Experimental Study on Concrete and Cement Plaster Using Partial Replacement of Quarry Rock Dust as Fine Aggregate

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Abstract— Conventional Cement Concrete (CCC) consists of Portland Cement (PC) as binder, which binds the inert aggregate system. Concrete has found its wide application in buildings throughout the world because of positive attributes such as durability, high resistance to loads, and the possibility of using local raw materials in the preparation of concrete (Sand, Crushed Stone). The use of river sand in making the concrete is the best Fine Aggregate (FA). Seasonal non–availability and scarcity leads to the higher cost. There is a need to tackle this problem. So the replacement of conventional river sand is necessary. For this the abundantly available material at all season at a cheaper rate is in need. The best way to deal with these environmental concerns is to use waste or recycled material, as substitute for natural river sand. This paper deals with replacement of sand used in concrete as fine aggregates by the waste generated by the stone quarry industry. Quarry rock dust can be an economic alternative to the river sand. Quarry Rock Dust as 100% substitute for Natural Sand in concrete. This project presents the feasibility of the usage of Quarry Rock Dust as hundred percent substitute for Natural Sand in concrete. Design Mix for M30 and M40 has been calculated using IS 10262-2009 for both conventional concrete and quarry dust concrete. Tests were conducted on cubes, cylinders and prisms to study the strength of concrete by using Quarry Rock Dust and the results were compared with the Natural Sand Concrete. Cement mortar cubes were cast and its compressive strength is calculated. Cement mortar ratios of 1:3 and 1:6 are prepared and observed the percentage of water absorption in both Quarry Rock Dust and Natural sand for plastering. The main objective of the present investigation is to evaluate the possibilities of using quarry dust as a replacement to fine aggregate. During the present study, 0%, 50%, 75% and 100% of traditional fine aggregate was replaced with quarry dust. Compression, split and flexural strengths were found after 7days and 28 days of curing.

Key words: Fine Aggregate, Portland Cement

I. INTRODUCTION

Concrete is an artificial conglomerate stone made essentially of Portland cement, water, fine and coarse aggregates. The mixture of the materials results in a chemical reaction called hydration and a change in the mixture from plastic to a solid state occurs over a period of time. The cost of concrete can be reduced by using alternative materials, instead of conventional materials. Ilangovalana et al (2008) studied the feasibility of usage of quarry rock dust as hundred percent substitutes for natural sand in concrete. Mix design has been developed for three grades using design approach of IS, ACI, USBR, RN.No.4 and BRITISH codes for both conventional concrete and quarry dust concrete. Tests were conducted on cubes and beams to study the strength of concrete made of quarry rock dust and the results were compared with the natural sand Concrete. An attempt has also been made to durability studies on quarry rock dust when compared with the natural sand concrete. It is found that the compressive, flexural strength and durability studies of concrete made of quarry rock dust are nearly 10% more than the conventional concrete. Sivakumar et al (2011) presented a paper on the hardened and durable properties of concrete using quarry dust. Also, the use of quarry dust as the fine aggregate decreases the cost of concrete production in terms of the complete replacement for natural river sand. His paper reports the experimental study which investigated the influence of 100% replacement of sand with quarry dust. Initially cement mortar cube was studied with various proportions of quarry dust (CM 1:3, CM 1:2, and CM 1:1). The experimental results showed that the addition of quarry dust for a fine to coarse aggregate ratio of 0.6 was found to enhance the compressive properties as well as elastic modulus. Anitha Selva Sofia S.D et al (2013) has studied on experimental investigation on quarry dust concrete with chemical admixtures. An attempt has been made to replace the fine aggregate with quarry dust with an objective of utilizing the waste material. It is found that quarry dust improves the mechanical properties of concrete when used along with super plasticizers. She has reported that when the conventional fine aggregate is completely replaced with quarry dust along with 1% dosage of super plasticizer increase in the compressive strength is around 85%.

Chandana Sukesh et al (2013) presented the paper on partial replacement of sand with quarry dust in concrete. This present work is an attempt to use Quarry Dust as partial replacement for Sand in concrete. Attempts have been made to study the properties of concrete and to investigate some properties of Quarry Dust the suitability of those properties to enable them to be used as partial replacement materials for sand in concrete. He was reported that decrease in workability of concrete when the percentage of the replacing increasing. The workability is very less at the standard water-cement ratio and the water that is required for making the concrete to form a zero slump with a partial replacement requires more water. The test conducted at 50% replacement showed that the water- cement ratio increased to 1.6 at which the slump cone failed completely. Lohini T.K et al (2012) studies about Optimum utilization of Quarry dust as partial replacement of sand in concrete. Design mix of M20 grade concrete with replacement of 0%, 20%, 30%, 40%, and 50% of quarry dust organized as M1, M2, M3, M4 and M5 respectively have been considered for laboratory analysis viz. slump test, compaction factor test, compressive strength (cube, cylindrical sample), split tensile strength, flexural strength, modulus of elasticity, water absorption of hardened concrete. Prof. M. Devi et al (2012) studies about
Inhibitive effect of organic inhibitors in concrete containing Quarry dust as a fine aggregate. The objective of this work is to study the strength and corrosion resistive properties of concrete containing quarry dust as fine aggregate along with organic inhibitors namely Triethanolamine and Diethanolamine at 1%, 2%, 3% and 4% by weight of cement. The optimum percentage addition of the organic inhibitors by weight of cement in concrete containing quarry dust as fine aggregate was also determined. Er. Lakhani Nagpal et al (2013) have studied on Evaluation of Strength Characteristics of Concrete Using Crushed Stone Dust as Fine Aggregate. The purpose of this study was to investigate the possibility of using crushed stone dust as fine aggregate partially or fully with different grades of concrete composites. The suitability of crushed stone dust waste as fine aggregate for concrete has been assessed by comparing its basic properties with that of conventional concrete. Two basic mixes were selected for natural sand to achieve M25 and M30 grade concrete. The equivalent mixes were obtained by replacing natural sand by stone dust partially and fully. The test result indicates that crushed stone dust waste can be used effectively used to replace natural sand in concrete. In the experimental study of strength characteristics of concrete using crushed stone dust as fine aggregate it is found that there is increase in compressive strength, flexural strength and tensile strength of concrete.

II. OBJECTIVES
The main objectives of this study are to carry out the following systems:
- To design the concrete mixes of M30 and M40 grade concrete as per the recommendation of IS: 10262:2009.
- To find the Volume proportions of the concrete mixes by partially replacing Sand by Quarry Rock Dust.
- To evaluate the compressive strengths for 7 and 28 days by replacing fine aggregate with Quarry Rock Dust in proportions of 0, 50, 75 and 100%.
- To evaluate the split tensile strengths for 7 and 28 days by replacing fine aggregate with Quarry Rock Dust in proportions of 0, 50, 75 and 100%.
- To evaluate the flexural strengths for 28 days by replacing fine aggregate with Quarry Rock Dust in proportions of 0, 50, 75 and 100%.
- To evaluate the compressive strength of cement mortar cube for 3, 7 and 28days by replacing fine aggregate with Quarry Rock Dust.
- To evaluate percentage of water absorption in plastering made with both Quarry Rock Dust and Natural sand.

III. METHODOLOGY
1) Concrete specimens were casted using 0%, 50%, 75% and 100% of replacement fine aggregate with Quarry Rock Dust. Details are furnished in below table
2) Cubes and cylinders were tested for 7days and 28 days
3) Prisms were tested for 28days
4) Cement mortar cubes were tested for 3, 7 and 28days.

IV. CHARACTERISTICS OF MATERIALS
A. Cement
Ordinary Portland Cement (53 grade) with specific gravity of 3.12 was used for this experimental investigation.
B. Coarse Aggregate
Natural granite aggregate having density of 1500 kg/m³ and fineness modulus (FM) of 6.65 was used. The specific gravity was found to be 2.85 and maximum size of aggregate was 20mm.
C. Fine Aggregate (Natural river sand)
Locally available river sand having density of 1550 kg/m³ and fineness modulus (FM) of 2.44 was used. The specific gravity was found to be 2.95 the fine aggregate was found to be confirming to zone – II as per IS 383:1970.

1) Quarry Rock Dust:
Crusher dust is fine rock particles. When boulders are broken into the small pieces crusher dust is formed. It is grey in color and it is like fine aggregate.
D. Water
Potable fresh water, which is free from concentration of acid or organic substances, was used for mixing the concrete.

V. SUITABILITY OF QUARRY ROCK DUST FOR PLASTERING
The particle size grading of sand for plaster work for internal as well as external wall. As per IS code 1542:1992, Grading of sand for internal wall or external wall.

<table>
<thead>
<tr>
<th>IS Sieve (mm)</th>
<th>Percentage Passing as per IS Code</th>
<th>Percentage Passing Quarry Rock Dust used for Plastering in this Thesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>95-100</td>
<td>98.9</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>95-100</td>
<td>77.55</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>90-100</td>
<td>55.9</td>
</tr>
<tr>
<td>0.6 mm</td>
<td>80-100</td>
<td>45.4</td>
</tr>
<tr>
<td>0.3 mm</td>
<td>20-65</td>
<td>33.3</td>
</tr>
<tr>
<td>0.15 mm</td>
<td>0-15</td>
<td>13.75</td>
</tr>
</tbody>
</table>

Table 1: Suitability of Quarry Rock Dust for plastering as per IS Code Recommendations
For crushed stone sands and crushed gravels sands, the permissible limit on 0.15 mm IS Sieve is increased to 20 percent
The fineness modulus of sand shall be not less than 1.4 in case of crushed stone sands and crushed gravel sands and not less than 1.5 in case of naturally occurring sands.

VI. STRENGTH STUDIES ON CONCRETE AND CEMENT PLASTER
A. Compressive Strength Test of Concrete Cube
Compression test on the cubes is conducted on the 200T compression testing machine. The cube was placed in the
compression testing machine and the load on the cube is applied at a constant rate up to the failure of the specimen and the ultimate load is noted. The cube compressive strength of the concrete mix is then computed. A sample calculation for determination of cube compressive strength is presented in Appendix-II (A). This test has been carried out on cube specimens at 7 and 28 days age. The values are presented in tables below for M30 and M40 grade concrete respectively.

Compressive strength = \( \frac{P}{A} \)

Where, \( P \) = Compressive load

\( A \) = Area of the cube (150 X 150 mm)

<table>
<thead>
<tr>
<th>% of Replacement Sand with Quarry Rock Dust</th>
<th>Average Compressive strength of the concrete at different ages (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Replacement</td>
<td>7days</td>
</tr>
<tr>
<td>0</td>
<td>28.59</td>
</tr>
<tr>
<td>50</td>
<td>31.33</td>
</tr>
<tr>
<td>75</td>
<td>30.96</td>
</tr>
<tr>
<td>100</td>
<td>26.29</td>
</tr>
</tbody>
</table>

Table 2: Average Compressive Strength of Concrete with Quarry Rock Dust in M 30 Grade (target mean strength-38.25)

<table>
<thead>
<tr>
<th>Cement mortar ratio (1:6)</th>
<th>Average Compressive strength of the cement mortar cube at different ages (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
</tr>
<tr>
<td>Natural sand</td>
<td>17.6</td>
</tr>
<tr>
<td>Quarry rock dust</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Table 3: Average Compressive Strength of Concrete with Quarry Rock Dust in M40 grade (target mean strength-48.25)

<table>
<thead>
<tr>
<th>% of Replacement Sand with Quarry Rock Dust</th>
<th>Average Compressive strength of the concrete at different ages (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of replacement</td>
<td>7days</td>
</tr>
<tr>
<td>0</td>
<td>32.14</td>
</tr>
<tr>
<td>50</td>
<td>37.3</td>
</tr>
<tr>
<td>75</td>
<td>31.03</td>
</tr>
<tr>
<td>100</td>
<td>26.51</td>
</tr>
</tbody>
</table>

Table 4: Average Compressive Strength of cement mortar cube 1:3 proportions (KCP CEMENT OPC 53 GRADE)

Fig. 4: Failure of the specimen

Fig. 5: Variation of 7Days and 28 Days Compressive Strength M30 Grade
B. Compressive Strength Test For Cement Mortar Cube

Cement to fine aggregate ratio of 1: 3 and 1:6 (by weight) and W/C ratio 0.45 was used for making the mortar specimens. Specimens were prepared and casted in 70.6mm X 70.6mm X 70.6 mm cube moulds and properly compacted in high frequency vibrating table. Specimens were then demoulded from the mould after 24 hours and kept in water for curing for 3, 7 and 28 days. At first apparent water absorption, and compressive strength was measured for the samples cured for 3, 7 and 28 days.

Compressive strength of mortar cube = \( \frac{P}{A} \)

Where, \( P = \) Compressive load
\( A = \) Area of the cube (70.6 X 70.6 mm)

\( A = \) Cross sectional area of the specimen

\( L = \) Length of the specimen

\( F = \) Split tensile load

\( D = \) Diameter of the specimen (150 mm)

\( L_s = \) Length of the specimen

\( A = \) Area of the cube (70.6 X 70.6 mm)

% of Replacement | Average Split Tensile Strength of the concrete at different ages(N/mm²)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>2.4</td>
</tr>
<tr>
<td>50%</td>
<td>2.54</td>
</tr>
<tr>
<td>75%</td>
<td>3.89</td>
</tr>
<tr>
<td>100%</td>
<td>3.80</td>
</tr>
</tbody>
</table>

Table 5: Average split tensile strength of Concrete with Quarry Rock Dust in M30 grade

\( F_{fr} = \frac{2P}{\pi D^3} \)

Where, \( P = \) Split tensile load
\( D = \) Diameter of the specimen (150 mm)
\( L_s = \) Length of the specimen

\( A = \) Cross sectional area of the specimen in mm².

VII. SPLIT TENSILE STRENGTH

This test is conducted on 200T compression testing machine as shown in figure 6.9. The cylinders prepared for testing are 150 mm in diameter and 300 mm height. After noting the weight of the cylinder, diametrical lines are drawn on the two ends, such that they are in the same axial plane. Then the cylinder is placed on the bottom compression plate of the testing machine and is aligned such that the lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and the load is recorded. From this load, the splitting tensile strength is calculated for each specimen. A sample calculation for computation of split tensile strength is presented in Appendix-II (B). In the present work, this test has been conducted on cylinder specimens after 7 and 28 days of curing. The values are tabulated in above tables for M30 and M40 grade concrete respectively.

% of Replacement | Average Flexural strength of the concrete at different ages(N/mm²)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>2.55</td>
</tr>
<tr>
<td>50%</td>
<td>4.64</td>
</tr>
<tr>
<td>75%</td>
<td>3.44</td>
</tr>
<tr>
<td>100%</td>
<td>3.04</td>
</tr>
</tbody>
</table>

Table 6: Average Flexural strength of the concrete at different ages(N/mm²)

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VIII. FLEXURAL STRENGTH TEST

The prism specimens of size 500 x 100 x 100 mm were used for the determination of the flexural strength. The bearing surface of the supporting and loading rollers were wiped clean and any other loose fine aggregate or other materials removed from the surface of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine and two point load was applied. Load was increased until the specimen failed and the load at failure was recorded and the flexural strength was determined. Flexural strength was taken as the average strength of three specimens. The average flexural strength of concrete with Quarry Rock Dust is given in Table 6.7 and 6.8.

Flexural strength = \( \frac{M}{Z} \) N/mm²

Where \( M \) is bending moment in N-mm

\( Z \) is section modulus of the specimen in mm³.

Table 7: Average flexural strength of Concrete with Quarry Rock Dust in M30 grade

<table>
<thead>
<tr>
<th>F.A with Quarry Rock Dust</th>
<th>Concrete at 28 days (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7.3</td>
</tr>
<tr>
<td>50</td>
<td>7.75</td>
</tr>
<tr>
<td>75</td>
<td>6.33</td>
</tr>
<tr>
<td>100</td>
<td>5.26</td>
</tr>
</tbody>
</table>

Fig. 10: Variation of 7 Days and 28 Days Split Tensile Strength M40 Grade

Fig. 11: Testing of the specimen.

IX. CALCULATION OF PERCENTAGE OF WATER ABSORPTION IN PLASTERING

In our present thesis we had taken 1:3 and 1:6 cement mortar proportions, by preparing the surface using wooden sticks of 12 mm and 20 mm, and made the cement mortar into bricklet shapes. After 24 hours placed them in curing tub for 72 hours. After 72 hours three samples of specimens were taken for weighing as a \( W_1 \) and then placed them in oven for 24 hours and weighted as \( W_2 \).

\( \% \) of Water absorption = \( \frac{W_1 - W_2}{W_2} \times 100 \%

Where, \( W_1 \) is the saturated weight of the specimen

\( W_2 \) is the oven dry weight of the specimen

Fig. 12: Variation of 28 Days Flexural Strength M30 Grade

Fig. 13: Variation of 28 Days Flexural Strength M40 Grade

Fig. 14: Preparation of the specimen
X. CONCLUSIONS

The effect of concrete with partial replacement of River sand with Quarry Rock Dust and determining the properties of normal strength concrete with water cement ratio of 0.45, 0.4 for 7 and 28 day’s compressive, split tensile and flexural strength of M30, M40 MPa were studied.

The effect of percentage replacement of Quarry Rock Dust on strength property and workability were evaluated and compared with reference mix of 0% replacement of River sand by Quarry Rock Dust.

1) The compressive strength of concrete specimens made with 50% replacement of river sand by Quarry Rock Dust gives higher strength of 8% to 13% and with 100% replacement gives decreases the strength of 9% to 20% as compare to reference mix.

2) The split tensile strength of concrete specimens made with 50% replacement of river sand by Quarry Rock Dust gives higher strength of 6% to 9% and with 100% replacement gives decreases the strength of 16% to 29% as compare to reference mix.

3) The flexural strength of concrete specimens made with 50% replacement of river sand by Quarry Rock Dust gives higher strength of 5% to 14% and with 100% replacement gives decreases the strength of 22% to 27% as compare to reference mix.

4) The effect of full replacement of River sand by Quarry Rock Dust on compressive strength of cement mortar of proportions 1:3 and 1:6 with water cement ratio of 0.45 compared with reference mix of 0% replacement of river sand by Quarry Rock Dust, The compressive strength of cement mortar with 100% replacement of river sand by Quarry Rock Dust gives 21% decrease as compared with reference mix.

5) The percentage of water absorption with river sand in 1:3 mix proportion is 5.11% and Quarry Rock Dust is 13.35% and the percentage of water absorption with river sand in 1:6 mix proportion is 4.77 and Quarry Rock Dust is 10.67. Quarry Rock Dust can be used for plastering. A small area is plastered with cement Quarry Rock Dust mortar and found that in workmanship there is no difference and is quite suitable for plastering.

XI. SCOPE OF FURTHER RESEARCH

Further research work is needed to explore the effect of Quarry Rock Dust on performance concrete.

1) Durability studies have to be carried out.

2) Permeability tests have to be carried out.

REFERENCES


