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Comparative Study of Engineering Properties of Fine Aggregates from Omamballa River and River Niger in Anambra State on Strength and Workability of Concrete

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ABSTRACT : *The Engineering properties of fine aggregates from Omamballa River (Sample 1) and River Niger (Sample 2) in Anambra State on strength and workability characteristics of concrete was investigated in this research. The physical properties of the two samples of fine aggregates were analyzed through sieve analysis, specific gravity test and moisture content test. Concrete mix was designed considering the properties of the investigated materials and workability test carried out. The ratio of 1:1.83:3.39:0.522 was used to produce 24 concrete cubes for a characteristic strength of 25N/mm^2 for the two samples of fine aggregates. An average of three cubes was considered as the compressive strength at 7-, 14-, 21- and 28-days curing ages. From the results, variations in the physical properties of the two fine aggregate sources significantly impacted the workability and strength of concrete. Sample 1 is densely graded having wide range of sizes. Sample 2 is moderately graded with predominantly finer particles compared to Sample 1. The investigations proved that depending on their properties and compositions fine aggregates can impact differently on properties of concrete. The fine aggregate from River Niger Onitsha, due to its particle size distribution and moisture content had the highest slump value of 63mm. Fine aggregate from Omamballa River Aguleri had a slump value of 50mm. For compressive strength at 7, 14, 21 and 28days, fine aggregate from River Niger Onitsha gave; 15.17N/mm^2, 24.4N/mm^2, 29.43N/mm^2 and 34.07N/mm^2 while fine aggregate from Omamballa River gave; 14.17N/mm^2, 23.77N/mm^2, 28.7N/mm^2 and 32.03N/mm^2 respectively. This highlights the importance of careful selection of concrete materials to achieve desired strength and characteristics in concrete.*

KEYWORDS: Strength, Workability, Physical properties, Fine Aggregates, Sample 1, Sample 2

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I. INTRODUCTION

Concrete which is a mixture of cement, fine aggregates, coarse aggregates and water has a very significant value in the construction of bridges, towers, tunnels, highways, beams and columns for buildings. The fine aggregates used for production of concrete in any project must have certain physical qualities, sizes and free of impurities in order to give some desired qualities in concrete, making Engineers more satisfied and confident in using the fine aggregate source. It will guaranty a good quality work if the fine aggregate is well graded as per ASTM C33/C33M conforming to standard specifications of BS 12620 (2018). The Portland limestone cement should also meet standard specifications as provided by BS EN 197-1 (2011) and regulatory authorities like Standard Organization of Nigeria (Oyenuga, 2014).

Poor understanding on how varying particle sizes and physical properties of fine and coarse aggregates collectively impact the strength and workability of concrete has resulted to structural failures, loss of lives and investments. Oke (2011) asserts that in Nigeria, more than half of the causes of building collapse are attributed to substandard fine aggregate. ASTM C33-03 clarifies that fine aggregates must be made of natural sand, manufactured sand or a combination of the two. In conformity with ASTM C33, a fine aggregate should pass through the 9.5mm (3/8) inch sieve, almost completely passing the 4.75mm (N0. 4) sieve, and primarily retained on the 75 micrometer (N0. 200) sieve. The Coarse aggregates' particles are larger than 4.75mm; therefore a 4.75mm sieve can retain them (Aginam et al., 2013).

Compressive strength and workability are important properties of concrete and they depend on the properties and qualities of the constituents of concrete. About 70-80% by mass of concrete (60-75% by volume) is occupied by the fine and coarse aggregates (Khadka and Mishra, 2022). According to Aginam et al., (2013), aggregates make up 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete. Different sources of fine aggregates are used in producing concrete, but in Nigeria, the main sources of fine aggregates are streams and Rivers. It is important to identify the properties of fine aggregates from different sources and their effects on the workability and strength of concrete since the properties of fine aggregates from different streams and rivers are different.

A. LITERATURE REVIEW

Since aggregates are thought of as the skeleton of concrete, Chen and Liu (2004); Rao and Prasad (2002) in their research, concluded that all types of coating should be avoided in order to produce good concrete. The form, size, surface texture and cleanliness of aggregates all have a significant impact on the strength of concrete.

Ekwulo and Eme (2017), studied the effects of aggregate sizes, shape and surface texture on the water requirement and strength of concrete for a rigid pavement, the study showed that at equal water/cement ratio, irregular shaped smaller size aggregates without coating achieved a better strength than smooth rounded large size aggregates. In a research on the workability and strength of concrete by Obi and Adinna (2023), they pointed out that aggregates with rough angular particles pack more tightly than aggregates with smooth rounded particles. They have more surface area and exhibit higher inter-particle friction. According to Young and Sam (2008), when compared to irregular aggregates with surface roughness, smooth spherical aggregates have low compressive strength.

According to Chirag et al., (2016), aggregates made up of particles of different sizes will result in a compressed mass with fewer voids than aggregates with uniformly sized particles. It is anticipated that the smaller particles in an aggregate mass with a range of particle sizes will fill the spaces between the bigger particles. They further studied the gradation of aggregates and how it affects the characteristics of concrete and concluded that proper aggregate gradation ensures workability of concrete mixtures, makes them easier to compact and minimizes issues like potential segregation, bleeding, loss of entrained air and cracking (Chirag et al, 2016).

In a research on the causes of structural failures in Napel, Khadka and Mishra (2022) investigated the effects of fine and coarse aggregates sources on compressive strength of concrete. Four different sources of aggregates were collected and tested for M20 grade of concrete. Fine and coarse aggregates were combined to test for compressive strength. They conducted sieve analysis test, fineness test, specific gravity test and loose bulk density test to know the properties of all aggregates. They found out that compressive strength of concrete varies depending on the fine aggregate and coarse aggregate sources and their gradation. With a 0.5 water-cement ratio, 1:1.5:3 nominal mix of M20 grade of concrete and a shivam cement of grade 43, they produced 48 cubes, 12 for each fine and coarse aggregate source. The average compressive strength for each source is as follows; Chisang 29.31N/mm2, Bakrah 24.63N/mm2, Mawa 25.95N/mm2 and Ratuwa 22.30N/mm2. They concluded that even though all fine aggregate sources met standard requirement for use in concrete, the Chisang aggregate source achieved higher value for average compressive strength because it was well graded and free of impurities.

The required type of concrete to be produced determines the quality of cement and aggregates to be used (Adewoke et al., 2014). There are many suppliers of aggregates sourcing their materials from different locations (Dinh and Truong, 2022). The properties of all the locations vary and may have some impurities which may affect the properties of concrete (Araromi et al., 2015). Some of these manufacturers and distributors of fine aggregates distributes low quality products which causes poor workability and strength. Utilizing them in concrete may lead to building collapse which is a major problem in the construction industry (Obi and Adinna 2023).

Aginam et al., (2013) investigated the influence of four mix design methods on the compressive strength of concrete. They carried out specific gravity test, moisture content test and gradation test on concrete materials and found them suitable for use in making concrete. Using Ibeto brand of Portland limestone cement, they produced four sets of cubes for each mix design and cured for 7, 14, 21 and 28daays. Their 28days compressive strength test includes; ACI 30.7N/mm^2, DOE 33.7N/mm^2, RN4 33.0N/mm^2 and CP110 35.1 N/mm^2. From their results, all the mix design methods exceeded their design characteristic strength by 50%. They concluded that there exists a relationship between aggregate sizes and quantity to the final strength of concrete, pointing to the importance of concrete mix design to enable the determination of the right type and specification of materials to use in making concrete.

The objectives and scope of the study are:

i. To study the Engineering properties of fine aggregates from Omamballa River and River Niger in Anambra State on the strength and workability of concrete.

II. MATERIALS AND METHODS

i. Cement

The Portland limestone cement used for this research is BUA cement. The cement is classified as CEM II, grade 42.5N and is in conformity with BS EN 197-1 (2011) and ASTM C150 (2019) Type 1. The cement was bought from Building Material Market in Umuokpu, Awka, Anambra State and stored in a dry place before use.

ii. Aggregates

The fine aggregates samples passing 4.75mm sieve used for this research includes; Sample 1 sourced from River Niger in Onitsha and Sample 2 sourced from Omamballa River in Aguleri both in Anambra state Nigeria. A 19mm maximum size coarse aggregate passing 25mm sieve was used, it was sourced from Ezza Abakaliki, Ebonyi State Nigeria. All the aggregates met the specifications of BS EN 12620 (2018) and are in conformity with ASTM C33/C33M. They were further tested for sieve analysis, specific gravity and moisture content before use.

iii. Water

Clean and drinkable tap water with PH 7.6, sourced within the Concrete Laboratory at Nnamdi Azikiwe University, Awka was used in mixing concrete. The water was in conformity with BS EN 17075 (2018) and tested in accordance with BS EN 1008: (2002).

iv. Sieve Analysis Test

Sieve analysis was carried out in accordance with BS 410-1 (2000) and BS 12620 (2018) to access the particle size distribution of the two samples of fine aggregates and coarse aggregate. The aggregates were allowed to pass through a series of progressively smaller mesh sizes; the materials retained on each sieve was weighed as a fraction of the whole mass.

v. Specific Gravity Test

Specific gravity test was carried out on the two samples of fine aggregates and coarse aggregate based on BS 1377: Part 2: clause 8, (1990). Specific gravity is the ratio of the density of a substance to the density of a reference substance like water.

vi. Moisture Content Test

To guide the choice of water-cement ratio used in this research, moisture content test was conducted on the two samples of fine aggregates to determine the amount of moisture present in them. The moisture content was conducted in conformity with the specifications of BS 1377 (1990).

vii. Experimental Procedure

In accordance with BS 8110: Part 1-(1985) and BS 206-1 (2013) concrete mix design was calculated for a characteristic strength of 25N/mm^2 as 1:1.83:3.39:0.522. Equipment used for laboratory work includes:

150 x 150 x 150 mm mould, slump cone, weighing balance, shovel, trowel, tamping rod, concrete mixing plate and curing tank. For the two sample of fine aggregates, 24 cubes were produce and labeled B1 and B2 to be tested for compressive strength at 7, 14, 21 and 28days curing ages. For Sample 1, 12 cubes were produced and the average of 3 cubes each was used as the compressive strength for 7, 14, 21 and 28days curing ages. Same method was repeated for Sample 2.

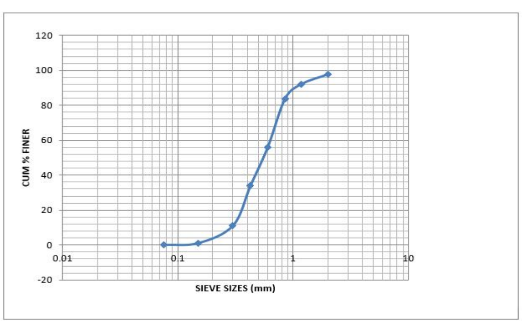
The different constituents of concrete was weighed based on the design mix ratio of 1:1.83:3.39:0.522 with target strength of 25N/mm^2 at 28days curing age. The weighed materials were homogenously mixed. Workability test was carried out on the fresh concrete and compressive strength was carried out on the hardened concrete at 7, 14, 21 and 28days curing ages.

Plate 1 Workability Test **Plate 2 Cubes to be Tested for Compressive Strength**

III. RESULTS, DATA ANALYSIS AND DISCUSSION

A. Sieve Analysis Results

From Fig.1 and Fig.2 three basic soil parameters were determined from the curves, they include; effective soil sizes, coefficient of uniformity (Cu) and coefficient of curvature (Cc). For Sample 1, Cu is 2.5 and Cc is 1.15 implying that Sample 1 is densely graded having wide range of sizes, low void content, low permeability, high stability and grain to grain contact. Air gaps between the aggregates are filled with finer particles. For Sample 2, Cu is 2.3 and Cc is 0.98 implying that Sample 2 is moderately well graded, but does not have equal amount of the aggregates in different sizes, it is predominantly finer particles compared to Sample 1. It has very low void content, low permeability, high stability and grain to grain contact. Air gaps are also filled with smaller particles. The coarse aggregate was also analyzed, it has Cu 1.88 and Cc 1.44 suggesting a uniformly graded aggregate with narrow range of sizes. It has grain to grain contact high void content, high permeability and difficult to compact. It is predominantly 19mm for the research purpose. All the fine aggregates met the specifications of ASTM C117 (2017).



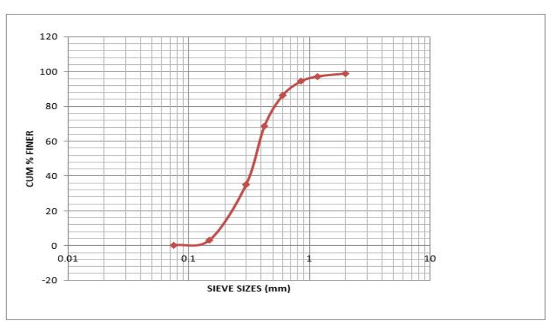


Fig.1: Cumulative %finer against sieve size Sample1. Fig. 2: Cumulative %finer against sieve sizes Sample2

B. Specific Gravity Result

The specific gravity results of concrete materials impact various aspect of concrete properties and performances. It is the measure of the density of concrete materials relative to the density of water and provides an understanding of the materials composition and potential influence in concrete mix. From the results, the specific gravity of Sample 1 is 2.63, Sample 2 is 2.65, coarse aggregate 2.72 and Portland limestone cement 3.19. The specific gravity value affects the overall density of concrete.

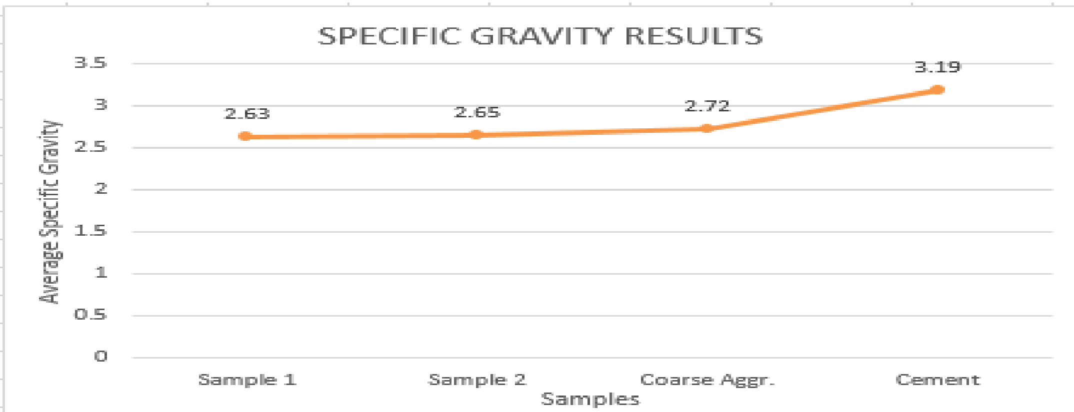


Fig.3: Average Specific Gravity against Concrete Materials

C. Moisture Content Test

From the moisture content test results presented in Fig.4, Sample 2 has a lower moisture content of (4.83%) compared to Sample 1 (6.48%). By implication, Sample 1 will make its concrete mix more workable and easier to handle and place. Also the water demand for Sample 1, will be less compared to Sample 2 because of the high percentage of moisture content. The moisture content of the two samples necessitated the adjustment of the mix design to maintain the desired water-cement ratio. Though both samples were dried to maintain the same level of moisture content.

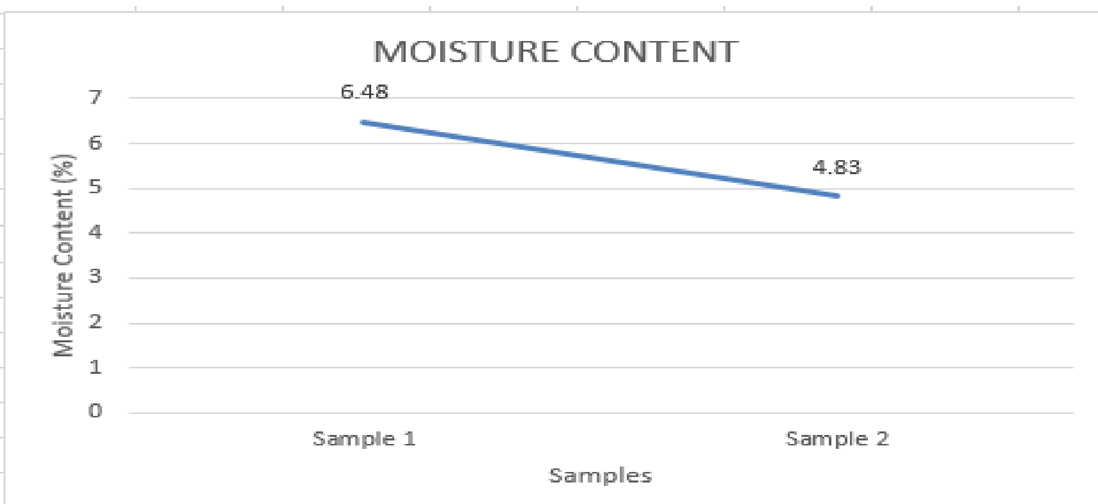


Fig. 4 Moisture Content against Sample 1 and Sample 2

D. Workability Test Result

From the workability test results presented in Fig.5, the two fine aggregate sources have a moderate slump value. However, Sample 1, due to its high percentage of moisture content and particle size distribution have the highest slump value of 63mm compared to Sample 1 50mm. This implies that Sample 1 is easier to mix, place and compact compared to Sample 2. Sample 2 on the other hand had less bleeding and faster setting time compared to Sample 1. All these properties are indications that concrete materials depending on their properties can influence differently the properties of concrete.

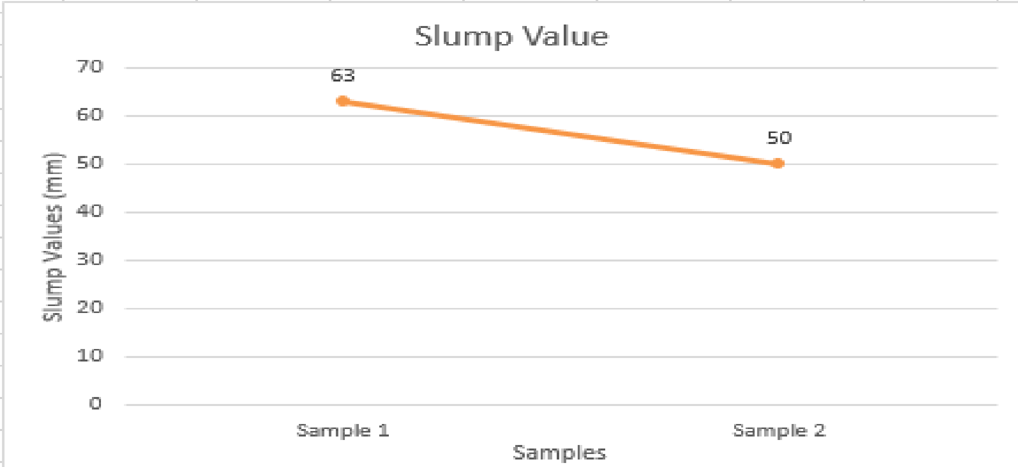


Fig. 5: Slump Values against Samples 1 and 2

E. Weight and Density Results

The results for the weight and density of cubes cured at 7, 14, 21 and 28days are presented in Figure 6. The weight and density of concrete cubes were determined to help inform how compacted the concrete materials are in each cubes. From the result, the density of concrete has an impact in the quality of concrete since the weight and density of cubes are indicator of the durability and strength of concrete. That is why denser concrete tends to be stronger and more durable. Low density sometimes imply there is high porosity in the cubes which can potentially lead to increased water absorption in the concrete.

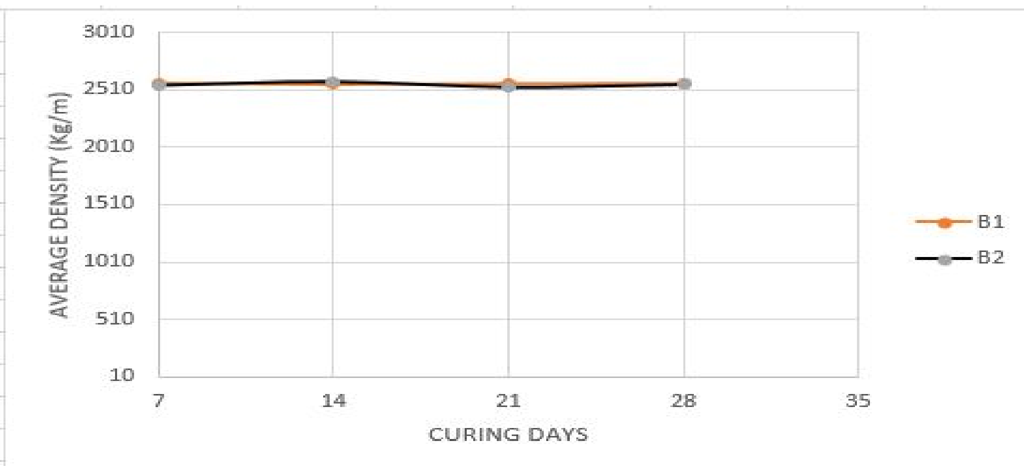


Fig. 6: Average Density against Curing Days

F. Compressive Strength Test

The concrete cubes were tested for compressive strength in conformity with EN 12390 and the average of three cubes taken after each curing ages. From the results presented on Fig.7, at 7days curing the compressive strength of Sample 1 is 15.17N/mm^2 and Sample 2 is 14.17N/mm^2. At 14days curing, Sample 1, 24.40N/mm^2 and Sample 2, 23.77N/mm^2. At 21days curing Sample 1, 29.43N/mm^2 and Sample 2, 28.70N/mm^2. At 28days curing Sample 1, 34.07N/mm^2 and Sample 2, 32.03N/m^2. It can be observed that the strength of concrete increases with curing age. This is as a result of ongoing hydration process of cement which leads to strength development in concrete. There is variation in the strength of concrete based on the sources of fine aggregates. Sample 1 fine aggregate exhibited higher compressive strength than Sample 2 due to its superior properties as observed from the sieve analysis and other investigations. The workability and moisture content also impacted the strength as sample 1 with higher slump and moisture content tend to have better workability which contributed to its strength development.

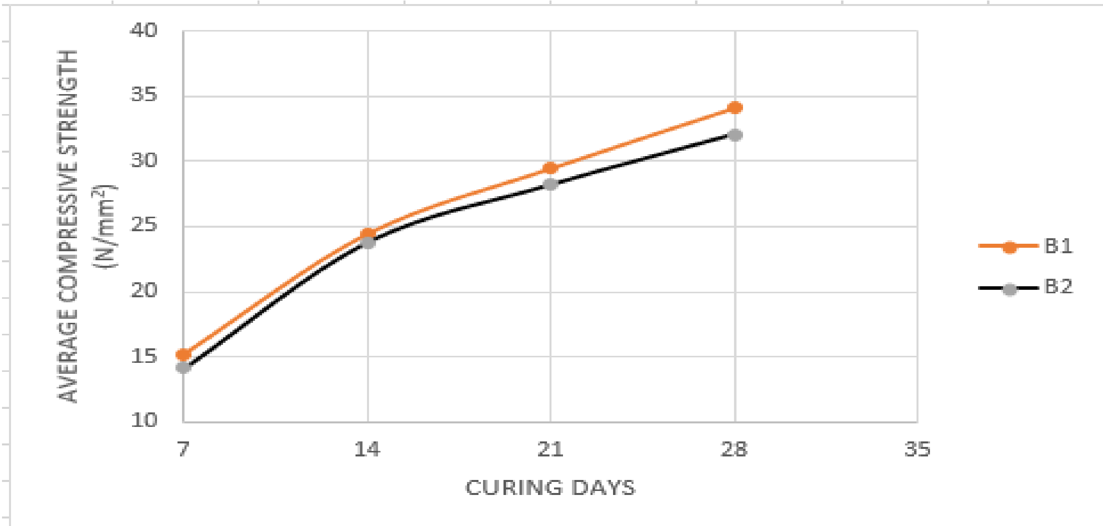


Fig.7 : Average Compressive Strength against Curing Days

IV. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The following conclusions were made from this research:

a) The two samples of fine aggregates are suitable for making concrete, they met the specifications of ASTM C117 (2017). Sample 1, fine aggregate from River Niger in Onitsha is densely graded having wide range of sizes, low void content, high stability and grain to gran contact. Sample 2, fine aggregate from Omamballa River Aguleri is moderately well graded. It is predominantly finer particles compared to Sample 1. It has low void content, low permeability and grain to grain contact.
b) A fine aggregate moisture content below 5% is negligible and has no significant impact on the mixing water quality of concrete. This is in agreement with the findings of Aginam et al., (2013).
c) The strength of concrete cubes increases with an increase in curing age.
d) The weight and density of concrete cubes is proportional to the degree of compaction of the concrete. Well compacted concrete gives high weight and density values compared to concrete that are not well compacted.
e) The fine aggregates from River Niger Onitsha gave a better compressive strength, compared to the fine aggregate from Omamballa River, Aguleri, due to its superior physical properties like particle size distribution that are not as fine as that of Omamballa River.

It is recommended that concrete materials should always be tested to ensure they meet the required specifications before they are use for construction. It is necessary for Engineers to acquire the required understanding of different sources of concrete materials and how they impact the workability and strength of concrete. This will help reduce the high rate of structural failures.

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