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Concrete Compressive Strength Using River Sand and Quarry Dust as Fine Aggregates

Benjamin Nnamdi Ekwueme[1*] Emmanuella Chioma Njoku[2] Anthony Chibuzo Ekeleme[3]
Ezenwa Chinenye Amanamba[3] Uzochukwu Ethelbert Uzoh[4] Hippolitus Ogedi Ibearugbulem[5]
Ethelbert Chukwunonye Nwadike[5] Patrick Okechukwu Ibe[5]
1. Department of Civil Engineering, University of Nigeria Nsukka, Enugu State, Nigeria
2. Department of Materials and Metallurgical Engineering, Federal University of Technology, Owerri, PMB 1526, Imo State Nigeria
3 Department of Civil Engineering, Abia State University Uturu, P.M.B 2000 Abia State, Nigeria
4 Department of Agricultural and Bioresources Engineering, Federal University of Technology, Owerri, PMB 1526, Imo State Nigeria
5 Department of Civil Engineering, Federal Polytechnic Nekede, P.M.B 1036, Owerri, Imo State

Abstract
The compressive strength of concrete built with river sand and quarry dust as fine aggregate was examined in this study. Ordinary Portland cement (OPC) was blended with river sand and quarry dust at five levels, namely 10%, 20%, 30%, 40%, and 50%, by partially substituting OPC with river sand and quarry dust. River sand was combined with quarry dust in five different ratios for each replacement level: 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, and 0:100. For each blend, ten cubes of (150 x 150 x 150) mm were created. As a control, ten cubes containing solely OPC were made, for a total of 60 cubes. The cementitious material to sand mix ratio was kept constant at 1:2:4 and the water to cement ratio was kept at 0.5. Three cubes for each mix and the control were crushed to obtain their compressive strengths at 28 days. The results showed that river sand and quarry dust with a compressive strength of 10 to 30% replacement is an excellent construction material for constructing concrete. As a result, quarry dust and river sand are suggested as construction materials for making concrete, and can be used to replace river sand up to 30% of the time to achieve the needed compressive strength of not less than the standard
Keywords: River sand; Quarry dust; Ordinary Portland Cement; Compressive strength
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1. Introduction

The rapid increase in population has led to increased need for infrastructures, which include; buildings, roads and highway constructions. All over the world, concrete material is majorly utilized in construction works, because it is versatile and lasts longer (Sandoval *et al.* 2019, Ramesh and Shivani, 2019, Gallegos-Villela *et al.* 2021, Ekeleme *et al. 2021*). Concrete is a composite material comprising cement, aggregate, and water fused together, which when hardened becomes a solid with outstanding mechanical properties, and good resistance to chemicals (Sonebi, 2016). There is high demand of aggregates used in concrete production. According to (Zhang *et al.* 2015), the world's demand for aggregates would increase from 45.9 – 66.3Gt from 2012 to 2022.

Conventionally, rivers sand has always been used as the fine aggregate in the production of concrete, for several eras. Nevertheless, there is drastic reduction of the river sand in many parts of the world, coupled with environmental and societal problems associated with collection of river sand deposits (Kankam, 2017). Several materials have been reported as alternatives in the partial replacement of river sand, which include; recycled aggregate, fly ash, limestone slag, silica fume, among others (Zhang *et al.* 2015, Sonebi, 2016, De Brito *et al.* 2018). For all the alternative materials being studied, the availability of large quantities of quarry dust in different parts of the world makes it appropriate for usage as fine aggregates in concrete production. During rock comminution (breaking and crushing), waste dust particles are released which are known as quarry dust. These quarry dust cause pollution and have disposal problems. Thus, their usage as concrete production materials would in turn reduce pollution and as well reduce the cost of production (Prakash *et al.* 2012).

Some studies have looked at the mechanical qualities of concrete made with quarry dust as a partial replacement for fine aggregates. The amount of quarry dust required to partially replace fine sand aggregate, on the other hand, has yet to be determined. Cheah *et al.* (2018) studied the mechanical properties of a ternary mixed concrete composite material with quarry dust as the fine component. With around 60% replacement, the strength qualities were improved. Ponnada *et al.* (2020) studied the strength and workability of concrete containing fine aggregates of untreated sea sand and quarry dust. For 50% untreated sea sand and 50 percent quarry dust, the best concrete mixture was obtained. Also, when the amount of quarry dust grew up to 100% replacement, the compressive strength improved.

Febin *et al.* (2019) examined the strength qualities of quarry dust in the construction of concrete. The elastic modulus and abrasion resistance rose by up to 30%, while the compressive strength increased by up to 60%. The project looks on using quarry dust in place of fine aggregates in various quantities. This would add to existing information on the industrial applications of quarry dust as the substitute material for fine aggregate in concrete production.

2. Materials and Methods

2.1 Materials

Cement, river sand, quarry dust, and coarse aggregate are among the materials utilized in the construction. Ordinary Portland Cement (Grade 42.5R) was obtained from Dangote Cement Company and met the requirements of BS EN 206: 2013. The river sand was taken from the Otamiri River in Nekede, Imo State, Nigeria, and was free of silt and organic contaminants. Both the quarry dust and coarse aggregates came from Lokpaukwu in Abia State. The maximum particle size of the coarse aggregate is 12.5mm. It was necessary to use portable water that was free of dirt and pollutants.

2.2 Methods

The weights of the various ingredients were batched using the 1:2:4 ratio, which denotes the ratio of cement to fine aggregate to coarse aggregate (Table 1). The fine aggregate was made up of river sand and quarry dust in a 10% step ratio, starting with 0% quarry dust (Tables 1 and 2). For the creation of fresh concrete, the constituent elements were properly mixed, and then the needed amount of water was added. Throughout the mixing procedure, a 12 (0.5) water to cement ratio was used (Ponnada *et al.* 2020).

Table 1: Mix ratios and amounts used

S/No.	Cement (1)	Fine aggregate (2)		Coarse aggregate (4)	Water/cement ratio
		River sand	Quarry dust		
1.	1	100%	-	4	0.5
2.	1	90%	10%	4	0.5
3.	1	80%	20%	4	0.5
4.	1	70%	30%	4	0.5
5.	1	60%	40%	4	0.5
6.	1	50%	50%	4	0.5
7.	1	40%	60%	4	0.5
8.	1	30%	70%	4	0.5
9.	1	20%	80%	4	0.5
10.	1	10%	90%	4	0.5
11.	1	-	100%	4	0.5

Table 2: Constituent mass values

S/No.	Percentage	Cement [kg]	River sand[kg]	Quarry dust[kg]	Coarse Aggregate[kg]	Water ratio
1.	Control	12.7	25.5	-	50.9	6.4
2.	10%	12.7	22.95	2.55	50.9	6.4
3.	20%	12.7	20.4	5.10	50.9	6.4
4.	30%	12.7	17.85	7.64	50.9	6.4
5.	40%	12.7	15.3	10.20	50.9	6.4
6.	50%	12.7	12.75	12.75	50.9	6.4
7.	60%	12.7	10.2	15.30	50.9	6.4
8.	70%	12.7	7.64	17.85	50.9	6.4
9.	80%	12.7	5.10	20.40	50.9	6.4
10.	90%	12.7	2.55	22.95	50.9	6.4
11.	100%	12.7	-	25.50	50.9	6.4

Slump tests were performed in accordance with (BS EN 12350-2:2019) to confirm the uniformity of the concrete mixtures. The freshly mixed concrete was put into molds measuring (150 x 150 x 150) mm in size. The material was then crushed (to remove voids and capillary cavities) in 50 mm layers, with each layer being tamped 35 times with the tamping rod. The top of the mold was used to level the concrete, and the samples were then preserved in wet sacks for one day. The concrete samples were then removed from the molds and placed in water tanks for a total of 28 days to cure A total of 60 cubes were manufactured, and after 28 days of curing, the samples were examined using a compression testing equipment. The cube sample was sandwiched between two hardened steel bearing plates, and then a load of 15 MPa per 60 seconds was applied in accordance with [BS EN 12390-3:2009]. The sample was cleaned of shingles and placed in the center of the machine, after which a continuous load was applied until it failed and the maximum failure load was determined. Each test consisted of ten samples, with the average values being used. By dividing the maximum load (N) by the cross-sectional area, the compressive strength was computed (mm^2). Mathematically, the compressive strength (Equation 1) can be expressed as:

$$Compressive\ strength = \frac{Crushing\ Load(N)}{Area\ of\ cube(mm^2)} \quad (1)$$

The characteristic strength of material (Equation 2) was also obtained which is the strength below which not more than 5% of tests results may be expected to fall. This is given as:

$$Characteristic\ Strength\ (F_{cu}) = F_m - 1.6S \quad (2)$$

Where:
F_{cu} = characteristic strength of concrete
F_m = mean strength of concrete from the test result.
S = standard deviation.

3. Results and Discussion

3.1 Physical Properties of Materials

The first presentation in this part covered the results of the physical properties of river sand and quarry dust. The properties of the newly created fresh and hardened concrete were then displayed. The specific gravity of river sand was 2.57, quarry dust was 2.63, and coarse aggregate had a specific gravity of 2.72. Illangovana (2008), reported similar results, hence the results are equivalent. The distribution of particle size of quarry dust, river sand, and coarse aggregates was depicted in Fig. 1 based on sieve analysis. 1.

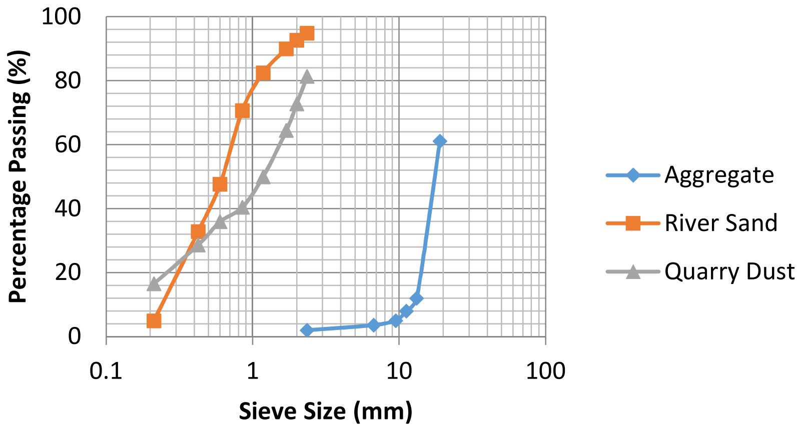

Figure 1: Distribution of particle size of aggregates

The particle size distribution in river sand was well-graded, with a homogeneity coefficient of 2.88. Quarry dust, on the other hand, had a uniformity coefficient of zero, indicating that the particle size was not adequately graded. The coarse aggregate particle sizes ranged from 5 to 20 mm, with a Coefficient of uniformity (Cu) value of 1.54. The curves for different combinations of fine aggregates were overlaid in Fig. 1 and were in conformity with the overall limits set forth in (BS 882:1992).

The densities of hardened concrete are shown in Table 3. The density ranged between 2325 and 2562 kg/m3. The range corresponds to that for normal weight concrete which ranges from 2000 – 2600 kg/m^3 (Ambrose *et al.* 2018)

Table 3: Density of hardened concrete

S/N	Percentage Replaced (%)	Density (kg/m^3)	Percentage Drop in Density (%)
1	0	2562	0.00
2	10	2471	3.55
3	20	2397	6.64
4	30	2434	5.00
5	40	2348	8.35
6	50	2325	9.25

(3)

3.2 Workability

The slump behavior of the produced concrete samples, which were made up of quarry dust and river sand as fine aggregates, was reliant on the water-cement ratio typical of standard weight concrete. As shown in Table 4, the slump test values ranged from 10mm to 20mm.

3.3 Compressive strength of concrete

In relation to the partial replacement of river sand with quarry dust, the findings of the characteristic strengths are displayed in Fig. 2. The compressive strengths of the concrete samples with quarry dust were lower than those of the samples without quarry dust. This could be owing to the use of a fixed water-to-cement ratio. In addition, as the amount of quarry dust added increased, more water was required for adequate mixing, resulting in a decrease in compressive strength compared to the concrete mixture without quarry dust (Osunade, 2002, Hameed and Sekar 2009, Demirel, 2010, Sukesh *et al.* 2013, Jayaraman *et al* 2014, Ambrose *et al.* 2018, Sivakuma and Prakash 2018).

Table 4: Average Values of the Slump Test

Percentage replaced (%)	Mix ratios	Actual value (mm) 28days
0	1.2.4	20
10	1.2.4	15
20	1.2.4	15
30	1.2.4	13
40	1.2.4	11
50	1.2.4	10

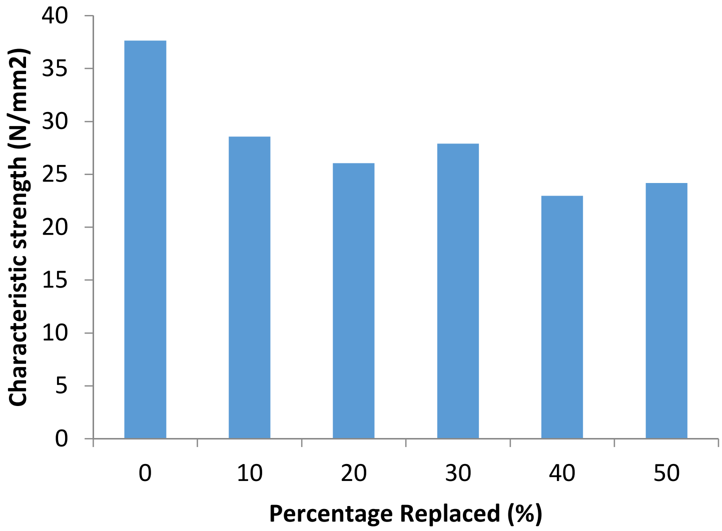

Figure 2: Characteristic strengths of the partially replaced concrete samples

However, the resulting compressive strengths for the produced concrete samples, with quarry dust met the specifications for normal-weight concrete, although up to 30% replacement with quarry dust was recommended (Prakash and Rao, 2016 Ambrose *et al.* 2018).

4. Conclusions

The notion of replacing natural fine aggregate with quarry dust highlighted in this study could increase the utilization of generated quarry dust, lowering the need for land fill area and ensuring the long-term sustainability of the hardly accessible natural sand. However, while the concrete samples met the standard permissible strength of 25 N/mm^2, the authors advocate using not more than 30% quarry dust as a replacement for river sand, based on the findings. Also from the study, concrete's workability deteriorates as its replacement rate rises. From the findings, it is concluded that quarry dust can be used as a fine aggregate substitute. Thus the negative effects on the environment can be considerably reduced.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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