[1.]Sunday Ayodele AGBALAJOBI, [2.]Reuben Ibukun OBARO, [3.]Suleiman Ajibola ADEBARA

# SUITABILITY OF SELECTED ROCK AGGREGATES FOR ROAD CONSTRUCTION: A CASE STUDY OF GBOSE QUARRY, OMU-ARAN

[1, 2.] Department of Minerals and Petroleum Resources Engineering Technology, Kwara State Polytechnic, Ilorin, NIGERIA
[3.]Department of Civil Engineering Technology, Federal Polytechnic Ede, Osun State, NIGERIA

**Abstract:** This study deals specifically with the investigating the suitability of rock aggregates for road construction. Aggregate rock samples were obtained from Gbose Quarry, Omu-Aran, Kwara State. The aggregate samples were tested in the laboratory for water absorption, mineral composition, Aggregate Impact Value (AIV), Aggregate Crushing Value (ACV), flakiness and elongation indices. The loose and compacted bulk densities were also carried out on the aggregate samples. The result shows that Water Absorption value for aggregate size of 4-16mm and 16–32mm is 0.77% with average loose and compacted bulk densities given as 23.35kN/m$^3$ and 25.33kN/m$^3$ respectively. However, it was also revealed that Aggregate Impact Value (AIV) is 14.3%, Aggregate Crushing Value (ACV) is 21.7%, flakiness and elongation indices for the aggregate granite are 24.9% and 28.1% respectively. In addition, the force or load required to produce 10% fines was estimated to be 184.86kN. Therefore, the results of tests are within the commonly acceptable limit suggested by BS 812:1983 for general use in heavy duty concrete floors and road construction, which will serve as database to prospective contractor involved in concrete and road construction.
**Keywords:** aggregate impact, crushing value, bulk densities, contractor, elongation, flakiness indices, granite, road construction

## 1. INTRODUCTION

Civil engineers routinely use rock as aggregate material in their construction project especially granite rocks. The engineering behaviour of near surface subtropical and topical soil and rock is a function of the impact of their interaction with the road environment and the weathering processes. Granitic rocks have variety in mineralogy, petrographic characteristics and engineering properties. As it is known that the geological background of natural road construction material used in all areas of construction of road has a profound effect on the engineering performance of those materials (granite). Granite is a hard, crystalline rocks which were formed by the cooling and solidification of molten rock (magma) either at or below the earth's surface. In determining the condition that fit road construction, it is very important to determine the mechanical properties of the rock and their respective mineralogy characteristics in determining the rock strength and it's capability from failure (Tugrul and Zarif, 1999). The properties of rock are influenced by the mineral composition, texture (grain size and shape), fabic (arrangement of mineral and voids and weathering state) (Irfan, 1996). Granitic rocks have variety in their mineralogy, petrographic characteristics and engineering properties.

The petrographic characteristics such as grain size shape of the grains, degree of interlocking, type of contacts and mineralogy composition could affect the mechanical properties of the rock. Johnson and De Graff (1988) reported that the mineralogy and texture combine to give strength and excellent elastic deformation characteristics for typical fresh igneous rock. The results shows that the strength of igneous rock decreased significantly as the grain sized increased Onoreda and Asoka (1980), investigated and clearly stated the relationship between the tensile strength and the percentage of quartz which has higher strength of rocks, in contrast of presence of feldspar, the strength of rock seems deceased.

Natural construction aggregate is one of the most abundant natural resources and one of the most widely used. Construction aggregate is the sized, or crushed and sized, rock material used in concrete and asphalt, which make up most of highways, bridges, houses and other engineering works. Aggregates range in size from large boulders (rip rap) used as fill in large construction projects to finely-ground flour-sized particles used in paint, glass, plastic, medicine, agricultural feed and soil conditioners, and many other industrial and household products. Construction aggregates are also used in water purification, emissions control, soil erosion control, and other environmental improvement products. More than 90% of asphalt pavement and 80% of concrete consist of construction aggregate. The remainder is a binder such as asphalt or cement. About 52% of all construction aggregate is crushed stone, while 48% of the remaining is sand and gravel (Bolen, 2005).

Aggregates are essential not only as a foundation for pavements, but also constitute the cement that makes the road itself. When a road is finished, the upper layers provide protection for the sub-base. Nevertheless, water can freely pass through the open structure, so the constituent rock must be able to maintain its properties when in the wet state. It must be able to resist the mechanical and chemical weathering processes. During the construction process, the sub-base is used as track along which heavy construction machinery can move that must therefore be able to withstand the weight and impact of such vehicles. Selecting the right aggregate material is imperative to overcome the frequent problem of pavement failure. In the various ways in which aggregate is used, it is exposed to a variety of stresses, and the response of the structure in which it is used will largely depend upon the properties of the aggregate.

There are lots of researcher and construction companies that have carried out a research on this topic for the improvement and certifying of the material (granite stone) to be used for their construction. Previous study report shows that when the grain is finer then the strength of the rock is greater (Tugrul, and Zarif, 1999). According to Agustawijaya, 2007, the strength of the materials are said to be influence mainly the mineral characteristics (grain size, grain shape, grain orientation and arrangement of material (Sharma et al., 2011). Other physical, mechanical factors that may be considered include and are not limited to the porosity, density and compressive strength. The type of study can accomplish the high demand of information required the construction industries before selecting the Gbose Olive granite for their road construction

More also, the mechanical properties of the rock sample were determined by a variety of laboratory tests in accordance with the procedures given in ISRM (1981) and ASTM (2005). The determination of point load strength index was done by the point load test in accordance to procedure recommended in ASTM D 5731. A Uniaxial Compression Testing machine was used to test core specimen according to the ISRM (1981) specification. The tensile strength of the granitic rock was determined using a Brazilian testing machine according to ASTM specification. The frequently distinct engineering behaviour of naturally occurring construction materials within sub-tropical and tropical regions, as compared with those in temperate zones, has been identified as a key factor in determining the long-term engineering success or failure of road projects in developing countries (Millard, 1990).

In developed countries, predominantly in temperate climatic zones, fill specifications are commonly based on relationships involving moisture content, plasticity and undrained strength, although more recently the use of the Moisture Condition Value (MCV) has become more widespread within the UK. The transfer of unmodified specifications for fill acceptability from temperate to tropical environments is not recommended and has been shown in many cases to be inappropriate (Wallace, 1973; Belloni, 1988 Moor and Styles, 1988)

Torrent et al., (1990) inferred that Aggregates are essential not only as a foundation for pavements, but also constitute the cement that makes the road itself. Selecting the right aggregate material is imperative to overcome the frequent problem of pavement failure. In the various ways in which aggregate is used, it is exposed to a variety of stresses, and the response of the structure in which it is used will largely depend upon the properties of the aggregate. It need to resist heavy loads, high impacts and severe abrasion, and it needs to be durable in the prevailing environmental conditions (Ukaegbu and Oti, 2005).

These properties will need to be tested and assured before the road is built. Similarly, after the initial trafficking and removal of any surface bituminous coating, vehicle will be traveling on the actual aggregate used in the mixture for the bulk of the life of the road surface. Thus they undergo substantial wear and tear throughout their life. In general, aggregate should be hard and tough enough to resist crushing, degradation, and disintegration from any associated activities. Furthermore, it must be able to adequately transmit loads from the pavement surface to the underlying layers, and eventually the subgrade, otherwise premature structural failure could occur. Therefore, selecting aggregates with the necessary characteristics for a particular site is imperative.

## 2. DESCRIPTION OF STUDY AREA

The study area Gbose Quarry is located in Omu-Aran,-Oko Road, Kwara State, Nigeria on coordinates of latitude ($08^0$ 09' N) and longitude ($004^0$ 08' E) as presented in Figure 1 with a corresponding Satellite imagery in Figure 2 respectively. Omu-Aran is the capital of Irepodun Local Government, which remain the seat of power with eleven wards and six Area Offices for Administrative services. It shares boundary with Ifelodun L.G.A. to the North, Osun State to the South, Ekiti and Offa Local Government to the East and West respectively. It is endowed with Savannah and Rain forest vegetation on a plain terrain with patches of Rivers and Streams. The people of Omu-Aran are predominantly farmers and speak Yoruba.

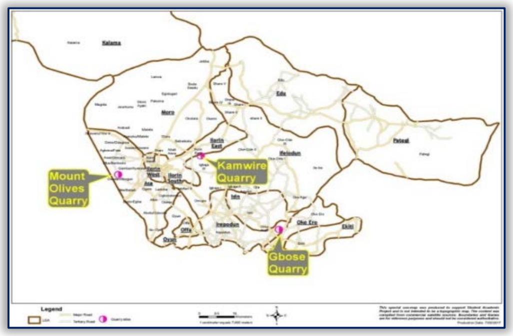


Figure 1: Map of Kwara State indicating Gbose Quarry

Figure 2: Satellite Imagery of Gbose Quarry

## 3. MATERIAL AND METHODS

### – MATERIAL

The aggregate rock samples obtained from Gbose Quarry used for this research were of grain size range of 4-32 mm. The samples were collected in sufficient quantities with the purpose of running a number of tests on representative specimens.

The electric oven, beaker, German sieve, refilling box, specific gravity bottle, electric weighing balance, and aggregate crushing test apparatus were the equipment used.

— METHODS

» Determination of chemical and mineral composition

X-Ray Florescence Spectrometer was used to determine percentage oxides of elements present in the sample as suggested by (ASTM, 2003). The RIX 3100 X-Ray Spectrometer equipped with a monitor process each sample inserted and analyze the percentage of each elements present in the sample. However, a thin section examination was carried out on the rock sample grounded to about 90μm and lapped to 30μm using carborundum grits and water on a glass plate. The lapped section now covered using cover slip and observed under a microscope and a modal analysis carried out to know the minerals present in the rock and their percentages.

» Determination of specific gravity and water absorption

The Specific Gravity is closely related to such other aggregate properties as the density, void ratio and unit weight (ISRM, 1981). The specific gravity is determined using Equation 1 and 2;

$$\text{SpecificGravity} = \frac{\rho_S}{\rho_W} \tag{1}$$

where: $\rho_s$ is density of the aggregate; and $\rho_w$ density of the water

$$S.G = \frac{w_2 - w_1}{(w_4 + w_1) - (w_3 - w_2)} \tag{2}$$

where: $W_1$ is the weight of cylindrical bottle; $W_2$ is the weight of cylindrical bottle + aggregate; $W_3$ is the weight of cylindrical bottle + aggregate + water; and $W_4$ is the weight of cylindrical bottle full of water.

However, a representative sample of aggregate were secured and dried thoroughly in the oven at a temperature of $105^0$C. The samples were cooled in air for about 1 hour and then immersed in water at room temperature for 24 hours. The test samples were removed from bath, dries off surface moisture and weighed in the saturated-surface dry condition to 0.1% of load. The percent water absorption was calculated using equation 3.

$$\text{Water Absorption} = \frac{W_{SSD} - W_{OD}}{W_{OD}} x100\% \tag{3}$$

where: $W_{SSD}$ = Weight of Saturated-Surface Dry Aggregate (g); and $W_{OD}$ = Weight of Oven Dry Aggregate in air (g)

» Determination of bulk density (loose) and bulk density (compacted)

In this test, the dry mass of aggregates filling a specified container without compaction for loose and with compaction for compacted was determined by weighing and the corresponding loose and compacted bulk density was calculated using Equation 4 and 5 respectively.

$$\text{Loose Bulk Density} = \frac{W_{agg}}{V_m} \tag{4}$$

$$\text{Compacted Bulk Density} = \frac{W_{agg}}{V_m} \tag{5}$$

where, $W_{agg}$ = weight of the aggregate; $V_m$ = Volume of mould

» Determination of ten percent fines value

The material used for this test is aggregate passing a 12.70 mm sieve and retained on a 9.52 mm sieve, cleaned and dried (washed if necessary) but longer than 4 hours nor at a temperature higher than 110°C. The required volume is obtained by filling the measuring cylinder in three layers, each tamped 25 times with the rod and the top struck level. This volume is then weighed to the nearest 0.1g (mass A) where the depth of the sample will then be about 100 mm. The cylinder, plunger and sample are placed in the compression testing machine and Force (20 KN) applied at a uniform rate so that the total penetration in 10 minutes is about: 15 mm for uncrushed gravel; 20 mm for normal crushed aggregates; 24 mm for honey combed aggregates (e.g., some slag and volcanic rocks). The sample is then sieved over a 2.36 mm but preferable to pass the whole sample over a larger sieve of 4.75 mm). The material passing 2.36 mm is then weighed as mass B and expressed as a percentage of the original mass A. If the percentage fine lies between 7.5% and 12.5%, equation 6 will be for Ten Percent Fines Value (TFV):

$$\text{TFV} = \text{Force of produce 10\% fines} = \frac{14x}{y+4} \text{ and } y = \frac{B}{A} x100\% \tag{6}$$

where: x is maximum force used (KN); and y is percentage fines from the test (%)

» Determination of aggregate impact and crushing value

The test was in accordance with BS 812-112:1990 with the test sample consists of aggregates that passes through the 12.5 mm and is retained on the 10.0mm International standard sieve. The crushed aggregate after 15 blows was removed and sieved through 2.36 mm. The aggregate impact value was calculated using Equation 7;

$$\text{Aggregate Impact Value (\%)} = \frac{100W_2}{W_1} \quad (7)$$

Where: $W_1$ is the total weight of dry sample (g); and $W_2$ is the weight of portion passing 2.36 mm sieve (g).
Also a sample of 14 mm size chippings of the aggregate were placed in a steel mould and subjected to a force rising to 400 KN over a period of 10 minutes. The material passing 2.36 mm was weighed (mass B) and expressed as a percentage of the original mass (mass A) to give the aggregate crushing value (ACV) which is expressed in Equation 8.

$$ACV = \frac{B}{A} x100 \quad (8)$$

where: A = the mass of surface-dry sample (g); and B = the mass of the fraction passing the 2.36 mm sieve (g)

» Determination of flakiness indices and elongation indices

The flakiness index and elongation index was found by expressing the weight of the flaky and elongation aggregate as a percentage of the aggregate tested as shown in equation 9 and 10 respectively.

$$\text{Flakiness Index} = \frac{W_1}{W_2} \text{ X } 100 \quad (9)$$

where: $W_1$ is the weight passing; $W_2$ is the weight of sample

$$\text{Elongation Index} = \frac{W_3}{W_2} \text{ X } 100 \quad (10)$$

where,: $W_3$ = weight not passing; $W_2$ = weight of the sample

» Determination of Los Angeles abrasion

According to the EN1097-2 (European Committee for Standardization, 1997) method, the 5000 ± 5g sample (10 to 14 mm fraction) were placed in a steel drum with eleven 45 to 49 mm steel balls (total weight 400-445g). The drum rotates 500 revolutions (30-33 rpm). Then the crushed materials were sieved through a 1.70 mm sieve and the Los Angeles value is calculated using equation 11:

$$LA = 5000 - \frac{m}{50} \quad (11)$$

where, m = weight of the material retained after 1.70 mm sieving, LA = Los Angeles.

## 4. RESULTS

### — CHEMICAL AND MINERAL COMPOSITION

The Geochemical analysis on rock sample which shows the chemical composition of the aggregate sample and the Mineralogical modal analysis of petrographic slide which shows the percentage mineral composition in the rock are presented in Table 1 and 2 respectively with the corresponding photomicrographs of the tested rock sample shown in Plates $A_1$ – $A_4$.

Table 1: Geochemical Analysis on Rock Sample

| XRF (METHOD): SAMPLE ID: GBQ | | | | |
|---|---|---|---|---|
| S/N | ELEMENTS | CONC. % | OXIDES | CONC. % |
| 1. | Ti | 0.517 | $TiO_2$ | 0.86 |
| 2. | Si | 28.715 | $SiO_2$ | 61.43 |
| 3. | Al | 8.828 | $Al_2O_3$ | 16.68 |
| 4. | Mn | 0.085 | MnO | 0.11 |
| 5. | Fe | 3.924 | $Fe_2O_3$ | 5.61 |
| 6. | P | 0.140 | $P_2O_5$ | 0.32 |
| 7. | Mg | 1.930 | MgO | 3.2 |
| 8. | Ca | 2.301 | CaO | 3.22 |
| 9. | Na | 3.531 | $Na_2O$ | 4.76 |
| 10. | K | 2.665 | $K_2O$ | 3.21 |
| 11. | | | LOI | 0.22 |

Table 2: Mineralogical Modal Analysis of Petrographic Slide

| Mineral | 1st Field of view No. of grid count | 2nd Field of view No. of grid count | 3rd Field of view No. of grid count | Line Total | Percentage Modal Composition (%) |
|---|---|---|---|---|---|
| Quartz | 37 | 38 | 34 | 109 | 45.42 |
| Orthoclase | " | " | " | 0 | |
| Microcline | 20 | 18 | 8 | 46 | 19.17 |
| Plagioclase | 2 | 4 | 15 | 21 | 8.75 |
| Biotite | 13 | 15 | 14 | 42 | 17.50 |
| Muscovite | " | " | " | 0 | |
| Hornblende | " | " | " | 0 | |
| Opaque Mineral | 7 | 5 | 8 | 20 | 8.33 |
| Olivine | " | " | " | 0 | |
| Hyperstene | " | " | " | 0 | |
| Pyroxine | " | " | " | 0 | |
| Others | 1 | " | 1 | 2 | 0.83 |
| Total | 80 | 80 | 80 | 240 | 100.00 |

From Table 2, the petrographic description of Gbose aggregate rock sample indicates a gneiss rock with the mineral in the thin sections includes majorly quartz, biotite, microcline, orthoclase, plagioclase and opaque minerals. The photomicrograph of the gneiss under crossed polar and polarized light is presented in Plate $A_1$ – $A_4$.

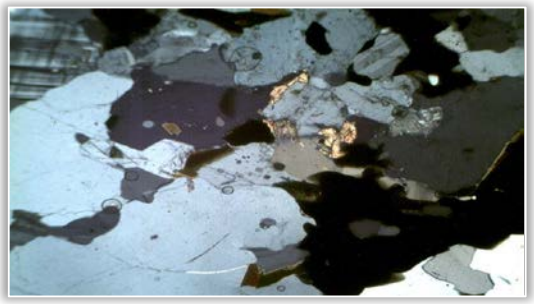

Plate $A_1$: Photomicrograph of the Sample of granite Under Cross Polar

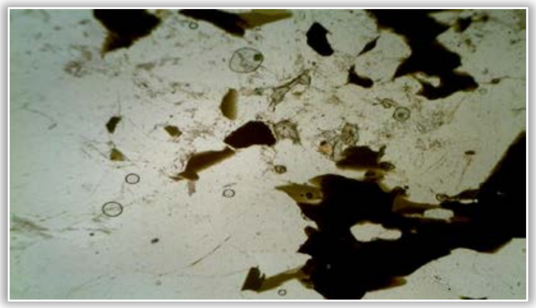

Plate $A_2$: Photomicrograph of the Sample of granite sample under Plan Polarized Light

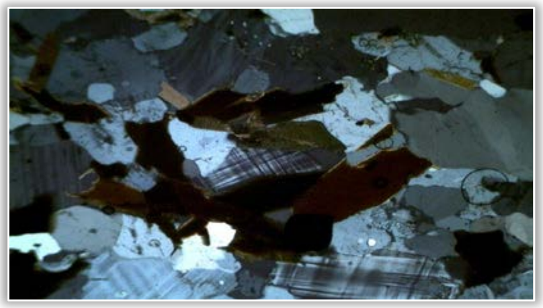

Plate $A_3$: Photomicrograph of the Sample of granite under cross Polar

Plate $A_4$: Photomicrograph of the Sample of granite plane polarized Light

MIC = MICROCLINE; QTZ = QUARTZ; BIO = BIOTITE; OPQ = OPAQUE MINERAL; PLG = PLAGIOCLASE.

## — SPECIFIC GRAVITY AND WATER ABSORPTION FOR COARSE AGGREGATES (IS: 2286 – PART 3)

Table 3 presented the results of Specific Gravity and Water Absorption, which shows that the fine-to-medium grained aggregate obtained from Gbose Quarry has a water absorption value of 0.78% from test 1 and 0.76% from Test 2 respectively. The average of the two tests is taken and recorded as the water absorption value for the 4-16 mm aggregate sample, which is 0.77% approximately. Likewise the specific gravity of 16-32 mm for fine-to-medium-grained granite from Gbose Quarry value of 2.70% and the app. Specific gravity of 2.75 recorded. The value of the water absorption, specific gravity and app. Specific gravity of the aggregate sizes is shown graphically in Figure 3. The aggregate sizes exhibit low value of water absorption, which is an indication that both aggregate sizes are suitable for road construction.

Table 3: Specific Gravity and Water Absorption for Coarse Aggregate

| | DESCRIPTION | SAMPLE NO. GBQ Test 1 | Test 2 |
|---|---|---|---|
| A. | Weight of Aggregate; (g) | 908.2 | 913.6 |
| B. | Weight of Saturated Aggregate & Basket in water (A); (g) | 3198.2 | 3202.9 |
| C. | Weight of Basket in Water (B); (g) | 2632.0 | 2632.0 |
| D. | Weight of Saturated Surface Dry Aggregate in air (C); (g) | 897.2 | 902.7 |
| E. | Weight of Oven Dry Aggregate in air (D); (g) | 890.4 | 895.7 |
| F. | Specific Gravity = [D/C – (A – B)] | 2.69 | 2.70 |
| G. | Apparent Specific Gravity = [D/D – (A – B)] | 2.75 | 2.76 |
| H. | Water Absorption, % Dry Weight = [C – D/D] x 100,% | 0.76 | 0.78 |
| Average Values | Specific Gravity in % | 2.70 | |
| | App. Specific Gravity in % | 2.75 | |
| | Water Absorption in % | 0.77 | |

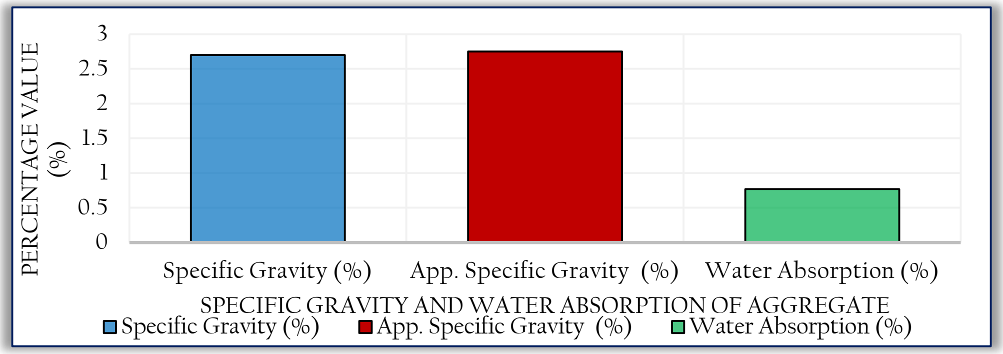


Figure 3: Specific Gravity and Water Absorption of Aggregate

## — BULK DENSITY AND COMPACTED BULK DENSITY

The results of the Bulk Density and Compacted Bulk Density are presented in Table 4. This shows that the sample has an average bulk density value of 23.35 kg/$m^3$ when loose and an average bulk density of 25.33 kg/$m^3$ when compacted. This implies that the sample when compacted assumes a high bulk density value than when loose. The bulk density of the aggregate sample when loose and compacted is shown in Figure 4.

Table 4: Bulk Density and Compacted Bulk Density

| DESCRIPTION | | SAMPLE NO. GBQ Test 1 | SAMPLE NO. GBQ Test 2 |
|---|---|---|---|
| A. | Weight of Empty Aggregate Vessel (A); (g) | 876.40 | 876.40 |
| B. | Weight of Vessel and Aggregate (B); (g) | 1694.06 | 1710.42 |
| C. | Weight of Vessel and Compacted Aggregate (C); (g) | 1763.38 | 1781.12 |
| D. | Volume of Vessel (V); ($cm^3$) | 3536.61 | 3536.61 |
| E. | Weight of Aggregate in Vessel; (g) | 817.66 | 834.02 |
| F. | Weight of Compacted Aggregate in Vessel; (g) | 886.98 | 904.72 |
| G. | Bulk Density in $KN/m^3$ | 23.12 | 23.58 |
| H. | Compacted Bulk Density in $KN/m^3$ | 25.08 | 25.58 |
| Average Values | Bulk Density in $KN/m^3$ | 23.35 | |
| | Compacted Bulk Density in $KN/m^3$ | 25.33 | |

— FINES VALUE (10%)

The ten percent fines values (TFV) are averaged to obtain the final result as presented in Table 5, which was recorded to the nearest 10 KN.

Table 5: Ten Percent Fines Value, TFV (BS 812 PART 111 1990)

| Sample Reference | Test No. | Dry weight (g) | Weight Passing (g) | Weight Retained (g) | 10 % Fines | Force to produce 10% fines, TFV (KN) |
|---|---|---|---|---|---|---|
| GBQ | 1 | 3654.4 | 281.4 | 3371.9 | 7.7 | 185.47 |
| | 2 | 3690.6 | 287.0 | 3402.8 | 7.8 | 184.26 |
| Average Force Required to produce 10% Fine Value TFV = 184.86 KN | | | | | | |

— AGGREGATE IMPACT VALUE AND AGGREGATE CRUSHING VALUE

The result of average impact value and aggregate crushing value is presented in Table 6 – Table t while the classification of aggregate using aggregate impact value shown in Table 8 respectively.

Table 6: Aggregate Impact Value, AIV (BS 812: PART 112 1990)

| Sample Reference | Test No. | Dry weight (g) | Weight Passing (g) | Weight Retained (g) | AIV |
|---|---|---|---|---|---|
| GBQ | 1.0 | 327.6 | 46.5 | 280.3 | 14.2 |
| | 2.0 | 323.5 | 46.6 | 276.1 | 14.4 |
| Average AIV = 14.3 % | | | | | |

Table 7: Aggregate Crushing Value, ACV (BS 812: PART 110 1990)

| Sample Reference | Test No. | Dry weight (g) | Weight Passing (g) | Weight Retained (g) | ACV |
|---|---|---|---|---|---|
| GBQ | 1.0 | 3643.2 | 776.0 | 2866.4 | 21.3 |
| | 2.0 | 3614.4 | 798.8 | 2814.8 | 22.1 |
| Average ACV = 21.7 % | | | | | |

Table 8: Classification of Aggregates using Aggregate Impact Value (AIV)

| Average Impact Value | Classification |
|---|---|
| <10% | Exceptionally Strong |
| 10 - 20% | Strong |
| 20 - 30% | Satisfactory for Road Surfacing |
| >35% | Weak for Road surfacing |

— FLAKINESS AND ELONGATION INDEX OF AGGREGATE

The flakiness and elongation index of aggregate on the sample is presented in Table 9. This was obtained by separating the elongated particles and expressing their mass as a percentage of the mass of sample tested as expressed in Equation 6 and 7.

Table 9: Flakiness and Elongation Index of Aggregate

| Size of Aggregate Passing through BS Sieve | Size of Aggregate Retained on BS Sieve | Corresponding Thickness Gauge Size | Weight of Aggregate Passing Through Thickness Gauge Test i | Weight of Aggregate Passing Through Thickness Gauge Test ii | Corresponding Length gauge size | Weight of Aggregate Retained on Length Gauge Test i | Weight of Aggregate Retained on Length Gauge Test ii |
|---|---|---|---|---|---|---|---|
| 28 | 20 | 14.4 | 0 | 0 | 43.2 | 0 | 0 |
| 20 | 14 | 10.2 | 171.9 | 171.2 | 30.6 | 175.8 | 188.8 |
| 14 | 10 | 7.2 | 93.0 | 98.7 | 21.6 | 121.5 | 117.2 |
| 10 | 6.3 | 4.89 | 16.9 | 20.3 | 14.67 | 22.4 | 19.5 |
| Sample Code: GBQ | | Total of (4) $W_2$ = | 281.8 | 290.2 | Total of (4) $W_3$= | 319.7 | 325.5 |
| | | Total Weight of sample used $W_1$ = | 1150.0 | 1150.0 | Total Weight of sample used $W_1$ = | 1150.0 | 1150.0 |
| | | Flakiness Index = $(W_2/W_1)$x100 | 24.5 | 25.2 | Elongation Index=$(W_2/W_1)$x100 | 27.8 | 28.3 |
| | | Average Flakiness index in percentage | 24.9 | | Average Elongation Index in percentage | 28.1 | |

The values of flakiness and elongation of the aggregate specimens within the three size fractions; 20-14 mm, 14-10 mm and 10-6.3 mm respectively are shown in Figure 5. Analysis of the individual fractions shows a higher average FI and EI of 24.9% and 28.1% respectively for the aggregate, which is an indication that the sample exhibits low value of elongation and almost negligible flakiness index.

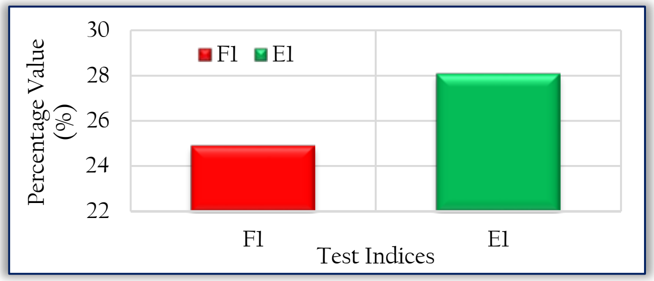

Figure 5: Comparative Flakiness and Elongation Index of the Aggregate Specimen

— LOS ANGELES AGGREGATE ABRASION VALUE

The results of Los Angeles aggregate abrasion value is presented in Table 10.

Table 10: Los Angeles Aggregate Abrasion Value

| | | | | | |
|---|---|---|---|---|---|
| Passing Sieves | 19mm | and | 13.2mm | | |
| Retaining Sieves | 13.2mm | and | 9.5mm | | |
| Mass of Aggregate | 2500g | and | 2500g | | |
| Separating Sieve | 1.7mm | | | | |
| Machine Speed | 30 rpm | No. of Revolutions required: | | | 500 |
| Mass Charge | 4584g | No. of Steel balls required: | | | 11 |
| ASTM Standards C 131and C 535 | | | | | |
| Sample Code: GBQ | | | | Test No. 1 | Test No. 2 |
| Original Mass of the Sample ($W_1$); (g) | | | | 5000.0 | 5000.0 |
| Mass of Aggregate Retained on 1.70mm sieve ($W_2$); (g) | | | | 3805.0 | 3780.0 |
| Loss of Weight ($W_1 - W_2$); (g) | | | | 1195.0 | 1220.0 |
| Percentage Wear [$((W_1 - W_2)/W_1) \times 100$]; (%) = | | | | 23.9 | 24.4 |
| Los Angeles Abrasion Value | | | | | 24.2 |

— SUITABILITY OF AGGREGATE FOR ROAD CONSTRUCTION

A comparison of the limited laboratory test results with typical, UK, aggregate acceptance values (BS 882) is shown in Table 12. This indicates that the aggregates (4-16 mm and 16-32 mm) produced from the fine to medium grained granite at Gbose Quarry are within the acceptable limits for general use in concrete and as road stone, in terms of aggregate crushing value, water absorption value, elongation and flakiness index as shown in Figure 6. This makes the aggregate tested in this study desirable for road construction purposes for heavy duty concrete floors.

Table 11: A Comparison of Aggregate Test Results from Gbose Olive Quarry with British Standard

| Aggregate Property | Test Value+ | Acceptance Value | Use | Authority |
|---|---|---|---|---|
| Aggregate Crushing Value, ACV | 21.7% | Max. 30% | C., R. | BS 812:1983 |
| Water Absorption (4-16 mm) | 0.77% | Max. 3[1]% | C., R. | BS 882:1983 |
| Water Absorption (16-32 mm) | 0.77% | Max. 3[1]% | C., R. | BS 882:1983 |
| Flakiness Index, $I_F$ | 24.9% | Max. 35[2]% | C., R. | BS 812:1983 |
| Elongation Index, $I_E$ | 28.1% | Max. 35[2]% | C., R. | BS 812:1983 |
| Notes: 1 - General use; C - Concrete; 2 – Difficult conditions; R – Road Aggregate; + - Average of two test results | | | | |

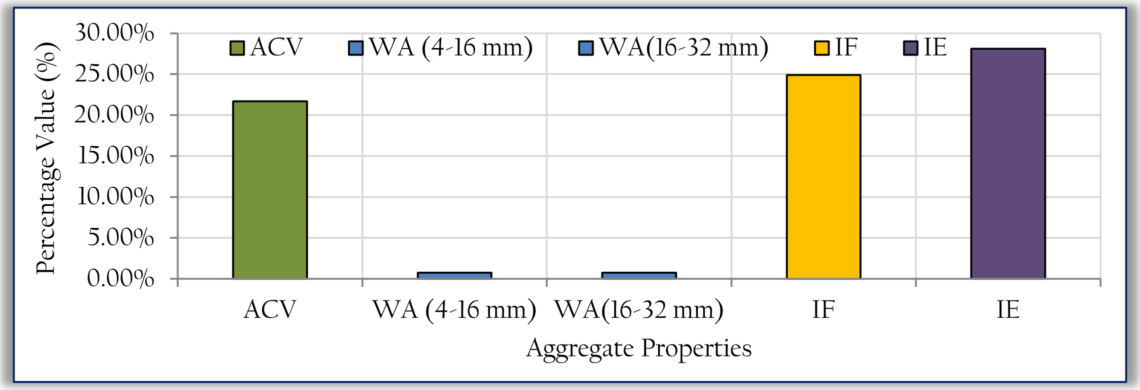

Figure 6: Aggregate Specimen Properties

## 5. CONCLUSION

The results of laboratory tests carried out on aggregate produced from fresh fine to medium-grained granite from Gbose Quarry are within the commonly accepted limiting values for general use in concrete and as road stone. There was no case where a higher value than acceptable value was obtained. These values (near or within the specified limiting) - aggregate crushing value, water absorption value, elongation and flakiness index make the aggregate from this particular locality more desirable for specific uses such as road construction and heavy duty concrete floors. However, any aggregate which do meet the required limit or specification should not be used for road construction purposes and governments should make provisions and funding for preventive maintenance, preservation, rehabilitation, and reconstruction of roadways in Nigeria.

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