An Experimental Investigation on Concrete by Partial Replacement of Fine Aggregate with Stone Dust and Waste Foundry Sand

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Abstract: This research study includes check the feasibility and performance of stone dust and waste foundry sand in concrete. In this study experimental investigation are performed to evaluate the fresh and hardened properties of concrete containing stone dust and waste foundry sand as fine aggregate replacement. Fine aggregate are replaced partially with stone dust and waste foundry sand. The percentages of replacement 0\%, 20\%, 30\%, 40\%, 50\% by weight of fine aggregate with stone dust and 0\%, 10\%, 15\%, 20\%, 25\% by weight of fine aggregate with waste foundry sand. The fresh properties like slump test, compaction factor test and hardened properties like compression strength test at 7 and 28 days of curing, split tensile strength test, flexural strength test at 28 days of curing performed for all replacement levels for M30 grade concrete. The test results indicates the stone dust and waste foundry sand can be used effectively to replace fine aggregate in concrete. In the experimental investigation of strength characteristics of concrete using stone dust and waste foundry sand as fine aggregate it is found that there is increase in compressive strength, split tensile strength and flexural strength.

Keywords: Fine Aggregate (FA), Stone Dust (SD), Waste Foundry Sand (WFS), Workability, Compressive Strength, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Concrete is the most vital material in modern day construction. It is known for versatile properties like high compressive strength and long lasting durability. Due to rapid growth in construction activity, the consumption of concrete is increasing every year. This results in excessive exploitation of natural resources. In some places either natural sand may not be of good quality or good quality sand has to be transported from long distances, which adds to the cost of construction. Therefore, it is becoming inevitable to replace natural sand in concrete by an alternative material either partially or completely without affecting the quality of concrete. Large scale efforts are required for reducing the usage of the raw materials that are currently available, so that large replacement is using the various by-product materials that are easily accessible in present day. Stone dust or quarry dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75 mm. It has very recently gained good attention to be used as an effective filler material instead of fine aggregate. Stone dust is an industrial by-product. It is formed by screening products of secondary and subsequent stages of crushing igneous rocks, sedimentary rocks or gravel. It can be classified by the size of the particles as 0 to 4.75 mm. Waste foundry sand is high quality silica sand that is a byproduct from the production of both ferrous and nonferrous metal castings. A foundry is a manufacturing facility that produces metal castings by pouring molten metal into a preformed mold to yield the resulting hardened cast. The characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. The innovative and new research must be required for utilization of foundry sand waste materials. These research efforts try to match society’s need for safe and economic utilization of foundry sand waste materials.
II. MATERIAL

A. Cement
Cement is the binding material in the cement concrete. The Ordinary Portland Cement of 53 grade conforming to IS: 12269-2013 was used for this experimental work.

B. Coarse Aggregate
Locally available 20 mm and 10 mm coarse aggregate is used for this experimental study. The coarse aggregate from crushed basalt rock confirming to IS: 383-2016 is used. It is mixed in proportion of 60:40 percent.

C. Fine Aggregate
The naturally available river sand used as fine aggregate. The fine aggregate Zone II passed through 4.75 mm and retained on 150 µ sieve is used confirming to the requirements of IS: 383-2016.

D. Stone Dust
Stone dust is collected from local stone crusher plant. Particle size passed through 4.75 mm and retained on 150 µ sieve and specific gravity 2.52 consists of used.

E. Waste Foundry Sand
Waste foundry sand is collected from Raj Technocast Pvt. Ltd.-Rajkot. Particle size passed through 4.75 mm and retained on 150 µ sieve and specific gravity 2.59 consists of used.

F. Water
The potable water used in the present study. Physical properties of experimental materials are as shown in Table 1.

| Sr. No. | Test                        | Coarse Aggregate | Fine Aggregate | Stone Dust | Waste Foundry Sand | IS Code               |
|---------|-----------------------------|------------------|----------------|------------|--------------------|-----------------------|
| 1       | Specific Gravity            | 2.84             | 2.71           | 2.52       | 2.59               | IS: 2386-1963 (Part III) |
| 2       | Water Absorption            | 0.51 %           | 0.76 %         | 0.94 %     | 0.78%              |                       |
| 3       | Free Surface Moisture       | Nil              | 0.60 %         | Nil        | Nil                |                       |
| 4       | Fineness Modulus           | -                | 2.92           | 2.60       | 2.01               | IS: 383-2016          |
| 5       | Sieve Analysis             | -                | Zone - II      | Zone - II  | Zone - III         |                       |

III. EXPERIMENTAL METHODOLOGY

A. Concrete Mix Design Proportions
In this experimental study trial mixes for different proportion of ingredients are designed for M30 grade of concrete as per IS: 10262-2009, the concrete mix design proportions are as shown in Table 2. The target mean strength was 38.25 N/mm² for the control mix, the W/C ratio kept 0.45.

| Volume of Concrete | Cement (kg/m³) | Fine Aggregate (kg/m³) | Coarse Aggregate (20 mm) (kg/m³) | Coarse Aggregate (10 mm) (kg/m³) | Water (litre) |
|--------------------|----------------|------------------------|---------------------------------|---------------------------------|---------------|
| By Weight          | 425.73         | 675.08                 | 722.77                          | 481.84                          | 198.72        |
| By Volume          | 1.00           | 1.59                   | 2.83                            | 0.45                            |               |

B. Mixing and Casting Details of Specimen
In this experimental study fine aggregate replaced with stone dust, waste foundry sand, combination of stone dust and waste founndry sand with different proportions, the details of mixing and specimen designations are as shown in Table 3. All the specimens used in the experimental work were recommended by IS: 516-1959, cubical moulds of size 150 x 150 x 150 mm were used for the finding compressive strength. Cylindrical moulds of 150 mm diameter and 300 mm length, concrete specimens were prepared for the determinations of split tensile strength. Beams having size of 100 x 100 x 500 mm were prepared to evaluate the flexural strength.
TABLE 3
DETAILS OF MIXING AND SPECIMEN DESIGNATION

| Identification Mark | FA % | SD % | WFS % | Description                          |
|---------------------|------|------|-------|--------------------------------------|
| M1                  | 100  | 0    | 0     | Control Mix                          |
| M2                  | 80   | 20   | 0     | 20% replacement of the FA by SD      |
| M3                  | 70   | 30   | 0     | 30% replacement of the FA by SD      |
| M4                  | 60   | 40   | 0     | 40% replacement of the FA by SD      |
| M5                  | 50   | 50   | 0     | 50% replacement of the FA by SD      |
| M6                  | 90   | 0    | 10    | 10% replacement of the FA by WFS     |
| M7                  | 85   | 0    | 15    | 15% replacement of the FA by WFS     |
| M8                  | 80   | 0    | 20    | 20% replacement of the FA by WFS     |
| M9                  | 75   | 0    | 25    | 25% replacement of the FA by WFS     |
| M10                 | 60   | 30   | 10    | 30% replacement of the FA by SD and 10% by WFS |
| M11                 | 55   | 30   | 15    | 30% replacement of the FA by SD and 15% by WFS |
| M12                 | 50   | 30   | 20    | 30% replacement of the FA by SD and 20% by WFS |
| M13                 | 50   | 40   | 10    | 40% replacement of the FA by SD and 10% by WFS |
| M14                 | 45   | 40   | 15    | 40% replacement of the FA by SD and 15% by WFS |
| M15                 | 40   | 40   | 20    | 40% replacement of the FA by SD and 20% by WFS |
| M16                 | 40   | 50   | 10    | 50% replacement of the FA by SD and 10% by WFS |
| M17                 | 35   | 50   | 15    | 50% replacement of the FA by SD and 15% by WFS |
| M18                 | 30   | 50   | 20    | 50% replacement of the FA by SD and 20% by WFS |

* FA = Fine Aggregate, SD = Stone Dust, WFS = Waste Foundry Sand.

IV. RESULTS AND DISCUSSION

A. Fresh Concrete Properties

Fresh properties of M30 grade of concrete are as shown in Table 4.

TABLE 4 FRESH CONCRETE PROPERTIES

| Concrete Mix | FA % | SD % | WFS % | Slump (mm) | Compacting Factor |
|--------------|------|------|-------|------------|-------------------|
| M1           | 100  | 0    | 0     | 63         | 0.89              |
| M2           | 80   | 20   | 0     | 56         | 0.83              |
| M3           | 70   | 30   | 0     | 52         | 0.78              |
| M4           | 60   | 40   | 0     | 46         | 0.74              |
| M5           | 50   | 50   | 0     | 41         | 0.71              |
| M6           | 90   | 0    | 10    | 58         | 0.87              |
| M7           | 85   | 0    | 15    | 54         | 0.84              |
| M8           | 80   | 0    | 20    | 49         | 0.79              |
| M9           | 75   | 0    | 25    | 44         | 0.72              |
| M10          | 60   | 30   | 10    | 54         | 0.83              |
| M11          | 55   | 30   | 15    | 51         | 0.79              |
| M12          | 50   | 30   | 20    | 45         | 0.75              |
| M13          | 50   | 40   | 10    | 51         | 0.76              |
| M14          | 45   | 40   | 15    | 47         | 0.74              |
| M15          | 40   | 40   | 20    | 42         | 0.70              |
| M16          | 40   | 50   | 10    | 48         | 0.73              |
| M17          | 35   | 50   | 15    | 44         | 0.71              |
| M18          | 30   | 50   | 20    | 41         | 0.68              |
1) **Slump Test:** From the observation replacement of SD with FA in concrete the slump was decreases. The percentages of replacement of SD was increases from 20% to 50%, the slump was decreases from 11.11% to 34.92% as compare to normal concrete test results. From the observation replacement of WFS with FA in concrete the slump was decreases. The percentages of replacement of WFS was increases from 10% to 25%, the slump was decreases from 7.94% to 30.16% as compare to normal concrete test results. From the observation replacement of both SD and WFS with FA in concrete the slump was decreases. The percentages of replacement of SD was increases from 30% to 50% and WFS was increases from 10% to 20%, the slump was decreases from 14.29% to 34.92% as compare to normal concrete test results.

Slump test results of concrete mix are as shown in Figure 1.

![Slump Test Results of Concrete Mix](image1)

2) **Compacting Factor Test:** From the observation replacement of SD with FA in concrete the compacting factor was decreases. The percentages of replacement of SD was increases from 20% to 50%, the compacting factor was decreases from 6.74% to 20.22% as compare to normal concrete test results. From the observation replacement of WFS with FA in concrete the compacting factor was decreases. The percentages of replacement of WFS was increases from 10% to 25%, the compacting factor was decreases from 2.25% to 19.10% as compare to normal concrete test results. From the observation replacement of both SD and WFS with FA in concrete the compacting factor was decreases. The percentages of replacement of SD was increases from 30% to 50% and WFS was increases from 10% to 20%, the compacting factor was decreases from 6.74% to 23.60% as compare to normal concrete test results.

Compacting factor test results of concrete mix are as shown in Figure 2.

![Compacting Factor Test Results of Concrete Mix](image2)
B. Hardened Concrete Properties

Hardened properties of M30 grade of concrete are as shown in Table 5.

### TABLE 5

| Concrete Mix | FA % | SD % | WFS % | Compressive Strength (N/mm²) | Split Tensile Strength (N/mm²) | Flexural Strength (N/mm²) |
|--------------|------|------|-------|-----------------------------|-------------------------------|--------------------------|
|              |      |      |       | 7 Days                      | 28 Days                       | 28 Days                  |
| M1           | 100  | 0    | 0     | 26.92                        | 40.22                         | 3.05                     |
| M2           | 80   | 20   | 0     | 27.76                        | 41.94                         | 3.19                     |
| M3           | 70   | 30   | 0     | 28.64                        | 42.84                         | 3.32                     |
| M4           | 60   | 40   | 0     | 29.97                        | 43.79                         | 3.44                     |
| M5           | 50   | 50   | 0     | 27.45                        | 40.79                         | 3.12                     |
| M6           | 90   | 0    | 10    | 28.55                        | 42.49                         | 3.17                     |
| M7           | 85   | 0    | 15    | 29.56                        | 43.60                         | 3.30                     |
| M8           | 80   | 0    | 20    | 28.44                        | 41.88                         | 3.21                     |
| M9           | 75   | 0    | 25    | 27.34                        | 40.74                         | 3.08                     |
| M10          | 60   | 30   | 10    | 27.49                        | 41.36                         | 3.14                     |
| M11          | 55   | 30   | 15    | 28.31                        | 42.27                         | 3.26                     |
| M12          | 50   | 30   | 20    | 27.45                        | 40.77                         | 3.13                     |
| M13          | 50   | 40   | 10    | 28.27                        | 42.19                         | 3.27                     |
| M14          | 45   | 40   | 15    | 28.80                        | 42.99                         | 3.38                     |
| M15          | 40   | 40   | 20    | 27.23                        | 40.64                         | 3.18                     |
| M16          | 40   | 50   | 10    | 27.61                        | 41.17                         | 3.15                     |
| M17          | 35   | 50   | 15    | 28.27                        | 42.16                         | 3.24                     |
| M18          | 30   | 50   | 20    | 27.19                        | 40.58                         | 3.13                     |

1) **Compressive Strength Test:** From the observation replacement of SD with FA in concrete the compressive strength was increases up to 40%. The percentages of replacement of SD was increases from 20% to 50%, the maximum compressive strength was observed at 40% as 8.88% as compared to normal concrete test results at 28 days. From the observation replacement of WFS with FA in concrete the compressive strength was increases up to 15%. The percentages of replacement of SD was increases from 10% to 25%, the maximum compressive strength was observed at 15% as 8.40% as compared to normal concrete test results at 28 days. From the observation replacement of SD and WFS with FA in concrete the compressive strength was increases up to 40% + 15%. The percentages of replacement of SD was increases from 30% to 50% and WFS was increases from 10% to 20%, the maximum compressive strength was observed at 40% + 15% as 6.89% as compared to normal concrete test results at 28 days.

Compressive strength test results of concrete mix are as shown in Figure 3.

![Fig. 3 Compressive Strength Test Results of Concrete Mix at 7 and 28 Days](image-url)
2) **Split Tensile Strength Test:** From the observation replacement of SD with FA in concrete the split tensile strength was increases up to 40%. The percentages of replacement of SD was increases from 20% to 50%, the maximum split tensile strength was observed at 40% as 12.85% as compared to normal concrete test results at 28 days. From the observation replacement of WFS with FA in concrete the split tensile strength was increases up to 15%. The percentages of replacement of SD was increases from 10% to 25%, the maximum split tensile strength was observed at 15% as 8.36% as compared to normal concrete test results at 28 days. From the observation replacement of SD and WFS with FA in concrete the split tensile strength was increases up to 40% + 15%. The percentages of replacement of SD was increases from 30% to 50% and WFS was increases from 10% to 20%, the maximum split tensile strength was observed at 40% + 15% as 10.84% as compared to normal concrete test results at 28 days.

Split tensile strength test results of concrete mix are as shown in Figure 4.

![Split Tensile Strength Test Results of Concrete Mix at 28 Days](image)

3) **Flexural Strength Test:** From the observation replacement of SD with FA in concrete the flexural strength was increases up to 40%. The percentages of replacement of SD was increases from 20% to 50%, the maximum flexural strength was observed at 40% as 14.05% as compared to normal concrete test results at 28 days. From the observation replacement of WFS with FA in concrete the flexural strength was increases up to 15%. The percentages of replacement of SD was increases from 10% to 25%, the maximum flexural strength was observed at 15% as 9.80% as compared to normal concrete test results at 28 days. From the observation replacement of SD and WFS with FA in concrete the flexural strength was increases up to 40% + 15%. The percentages of replacement of SD was increases from 30% to 50% and WFS was increases from 10% to 20%, the maximum flexural strength was observed at 40% + 15% as 13.07% as compared to normal concrete test results at 28 days.

Flexural strength test results of concrete mix are as shown in Figure 5.

![Flexural Strength Test Results of Concrete Mix at 28 Days](image)
Following broad conclusions are drawn from this experimental investigation.

A. The percentage of replacement of stone dust and waste foundry sand was increases, workability of fresh concrete was decreases.
B. Partial replacement of fine aggregate with SD (up to 40%) and WFS (up to 15%) increases strength properties such as compressive, split tensile and flexural strength of M30 grade of concrete.
C. By replacement 40% fine aggregate with stone dust the compressive strength was increases by 8.88% at 28 days as compared to normal concrete. By replacement 15% fine aggregate with waste foundry sand the compressive strength was increases by 8.40% at 28 days as compared to normal concrete. By replacement 40% fine aggregate with stone dust and 15 % fine aggregate by waste foundry sand the compressive strength was increases by 6.89% at 28 days as compared to normal concrete.
D. By replacement 40% fine aggregate with stone dust the split tensile strength was increases by 12.85% at 28 days as compared to normal concrete. By replacement 15% fine aggregate with waste foundry sand the split tensile strength was increases by 8.36% at 28 days as compared to normal concrete. By replacement 40% fine aggregate with stone dust and 15 % fine aggregate by waste foundry sand the split tensile strength was increases by 10.84% at 28 days as compared to normal concrete.
E. By replacement 40% fine aggregate with stone dust the flexural strength was increases by 14.05% at 28 days as compared to normal concrete. By replacement 15% fine aggregate with waste foundry sand the flexural strength was increases by 9.80% at 28 days as compared to normal concrete. By replacement 40% fine aggregate with stone dust and 15 % fine aggregate by waste foundry sand the flexural strength was increases by 13.07% at 28 days as compared to normal concrete.
F. Fine aggregate can be effectively replaced by SD (up to 40%) and WFS (up to 15%) increase strength properties of M30 grade of concrete.

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