Effects of The Total and Partial Replacement of Sharp Sand with Quarry Dust on Concrete

Ezeagu CA¹, Agusi MS²

¹,²Nnamdi Azikiwe University Awka.

Abstract

Sharp sand is now unsustainable due to large-scale depletion and this creates environmental problems. As environmental concerns and other constraints make the availability and use of sharp sand less attractive, a substitute or replacement product for concrete industry needs to be found. Sharp sand is most commonly used as fine aggregates in the production of concrete and an adequate substitute is being investigated to reduce its usage worldwide. In such a situation, quarry dust can be an economic alternative to sharp sand. Quarry dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Usually, quarry dust is used in large scale in the highways as a surface finishing material and also used for manufacturing of hollow blocks and lightweight concrete prefabricated elements. Use of quarry dust as a fine aggregate in concrete draws serious attention of researchers and investigators. This project presents the feasibility of the usage of quarry dust as 100% and 50% substitutes for sharp sand in concrete. Tests were conducted on cubes to study the properties and strength of concrete made of various samples of quarry dust and sharp sand from different locations and also their 50-50% combinations. Previous research carried out on this shows positive results and hence quarry dust has very recently gained good attention to be used as an effective filler material instead of sharp sand. This project will investigate the effect of the total and partial replacement of sharp sand with quarry dust on concrete.

Keywords: Concrete, Quarry dust, Sharp sand, Replacement, Compressive strength

Introduction

Sustainability is a global concern and methods are being employed to minimize wastage to ensure adequate reserves are left for future generations. Sharp sand is the most popular choice for the fine aggregate component of concrete with its consumption in concrete generation at about one billion tons per year but overuse of the material has led to environmental concerns, depleting securable sand deposits and a concomitant price increase in the material. The rapid extraction of sand from the river beds causes problems like erosion, lowering of the water table, sinking of bridge piers, change in river courses leading to floods, deepening of the river beds, loss of vegetation on the bank of rivers etc. Quarry dust, a waste material that causes disposal problem in quarries is made as a valuable resource by its successful utilization as fine aggregate and this will help overcome the strain on the demand and supply of sharp sand. Quarry dust is obtained during the crushing of large rock boulders into coarse aggregates. About 20-25% of the total material crushed in a crusher unit for extraction of aggregates is left as fine dust and is considered to be waste. They are sieved aggregates usually less than 5mm in size with a particle size distribution close to that of sand and are usually produced in large volumes daily. Quarry dust has been proposed as an alternative to sharp sand that gives additional benefit to concrete. It is known to cause an increase in the strength of concrete over that made with equal amount of sharp sand. Utilization of quarry dust not only relieves pressure on sand but also reduces the need for its dumping as quarry dust is considered a waste product in the quarries. As a result of
sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilization of quarry dust in industrialized nations has reached more than 70% of its total production

**Aim and Objectives**

The aim of the study is to investigate the possible replacement of sharp sand with quarry dust as fine aggregates in concrete production. The objectives of the study are as follows:

- To determine the significant properties of quarry dust and sharp sand.
- Establishment of optimum cement, quarry dust, sharp sand, coarse aggregate, and water combinations in concrete to achieve suitable and economical concrete strength.
- To determine the workability and compressive strength in the replacement of various samples of sharp sand with quarry dust from different quarries as fine aggregates in concrete production.
- To determine the combination that gives the best results for compressive strength.
- To make recommendations with regards to the use of quarry dust in concrete production.

**Scope of Work**

This report is only concerned with quarry dust as a fine aggregate in concrete production. It will mainly focus on the compressive strength of concrete cubes made with quarry dust, sharp sand and a combination of both. Strength results will be taken after seven, fourteen and twenty-eight days of curing. It will not be concerned with other known substitute by-products like fly ash, rice hush ash etc and there will be no use of admixtures. It will study only the effects of quarry dust on the compressive strength of concrete. Grading of the aggregates will also be investigated.

**Justification**

Currently, Nigeria has taken a major initiative in developing its infrastructure such as highways, dams, industrial structures and power projects to meet its globalization requirement. Concrete thus plays a big role and large quantities are being utilized, so there is high demand like resources like sharp sand which has become highly environmental unfriendly and unsustainable. There is thus a need for alternative materials from industrial waste to act as sand replacement and thus address the problems inherent in the use of sharp sand as fine aggregate. In such a case, quarry dust can be an economical alternative to sharp sand. Quarry rock dust can be defined as residue or other non volatile waste materials that are products of the extraction and processing of boulders to form particles less than 5 mm. The ready availability of the dust and its effect when left to accumulate leads to the need to use it as sand replacement material.

**Literature Review**

Numerous attempts have been made to investigate the ability of quarry dust to serve as a replacement for sand in concrete. Below are some of these investigations and their outcomes;

Gowrisanker et al (2016) carried out an experimental study on the variation in strength of concrete when replacing sand with quarry dust and cement with lime powder with replacement from 0% - 30%. From the test results, it was found that the maximum compressive strength and tensile strength was obtained at 30% replacement. They reported that quarry dust can be utilized as a good substitute for sharp sand. Mohankumar and Sudharsan (2017) carried out an investigation into the replacement of cement and fine aggregate with quarry dust. The sharp sand was totally replaced with quarry dust while the cement was partially replaced at 0, 2, 4, 6, 8 and 10% by weight. It was observed that the optimum replacement level of cement with sharp sand was at 6%. Krishnamoorthi and Mohankumar (2012) made preliminary studies on the strength properties of quarry dust based concrete. A trial mix design for M30 grade concrete and sand replaced at different percentages with quarry dust. They recommended a total replacement of sand with quarry dust. Allam et al (2016) studied the behaviour of M35 grade concrete having partial replacement of cement or sand with granite waste. It concluded that the optimum percentage of cement with granite fine powder was 5%. Nanda et al (2010) studied the replacement of stone crusher dust as fine aggregate in concrete for paving blocks in various percentages. The test results showed that the replacement of stone dust more than 50% by weight had a negligible effect on any physical or mechanical properties of the concrete paving blocks. Anzar (2015) made a study on the suitability of quarry dust as sand replacing material and discovered that it improves the mechanical properties of concrete as well as its elastic modulus. The optimum compressive strength was achieved at a proportion of fine to coarse aggregates of 60:40. Agrawal et al (2017) made a study focusing on determining the suitability of using quarry dust as fine aggregate in traditional concrete. The compressive strength of concrete was determined after replacing sand with quarry dust at several ratios. The results of the study showed encouraging results for replacement of 50% of sand with quarry dust. Ukpata et al (2012) studied the compressive strength of concrete using lateritic sand and quarry dust at various combinations as fine aggregates. The results compared favourably with those conventional concrete. The concrete was found to be suitable for use as structural members where lateritic sand did not exceed 50%.
Concrete is a composite material composed mainly of cement, aggregates (fine and coarse), and water. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredient together into a durable stone-like material with many uses.

Aggregates are mainly divided into two categories from consideration of size; coarse aggregate and fine aggregate. Aggregates greater than 4.75mm are considered as coarse aggregates and aggregates less than 4.75mm are considered as fine aggregates. Usually aggregates compose the greatest possible volume of mix. The mere fact that the aggregates consists of 70-80% of the volume of the concrete means that they have immense impact on various characteristics and properties of concrete.

Cement is one of the most important components of concrete. The volume of cement in concrete greatly affects its strength. Cement is a combination of compounds which includes lime, silica and alumina. Cement are made of finely grounded powders that when mixed with water, a chemical reaction (i.e. hydration) takes place, which produces very hard and strong binding medium for the aggregate. Among all the various types of cement, Portland cement is the most widely used in construction.

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Water used in concrete should generally be of drinking water quality and free of excessive turbidity and organic matter. Some specifications require that if the water is not obtained from source that has proved satisfactory, the strength of concrete or mortar made with it should be compared with similar concrete or mortar made with pure water. Some specifications state that water for making concrete should have a pH value between 6 and 8 and should be free from organic matter.

Quarry dust or stone dust or crusher dust or quarry fines refer generally to undersized materials typically finer than 4mm from crushing plants. They receive no further processing and are generally considered as of no economic value thus accumulated as unwanted waste. Quarry dust are produced from crushed rocks to obtain coarse aggregates. The proportions of fines vary according to the rock material used on the crushing process.

**Research Methodology**

**Materials**

Materials to be used in this project work were found to be in accordance with the required standards. The experiments were carried out in the Unizik Concrete and Soil Laboratories, Awka and the IDC Quality Control Laboratory, Ugwuene, Enugu. The materials used include the following:

- **Portland Cement** The Dangote 3x brand of Ordinary Portland Cement (OPC) Grade 42.5 according to the Standard Organization of Nigeria (SON) was used in the course of this project. It has a specific gravity of 3.07 and normal consistency of 30.5%. Bags were carefully kept away from dampness to avoid lumps.

- **Coarse aggregates** Natural crushed granite was used as the coarse aggregate with a maximum diameter of 20 mm. It was bought from in Awka but was gotten from Ebonyi State.

- **Sharp Sand** Sharp sand was used as the fine aggregate and was found suitable for the purpose of these experiments. Three different samples were gotten from three different locations namely; B gotten from Nsukka, Enugu; A gotten from Isiagu quarry, Ebonyi State and A gotten from IDC quarry, Okigwe, Imo State. All three samples were found suitable for the purpose of these experiments.

- **Water** Portable water gotten from rainwater harvesting was used for the experiment. The water to be used for curing was also gotten from the same source. The water was colourless, odourless and generally satisfactory for the work to be carried out.

**Methodology**

**Determination of Specific Gravity**

- Weigh the oven dried bottle to the nearest 0.001 grams (W_1).
- Take about 15 grams of oven dried sample sieved through B.S sieve No. 7. Put it in the density bottle and weigh to the nearest 0.001 grams (W_2).
- Add air free distilled water and use paraffin just to cover the sample. Place it in the water bath or vacuum dessicator to evacuate the air. The bottle shall remain in the dessicator until no further air is released from the sample.
- The bottle and contents shall then be removed from the desiccator and air free liquid added until the bottle is full. Insert the stopper and weigh the bottle with contents to the nearest 0.001 grams (W_3).
- The bottle shall then be completely cleaned and filled with air free liquid and stopper inserted. Wipe dry the bottle and weigh it to the nearest
Particle Size Distribution

- The test sieves are arranged from top to bottom in order of decreasing aperture sizes with pan and lid to form a sieving column.
- The aggregate sample was then poured into the sieving column and shaken thoroughly.
- The sieves were removed one by one starting with the largest aperture sizes (top most) and each sieve shaken ensuring no material is lost. All the material which passed each sieve was returned to the column before continuing with the operation with that sieve.
- The retained material was weighed for the sieve with the largest aperture size and its weight recorded.
- The same operation was carried out for all the sieves in the column and their weights recorded.
- The screened material that remained in the pan was weighed and its weight recorded.

Slump Test

The slump test is carried out on the design mixes. The standard slump cone with a base plate was used. The inside of the mould was cleaned and oiled before the test and the mould made to stand on a smooth hard surface. The mould was held down using the feet, rested on the foot rests and the mould filled in three layers of approximately equal sizes. Each layer was then tamped with 25 strokes using the tamping rod and the strokes being uniformly distributed over the cross section of the layer. The surface was smoothened using the trowel and the surface of the cone and base plate wiped clean. The cone was then lifted vertically upright and the slump measured for each sample design.

Compressive Test

After curing the cubes for the specified period, they were removed and wiped to remove surface moisture in readiness for compressive test. The cubes were then placed with the cast faces in contact with the platens of the testing machine that is the position of the cube when tested should be at right angles to that of the cast. The load applied was applied at a constant rate of stress of approximately 15 N/mm² to failure. The readings on the dial gauge were then recorded for each cube.

Test & Results

Sieve Analysis

For the coarse aggregate, coefficient of uniformity \( Cu = 1.35 \)

For the sharp sand, coefficient of uniformity \( Cu = 3.45 \)

For the quarry dust, coefficient of uniformity \( Cu = 31.90 \)

It shows that coarse aggregate and fine aggregate is uniformly graded sample containing particles of the same size, while quarry dust is well graded sample. Hence there was no need for grading as the samples lies within the appropriate limits.

<table>
<thead>
<tr>
<th>Test</th>
<th>Quarry Dust (%)</th>
<th>Sharp Sand (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_1</td>
<td>100 (Abuja)</td>
<td>0</td>
</tr>
<tr>
<td>A_2</td>
<td>100 (Abakaliki)</td>
<td>0</td>
</tr>
<tr>
<td>A_3</td>
<td>100 (Okigwe)</td>
<td>0</td>
</tr>
<tr>
<td>B_1</td>
<td>0</td>
<td>100 (Onitsha)</td>
</tr>
<tr>
<td>B_2</td>
<td>0</td>
<td>100 (Awka)</td>
</tr>
<tr>
<td>B_3</td>
<td>0</td>
<td>100 (Ekwulobia)</td>
</tr>
<tr>
<td>A_1B_1</td>
<td>50 (Abuja)</td>
<td>50 (Onitsha)</td>
</tr>
<tr>
<td>A_1B_2</td>
<td>50 (Abuja)</td>
<td>50 (Awka)</td>
</tr>
<tr>
<td>A_1B_3</td>
<td>50 (Abuja)</td>
<td>50 (Ekwulobia)</td>
</tr>
<tr>
<td>A_2B_1</td>
<td>50 (Abakaliki)</td>
<td>50 (Onitsha)</td>
</tr>
<tr>
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<tr>
<td>A_2B_3</td>
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</tr>
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<tr>
<td>A_3B_3</td>
<td>50 (Okigwe)</td>
<td>50 (Ekwulobia)</td>
</tr>
</tbody>
</table>

Figure 1. Particle Size Distribution Analysis of Coarse Aggregate, Sharp Sand and Quarry Dust

Figure 2. Slump Test Results

Based on the results of the slump test, it is observed that quarry dust causes a reduction in the workability of concrete. Quarry dust require considerate higher amount of water as compared with sharp sand. The samples containing quarry dust had a generally low workability as compared to the sample with sand alone. This shows that the high proportion of fine particles in concrete made with quarry dust reduces the water effect; so much of the water is first used to wet the fine aggregates before bonding them together.
From Figure 4.8, the Abakaliki quarry dust-Awka sharp sand combination test \((A_2B_2)\) gave the highest value at 26.6 N/mm\(^2\) while the lowest was gotten by the Abuja quarry dust-Onitsha sharp sand combination test \((A_1B_1)\) at 20.5 N/mm\(^2\). The remaining tests ranged from 21.4 – 25.5 N/mm\(^2\).

### Recommendations

From the laboratory test results and analysis, I would recommend that quarry dust be used as a replacement for sharp sand in concrete production by contractors in the industry. Results from this project and other works indicate that total or partial replacement of sand with quarry dust is possible as shown by the strength tests. However, trial casting with the proposed quarry dust should be carried out to achieve the most suitable water content and mix proportions to suit the required workability levels and strength requirements. Also, special attention should be given to quarry dust concrete during the first 14 days after casting in construction as it has a low rise strength compared with that made with sharp sand.

Also further research should be carried out on:

- The effect of quarry dust on the tensile strength of concrete when totally or completely replaced by sharp sand as fine aggregate.
- The behaviour of quarry dust in reinforced concrete i.e. its suitability in RC beams, slabs, columns etc. Also, its use in pre-cast elements.
- Long term behaviour of quarry fines concrete under moderate weather conditions that is external exposure.
- The use of fly ash and admixtures like super plasticizers with quarry dust in concrete production should also be looked into to determine if significant properties can be attained most especially the increase in its workability.
- The physical and chemical properties of the samples of quarry dust and sharp sand from different locations.
so as to deduce why they and their combinations gave relatively different values.

References


