Strength and Durability Properties of Concrete Containing Quarry Rock Dust as Fine Aggregate

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Abstract: ***Quarry rock dust is investigated as fine aggregate in replacement with sand in cement concrete admixture, as the properties of the rock dust are suspected to be as good as sand. This Paper presents the practicability of using quarry rock dust as partial replacement for river or sharp sand using design mix of M20 grade concrete with replacement of 0 %, 20 %, 40 %, 60 %, 80 % and 100 % of quarry dust considered for laboratory analysis in Slump test, water absorption test and compressive strength of the hardened concrete admixture. After 7 days of curing, at maximum load, 13.78 N/mm^2 was recorded for the control specimen as compressive strength while the cube with 80 % dust recorded 16.01 N/mm^2 at maximum load as average compressive strength respectively, giving rise to an increment of 16.43 % of the compressive strength of the control specimen. Also the cube with 100 % quarry dust recorded 16.83 N/mm^2 at maximum load as average compressive strength, giving rise to an increment of about 18 % of the compressive strength of the control specimen. Through reaction with the concrete admixture, quarry dust, thus show improved pozzolanic reaction, micro aggregate filling and concrete durability.***

Keywords: Strength and Durability Properties, Concrete, Quarry Rock Dust, Fine Aggregate

1. Introduction

Concrete is a blend of cement, sand, aggregate and water in precise proportions that harden to a solid stony consistency over varying lengths of time. it is the most widely used construction material in the world (Umamaheswari, Elangovan & Rajendran, 2016). It is the only major building material that is delivered to the job site in a plastic state. This distinctive quality makes concrete obligatory as a building material because it can be moulded to virtually any form or shape as desired by the client or the builder. It provides a wide range in the choice of surface textures and colours and is in use to construct a wide variety of structures: highways and streets, bridges, dams etc. Other desirable qualities of concrete as a building material are its strength, economy and durability.

As a result of urban development that has given rise to high-rise buildings and other infrastructural facilities in concrete, the sand under our feet has never been in higher demand than now. We have come to depend more and more on sharp sand as a major constituent of the concrete admixture. Due to the rising cost of the constituent materials, the construction industry is being pressured into research for option that lowers the costs, improve efficiency and enhance mechanical properties that guarantee structural integrity of concrete (Amusat & Biliaminu, 2015).

The onus therefore lie on the Engineer and engineering researcher to find alternatives that circumvent cost while preserving the earth we have inherited from our forebears. Quarry rock dust refers to fine rock particles formed when boulders are broken into small pieces at the quarry. Quarry rock dust consists of finely crushed rock, processed by natural or mechanical means, containing minerals and trace elements widely used in organic farming practices. A lot of work was done on improvement of concrete properties as well as with the goal of preserving natural sand to forestall environmental problems. The global consumption of natural sand is very high due to the extensive use of sand in concrete admixture. In general, the demand of natural sand is quite high in developing countries to satisfy the rapid infrastructural growth. The needs for other materials are essential in the production of concrete admixture to increase environmental and sustainable development.

2. Materials and Methods

The procedure adopted in carrying out this research work is divided into stages. First is the design of mix proportion second is the procurement and preparation of materials to be used (c cement, granite, sand and water). Lastly is the mixing of concrete, casting, curing and crushing of the cubes. The materials required for the purpose of this study are: Ordinary Portland cement, Fine aggregate (sharp sand), Quarry rock dust, Coarse aggregate (granite), Hard wood and nails, Water, Polythene nylon, and Spring balance. The formwork used is wooden and metal, with dimension 150 x 150 x 150 mm. The formwork was constructed to give a fair faced concrete cube. Its interior was coated with very thin layer of mould oil (black oil) to facilitate easy removal and avoid honeycomb in the cube. A mix ratio of 1:2:4 was adopted and the batching of the materials was done by weight. The samples were cured within a period of 7-28days and the compressive strength was determined at interval of 7days on the compressive strength test machine.

2.1 Tests on Materials

a) Specific Gravity

A pycnometer was used to measure the specific gravity of the aggregates as the particle size is less. The same method is used for determining the specific gravity of the raw quarry dust.

b) Bulking

The bulking test is done by following the procedure given in IS 2386 (part III) – 1963. A measuring jar is taken and sand is filled up-to a mark in the measuring jar. Then water is added up to the highest mark in the vessel and left it for settling and the settled height is measured and the percentage bulking is calculated.

c) Workability

The workability is one of the physical parameters of concrete which affects the strength and durability and the appearance of the finished surface. The slump test was carried out using a cone having a bottom diameter of 200 mm with a top diameter of100 mm and height of 300 mm with the concrete having the partial replacement of sand with raw quarry dust at various percentages: Q1 (0 % quarry dust), Q2 (20 % quarry dust), Q3 (40% quarry dust), Q4 (60% quarry dust), Q5 (80% quarry dust), (100% quarry dust) respectively as shown in the table below:

Table 1: Showing the description of specimen

Samples	% of Quarry Dust	% of Sharp Sand
Q1 (Control)	No dust	100 %
Q2	20 %	80 %
Q3	40 %	60 %
Q4	60 %	40 %
Q5	80 %	20 %
Q6	100 %	No sand

d) Water Absorption

This is a durability test adopted to study the change in weight of specimens after 28 days curing. E. Compressive Strength. The compressive strength test was carried out in accordance with BS 1881 for various grades of concrete. In this case, all the samples were made in the standard mould of the dimensions: 150 mm X 150 mm X 150 mm and then the cubes are kept for curing and the compressive strength test was carried for ordinary mix and partially replaced samples.

3. Results and Discussions

The summary of the laboratory tests (Specific Gravity Test, Bulking Test, Workability Test, Water Absorption Testand Compressive Strength Test) is presented in the tables and figure below.

3.1 Mix design ratio

The mass of each constituent was determined relatively to the mass of cement required in the mix. Also a control mix of normal weight concrete using the same ratio was prepared as shown in table 2 below.

Table 2: Showing the Result of Calculated Material

Dust (%)	Cement (kg)	Sand (kg)	Dust (kg)	Granite (kg)
0.00	12.00	22.26	-	44.53
20.00	12.00	17.81	4.45	44.53
40.00	12.00	13.36	8.90	44.53
60.00	12.00	8.90	13.36	44.53
80.00	12.00	4.45	17.81	44.53
100.00	12.00	-	22.26	44.53
Total	72.00	66.78	66.78.	267.18

Cube size = 150 mm x 150 mm x 150 mm = 0.003375 m^3
For 12 cubes: 0.003375 m^3 x 12 = 0.0405 m^3
Mixing ratio = 1 : 2 : 4 = 7
Cement
Ratio/7 + (waste + shrinkage)
= 1/7 + 40/100 x 1/7 + 5/100(40/100 x 1/7 + 1/7)
= 0.2 + 0.01) = 0.21 m^3
= 0.21 x 0.0405 = 0.008505 m^3
If Volume of 1 bag of cement = 0.035 m^3
Then, 0.008505 m^3/0.035 m^3 = 0.243 bag
And if 1 bag = 50 kg
Then, 0.243 X 50 =12.15 kg
Sand
2/7 + 40/100 x 2/7 + 5/100 (40/100 x 2/7 + 2/7) x 0.027 m^3
(0.4 + 0.05(0.4)) x 0.027
0.42 x 0.0405 = 0.01701 m^3
5 tons = 3.82 m^3
X ton = 0.01701m^3
(0.01701m^3 / 3.82) x 5 =0.0222644 x1000 =22.26 kg
Replacement of Sand
0 % Quarry dust (control)
0/100 x 22.26 = 0.0 dust
22.26 – 0 = 22.26 sand

3.2 Specific Gravity Test

It was observed that the specific gravity of sand is below the specified value of 2.6 while that of quarry dust is just within the acceptable value as shown in table 3 below.

Table 3: Showing the Specific Gravity of both sand and quarry rock dust

Items	Sand (g)	Quarry Rock Dust (g)
Weight of Pycnometer (A)	447.00	439.00
Pycnometer + Sand (B)	1304.00	1448.00
Pycnometer + Sand + Water (C)	1773.00	1878.00
Pycnometer + Water (D)	1270.00	1257.00

Sand

$$\text{Specific Gravity} = \frac{B - A}{((D - A) - (C - B))}$$

$$= \frac{1304 - 447}{((1270 - 447) - (1773 - 1304))}$$

Specific Gravity of Sand= 857/354 = 2.42094 ≈ 2.421
Average Density= 2.421 X 1000 = 2421 kg/m^3

Quarry Rock Dust

$$\text{Specific Gravity} = \frac{(1448 - 439)}{(1257 - 439) - (1878 - 1448)}$$

Specific Gravity = 1009/388 = 2.6005155 ≈ 2.601
Average Density= 2.601 X 1000 = 2601 kg/m^3

3.3 Bulking Test

From table 4 below, the bulking rate of sand used is 11.11 % while 8.11 % bulking rate for quarry rock dust. It was observed that sand has a higher bulkiness value of 37 % increment when compared with quarry rock dust.

Table 4: Showing bulkiness of sand and dust in percentage

	Sand (ml)	Quarry Rock Dust (ml)
Level of Specimen before Settling (B)	400.00	400.00
Level of Specimen after Settling (A)	360.00	370.00
Depth of Water	730.00	730.00
Bulking Rate	[(B/A) – 1] X 100 [400/360 – 1] X 100 = 11.11%	[(B/A) – 1] X 100 [400/370 – 1] X 100 = 8.11%

3.4 Workability Test

Table 5 and figure 1 shows the measured slump values of quarry dust with constant water-cement ratio for different percentage-mixes of quarry rock dust with natural river sand. It is observed that the slump value increases with increase in percentage replacement of sand with quarry dust for the same water-cement ratio.

Table 5: Showing the workability of each specimen at constant water-cement ratio

% Mix of Quarry Dust	Mixing Ratio	Mass of Water (g)	Water-Cement Ratio	Slump Value (mm)
0	1:2:4	4735.00	0.58	50.00
20	1:2:4	4735.00	0.58	56.00
40	1:2:4	4735.00	0.58	60.00
60	1:2:4	4735.00	0.58	75.00
80	1:2:4	4735.00	0.58	82.00
100	1:2:4	4735.00	0.58	90.00

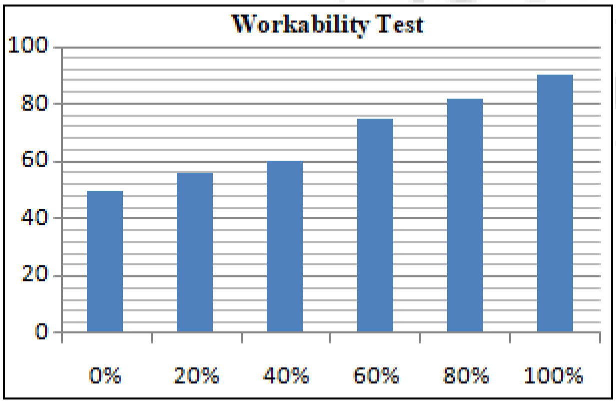

Figure 1: Slump Values of Different Mix-Percentages of Quarry Rock Dust

3.5 Water Absorption Test

Table 6 displays a durability test also known as water absorption test carried out on cubes after 28 days curing. It shows the percentage water absorption of all cubes at different percentage of quarry rock dust contents. It was observed that control specimen has the lowest value of 1.3 % and 100 % quarry rock dust has the highest value of 7.03%. It is observed that as quantity of quarry dust increases, the percentage of water absorption also increases.

Table 6: Water Absorption Test

Quarry Rock Dust %	Weight of cube after curing, w_1 (kg)	Weight of cube before curing, w_2 (kg)	% Water Absorption $(w_2-w_1)/w_1 \times 100$
0	7.49	7.62	1.30
20	7.50	7.70	2.67
40	7.40	7.75	2.80
60	7.52	7.77	4.84
80	7.44	7.80	5.73
100	7.85	8.30	7.03

3.6 Compressive Strength Test

Figure 2, Table 7 and Table 8 shows the summary of the average compressive strength values and percentage increment of the strength values on all specimens with percentage mix of quarry rock dust for a mix ratio of 1:2:4 with each cube having 150 mm x 150 mm x 150 mm.It was observed that with percentage increase in quantity of quarry dust, the compressive strength also increases to 80 % before falling from (5.61 % to 2.90 %) at 100 % quarry dust. the compressive strength of concretes with quarry rock dusts at different percentages give higher strength than that of conventional concrete. This is as a result of cement contents of quarry dust and low percentage of bulkiness when compare with sharp sand. This implies that adequate increment in strength can be achieved at 80 % quarry dust as partial replacement for sharp sand.

Table 7: Average compressive strength of cube at different curing date

	Compressive Strength in (N/mm^2)					
Days	Control Mix	20%	40%	60%	80%	100%
7 days	13.38	13.78	14.50	15.00	16.01	16.83
14 days	16.89	16.95	17.49	18.20	19.63	19.98
21 days	20.04	20.15	20.52	21.67	22.50	23.22
28 days	23.92	23.99	24.20	24.52	25.85	26.35

Table 8: Percentage Increment of Compressive Strength

Days	Control Mix	20%	40%	60%	80%	100%
7 days	13.38	2.90	4.97	3.33	6.31	4.87
14 days	16.89	0.35	3.09	3.90	7.28	1.75
21 days	20.04	0.55	1.80	5.31	3.69	3.10
28 days	23.92	0.29	0.87	1.31	5.15	1.89
Mean	18.55	1.02	2.68	3.21	5.61	2.90

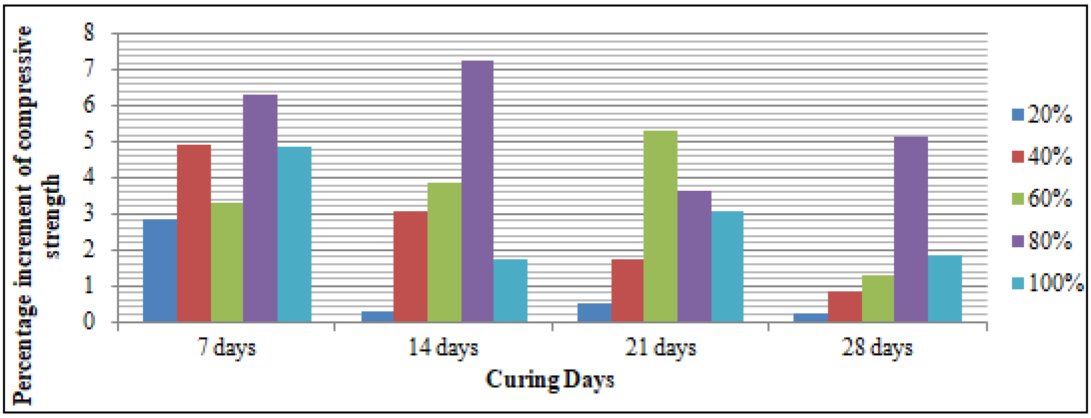

Figure 2: Percentage increment of Compressive Strength at various Curing Days

4. Conclusion and Recommendations

The study investigated the application of Quarry dust as partial replacement for fine aggregate . The inclusion of quarry dust considerably increases the strength of the concrete, which is reflected in the higher Compressive strength values. The study shows that the strength of the Concrete is significantly altered positively by the varying percentages with Quarry dust. It was observed that the highest percentage increment in strength is achieved at 80% although has satisfactory result at 20%, 40% and 60% respectively. The use of quarry dust as admixture to concrete improves its strength; It should therefore be encouraged as an effective and modern form of improving Concrete Production. Long term durability study and chemical test such as dryness and shrinkage studies, deterioration, and water absorption studies should be carried out on quarry dust when use as replacement of sharp sand in concrete.

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