3.801 |
| 4. | 30% | 3.733 | 4.183 |
| 5. | 40% | 3.422 | 3.974 |

- From the above Graph i.e. M25 & M30 grade of concrete, the Flexural Strength of concrete is increased gradually from 0% to 20% and attained a maximum value at a replacement of 30% Steel slag in fine aggregate afterwards decreased for 40% replacement of steel slag.
- However Flexural strength of concrete for the partial replacement of Fine aggregate with Steel slag of 40% does not show major decrement as compared to 30% and can be use by control mix.

## CONCLUSIONS

Based on the deep study of experimental results and discussions the following conclusions are made.

- Comparison and observations for the compressive strength, flexural strength and split tensile strength of normal concrete and concrete with Steel slag as partial replacements, the results shows that the strength of the normal concrete is slightly lower than the Steel slag replaced concrete.
- The increment in compressive strength is about 31.47% for 7 days curing 20% for 14 days curing 18% for 28 days while at 40% a slight decrement of 4.2% noted for 7 days and 3.4 % for 28 days of curing as compared to 30%.
- The increment in compressive strength of M 30 grade of concrete is about 24.9% for 7 days of curing 17.5% for 14 days of curing and 15.5% for 28 days of curing while at 40% a slight decrement of 3.6% noted for 7 days and 2.5% for 28 days of curing as compared to 30%.
- The split tensile strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate. The increment in split tensile strength is about 16.7% for 28 days curing for M 25 grade of concrete and increment about 15.6% for 28 days curing for M 30 grade of concrete.
- The Flexural strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate. The increment in flexural strength test is about 36.7% for 28 days curing for M 25 grade of concrete and 24.7% for 28 days curing for M 30 grade of concrete.
- From the results of compressive strength, split tensile strength, flexural strength 28 days curing, 30% replacement of fine aggregate by steel slag is the optimum percentage of replacement of M 25 & M 30 grade of concrete.

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