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Assessment of Qualities of Coarse Aggregate Used in Concrete Production in Anambra State, Nigeria

Ezeokonkwo John U, Okolie Kelvin Chuks, Ogunoh Peter

Department of Building Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

Abstract Concrete fails when it can no longer provide the required strength to support its designed load. This failure can be mild with visible cracks and deflections or severe, leading to partial or total collapse of the structure either during the construction or post- construction stage. It has been observed that the major cause of this collapse is the use of sub- standard materials mainly poor quality of stone aggregates materials used for concrete production. Previous study on this area centred mainly on other causes of building collapse, with little 'emphasis on coarse aggregate. Therefore, the study is aimed at establishing the qualities of coarse aggregate sourced within Anambra State. Primary and secondary data were used for this study. Samples for the laboratory experiment were obtained from quarry sites at Enugwu-ukwu, Aguleri, Nsugbe, Nikwelle–Ezunaka and Ogbunka. Sieve analysis, Slump test and Cube (crushing strength) were performed using each of the samples. The study observed that the crushing strength and/or compressive strength of the samples at 7 day are between 20-29N/mm' with Ogbunka samples having the highest compressive strength of 29.33N/mm2. Thus, at 7th day, four out of the five samples tested have attained the minimum strength of boncrete (i.e. 21N/mm'). For workability test, the study observed that the percentage of slump for the samples ranges from 21.5 – 41% with Nsugbe samples having the best slump value of 21.5%, For sieve analysis, the researchers observed that the samples were fairly graded. The percentage of the grains passaging through 19.05 diameters is between 64.3 – 84.0%. The study ended with the following recommendations that stones should be properly graded using machines rather than hand breaking. Also stones should be properly washed before using them since most of them are coated with impurities and other clayey substances and muds which may interfere with the process of bonding. Finally, more research should be carried out using un-wash samples from other quarry sites/towns not covered by this study.

Keywords Concrete, coarse aggregate, compressive strength, Anambra state, quarry site.

1. Introduction

Concrete is arguably the most important building material, playing a part' in all building structures [6]. Its virtue is: versatility, *i.e.* its ability to be molded to take up the shapes required for the various structural forms, durability and fire resistant when specification aid construction procedures are correct [6]. Based on its properties *i.e.* strength, rigidity and easy formability, coupled with the easy availability of the component materials, have made concrete the material of choice for architects, engineers, builders and project owners.
The three basic component of concrete – cement, aggregate and water greatly affect the quality of concrete [4]. Aggregate occupy about 70-80 per cent of the volume and this considerably influence the properties of the concrete [4]. In line with this [9] opined that "The compressive strength of concrete cannot exceed that of the aggregate used therein."

Aggregates as defined by [9] UNESCO-NT&VERP, (2008) are "materials comprising of percentage required of gravel, crushed stone and natural sharp sand of their specific size of particle mixed together at a required ratio to form part of concrete mortar." Aggregate used in construction basically comes in two different sizes-the bigger ones known to be coarse aggregate (grit) and the smaller ones fine aggregate (sand) [4]. The coarse aggregate forms the main matrix of concrete and the fine aggregate form the filler matrix between the coarse aggregate [4]. Since approximately 80 percent of the total volume of concrete consists of aggregate, aggregate characteristics significantly affect the performance of fresh and hardened concrete and have an impact on the cost effectiveness of concrete [8]. Aggregate characteristics of shape, texture, sand grading influence workability, finishability, bleeding, pumpability, and segregation of fresh concrete and affect strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete. Construction and durability problems have been reported due to poor mixture proportioning and variation on [8].

1.1. Statement of the Problem

Concrete fail when it can no longer provide the required strength to support its designed load [3,5]. The failure of Concrete can sometimes be mild with visible cracks and deflections or severe crack, leading to partial or total collapse of the structure either during the construction or post- construction stage. Incidences of failures of structures linked to bad concrete practice are abounding in Nigeria particularly in our major cities such as Lagos, Port-Harcourt, and Abuja, among others. The findings of the committee of enquiry that investigated the collapsed of four-storey building at Okpuno, Awka, Anambra state capital in September 2008 reported that the building collapsed the same day the casting of the concrete third floor slab was concluded. The incident, took the lives of four persons. The report further revealed that among the causes of the collapse was the use of sub- standard materials' stating that - poor quality of stone aggregates materials were used for concrete production [2].

In order to curb the incidence of building collapse across the globe, several researches has been carried out at different time by different individuals, corporate bodies and civic society to ascertain the strength and/or quality of materials used in concrete production. Attention mainly is placed on reinforcements and cements, with little on the aggregates. However, in Anambra state little research has been made in order to ascertain the quality of the coarse aggregate sourced within.

1.2. Aim and Objectives

The aim of this research is to establish the qualities of coarse aggregate sourced within Anambra State.
The research aim was achieved using the following objectives, to:

- Established qualities of good coarse aggregate, possible tests and procedures.
- Identify quarry sites within state.
- Obtain specimen samples (i.e. coarse aggregate) from these quarry sites and investigate in the laboratory their compressive strengths, aggregates particle size distribution and slump test to determine their suitability in the production of concrete.

2. Review of related Literature

2.1. Aggregates

An aggregate according to UNESCO-NT&VERP, (2008), [9] can be defined as the material comprising of percentage required of gravel, crushed stone and natural sharp sand of their specific size of particle mixed together at a required ratio to form part of concrete mortar. To Council of Registered Builders of Nigeria (CORBON) and Nigeria Institute of Building (NIOB), (2014) [3], Aggregates are the granular filler material such as sand, stone dust, gravel, crushed stone, crushed blast-furnace slag, etc. that are used with binder such as Portland cement to produce concrete or mortar.
It includes boulders, cobbles, crushed stone, gravel, air-cooled blast furnace slag, native and manufactured sands, and manufactured arid natural lightweight aggregates [1]. The aggregate (both fine and coarse) makes up about 80% of the volume of the concrete [10]. Reed, Schoonees and Salmond [10] generalized the volume of aggregate in concrete production but Aker (2000) [1] was more specific. According to Aker, (2000) [1], in a Portland-cement, concrete mix, coarse and fine aggregates occupy about 60 to 75% of

the total mix volume and for - asphaltic concrete, aggregates represent 75 to 85% of the mix volume. But Anosike, 2011 [2] state that in any Concrete, aggregates (fine sand and coarse) usually occupies about 70-75%. Thus, aggregate generally occupy about 60-80% of the total concrete volume.

Aggregates are used in concrete to; increase its volume, increase strength and durability, red ice shrinkage, reduce creep, reduce overall cost, imparts sound and thermal properties, imparts density, increase chemical resistance etc [3]. When aggregate for concrete is being selected, the chemical inertness, strength, clean, cost, availability in required size, grading, shape and surface texture are considered [3]. Also, Anosike (2011), [2] opined that While selecting aggregate for a particular concrete, the economy of the mixture, the strength of the hardened mass and durability of the structure must first be considered.

2.2. Classification of Aggregate

Anosike (2011); Duggal (2008); Ezeokonkwo (2013) [2,4,5] classified aggregate based on the source (Natural and artificial aggregates); According to mineralogical composition (aggregates here are classified as siliceous or calcareous); According to mode of preparation (in this situation distinction is made between aggregates reduced to its present size by natural agents and crushed aggregates obtained by a deliberate fragmentation of rock); According to size (divided again into coarse and fine aggregates). CORBON and NIOB, (2014); McGinley & Choo (2003) [3,6] classified aggregate only in terms of size. Finally UNESCO-NT&VERP (2008) [9] classified aggregate based on origin with other subdivisions.

However, for the purpose of this work, the classification based on size will be adopted. Namely:

i. coarse aggregate-gravel or crushed rock 5 mm or larger in size
ii. fine aggregate-sand less than 5 mm in size

Coarse Aggregate: Aggregate retained on 4.75 mm sieve is identified as coarse [3,4]. They are obtained by natural disintegration or by artificial crushing of rocks. The maximum size of aggregate can be 80 mm. It ranges between 20mm-10mm [9]. Particles with larger sizes cause reduction in strength of concrete [9]. The size is governed by the thickness of section, spacing of reinforcement, clear cover, mixing, handling and placing methods [4].

Fine Aggregate: Aggregate passing through 4.75 mm sieve are defined as fine [4,3]. Alternatively, UNESCO-NT&VERP (2008), [9] defined fine aggregate as particle's passing 25mm which are retained on a 600 microns sieve. They may be natural sand' deposited by rivers, crushed stone sand-obtained by crushing stones and crushed gravel sand. The smallest size of fine aggregate (sand) is 0.06 mm.

2.3. Properties of Aggregate:

The properties to be considered while selecting aggregate for concrete is grouped into two: mechanical and physical properties.

2.3.1. Mechanical Properties of Aggregates

a) Bond Strength of Concrete: The resistance developed to shear particles from the hardened cement paste is called bond strength of aggregate. Bond is partly due to the interlocking of the aggregates and the paste owing to the roughness of the surface of the aggregate particle. A rougher texture as that of crushed stone results in a greater adhesion or bond between the particles and the cement matrix. Generally, when bond is good, a crushed concrete specimen should contain some aggregate particles broken right through, in addition to the more numerous ones separated from the paste matrix. However, an excess of fractured particles suggests that the aggregate is too weak. Bond strength is found to increase with the age of the concrete. The strength of concrete is therefore dependent on the bond strength.

b) Crushing Strength of Aggregate: The compressive strength of concrete cannot exceed that of the aggregates used therein. Usually, aggregate is considered ten times stronger than the crushing strength of concrete, but some particles break also and influence its strength. Therefore, aggregate to be used in cement concrete-should not be weaker than the strength of hardened cement paste. BS 882:1992 prescribes a minimum value of 150KN (15 tons) for aggregate to be used in heavy duty concrete floor finishes, 100KN (10 tons) for aggregate to be used in concrete pavement wearing surface, and 50KN (5 tons) when used in other concretes. In addition CORBON and NIOB (2014), [3] classified concrete based on its crushing strength as: ***High-strength concrete***, concretes with compressive strengths: greater than 60N/mm^2 (9000psi) at 28 days or 56 days (age depends on the specification). Other higher classes of high strength concrete are the ultrahigh strength and high performance *concretes: Normal-strength* (also called ordinary or moderate-strength) concretes, concretes with 28-day compressive strengths of between 20 to 60N/mm^2 (3000 to 9000psi). They are used for normal structural work. The normal strength concretes are divided into various strength grades for different structural uses: ***Low-strength concretes***, concretes' with 28-day" compressive strengths of less than 20N/mm^2, (3000psi), Used where light loading is expected e.g.; for stabilization of embankments, strip footings, ordinary ground floor slabs, etc.

2.3.2. Physical Properties of Aggregates

a) Absorption, Porosity, and Permeability: The porosity, permeability and absorption in aggregates influence the bond between it and the cement paste, the resistance of concrete to freezing and thawing, as well as chemical stability, resistance to abrasion and specific gravity [9]. Absorption relates to the particle's ability to take in a liquid. Porosity is a rate of the volume of the pores to the total volume of the particle. Permeability refers to the particle's ability to allow liquids to pass through.

The porous aggregate absorb more moisture, resulting in loss of workability of concrete at a much faster rate [4]. High moisture content increases the effective water/cement ratio to an appreciable extent and may render the concrete weak [4].Absorption and Surface Moisture affects Mix-design, Soundness, and Strength/abrasion resistance [6].

The water absorption is determined by measuring the decrease in mass of a saturated and surface-dry sample after oven drying for 24 hours. The ratio of the decrease in mass of the dry sample expressed as a percentage is termed absorption [9].

b) Surface Texture and Shape: Surface texture is the pattern and the relative roughness or smoothness of the aggregate particle. Surface texture plays a big role in developing the bond between an aggregate particle and a cementing material. The shape of the aggregate will also affect the workability of the concrete. An extremely rough, angular aggregate is less workable and may require more water to be added to the mix to increase its workability, thus reducing strength and producing, a more porous concrete [10]. Also, Mehta and Monteiro, [6] stated Rough-textured and elongated particles require more cement paste to produce workable concrete mixtures, thus increasing the cost.

A rough surface texture gives the cementing material something to grip, producing a stronger bond, and thus creating a stronger hot mix asphalt or Portland cement concrete. Surface texture also affects the workability of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the water requirements of Portland cement concrete.

c) Strength and Elasticity: Strength is a measure of the ability of an aggregate particle to stand up to pulling or crushing forces. Elasticity measures the "stretch" in a particle. The strength of the aggregate should be at least equal to that of the concrete [4]. To Anosike (2011) [2] aggregates are considered to be ten times stronger than the crushing strength of concrete, but some particles break also and influence its strength. Rocks commonly used as aggregates have a compressive strength Much higher than the usual range of concrete strength [4].The tests conducted for strength evaluation are crushing test, impact-test and ten per cent fines test [4]. BS 882: 1992 prescribes a minimum value of 150KN (15 tons) for aggregate to be used in heavy duty concrete floor finishes, 100KN (10 tons) for aggregate to be used in concrete pavement wearing surface, and 50KN (5 tons) when used in other concretes.

d) Density and Specific Gravity: Density is the weight per unit of volume of a substance. Specific gravity is the ratio of the density of the substance to the density of water. The specific gravity and porosity of aggregates greatly influence the strength and absorption of concrete. Specific gravity of aggregates generally is indicative of its quality. A low specific gravity may indicate high porosity and therefore poor durability and low strength.

The bulk density of aggregate depends upon their packing, the particles shape and size, the grading and the moisture content. For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand and cement:

Table 1: Specific Gravity of Cement and Aggregates

Material	Specific Gravity
Cement	3.15
Average Sand	2.00
Granite	2.80
Gravel	2.66
Sand	2.65

Source: Anosike, (2011) [2]

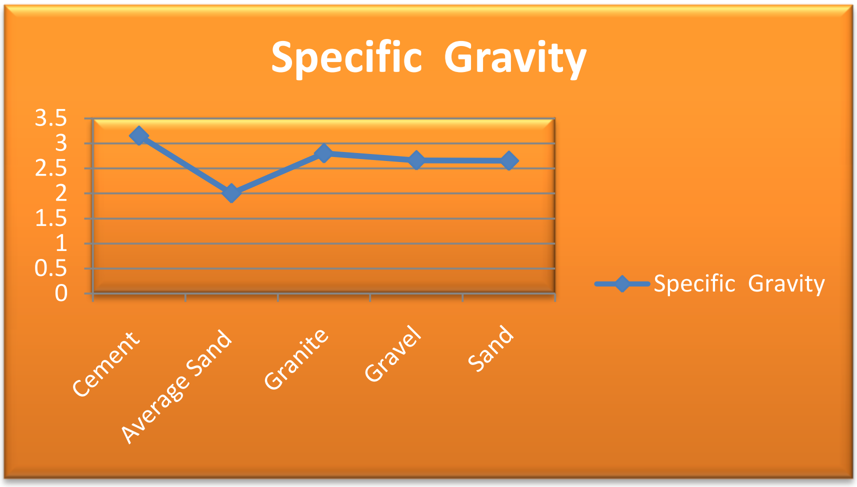

Figure 1: *Specific Gravity of Cement and Aggregates*

e) Aggregate Voids: With respect to a mass of aggregate, the terms voids refer to the space between the aggregate particles: Numerically this voids space is the difference between the gross volume of aggregate mass and the space occupied by the particles alone. The voids within an aggregate particle should not be confused with the void system which makes up the space between particles in an aggregate mass. The voids between the particles influence the design of hot mix asphalt or Portland cement concrete and/or strength. To this end, Duggal, (2008) [4] affirms that "if the voids in the concrete are more the strength will be low."

f) Undesirable Physical/Chemical Components (Deleterious Substance): Deleterious substances are impurities capable of causing damage to the immediate environment where they occur [2]. Particles with undesirable physical characteristics include but are not limited to the following:

- Non-durable soft or structurally weak particles
- Clay lumps or clay balls -
- Flat or elongated particles
- Organic matter contaminants
- Lightweight chest

The effects of deleterious materials on aggregates according to Anosike, (2011) [2] are: They interfere with the hydration of cement; they affect bond between cement paste and aggregates; they reduce the strength and durability of concrete; they modify the setting action of cement concrete and contribute to efflorescence.

2.4. Testing of Aggregate

The size, shape, grading of aggregate and their surface moisture affect directly the workability and strength of concrete whereas soundness, alkali-aggregate reaction and presence of deleterious substances adversely affect the soundness and durability of concrete. The following tests are conducted to ensure satisfactory performance of aggregate.

a) Particle Size Distribution Test/Grading: The grading of coarse aggregate is of a vital factor in determining the determining the properties of concrete, since it influences to a large extent the degree of pores contained in the hardened concrete [7].Grading and size of aggregate both affect the amount of water needed to obtain workability. A well-graded aggregate, i.e. one with a range of particle size, improves the workability, as does using the largest possible particle size that can be compacted around and over the reinforcing rods [10].

The process of dividing a sample of aggregate into fractions of same particle size is known as a sieve analysis, and its purpose is to determine the grading or particle size distribution of the aggregate.

A sample of air-dried aggregate is graded by shaking or vibrating a nest of stacked sieves with the largest sieve at the top, for a specified time so that the Material retained on each sieve represents the fraction coarser than the sieve in question but finer than the sieve above. Usually sieve sizes for concrete aggregate are 75.0, 50.0, 37.5, 20.0, 10.0, 5.0, 2.36, 1.18mm and 600, 300 and 150micron [9].

The air dried sample is placed on a set of specific sieves with largest size on the top. The set of sieve is shaking for 2 minutes; Arrangement of sieve for coarse aggregate is as follows: 40mm, 20mm 16mm l0mm 4.75 mm 2.36 mm [9]. Table 2 gives the grading requirement for coarse aggregate

Table 2: Grading Requirements for Coarse Aggregate Concrete (ASTM C-637)

Sieve Size	Grading (37.5mm max-size Aggregate)	Grading (19.0mm max-size Aggregate)
Coarse Aggregate		
50min ,	100	-
37.5min	95-100	100
25.0mm	40-80	95-100
19.0mm	20-45	40-80
12.5mm	0-10	0-15
9.5mm	0-2	0-2

Source: Anosike, (2011) [2]

Finally a curve should be plotted with sieve sizes on abscissa on a graph and percentage of aggregate passing as ordinate. From this graph relative amount of various sizes of aggregate can be readily compared.

b) Deleterious Materials and Organic Impurities Test: Harmful substances that may be present in aggregates include organic impurities, silt, clay, shale, iron oxide, coal, lignite; and certain lightweight and soft particles [4]. UNESCO-NT&VERP, (2008); Duggal, (2008) [9,4] grouped these deleterious substances into these three categories;

i. Impurities which interfere with the process of hydration of cement i.e. organic matters,
ii. Coating on aggregate which prevent the development of good bond between aggregate and the cement paste e.g. clay. These materials should not be present in excessive quantity because they need more water for concrete of a definite workability.
iii. Unsound or weak particles which are weak or bring about chemical reaction between aggregate and cement paste

Aker, (2000) [1] opined that erratic setting times and rates of hardening may be caused by organic impurities in the aggregates, primarily the sand i.e. Organic impurities may delay setting and hardening of concrete, may reduce strength gain, and in unusual cases may cause deterioration. Also, Coal and lignite may also cause staining of exposed concrete surfaces [1]. Moreover, Duggal (2008) [4] postulated that impurities affect the properties of concrete in green as well as in hardened state and are undesirable. In all, Aggregates are potentially harmful if they contain compounds known to react chemically with Portland cement concrete and produce any of the following:

i. Significant volume changes of the paste, aggregates, or both;

ii. Interference with the normal hydration of cement; and
iii. Otherwise harmful to products.

The acceptable international standard method of testing for their presence is provided in the last column of the table 3.

Table 3: Limits of Deleterious Substances in Coarse Aggregates

Deleterious Substances	Coarse Aggregate		Method of test
	uncrushed	crushed	
Coal and lignite	1.00	1.00	IS —2386 1963 PT II
Clay lumps	1.00	1.00	77
Soft fragments	3.00	-	71
Materials passing 75mm micron sieve	3.00	1.00	PART I
Shale	-		-do- Part II
Total	8.00	3.00	

Source: Anosike, (2011) [2]

c) Crushing Strength Test: The strength of the coarse aggregate influence to a great extent thestrength of the concrete made from it. Due to it, UNESCO-NT&VERP, (2008), [9] posited "the compressive strength of concrete cannot exceed that of the aggregate used therein." That is, the compressive strength of the concrete should be equal the compressive of the coarse aggregate [10]. According to Duggal, (2008) [4], the compressive strength of building stones in practice ranges between 60 to 200N/mm^2.

Concrete compressive strength is easy to determine and for this reason it is the one most universally used in concrete practice [3]. This strength tests is usually made on 150mm or 100mm cubes, also, 150mm diameter by 300mm cylinders are used. It has been found that cylinders fail at lower compressive stress than 100mm and 150mm cubes of the same quality of concrete [3].

The quality of concrete is generally assessed by its crushing strength. This strength is determined by testing suitably prepared specimen of the concrete in compression machine in accordance with BS EN 12390 - 3: 2000 International Standard.

The concrete cube compressive strength can be as high as 150N/mm2 (strength still rising due to the use of better materials procedures and technologies), but the minimum strength required for ordinary reinforced concrete is about 21N/mm'˜ [3].

d) Workability Test: The quality of plastic concrete mix (fresh concrete) is assessed by workability test. Workability is the fluidity of concrete. Generally; workability is defined as the ease with which a given set of materials can be mixed into concrete and subsequently handled, transported - and placed with minimum loss of homogeneity. Thus, the term workability means compatibility, placeabilty, pumpability, mobility, and stability. Factors Affecting Workability according to CORBON and NIOB, (2014) [3] are: Aggregates grading; Maximum aggregate size; Water/cement ratio (cement and water content); Aggregate/cement ratio; Aggregate shape and Aggregate texture. Workability test is carried out in two phases, namely:

i. Slump test
ii. Compacting Factor test

i. Slump Test: This test together with careful observation of the concrete is the best means of assessing workability of a mix. The slump test assists in assessing the consistency of a mix. The plasticity and harshness is best noted by observing the appearance of the slump specimen after the mould has been removed. A plastic mix (workable mix) will tend, to stick together and subsides unbroken when the mould is removed, while a harsh mix breaks. Using the slump test a mix could have:

- True slump: representing mix with low to medium workability
- Shear slump: representing harsh mix, low cement content, poor aggregates grading, improper shapes and textures etc.
- Collapse slump: representing mix with high workability

ii. Compacting Factor test: Slump test is satisfactory for medium and high workability. Where concrete of very low workability is to be tested, the compacting factor test is more appropriate. This test is done with a compacting factor apparatus. Compacting factor test measures the degree of compaction achieved by a standard amount of work done.

Table 4: Comparison between workability assessment methods slump and compacting factor test

Slump (mm)	Compacting Factor	Degree of Workability
0 --25	0.78	Very low
25-50	0.85	Low
50-100	0.92	Medium
100-175	0.95	High

Source: CORBON and NIOB, (2014) [3]

3. Research Methodology

The study evaluates the quality of aggregate from selected sources in Anambra state. Thus by adopting sampling techniques postulated by Jude, Obiegbu, (2005), the randomly selected sample of the research were drawn from Ogbunka (Anambra south senatorial district), Enugwukwu (Anambra Central Senatorial District), and Aguleri, Nsugbe and Nkwelle Ezunaka (Anambra north senatorial district) respectively. Eventually, the research survey selected and sampled one quarry sites at different locations in each of the five towns. That is, the total of five quarry sites producing coarse aggregates were surveyed in addition to the laboratory experiments conducted. The study sampled local stones only.

The grade of *in-situ* concrete specimen was 1:3:6 mix ratios with the aggregate properly washed the result obtained from these five quarry sites and the pilot laboratory investigations conducted that was used to represent other quarry site within the senatorial zone not surveyed. The result of the survey was used to draw conclusions and recommendations. The study used two methods to source data:

1. Secondary Data Collection: Secondary data was used to extract relevant data and information from texts, local and foreign journals, dissertations/thesis, technical papers, local and foreign documents on standards, specifications, quality management and control, some selected codes of practice, and the internet;
2. Primary Data Collection: Primary data involved field sampling and laboratory specimen tests of some properties of concrete and materials of concrete sampled at selected quarry sites.

Sample Size: A total of 5 cubes of 150mm x 15Ornm x 150mm concrete moulds were cast, cured and tested. All the specimens were prepared with washed aggregate samples. Two quarry sites per town were used to conduct the laboratory experiments. Cube prepared with Enugwukwu aggregate is referred as Sample A, Aguleri as Sample B, Nsugbe As Sample C, Ogbunka as Sample D and Nwelle Ezunaka as Sample E.

3.1. Sieve Analysis of Coarse Aggregates

Apparatus

i. Sieves, mounted on suitable frames, designed not to leak. Sieves shall conform to AASHTO M92.
ii. Mechanical sieve shaker, if used, must provide a vertical or lateral vertical motion to the sieve, causing the particles thereon to bounce and turn so as to present different orientations to the sieving surface. Sieve shakers must provide sieving thoroughness within a reasonable time.
iii. Oven, capable of maintaining 230 ± 9°F (110 ± 5°C). When tests are performed in the field where ovens are not available, test samples may be dried in suitable containers over open flame or electric hot plates with sufficient stirring to prevent overheating.

Sample Preparation

Samples were obtained in the field and reduced to test sizes. Also wet samples were spread under the sun to dry. The original sample must be reduced to a test sample size which falls within the minimum and maximum weight in the following table.

Summary of Test

A known weight of material, the amount being determined by the largest size of aggregate, is placed upon the top of a group of nested sieves (the top sieve has the largest screen openings and the screen opening sizes decrease with each sieve down to the bottom sieve which has the smallest opening size screen for the type of material specified) and shaken by mechanical means for a period of time. After shaking the material through the nested sieves, the material retained on each of the sieves is weighed.

3.2. Compression Test

(i) Compression testing machine conforming to IS: 516-1959

Procedure

i. The specimens were prepared using the ratio of 1:3:6. The cubes were stored in water to cure and were tested after 7 days.
ii. The bearing surfaces of the compression testing machine was wiped clean and any loose sand or other material removed from the surfaces of the specimen, which would be in contact with the compression platens.
iii. The specimen was placed in the machine in such a manner that the load could be applied to the opposite sides of the cubes, not to the top and the bottom. The axis of specimen was carefully aligned with the centre of thrust of the spherically seated platen. As the spherically seated block was brought to rest on the specimen, the movable portion was rotated gently by hand tiller uniform seating was obtained.
iv. The load was applied without shock and increased continuously at a rate of approximately Ling/sq.cm/minute until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was recorded and the appearance of the concrete and any unusual features in the type of failure noted.

3.3. Workability Test (Slump)

Procedure

i. The internal surface of the mould was thoroughly cleaned and applied with a light coat of oil.
ii. The mould was placed on a smooth, horizontal, rigid and non- absorbent surface.
iii. The mould was then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of the mould.
iv. Each layer was tamped 25 times by the rounded end of the tamping rod (strokes are distributed evenly over the cross- section).
v. After the top layer is rodded, the concrete was struck off the level with a trowel.
vi. The mould was removed from the concrete immediately by raising it slowly in the vertical direction.
vii. The difference in level between the height of the mould and that of the highest point of the subsided concrete was measured.
viii. This difference in height in mm is the slump of the concrete.

4. Presentation of Results of Experiments

4.1. Test No.1-Compressive Strength and Slump Test of Sampled washed Aggregate Concrete Materials (Specimen 1).

The technique adopted was to conduct laboratory tests which entailed preparation of concrete samples using coarse aggregates obtained from selected quarry sites into available 150 mm square metal cube moulds. These cubes were cured and. tested in the laboratory to determine their compressive strength. The measured compressive strength of the specimen was calculated by dividing the maximum load (*i.e.* crushing-value) applied to the specimen during the test by the cross - sectional area, calculated from the mean dimensions of the section and was expressed as N/mm^2

Table 5 results indicate that concrete produced using the coarse aggregate obtained from Enugwu-ukwu, Awka, Aguleri, Nsugbe , Ogbunka and Owelle-Ezukala has a compressive strength of 24N/mm', 19.5N/mm2, 25.77N/mm2, 20N/mm2, 29.33N/mm2 and 27.59N/mm2 respectively. The result implied that the concrete produced using coarse aggregate obtained from the quarry sites at Ogbunka yielded a higher compressive strength. Also the result of the slump connotes low workability since it is within the range of low workability (i.e. 25-50%) except Nsugbe that falls within the class of very low workability.

4.2. Test No. 2-Sieve Analysis

Sieve sizes used for concrete aggregate as per -LS. 383-1970 are as follows:- 80mm, 63.0, 40mm, 20mm, 10mm and 4.75mm for grading of coarse aggregate, whereas 4.75mm, 2.36mm, 1.18mm, 600micro, 300rnicro and 150micro are used for grading of fine aggregates. Or BS 812, Part-1, in U.K. this experiment was carried out using a given quantity of dry coarse aggregate samples in each case from sampled specimen.

Table 5: Values of Compressive Strength Test and slumps test Results Obtained from washed Aggregate Specimens

Location	Sample Specimen	Concrete Mix Ratio	Cube Weight. (Kg)	Slump Value . (mm)	Curing Period (Days)	Crushing Value (KN)	Compressive Strength (N/mm2)
Enugwu- ukwu	A	1:3:6	7.3	38	7	540	24
Aguleri	B	1:3:6	7.3	39	7	580	25.77
Nsugbe	C	'1:3:6	7.2	21.5	7	450	20
Ogbunka	D	1:3:6	7.1	40	7	660	29.33
Nkwelle-Ezunaka	E	1:3:6	6.8	41	7	522.675	23.23

Source: Researchers Field Work, (2014)

Table 6: Results on Sieve Analysis for Coarse Aggregate

Set of sieve Dia (mm)	Weight Retained					Percentage Retained (%)					Percentage cumulative (%)					Percentage Passing (%)				
	A	B	C		E	A	B	C	D	E	A	B	C	DE		A	B	C	D	P
38.10																				
31.75																				
25.40																100	100	100	I10.0	100
19.05	481.8	437.2	288.0	162	254.6	35.7	34.5	16.4	12.62	16.0	35.7	34.5	16.4	16.2	16.0	64.3	65.5	83:6	87:38	84.0
12.70	636.6	637.2	1440.8	972	1289.6	47.1	50.3	81.8	75.71	81.2	82.8	84.8	98.2	97.9	97.2	17.3	15.2	1.8	11.67	2.8
9,152	225.8	186.7	10.6	150	14.4	16,7	14.7	0.6	11.68	0.9	99.5	99.5	98.8	98.2	98.1	0.5	0.5	1.2	0.14	1.9
4.75 236 118 0.6																				

Source: Researchers field work (2014)

This was weighed before it was poured into the largest diameter size of sieve arranged in order of size with the largest size, 80mm diameter on top followed by the next smaller size unto the smallest size, 4.75mm at the bottom. Wet coarse aggregate specimen is oven-dried in the laboratory before utilization. The quantity retained in each size category weighed and its percentage value was calculated against the total volume/quantity measured. Below are the tabulated results:

From the result obtained in Table 6, the percentage passing for a single sized aggregate of nominal size 20mm fall within 85-100 for sample C, D, and E. with sample A and B falling below 80%. All the samples fall below 20% for sieve diameter of 12.70mm and far the value also drop for sieve diameter of 9.52mm. However, the gradation curve indicated the presence of insignificant quantity of coarse sand in the fine sand zone, large quantity of fine in the gravel zone and some coarse aggregates higher than 20rnm diameter are present in the gravel zone distribution. We concluded that Specimens were suitable for a 1:3:6 -20mm aggregate specification requirements and thus fairly graded although it would provide good workability as shown in table 1.

5. Summary, Conclusion and Recommendation

5.1. Summary

The study evaluate the qualities of coarse aggregate used in concrete production in Anambra state especially the one sourced within the state. In line with the set objectives the following were;

Firstly, in objective No.1 (i.e. establish qualities of good coarse aggregate, possible tests and procedures), the researchers observed that properties of a coarse aggregate are grouped into 2: Mechanical and physical properties. Key among them are strength; Absorption, -Porosity, and Permeability; Surface Texture and Shape; Density and Specific Gravity, Aggregate Voids and Undesirable Physical/Chemical Components (Deleterious substance). The researchers observed that compressive strength of concrete can be as high as 150N/mm2 but the minimal is 21N/mm2. Based on classification high strength, normal strength, and low strength concrete attains compressive strength of more 60N/mm2, 20-60N/mm2 and below 20N/mm2 respectively at 28days. Also, grading requirements for coarse aggregate concrete for 37.5mm max and 19mm max should consist 95-100% and 40-80% passing through 37.5mm sieve and 19.5mm sieve respectively. Finally on objective NO 1, the researchers observed that slump below 50% is rated low workability.

Secondly, in objective No 2, the researchers observed that there are many quarry sites in Anambra North but few at both south and central. However, the samples for the study were collected at 3 towns in North (Aguleri, Nsugbe and Nkwelle Ezunaka), Enugwu-ukwu (Central) and Ogbunka (South). The researchers found-out that of all the quarry sites visited the breakings of stones were done with hands. Use of child labour is prevalent in the entire quarry sites and finally roads leading to this quarry are not tarred.

Thirdly, or objectives No 3, samples collected were taken to laboratory for test. At the end of the test, the following observations were made: Concrete produced using the coarse aggregate obtained from Ehugwu-ukwu, Awka, Aguleri, Nsugbe , Ogbunka and Owelle izukala has a compressive strength of 2 N/mm^2, 19.5N/mm2, 25.77N/mm2, 20N/mm2, 29.33N/mm2 and 27.59N/mm2 respectively. Also th result of the slump connotes low workability since it is within the range of low workability (i.e. 25- 50%) except Nsugbe that falls within the class of very low workability. Finally, the percentage passing for a single sized aggregate of nominal size 20mm fall within 85-100 for sample C, D, and E. with sample A and B falling below 80%. All the samples fall below 20% for sieve diameter of 12.70mm and far the value also drop for sieve diameter of 9,52mm

5.2. Conclusion

Based on the findings of the research the following conclusions were drawn:

- Except the concrete made with the Nsugbe samples others achieved the minimum compressive strength of concrete (i.e. 21N/mm2) within 7 days.
- The crushing strengths/compressive strength attained by the samples fall within the normal strength concrete (20-60N/mm2) within 7 days of age.

- The sample prepared with Ogbunka stone yielded best compressive strength.
- Local stone if properly graded can compete favourably with granite chipping in term of strength and other properties such as workability.
- Since the stones were break using hands but the use of machine would yield better the gradation of the stones drastically.

5.3. Recommendation:

The study recommends the following:

- The key *advantage* that granite chippings have over local stone is that it is properly graded. Therefore, the researchers recommend that stones should be properly graded-using machines rather than hand breaking;
- Aggregate should be properly washed before using since most of them are coated with impurities and other clayey substances and muds which may hinder the process of bonding;
- Further study should be carry out using un-wash samples;
- Research should be extended to other quarry sites/towns not covered in the study;

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