EVALUATION OF COMPRESSIVE STRENGTH OF CONCRETE MADE BY PARTIAL REPLACEMENT OF SAND WITH QUARRY DUST

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Abstract

The demand for natural sand in the construction industry has continually increased which has resulted in the reduction of its sources and an increase in price. In such a situation, the quarry dust being a waste product can be an alternative to the river sand. This study investigates the use of quarry dust as partial replacement of fine aggregate; sand, in concrete production. Quarry dust was used to replace fine aggregates from 0% to 40% in steps of 10%. Concrete cubes measuring 150 x 150 x 150mm were cast using the ratio 1:2:4 by weight and Water/Cement (W/C) ratio of 0.60 and their compressive strengths evaluated at 7, 14, 21 and 28 days curing. The results shows that of all concretes slumps for different percentage of quarry dust, none has collapsed slump and the optimum compressive strength of 27.85 N/mm2 was obtained with 20% replacement which gives a higher value than concrete made with 0% replacement. It is therefore recommended that the concrete can be used for non-structural elements

Key words: Concrete, Compressive strength, Quarry dust

1. Introduction

Concrete is one of the most commonly used artificial construction material in the world today. Normally concrete is a mixture of cement, sand, stone and water sometimes admixtures are added to improve its properties. Within a minimum duration of 28 days, the concrete is confirmed to have attained its nominal Ultimate strength according to BS 5328, 1997. Concrete is virtually used in roads and road infrastructures, buildings, hydraulic structures and virtually all civil and building construction industry. This makes all natural components of concrete used to be high in demand and consequently limiting its supply-scarce. At present, the cost of sand and stone are higher because the material are gradually becoming depleted. Usually River sands are used for construction purposes and are becoming more expensive and its sources are becoming scarce (Siva Kumar et.al 2011). In the central part of Nigeria for example prices of sand per cubic meter was 625 Naira in 2003 and it increased to 1000 Naira in 2008 (Manasseh, 2010). In recent times the possibility of using waste materials in engineering and engineering structures to solve environmental problems and utilizing the wastes has been considered and several attempts have been made for successful utilization of various industrial products e.g. fly ash, silica fumes, rice husk ash, and foundry wastes to mention a few (Neville, 2002). According to Commission of European Communities' report, 2007; if materials are not useable and does not meet technical specification required for its use or no specified market for it, then it remains a waste until a useful output has been identified. Quarry dusts are similar to the aforementioned solid waste materials since it is obtained as a result of quarrying process in the manufacturing of mechanical aggregates and similar properties such as fineness. Agbede and Joel described quarry dust as a cohesion less sandy material acquired either naturally (which is rare) or artificially by the mechanical disturbance of parent rocks (blasting of rocks) for construction purposes, composed largely of particles with diameter range of 0.05mm to 5.00mm. Quarry dust basically has the same physical characteristics with sand as the size and its properties are very close (Agbede et.al, 2004).

Although some developing countries are trying to use quarry dusts, it has long been accepted as a building material in the industrially advanced countries of the west (Illangovanet.al, 2007). Quarry dust have been used for different activities in the construction industry such as road construction – an effective filler material, and manufacture of building materials categorized as light weight aggregates e.g. bricks, tiles and autoclave blocks (Nataraja et.al, 2001). Quarry dust was used as an admixture in stabilizing an expansive soil and due to its sharp and angular particles it provides for better interlock and consequently increases strength (0nyelowe et.al, 2012). Also studies have been conducted to replace sand with quarry dust 100% and it was found that the compressive strength, flexural strength and durability studies of concrete made of quarry dust are almost 10% more than conventional concrete(Ilangovana et.al, 2007). Also partial replacement of Makurdi river sand with quarry dust yields compressive strength higher than that of conventional concrete (Manasseh, 2010).

2. Methodology

It is on the basis of critical assessment of other mutually related research work that necessitated the use of 0.60 as the water/cement ratio, mix ratio of (1:2:4) and replacement percentages of (0%, 10%, 20%, 30% and 40%) between sand and quarry dust for compressive strength analysis. The mix design method employed is the absolute volume method which equates the total volume of the concrete ingredients to

1m^3 including percentage volume of air, 0.02m^3 and 20% addition of the mix to cater for unavoidable losses. Subsequently, the physical properties of quarry dust were determined and the workability of the concrete was evaluated using slump test. Sixty units of concrete cubes measuring 150×150×150 mm were produced from which the compressive strengths can be determined after curing and crushing between intervals of 7, 14, 21 and 28 days.

3. Results and Discussion

3.1 Quarry dust Characteristics

The dust was obtained from Zungeru quarry site where large masses of granite rocks are found. It is composed largely of particles with a diameter range of between 0.05mm and 5.00mm. Specifically, it was ensured that the quarry dust particles employed here has a physical identity of being rough, sharp and angular in which case providing additional strength due to better interlocking. Based on ASTMC 128-88, the specific gravity of quarry dust is 2.65 where it can be categorised as fine aggregate. The physical properties of the dust were found to have specific gravity 2.68, average bulk density compacted 1842kg/m^3 and un compacted 1803kg/m^3, void ratio=0.33, porosity is 2.1 %, and natural moisture content of 2.34%. Also particle size distribution was carried out on the sample and the results are shown on the table 1 below:

Table 1 Particle Size Distribution

BS Sieve sizes	Weight retained (g)	Percentage weight retained	Cumulative Percentage weight	Cumulative Percentage weight
5.00mm	1.00	0.20	0.20	99.80
3.32mm	48.00	9.60	9.80	90.20
2.00mm	105.00	21.00	30.80	69.20
1.81mm	93.00	18.60	49.40	50.60
850µm	7.00	1.40	50.80	49.20
600 µm	22.00	4.40	55.20	44.80
425µm	37.00	7.40	62.60	37.40
300µm	12.00	2.40	65.00	35.00
150µm	114.00	22.80	87.80	12.20
75µm	40.00	8.00	95.80	4.20
Pan	21.00	4.20	100	0
Total	500g		607.40	

Fineness Modulus = Total Cumulative Percentage weight retained/ 100

$$= \frac{607.40}{100} = 6.07$$

3.2 Fresh Properties of Concrete

Fresh properties are used to evaluate the workability of concrete. Amongst other numerous methods slump test was chosen and the results are shown in the table 1 below

Table 1 Slump Test Results

%Quarry dust (%)	Average Slump (mm)	Mix ratio	Water/Cement ratio
0	130	1:2:4	0.6
10	140	1:2:4	0.6
20	165	1:2:4	0.6
30	150	1:2:4	0.6
40	165	1:2:4	0.6

3.2 Hardened Properties of Concrete

Compressive strength of concrete was used to evaluate the hardened properties of concrete and the results are shown in the table 2 below:

Table 2 Compressive Strength Results

Percentage of Quarry dust (%)	Age (days)	Average Compressive strength (N/mm^2)
0	7	19.24
	14	19.18
	21	18.80
	28	23.25
10	7	17.29
	14	16.19
	21	17.24
	28	21.92
20	7	22.48
	14	26.81
	21	26.60
	28	27.85
30	7	24.17
	14	14.50
	21	11.67
	28	25.07
40	7	13.55
	14	12.14
	21	12.07
	28	14.47

3.3 Discussion of Results

3.3.1 Particle size distribution

From the particle size distribution of the quarry dust as shown in figure 1 below the coefficient of gradation was found to be 0.80 which is approximately 1 that is the quarry dust is a well graded

$Cc = (D_{30})^2 / (D_{60} * D_{10})$

Where $D_{30} = 35$, $D_{60} = 190$ and $D_{10} = 8$.

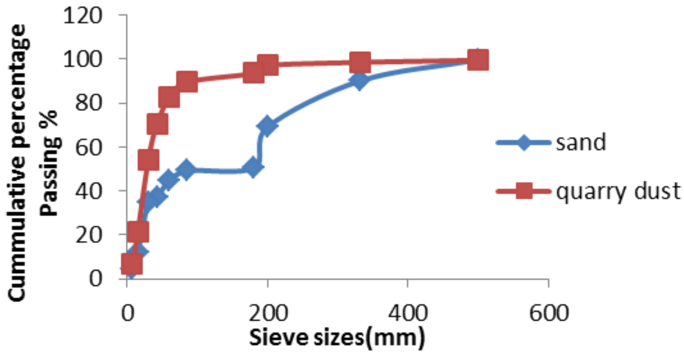

Figure 1 Particle Size Distribution

3.3.2 Slump test

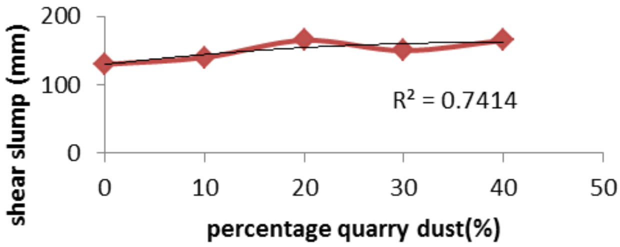

Figure 2 Shear Slump vs. Percentage Quarry Dust

The slump values thus obtained were definitely within the limits between 140mm – 165mm and non-concrete slumps made from these partial replacements had collapse slumps hence the concrete made from these replacements are workable.

3.3.3 Compressive strength

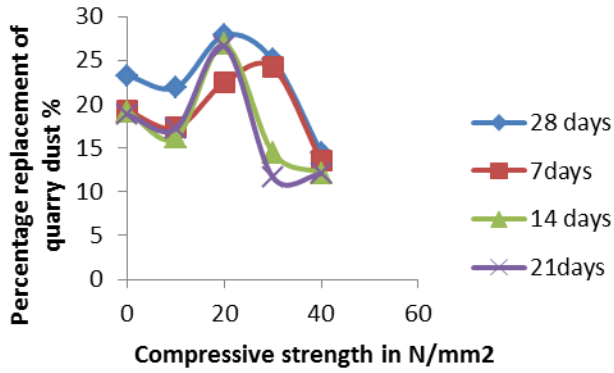

Figure 3 the Compressive Strength of Concrete vs. Curing Age

A careful observation of figure 3 indicates that for an initial input of quarry dust into the concrete, there was a slight reduction in the strength of the cube (about 6% of the control cube), but then, a further increase (8% of the control cube strength)in the percentage of quarry dust induces the maximum strength of the concrete cubes at 20% and then additional percentage introduced yields a declining strength of the concrete cubes so much that the minimum strength attained was at 40% quarry dust addition (decrease of about 38% of control cube).

Noticeable among the observations too is the fact that to a large extent, an increase in the curing age tend to increase the strength of the concrete especially at 20% quarry dust input. This is often the case as cubes having longer curing ages give a higher value of compressive strength, this results agrees with the results obtained by Manasseh, 2010

4. Modeling

Fresh properties of concrete (slump) and percentage replacement of quarry dust were used to model the equation corresponding to nominal compressive strength which is at 28days. Using Microsoft excel spreadsheet the model equation was generated

$$y = -0.68445X1 + 0.557X2 \text{...........} (1)$$

Where

y= compressive strength at 28days curing

X_1 = slump value in mm

X_2 = Percentage replacement of Quarry dusts with sand

The equation (1) has 0.95 R^2 (root mean square) which implies that slump value and percentage quarry dust replacement have the capability of predicting the compressive strength of the concrete. Also validating the model, the predicted values were plotted against the observed values as show in the figure4 below; shows R^2 = 0.95 which implies minimal residuals.

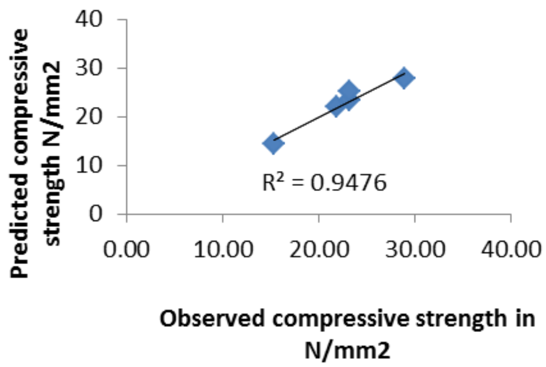

Figure 4Predicted compressive Strength Vs. Observed Compressive strength (N/mm^2)

5. Conclusion

The use of quarry dust obtained from Zungeru Quarry site was used to partially replace sand and the following conclusion were deduced from this work

1. The workability of fresh concrete varies inconsistently with subsequent increase in the quantity of quarry dust replacement although all of the samples

met the standard requirements i.e. none of the concrete slumps collapsed

2. The optimum compressive strength of the concrete obtained at 20% replacement at 28days curing is 27.85 N/mm^2.
3. The percentage replacement of quarry dust and its slump value are statistically good at predicting the compressive strength of the concrete.

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References

1. Agbede I.O and Joel M. (2004) "Suitability of Quarry dust as Partial Replacement for Sand in Hollow Block Production"; Nigeria Journal of Engineering Research and Development.2004.
2. ASTM Standard C 128-88, 2003" Standard Test Method for Density, Specific Gravity, and Absorption of Fine Aggregates," ASTM International.www.astm.org.
3. BS 5328: Part 1 1997. Guide to specifying concrete. British Standards Institute, London, UK.
4. Commission of the European Communities (2007). "Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on waste and by-products." COM (2007) 59 final.
5. Ilangovan R., Nagamani K., (2007) Application of Quarry Dust in Concrete construction. High Performance Concrete, Federal Highway Administration PP1-3 http://knowledge.fhwa.dot.gov/cops/hpcx.nsf.
6. Manasseh Joel, (2010) "Use of Crushed Granite Fine as Replacement to River

Sand in Concrete Production" Leonardo Engineering Journal of Practices and Technologies. Issue 17, ISSN 1583 -1078, pp. 85- 96

7. Neville A.M, (2002) – "*Properties of Concrete"*, Fourth and Final Edition, Pearson Education limited Essex.
8. Onyelowe Ken C., Okafor F. O. and Nwachukwu D. G (2012) Geophysical Use of Quarry Dust (as admixture) as applied to Soil Stabilization and Modification-A Review. Asian Research Publishing Network, Vol. 1, No. 1, ISSN 2305-493X
9. Raman S.N., Saifiuddin M., Zain M.F.M.,(2007) Non-Destructive Evaluation of Flowing Concretes incorporating Quarry waste, Asian Journal of Civil Engineering (Building and Housing), 8(6), p. 597-614.
10. Sivakumar A., Prakash M., Characteristic studies on the mechanical properties of quarry dust addition in conventional concrete, Journal of Civil Engineering and Construction Technology Vol. 2(10), pp. 218-235, October 2011