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# ASSESSMENT OF THE PROPERTIES OF HIGH STRENGTH CONCRETE MADE USING QUARRY DUST AS FINE AGGREGATE

**Mohammed T.A.[1]; *Yusuf A.[2] & Abdullahi A.[2]**
[1] Department of Civil Engineering, Federal University of Technology, Minna
*Corresponding author email: yusuf.abdul@futminna.edu.ng

**ABSTRACT**
The study was carried out to assess the properties of High-strength concrete made using Quarry dust as Fine aggregate. Preliminary tests were carried out on the aggregates to determine their suitability for use in High- strength concrete. The aggregates were well graded and other properties met the requirements of aggregates to be used for High-strength concrete. Superplasticizer and Rice husk were used as chemical and mineral additives to improve the workability and other properties of the concrete. Based on the properties of the aggregates, a mix ratio of 0.23:0.51:0.044:1.05:0.7:0.2, representing cement: fine aggregate: coarse aggregate: superplasticizer: water: rice husk was used. Concrete cubes of 100x100x100 mm were cast, cured and the 28-day compressive strength determined. An average 28-day compressive strength of 63 N/mm$^2$ was obtained. This can be categorized as class I high strength concrete and is applicable in the construction of high rise buildings. The Study therefore concludes that quarry dust can be used as total replacement for fine river sand in high strength concrete production.

**Keywords:** *Rice Husk Ash, High-strength Concrete, Natural River Sand, Quarry Dust.*

## 1 INTRODUCTION

Concrete is a construction material made up of cement, fine aggregate, coarse aggregate, water and mineral and/or chemical admixtures. Concrete is a widely used material in the Nigeria and the world at large for various building and civil engineering works. Based on global usage, it is placed at second position after water (Azhagarsamy**,** 2017). Based on compressive strength, concrete can be categorized as normal strength and high strength. High strength concrete are characterized with a compressive strength in excess of 62.5 N/mm$^2$ (Caldarone, 2009). Because of the superior mechanical properties and the significant economic savings offered by high strength concrete, the use of it has accelerated far beyond the current status of research on the material. Up to now, the major application of high strength concrete has been for cast-inplace columns in tall buildings. However, the use of high strength concrete in the precast, prestressed concrete industry can offer several benefits. For instance, the use of high strength concrete, in general, can shorten turnover times of casting beds and speed up construction time. Also, the increased concrete strength would allow for the use of more slender members, thus reducing the dead load of sections. It would also allow for an increase in the length of members, limited only by stability and transportation concerns (Fahim and Esko, 2015).

Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is Natural River or pit sand (Azhagarsamy**,** 2017). The global consumption of natural sand is very high due to the extensive use of concrete as a result of rapid infrastructural growth. In order to lessen the use of the natural river sand, the construction industry of developing countries have been saddled with the responsibility of identifying alternative materials to reduce or eliminate the demand for natural sand. This research is therefore aimed at assessing the suitability of quarry waste as fine aggregate in high-strength concrete production.

Quarry dust, stone dust or crusher dust as it is variably called, is a by-product of the cutting and crushing process of stones. Quarry dust are produced as a result of mostly controlled blasting operation. The primary object of quarrying is to obtain coarse aggregate of various sizes to be used for various construction purposes. Quarry dust has been identified over the years as a substitute material for fine aggregate in concrete. Quarry dust can be used in building works, which would decrease the cost of construction and the construction material would be saved and the natural resources could be used properly. Quarry dust have been used for different purposes in the construction industry, such as building materials, road construction materials, fine aggregates, bricks and tiles.

The world around us is rapidly evolving and so is the world of infrastructure (Agrawal, *et al*., 2017). The use of the resources required to achieve the construction of these infrastructures are also in rapid use. Fine aggregate, one of the major component of concrete (which is the most common material used for infrastructural development) is being mined at an exponential rate. The sand mining from pits and river bed is a direct cause of erosion. The physical impact of sand mining include;

1. Downstream erosion due to increased carrying capacity of stream, downstream changes in patterns of deposition and the changes in channel bed and habitat type
2. Upstream erosion as a result of an increase in channel bed slope and changes in the flow velocity
3. The loss of adjacent land and/or structures
4. The undercutting and collapse of river banks (Saviour and Stalin, 2012).

Sand mining is regulated by law in many places, but it is still often done illegally (Kadi, *et al*., 2012). Quarry dust, a by-product of stone blasting in quarries constitute air pollution and disposal problem. However, the better geotechnical properties that quarry dust possess makes it strong candidate for the replacement of fine aggregate in concrete. This study was carried out to determine the suitability of quarry dust as fine aggregate in High Strength Concrete (HSC).

Due to the need to replace river sand in convectional and high-strength concrete so many research work have been carried out to this effect. Anzar (2015) attempted to improve the properties of concrete using quarry dust as replacement for natural sand, he found out that quarry dust improved the mechanical properties of concrete. He concluded that the optimum compressive strength is achieved at the proportion of coarse to fine of 40:60. Radhikesh *et al*. (2010) examined the suitability of stone crusher dust as a fine aggregate in concrete paving blocks. Some of the physical and mechanical properties of paving blocks with fine aggregate replaced by various percentages of stone dust were investigated. The experiment results showed that the replacement of fine aggregate by stone dust up to 50% by weight had negligible effect on the reduction of any physical and mechanical properties of the concrete. He also found out that there was 56% saving in money. Arivumangai and Felixala (2014) examined the strength and durability properties of granite powder concrete. The main parameter investigated was M39 grade concrete with replacement of sand by granite powder by 0, 25 and 50%, the cement was partially replaced by superplasticizer, slag, fly ash and silica fume. The test result indicated that use of granite powder and admixtures in concrete improved the performance of concrete durability and compressive strength. Anitha *et al*. (2013) investigated the use of quarry dust as replacement of river sand alongside chemical admixture in concrete. They found that as the replacement percentage increased, there was appreciable increase in flexural strength of the concrete. They also found out that a superplasticizer dosage of 1% increased the flexural strength compared to conventional concrete. They concluded that quarry dust can be used as an alternative material to natural river sand with a considerable increase in flexural strength reduction in disposal problem and economy in construction. Subramanian and Kannan (2013) experimented on the usage of quarry dust as partial replacement for sand in concrete and mortar. They reported that it is possible to replace river sand in conventional concrete with quarry dust. They found out that washed quarry dust gave better results due to more silicon (iv) oxide ($SiO_2$) and iron (iii) oxide ($Fe_2O_3$) and less amount of fines of size up to 150 microns. They recommended that trial casting with quarry sand proposed to be used in order to arrive at the water content and mix proportion to suit the required workability levels and strength requirement should be done. They also expressed the importance of removing excess fines of size up to 150 microns by washing. According to Nur *et al*. (2018) fifty percent of quarry dust gave optimum workability in concrete mix, beyond this percentage, the workability of the concrete was greatly affected. They concluded that realization of quarry dust from quarrying industry is a sustainable approach in order to comply with future need of the environment and concrete technology. From the test conducted by Sivakumar and Prakash (2011), it was inferred that quarry dust may be used as an effective replacement material for natural sand. The increase in cement content in the mortar phase showed an increase in strength. They added that fine quarry dust tends to increase the amount of plasticizer needed for the quarry mixes in order to achieve the rheological properties. When the river sand was replaced 100% with quarry dust they found out that the compressive strength was higher by 11.8% than the controlled cement mortar cube. The elastic modulus of the “quarry dust” concrete also increased. They concluded that “though there is an appreciable increase in strength gain of concrete when river sand (fine aggregate) is replaced with quarry dust at 100%, but the fines present in quarry dust increased water demand". With the addition of 15% of fly ash and 15% of quarry dust, the compressive strength increased to 22% than control mix M40 grade at day 28 (Arfat *et al*., 2016). Arfat *et al*. (2016) found out that using fly ash and quarry dust, more durable and sustainable concrete can be produced by evaluating optimum content of both. Ukpata and Ephraim (2012) identified the flexural and tensile strength properties compared with those for normal concrete. They found out that concrete proportion of lateritic sand and quarry dust could be used for construction provided the mixture of lateritic sand content is reserved below 50%. Both flexural strength and tensile strength were increased with increase in lateritic content. Ganesan (2009) reported that volume fraction of steel fibre to be used are 0.5, 1.5, 2.0%. For M60 compaction factor ranges from 0.88 to 0.92. Raman *et al.* (2007) indicated that quarry waste did not significantly affect the non-destructive properties of the concretes except initial surface absorption. Dynamic modulus of elasticity, ultrasonic pulse velocity, and initial surface absorption varied linearly with compressive strength. Moreover, dynamic modulus of elasticity and ultrasonic pulse velocity were well-correlated. Ilangovan and Nagamani (2006) reported that natural sand with quarry dust as full replacement in concrete as possible with proper treatment of quarry dust before utilization. Quarry waste fine aggregate was used in presence of silica fume. The overall test results revealed that quarry waste fine aggregate can be utilized in concrete mixtures as a good substitute of natural sand. 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. Sahu, *et al.* (2003) reported significant increase in compressive strength, modulus of rupture and split tensile strength when 40 percent of sand is replaced by quarry rock dust in concrete. Nagaraj (2000) studied that the consumption of cement content, workability, compressive strength and cost of concrete made with quarry rock dust. The mix design proposed showed the possibilities of ensuring the workability by wise combination of rock dust and sand, use of super plasticizer and optimum water content. Hudson (1997) reported that the strength of quarry rock dust concrete is comparatively 10-12 percent more than that of similar mix of conventional concrete. Also the result of this investigation showed that drying shrinkage strains of quarry rock dust concrete were quite large to the shrinkage strain of conventional concrete. However, at the later age, showed equal strain than conventional concrete. Durability of quarry rock dust concrete under sulphate and acid action was higher inferior to the Conventional Concrete Permeability Test results clearly demonstrated that permeability of quarry dust concrete was less compared to conventional concrete. Nagaraj *et al.* (1996) produced concrete using the rock dust as an alternative to natural sand. They studied the effect of rock dust on the strength and workability of concrete.

## 2 METHODOLOGY

High strength concrete (HSC) was prepared by selecting suitable materials, good quality control and proportioning. The materials conformed to British Standard requirements. The materials used in this research include;

1. Cement: The Ordinary Portland cement used in this study conform to BS EN 197-1 (2000). The specific gravity of cement was 3.15. The initial and final setting times were found as 30 minutes and 120 minutes respectively. Standard consistency of cement was 31%.
2. Superplasticizer: The superplasticizer was sourced from Armosil Manufacturing Incorporation, a supplier of different kinds of concrete admixtures. Hydroplast 300, a light blue colourless liquid with specific gravity of $1.175 \pm 0.005$ at $20^0$C was used. Hydroplast 300 is a high performance water reducing superplasticizer formulated to comply with ASTM C-94 type F and EN 943, part 2.
3. Quarry stone dust: The quarry stone dust used as the fine aggregate in this research was sourced from Abuja, Nigeria. The specific gravity, fineness modulus and compacted density are 2.63, 4.39 and 1435.75 kg/$m^3$ respectively. The quarry dust passing through sieve 5 mm and retrained on sieve 150 μm were used.
4. Coarse aggregate: A well graded crushed granite with a specific gravity of 2.64 and compacted density of 1582.87 kg/$m^3$ was used as coarse aggregate in this research.
5. Rice Husk Ash (RHA): The RHA used was sourced from Gidan Kwano village, burnt at a controlled temperature of 600$^o$C and sieved. The chemical composition of RHA used is given in Figure 1. The RHA possess major oxides in excess of 70% as recommended by standards.

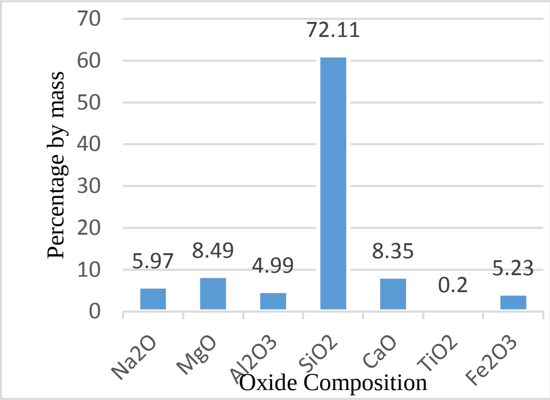


**FIGURE 1**: CHEMICAL COMPOSITION OF CHEMICAL ADMIXTURE

## 2.1 TEST ON AGGREGATE

The various tests conducted on the aggregates used in this research are sieve analysis, specific gravity test; and compacted density test. The tests were carried out in accordance to BS EN 12620 (2008).

## 2.2 CASTING AND CURING OF TEST SPECIMENS

The mix ratio adopted was 0.23:0.51:0.044:1.05:0.7:0.2 representing cement: fine aggregate: coarse aggregate: superplasticizer: water: rice husk. 100x100x100 mm moulds used were cleaned, assembled and oiled. The concrete was cast in moulds in three layers. Each layer was compacted using a tampering rod to remove entrapped air. The concrete surfaces were levelled by trowel, and the specimens were covered with nylon sheets to prevent evaporation of water for 24 hours. The specimens were demoulded after 24 hours and cured in a curing tank.

## 2.3 SLUMP TEST

This test was carried out to determine the workability of concrete mixture according to BS EN 12350:5 (2009) by using standard slump cone. The average slump obtained was 120mm.

## 3.0 RESULTS AND DISCUSSION

### 3.1 PARTICLE SIZE DISTRIBUTION

Table 1 shows the result of particle size distribution analysis conducted using quarry dust size sample. Total mass of dry sample used was 500g, but summing the masses of the retained sand we have 499.9g. The reduction is due to losses mainly from small quantities of sand that gets stuck in the meshes of the sieves.

TABLE 1: PARTICLE SIZE DISTRIBUTION OF FINE AGGREGATE (QUARRY STONE DUST)

| Sieve sizes (mm) | Weight of empty sieve (g) | Weight of sieve + Sample (g) | Weight of sample retained (g) | Percentage weight retained | Cumulative percentage retained | Percentage passing |
|---|---|---|---|---|---|---|
| 5.00 | 475.4 | 489.2 | 13.8 | 4.6 | 4.6 | 95.40 |
| 3.35 | 468.0 | 501.0 | 46.8 | 11.6 | 16.2 | 83.80 |
| 2.36 | 434.0 | 462.2 | 28.2 | 9.4 | 25.6 | 74.40 |
| 2.00 | 416.9 | 428.9 | 12.0 | 4.0 | 29.6 | 70.40 |
| 1.18 | 385.2 | 416.9 | 31.7 | 10.57 | 40.17 | 59.83 |
| 850 | 352.5 | 371.0 | 18.5 | 6.17 | 46.34 | 53.66 |
| 600 | 467.9 | 492.0 | 24.1 | 8.03 | 54.37 | 45.63 |
| 425 | 435.0 | 457.1 | 22.1 | 7.37 | 61.74 | 38.26 |
| 300 | 384.7 | 398.9 | 14.2 | 4.73 | 66.47 | 33.53 |
| 150 | 420.6 | 501.5 | 80.9 | 26.97 | 93.44 | 6.56 |
| 75 | 383.1 | 402.0 | 18.9 | 6.3 | 99.74 | 0.26 |
| Pan | 298.1 | 300.7 | 2.6 | 0.87 | 100.0 | 0 |
| **Total** | | | **499.9** | | | |

Cumulative percentage retained from 150mm sieve size and above:

93.44+ 66.47 + 61.74 + 54.37 + 46.34+ 40.17 + 29.60 + 25.60 + 16.20 +4.60 = 438.53

Finest Modulus = 4.39

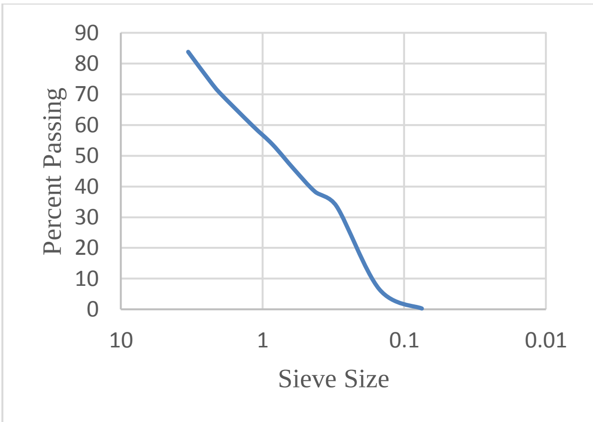


**FIGURE 1:** SIEVE ANALYSIS OF QUARRY DUST

### 3.2 SPECIFIC GRAVITY

Table 2 shows the result for the specific gravity of fine aggregate (Quarry stone dust). The specific gravity of fine aggregate obtained is 2.63, which is appropriate for use in High-strength concrete BS EN 12620 (2008).

**TABLE 2:** SPECIFIC GRAVITY OF FINE AGGREGATE

| **Trial** | **1** | **2** | **3** |
|---|---|---|---|
| Weight of Cylinder: $M_1$ (g) | 162.4 | 164.1 | 152.1 |
| Weight of Cylinder + Dry Sample: $M_2$ (g) | 334.5 | 338.8 | 331.0 |
| Weight of Cylinder + Dry Sample + Water: $M_3$(g) | 306.5 | 309.1 | 308.9 |
| Weight of Cylinder + Water: $M_4$ (g) | 116.6 | 116.6 | 116.6 |
| $M_2$-$M_1$ (g) | 45.8 | 47.5 | 35.5 |
| $M_4$-$M_1$ (g) | 189.9 | 192.5 | 192.3 |
| $M_3$-$M_2$ (g) | 172.1 | 174.7 | 178.9 |
| $G_S$ | 2.57 | 2.67 | 2.65 |
| **Average $G_S$** | | **2.63** | |

### 3.3 WATER ABSORPTION

Table 3 shows the result of water absorption test of Fine aggregate (Quarry stone dust). A mean value of 21.71% was obtained which is adequate for use in High-strength concrete.

TABLE 3: WATER ABSORPTION OF FINE AGGREGATE

| **Trial** | **1** | **2** |
|---|---|---|
| Weight of empty can: $M_1$ (g) | 76.3 | 79.8 |
| Weight of can + Dry sample: $M_2$ (g) | 315.5 | 284.8 |
| Weight of can + Sample + Water: $M_3$ (g) | 367.3 | 329.4 |
| Moisture weight $M_3$-$M_2$ (g) | 51.8 | 44.6 |
| Weight of dry sample: $M_2$-$M_1$ (g) | 239.2 | 205.0 |
| %Water absorption | 21.66 | 21.76 |
| %Mean water absorption | | 21.71 |

### 3.4 BULK DENSITY

Table 4 shows the results of compacted bulk density of fine aggregate (Quarry stone dust). The test result shows that the bulk density of the dust is 1435.75 kg/m$^3$, which is well above the average value required for use in High-strength concrete.

**Table 4:** Bulk Density of Fine Aggregate

| **Trial** | **1** | **2** | **3** |
|---|---|---|---|
| Weight of empty mould: $M_1$ (kg) | 1.08 | 1.08 | 1.08 |
| Weight of empty mould + sample: $M_2$ (kg) | 3.68 | 3.62 | 3.65 |
| Weight of loose sample: $M_3 = M_2 - M_1$ (kg) | 2.60 | 2.54 | 2.57 |
| Volume of mould: V (m$^3$) | 0.00179 | 0.00179 | 0.001179 |
| Bulk Density = $M_3$/V (kg/m$^3$) | 1452.51 | 1418.99 | 1435.75 |
| **Mean Bulk Density (kg/m$^3$)** | | **1435.75** | |

### 3.5 Compressive Strength of Concrete

The compressive strength of the hardened HSC as obtained in the laboratory are presented in table 4.9. The test was conducted in accordance with BS EN 12690:3 (2009). The cured concrete samples were crushed at day-3, day-7 day-21 and day-28. There was about 13% increase in strength from day 3 to day 7, about 50% increase in strength from day 7 to 21 and about 22% increase in strength from day 21 to 28. Overall, there was about 100% increase in strength from day 3 to day 28. The accelerated gain in strength is an attribute of HSC.

TABLE 5: COMPRESSIVE STRENGTH OF CONCRETE SPECIMENS

| **S/N** | **Curing Age (Days)** | **Dry density (kg/m$^3$)** | **Weight density (kg/m$^3$)** | **Specific area (mm$^2$)** | **Crushing loads (N)** | **Compressive strength ($\frac{kN}{m2}$)** |
|---|---|---|---|---|---|---|
| 1 | 3 | 2490 | 2520 | 10000 | 310000 | 31.00 |
| 2 | 7 | 2560 | 2590 | 10000 | 350000 | 35.00 |
| 4 | 21 | 2640 | 2660 | 10000 | 520000 | 52.00 |
| 5 | 28 | 2660 | 2670 | 10000 | 630000 | 63.00 |

### 5.0 CONCLUSION

The physical and mechanical properties of aggregates were determined and found to be adequate for high strength concrete production. The strength of the concrete obtained falls within class I high strength concrete and can be used to construct high rise buildings.

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