A Study into the Qualities of Concrete made with Coarse Aggregate obtained from Selected Quarry Sites in Anambra State, Nigeria[1]

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ABSTRACT

The study examined the qualities of coarse aggregate sourced from different quarry sites within Anambra State, Nigeria. Samples for this study were obtained from quarry sites at Enugwu-Ukwu, Aguleri, Nsugbe, Nkwelle –Ezunaka and Ogbunka. The study carried out sieve analysis test, slump test and cube (crushing strength) using the samples obtained from the listed quarry sites. From the test, the study observed that the crushing/compressive strength of the samples at 7 day are between 20-29N/mm^2 with Ogbunka samples having the highest compressive strength of 29.33N/mm^2. Thus, at 7th day, four out of the five samples tested attained the minimum strength of concrete (i.e. 21N/mm^2). Also, the study observed that the percentage of slump ranges from 21.5 – 41% with Nsugbe samples having the best slump value of 21.5%. The study observed that the samples were fairly graded. The percentage of the grains passing through 19.05 diameters is between 64.3 – 84.0%. The study concluded by recommending that stones should be properly graded and properly washed before utilization since most of them are coated with impurities which may interfere with the process of bonding.

1.0 INTRODUCTION

Concrete is a major component of infrastructural facilities in the 21st century because of its versatility in use. Concrete is used more than any other man-made material in the world (Anosike, 2011). Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as 'fly ash' and 'slay cement', aggregates (overall coarse aggregate made of gravel or crushed rocks such as limestone, or granite plus fine aggregate such as sand), water, and chemical admixture, (Bert-Okonkwor, 2012). 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 developers. The three-basic component of concrete - cement, aggregate and water greatly affect the quality of concrete (Duggal, 2008). In-furtherance, Duggal (2019) stated that aggregate occupy about 70-80 percent of the volume and thus considerably influence the properties of the concrete. In line with this, UNESCO-Nigeria Technical & Vocational Education Revitalisation Project-

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Phase II (UNESCO-NT&VERP II), (2008) opined that "The compressive strength of concrete cannot exceed that of the aggregate used therein."

Aggregates as defined by UNESCO-NT&VERP II, (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." To Council of Registered Builders of Nigeria (CORBON) and Nigeria Institute of Building (NIOB), (2014), 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. Ezeokonkwo (2014) also described aggregates as inert or chemically inactive materials which form the bulk of cement concrete and are bound together by means of cement as a binder. Aggregate used in construction basically comes in two different sizes—the bigger ones known to be coarse aggregate (grit) and the smaller one's - fine aggregate (sand) (Ezeokonkwo, Okolie & Ogunoh, 2015). Furthermore, Ezeokonkwo, Okolie and Ogunoh, (2015) stressed that coarse aggregate form the main matrix of concrete and the fine aggregate form the filler matrix between the coarse aggregate. Since up to 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 (Quiroga & Fowler, 2003). Aggregate characteristics of shape, texture, and 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 grading (Quiroga & Fowler, 2003).

Conversely, failures 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 (Ezeokonkwo, 2014). The findings of the committee of enquiry that investigated the collapsed 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 revealed that the main causes of the collapse was the use of sub- standard materials particularly coarse aggregates used for concrete production. In order to curb the incidence of building collapse across the globe, several researches have 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. In continuation, little research has been made in order to establish the quality of the coarse aggregate sourced within study area. Therefore, this study examined the qualities of coarse aggregate sourced from different quarry sites within study area, with a view to determining their suitability for concrete production. The study identifies and obtained samples of coarse aggregate from the different quarry sites within the study area. Also, the study carried out laboratory experiment to ascertain the compressive strengths, aggregates particle size distribution and slump test for the various samples.

2.0 REVIEW OF RELATED LITERATURE

2.1 Aggregates & Its classification

Aggregate includes boulders, cobbles, crushed stone, gravel, air-cooled blast furnace slag, native and manufactured sands, and manufactured and natural lightweight aggregates (Akers, 2000). The aggregate (both fine and coarse) makes up about 80% of the volume of the concrete (Reed, Schoonees & Salmond, 2008). Reed, Schoonees and Salmond generalised the volume of aggregate in concrete production but Aker (2000) was more specific. According to Aker (2000), 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), state 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, strength and durability, reduce shrinkage, reduce creep, reduce overall cost, imparts sound and thermal properties, imparts density, increase chemical resistance etc (CORBON&NIOB, 2014). When aggregate for concrete is being selected, the chemical inertness, strength, clean, cost, availability in required size, grading, shape and surface texture are considered (CORBON&NIOB, 2014). Also, Anosike (2011), 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.

On the other hand, Ezeokonkwo (2014); Bert-Okonkwor (2012); Anosike (2011) and Duggal (2008), classified aggregate based on the following: According to source (Natural and artificial aggregates); mineralogical composition (aggregates here are classified as siliceous or calcareous); 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); sizes (divided again into coarse and fine aggregates). CORBON and NIOB, (2014); McGinley and Choo (2003) classified aggregate only in terms of size. And UNESCO-NT&VERP (2008) classified aggregate based on origin with other subdivisions. However, for the purpose of this work, the classification based on size was 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

2.2 Properties of Aggregate:

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

2.2.1 Mechanical Properties of Aggregates

1. **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 particles. 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.

2. **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), classified concrete based on its crushing strength as: High-strength concrete, concretes with compressive strengths greater than 60N/mm2 (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/mm2 (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/mm2 (3000psi). Used where light loading is expected e.g.; for stabilization of embankments, strip footings, ordinary ground floor slabs, etc

2.2.2 Physical Properties of Aggregates

1. **Absorption, Porosity, and Permeability:** The porosity, permeability and absorption of 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 (UNESCO-NT&VERP II, 2008). Absorption relates to the particle's ability to take in a liquid. Porosity is a ratio 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. Porous aggregate absorbs more moisture, resulting in loss of workability of concrete at a much faster rate (Duggal, 2008). High moisture content increases the effective water/cement ratio to an appreciable extent and may render the concrete weak (Duggal, 2008). Absorption and Surface Moisture affects Mix-design, Soundness, and Strength/abrasion resistance.

2. **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 affects 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 (Reed, Schoonees and Salmond, 2008). Also, rough-textured and elongated particles require more cement paste to produce workable concrete mixtures. 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.

3. **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 (Duggal, 2008). To Anosike (2011) 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 (Duggal, 2008). The tests conducted for strength evaluation are crushing test, impact-test and ten per cent fines test (Duggal, 2008). 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.

4. **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.

5. **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) affirms that "if the voids in the concrete are more the strength will be low." 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.

2.3 Grading of Aggregates

According to Nawy (2008), during concrete production, aggregates must be graded such that the smaller particles of the fine aggregates fill the voids created by the coarse aggregates thus forming a very dense and compacted mix. 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 (Okereke, 2003). 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 (Reed, Schoonees & Salmond, 2008).

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 (UNESCO-NT&VERP, 2008).

The air-dried sample is placed on a set of specific sieves with largest size on the top. The set of sieves is shakes for 2 minutes. Arrangement of sieve for coarse aggregate is as follows: 40mm, 20mm 16mm l0mm 4.75 mm 2.36 mm (UNESCO-NT&VERP, 2008). Table 1 gives the grading requirement for coarse aggregate

Table 1: Grading Requirements for Coarse Aggregate Concrete (ASTM C-637)

Percentage Passing		
Sieve Size	Grading (37.5mm max.–size Aggregate)	Grading (19.0mm max.-size Aggregate)
Coarse Aggregate		
50mm	100	-
37.5mm	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)

3.0 RESEARCH METHODOLOGY

Data for this study were obtained through:

a. Secondary sources: 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.

b. Primary sources: Primary data involved field survey and laboratory tests of concrete and coarse aggregates samples.

The samples for this study were collected from quarry sites at: Ogbunka (Anambra south senatorial district), Enugwu - ukwu (Anambra central senatorial district), and Aguleri, Nsugbe and Nkwelle Ezunaka (Anambra north senatorial district) respectively. That is, a total of five quarry sites producing coarse aggregates were surveyed in addition to the laboratory experimentations conducted. The study sampled local stones only.

Accordingly, a total of 5 cubes of 150mm x 150mm x 150mm concrete moulds were cast, cured and tested. All the specimens were prepared with washed aggregate samples. Cube prepared with Enugwu-ukwu aggregate is referred as Sample A, Aguleri as Sample B, Nsugbe as Sample C, Ogbunka as Sample D and NkwelleEzunaka as Sample E. (see plate 1)

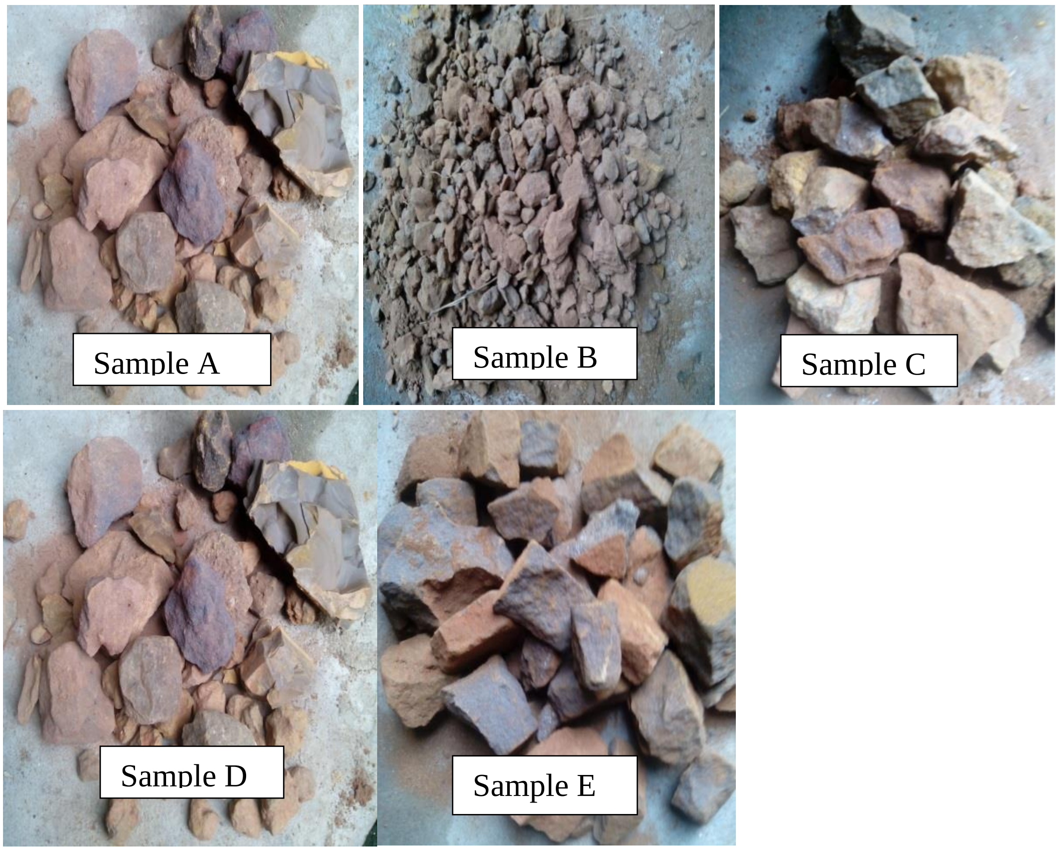

Plate 1: Samples of the coarse aggregate obtained from the different quarry sites in the study area.

3.1 Sieve Analysis Coarse Aggregates

a) **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 and 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.

Procedure: Samples were obtained in the field and reduced to test sizes. Also, wet samples were spread under the sun to dry. 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

Apparatus

Plate 2: universal testing machine

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

Procedure: The specimens were prepared using the ratio of 1:3:6. **T**he cubes were stored in water to cure and were tested after 7 days. 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. 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 the 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 till a uniform seating was obtained. The load was applied without shock and increased continuously at a rate of approximately 140kg/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.

Plate 3: preparation of the specimens (concrete cube)

Plate **4: testing of the specimen**

Plate 5: specimens after crushing

3.3 WORKABILITY TEST (SLUMP)

Apparatus

Plate 6: slump cone

i) Slump cone

ii) Tamping rod

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

4.0 RESULTS & DISCUSSION

Table 2: Compressive Strength & Slumps test Results

Sample NO	Concrete Mix Ratio	Cube Weight. (Kg)	Slump Value (mm)	Curing Period (Days)	Crushing Value (KN)	Compressive Strength (N/mm2)
A	1:3:6	7.3	38	7	540	24
B	1:3:6	7.3	39	7	580	25.77
C	1:3:6	7.2	21.5	7	450	20
D	1:3:6	7.1	40	7	660	29.33
E	1:3:6	6.8	41	7	522.675	23.23

Source: Field Survey (2018)

The result in table 2 result indicate that the compressive strength of sample A, B, C, D, and E are 24N/mm^2, 19.5N/mm^2, 25.77N/mm^2, 20N/mm^2, 29.33N/mm^2 and 27.59N/mm^2 respectively. Also, the result the slump value from table 2 ranges from 20 – 30 for all the samples. In furtherance, the result in table 2 indicate that sample D yielded a higher compressive strength while sample D yielded the lowest slump values. That's sample C performed best in compressive strength with sample C for the slump.

The concrete cube compressive strength can be as high as 150N/mm2 (strength still raising due to the use of better materials procedures and technologies), but the minimum strength required for ordinary reinforced concrete is about 21N/mm^2 (CORBON & NIOB, 2014). Based on this, it could be deduced at 7th day all the samples excluding that of C have attained the needed minimum strength.

Furthermore NIOB, (2015) stated that when compressive strength of concrete at 28th day is above 60N/mm^2, 20-60N/mm^2 and below 20N/mm^2 is regarded as High, normal and low strength respectively. Considering the compressive value of the samples in table 2, it was discovered that none of the value is below 20N/mm^2. Therefore, none of them belong to lower classification of concrete at 7th day.

Table 3: Sieve Analysis Results

Set of Sieve Dia. (mm)	Weight Retained					Percentage Retained (%)					Percentage cumulative (%)					Percentage Passing (%)				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
38.10																				
31.75																				
25.40																100	100	100	100	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
9.52	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																				
2.36																				
1.18																				
0.6																				

Source: Field Survey (2018)

From the result obtained in Table 3, the percentage passing for a single sized aggregate for nominal size of 20mm fall within 85-100 for sample C, D, and E while sample A and B falls below 80%. For 25.40mm and 12.70mm sieve, all the samples recorded 100% and below 20% respectively and the value also drop for sieve diameter of 9.52mm. Comparing this result to NIOB (2014) observation on grading requirement of coarse aggregate that is "grading requirements for coarse aggregate concrete for 37.5mm max and 19mm min should consist 95-100% and 40-80% passing through 37.5mm sieve and 19.5mm sieve respectively" indicates that all the samples falls within the required percentages of 95-100% for 37.5mm sieve and only sample A and B falls with the required value of 40-80% of 19.5mm sieve.

Based on the results in table 3, the research observed that in all quarry sites visited the gradation of the aggregate were done manually. Use of child labour is prevalent in the entire quarry sites and finally roads leading to this quarry are not tarred.

5.0 CONCLUSION & RECOMMENDATIONS

Anambra state is blessed with the large presences of stones in the northern part of the state. Thus, lot of quarry sites are found in there compared to south and central parts of the state. Extraction and processing of the coarse aggregate in the quarry sites within the study area were done manually. Most of the roads leading to this quarry were not tarred making transportation of the aggregates difficult during rainy season. Also, all the aggregates were discovered to be coated with debris and needed to be washed before utilisation but it's rarely done at most sites. From the findings of this research the following conclusions and recommendations were drawn:

1. Except the concrete made with the Nsugbe samples other achieved the minimum compressive strength of concrete (i.e. 21N/mm2) within 7 days.
2. The crushing strengths/compressive strength attained by the samples fall within the normal/acceptable/minimum strength of concrete (20-60N/mm2) within 7 days of age.
3. The sample prepare with Ogbunka stone yielded best compressive strength.
4. Local stone if properly graded can compete favourably with granite chipping in term of strength and other properties such as workability etc.
5. Since the stones were processed manually, use of machine will improve the gradation drastically
6. Aggregate should be properly washed before using since most of them coated with impurities and other clayey substances and muds which may interfere with the process of bonding

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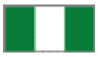

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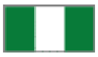

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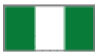

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