NSUK Journal of Science & Technology (NJST), Vol. 7: No. 2, 2020. pp. 94-100. Print: ISSN: 2756- 696X
On-line: ISSN2756-6951
Website: www.nsukjst.org.ng

ESTIMATION OF RESERVES AND ROCK SUITABILITY FOR CONSTRUCTION USING BASIC GEOLOGIC MAPPING AND GEOTECHNICAL METHODS: A CASE STUDY OF AN ABANDONED QUARRY SITE AT BUARI, SOUTHWESTERN NIGERIA

Alu, O. O.[1], Bappah, A. A.[1], Amir, A. W.[1], *Ojulari, B. A.[2], and Agboola, R. O.[3]

[1]Department of Chemical and Geological Sciences, Al-Hikmah University Ilorin.P.M.B. 1601, Ilorin.
[2]Department of Geology and Mineral Sciences, University Ilorin. P.M.B. 1515, Ilorin.
[3]Department of Science Education, Al-Hikmah University Ilorin. P.M.B. 1601, Ilorin.

Corresponding author's email: bashiruojulari@gmail.com

ABSTRACT
Assessment of economic viability and rock suitability for construction at an abandoned quarry site at Buari village which lies between co-ordinates $8^{0}27'24.1''$N to $8^{0}27'22.6''$N and longitude $004^{0}55'36''$E to $004^{0}55'$ 26.4"E in Southwestern Nigeria was carried out by estimating the reserve tonnage at the area of study. This involves gridding, specific gravity determination, reserve estimation and life span determination. The entire area was gridded into 50 regular grids and was labeled 1-50. The elevations of different points on the area were measured in order to produce the contoured elevation map. Rock thickness of each grid was calculated. To ascertain the suitability of the rock from the area of study geotechnical tests was carried out on a sample. This involves thin section analysis, bulk density determination, Aggregate Impact Value (AIV) test and Aggregate Crushing Value (ACV) test. The elevation contoured map shows that the lowest elevation in the study area is 275 m while the highest elevation is 290 m. The 3D model of the rock generated from elevation using Surfer 12 shows that elevation is lowest in the southern part of the study area .The elevation increases northwards from the previous quarry face to the top of the hill. The Specific Gravity (SG) = 2.71, Σ (reserve volume of the each grids (RVG) (m^3) = 2457.84 $m^3$and the reserve tonnage of rock in the area of study is 6660.75 tons. This can only support an adopted exploitation rate of 18.25 ton per day for one year. Hence, the rock is considered unsuitable for mining and their economic viability is considered is very low. The specific gravity (SG) of the rock sample tested is higher than the minimum value of 2.60 recommended for rocks that are suitable for construction purposes. Average value of the results of Aggregate Impact Value (AIV) of the rock sample is 22.79%. Hence, this value certified the rock sample for use as concrete and for wearing surfaces, such as runways roads and pavement. Result of the Aggregate Crushing Value (ACV) test conducted on the selected samples is 11.17%. Hence, the rock sample from the study area is suitable for use as concrete for roads and pavements and for other structures.
Keywords: *rock, construction, suitability, aggregate impact value, aggregate crushing value, exploitation rate*

INTRODUCTION
The current national drive towards breaking the much dependence of Nigerian economy on oil has identified the need to develop solid minerals and rocks as alternate sources of income to the government (Abudulawal *et al*., 2017). Consequently, it is necessary to annex all the nations' resources to build both institutional and infrastructural capacity within government agencies and private sector. Construction of roads is critically important for all form of development. Also, the choice of construction materials essentially depends on their suitability. Estimating reserve and tonnage of mineral or rock resources is a highly methodical process and has been the focus of various discussions. Hence, the search for appropriate and suitable materials for construction works has brought about the need to qualitatively determine the usefulness of materials available for use. Rocks have varied behavior depending on the geotechnical and mineralogical properties. Some are hard while others are soft. However, most soft rocks are inappropriate for use as aggregates or stones in construction projects. As indicated by Yagiz (2001), it is the most problematic weak rock that causes many problems in the field before and after construction or excavation.

However, a good understanding of the properties of the soil/rock and its behavior under load is important before application in road construction (Agbede and Osuolale, 2005). Nandi *et al*. (2009) noted that rocks are often intensely fractured and weathered and have highly variable geotechnical characteristics, which cause significant construction problems and damage to civil structures each year. According Egesi and Tse (2012) construction aggregate need to resist heavy loads, high impacts and several abrasion and it needs to be durable in the prevailing environmental conditions.The quarrying of the rocks of the crystalline basement complex is well suited for this purpose due to their geotechnical characteristic and abundance. The Migmatite – Gneiss Complex is generally considered as the basement complex sensustricto (Rahaman, 1988; Dada, 2006) and it is the most widespread of the component units in the Nigerian Basement (Obaje, 2009). Hence, this study evaluates the technical feasibility and commercial viability of resuming mining operations at an abandoned quarry site at Buari village Southwestern Nigeria by determining the reserve and tonnage and geotechnical suitability (as construction material)of rock in place at the abandoned quarry site. This will provide source of construction material for roads and other construction purposes in the area of study.Road network is considered very vital in the economies of many nations, especially the developing ones, like Nigeria, that require(s) roads and highways for transportation of most goods and services (Aghamelu and Okogbue, 2011). High cost of transportation is also a major consequent of the bad road condition. Also, it is obvious such effort will go a long way in protecting the capital invested.

Location of Study Area
The location of the study area is Buari, Kwara State Nigeria (Fig. 1). The area shares a boundary with Okeya, Egi, Ilala and Esie. Buari abandoned quarry falls within the south western part of Nigerian Precambrian basement complex. The site lies between co-ordinates $8^{0}27'24.1''$N to $8^{0}27'22.6''$N and

longitude 004°55'36"E to 004°55'26.4"E. The area of study can be assessed by the tarred Ajase-Ipo-Oke-Oderoad and the site is located about 700 meters off the tarred road. The location of the rock mass is far from human settlements and highways.

Description of the Project Environment

Geology

The study area lies within the Southwestern part of the Precambrian Basement Complex of Nigeria. The geology of Nigeria has been described to consist of older and younger metasediments, Older and Younger Granites and volcanic intrusive which are overlain unconformable by younger sedimentary basins of Lullumeden, Niger-Delta, Bida, Benue and Dahomey. The rocks that dominate the study area are just the gneiss, migmatite and pegmatites (embedded in migmatitic rocks mostly but in very minute constituents; veinlets and minor intrusions). Field observations at the time of mapping revealed that the lithology is the gneiss and migmatite rocks types. The outcrops present are mainly low-lying. A characteristic feature of the Basement Complex tectonics is the widespread occurrence of fractures. Thus, varieties of structural features such as foliations, folds, faults, joints, fractures and fissures exist in the study area.

The migmatite gneisses were trending south-west of the mapped area (Fig. 2). Most of the mapped migmatite gneiss occurs as low-lying outcrop ranging in textural characteristics from fine to medium-grained with mafic and mostly felsic bands; the mafic constituents are defined by biotite, hornblende

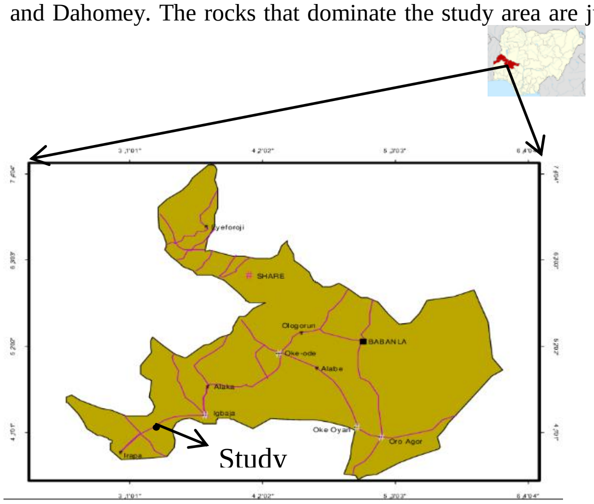

Figure 1: Map of Ifelodun Local Government Area of Kwara State Showing the Study Area(Yahaya et al., 2014)

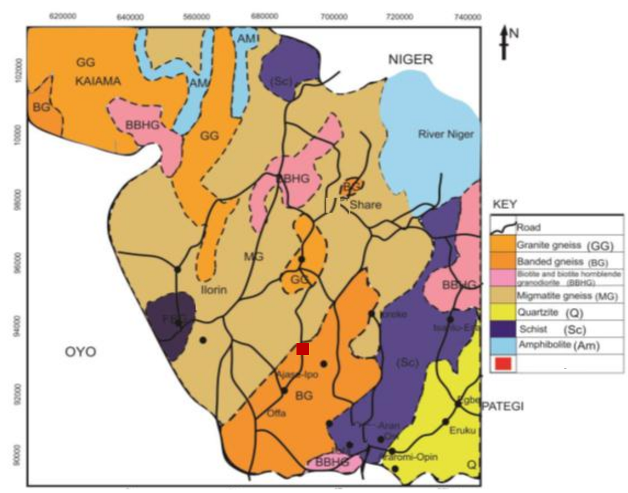

Figure 2: Geologic Map of Part of Kwara State Showing the Study Area (NGSA, 2006)

and other ferromagnesian minerals. There was clear evidence of flowing of the materials during metamorphism that affect the country rock and which causes folds and there are also evidence of resistance of the country rock which did not metamorphose in the mapped outcrops. Structural elements which include micro folds, dykes, veins and veinlets etc. were found present on the outcrops. Pegmatitic veins were very abundant on the migmatite rocks but were almost absent on the gneissic rocks.

Climate and Vegetation

The climate of the study area is characterized with dry and rainy season. The area lies within the middle belt of Nigeria with a total annual rainfall between 1270 mm and 1524 mm, spread over the month of April to October (Olasehinde, 1999). The highest amount of rainfall is observed in the month of September. Monthly temperature is highest in March at about 30°C and lowest in August at about 25°C (Ajibade, 1988).

The vegetation of the area is that of the guinea savannah which comprises of various species of shrubs and forest plants. Vegetation is especially dense along stream courses, with trees lining the banks in gallery forests.

METHODOLOGY

Assessment of economic viability of the abandoned quarry site was carried out by estimating the reserve tonnage (quantity of rock) at the area of study. This involves gridding, specific gravity determination, reserve estimation and life span determination. Basic sampling grids are of two types; regular and irregular (Hartman and Mutmansky, 2010).The entire area was gridded into 50 regular grids and was labelled 1-50. The elevations of different points on the area were measured in order to produce the contoured elevation map. The contour map produced was divided into grids and the average value of contour lines passing through each grid was determined in order to obtain the average elevation grid (AEG) for the area. The predetermined elevation datum levels (PEDL) were chosen to correspond the lowest elevation measured in the area of study. Hence, rock thickness of each grid was calculated:

Rock thickness of each grid= Average elevation grid (AEG) - Predetermined elevation datum levels (PEDL)

The reserve volume of the grids was then calculated using the formula in Bell (2008):

Reserve volume (m^3) =∑ (area grid x rock thickness of each grid).

It is the product of the average the area grid and rock thicknessof each grid.

Specific Gravity (SG) was determined in the laboratory using:

$$\text{Specific Gravity (S.G)} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

Where: M_1 = Mass of density bottle and stopper, M_2 = Mass of density bottle, stopper and sample, M_3 = Mass of density bottle, stopper, sample and distil water, M_4 = Mass of density bottle, stopper and distil water.

Reserve Tonnage

It is usual to split the reserves and resources into three broad categories namely Proved Probable and possible reserve associated with different levels of risk. In this research only proved reserves confirmed by surface occurrence and exposed by quarried face to fully support the consistency of the resource are estimated. The proved reserves indicate a high level of certainty as to the quality and quantity of the reserve. The reserve tonnage is given by:

Reserve Tonnage = Reserve Volume x Specific Gravity of the rock in the area.

To ascertain the suitability of the rock from the area of study geotechnical tests was carried out on a sample. This involves thin section analysis, bulk density determination, Aggregate Impact Value (AIV) test and Aggregate Crushing Value (ACV) test.

Aggregate Impact Value Test (AIV)

Aggregate Impact Value Test is used for determination of the aggregate impact value of coarse aggregate, which passes 12.5 mm IS sieve and retained on 10 mm IS sieve. Aggregate

The aggregate impact values were calculated using equation below

$$AIV(\%) = 100\frac{W_2}{W_1}$$

Where: W_1 is the total weight of dry sample (g); and W_2 is the weight of portion passing 2.36mm sieve (g).

Aggregate Crushing Value (ACV)

Aggregate Crushing Value is used for determination of the aggregate crushing value of coarse aggregate, which passes 12.5 mm. IS sieve and retained on 10 mm. IS sieve.Aggregate Crushing Value Test Apparatus include:

The aggregate crushing value was calculated using the equation below:

$$ACV(\%) = 100\frac{W_2}{W_1}$$

Where: W_1 is the total weight of dry sample taken (g); and W_2 is the International Standard sieve (g).

RESULTS AND DISCUSSION

Contour map, 3D model and Average Elevation Grid (AEG)

The elevation contoured map obtained by contouring the elevations measured at different points on the area is presented in Figures 3. This elevation contoured map shows that the lowest elevation in the study area is 275 m while the highest elevation is 290 m. Also, the 3D model of the rock generated from elevation using Surfer 12 is also presented in Figure 4. The 3D model shows that elevation is lowest in the southern part of the study area which corresponds to the quarry face which evolved from previous quarry operation in the study area. The elevation increases northwards from the quarry face to the top of the hill.The elevation contour map (Fig. 3) was divided into 50 regular grids labelled 1-50. The value of the contour line or average value of contour lines (where 2 or more contour lines pass through a grid) passing through each grid was determined in order to obtain the average elevation grid (AEG) for the area of study (Fig. 5).

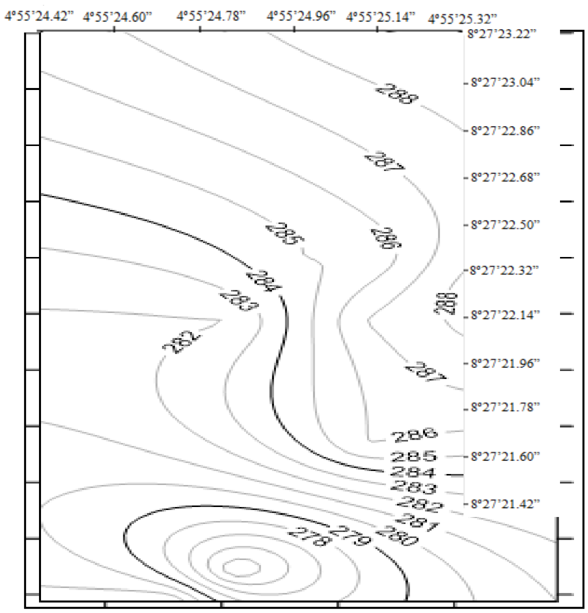

Figure 3: The Elevation Contoured Map of the Study Area

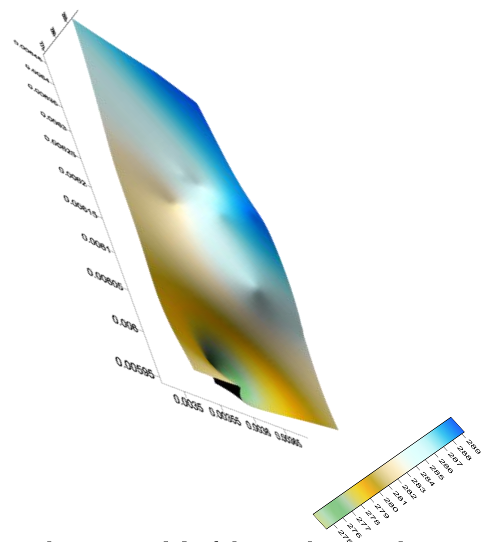

Figure 4: The 3D Model of the Rock in Study Area

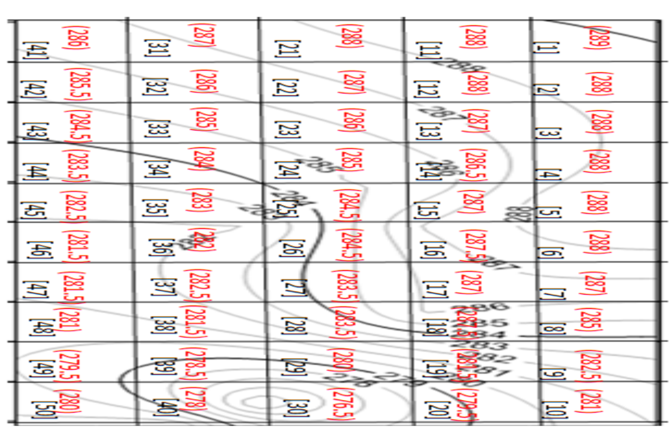

Figure 5: Average Elevation Grid (AEG) for the Area of study

Specific Gravity Determination was carriedout in the laboratory and the results is presented in Table 1.

Table 1: Specific Gravity Determination

Wt of Empty Cylinder (g) = (W_1)	125	125
Wt of Empty Cylinder + Sample (g) = (W_2)	189.5	184
Wt of Empty Cylinder + Sample + Water (g) = (W_3)	265.9	262
Wt of Empty Cylinder + Water only (g) = (W_4)	225	225
Specific Gravity	2.73	2.68
Average Specific Gravity	2.71	

In order to estimate the reserve tonnage, the following parameters were determined and presented in Table 2:

i. Specific Gravity (SG) of the rock as determined in the laboratory is 2.71.
ii. Area of each grid as measured on ground (A)(m^2)= 2.2 m x 2.4 m=5.28 m^2.
iii. Average Elevation of each Grid (AEG)- from Figure 3.
iv. The predetermined elevation datum (PED) = 275 m (chosen to correspond the lowest elevation measured on the area of study.
v. Reduced Elevation Grid (REG)/ Rock thickness = Average Elevation Grid (AEG)- The predetermined elevation datum (PED).
   This corresponds to the actual rock thickness in each grid.
vi. The Reserve Volume of Grid (RVG) was then calculated for each the grid using:
   Reserve volume of each Grid (m^3) = (Area of each grid x rock thickness of each grid).
vii. The Reserve Tonnage (tons) = Σ(reserve volume of the each grids (RVG) (m^3) x specific gravity (SG) of the rock) (Bell, (2008)

From Table 2
Specific Gravity (SG) = 2.71
Σ (reserve volume of the each grids (RVG) (m^3) = 2457.84m^3
Reserve Tonnage (tons) = 2457.84 x 2.71 = 6660.75 tons
Life Span of the Reserve
Life span of the reserve is very important (Bayewu *et al*., 2013). For a reserve to be considered to be economically viable, the tonnage must sustain not be less than 20 years of quarrying in this area (Bell, 2008). The reserve tonnage of rock in the area of study is 6660.75 tons. This can only support an adopted exploitation rate of 18.25 ton per day is one year. Hence, the rock is considered unsuitable for mining based on Bell (2008) recommendation and their economic viability is considered is very low. Value of the Reserve can be determined from:
Value of the Reserve = Reserve Tonnage (tons) x cost/ton (₦)

= 6660.75 tons x ₦4,000.00 /ton
= ₦ 26,643,000.00

Thin Section Analysis
The thin section of the rock sample was observed under both plane and cross polarized light and was found to consist of consist of quartz, orthoclase, plagioclase, amphibole, muscovite, biotite and opaque minerals. In the thin section, the modal composition is quartz 40%, Feldspars 25%, biotite 30% muscovite 4%, and opaque minerals 1% (Fig. 4). Quartz occupies interstitial positions between biotite and plagioclase. Biotite is black in colour while crystals of plagioclase exhibit albite twinning.
Specific Gravity (SG) Generally, there is a direct positive relationship between high specific gravity and high strength of aggregates. Rock of high quality often possesses good specific gravity properties. The specific gravity of the sample was determined using AASHTO: T-85 standards and the value obtained is 2.71 (Table 1). The specific gravity (SG) of the rock sample tested is higher than the minimum value of 2.60 recommended for rocks that are suitable for construction purposes (Krynine and Judd, 1957).

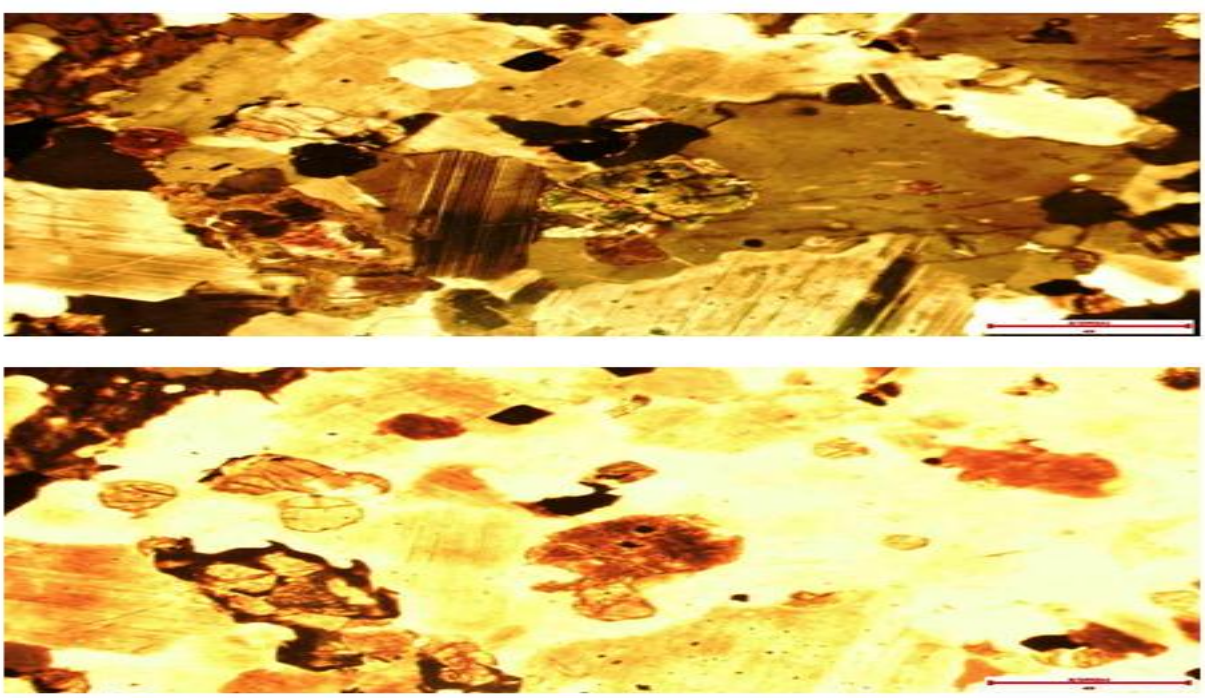

Figure 4: Photomicrograph of Rock Sample under (a)Cross polarized light and (b)Plane polarized light

Bulk Density

Bulk density is a function of the particle specific gravity and the void ratio. The bulk density of an aggregate takes into account the effects of voids present in the aggregate at a given degree of compaction (Waqa, 2004). The average bulk density of the studied sample is 2.31 g/cm^3. The results are shown in Table 3. These values fall below the acceptable limit of greater than 2.60 g/cm^3 according to Mallo and Sanni, 2012.

Table 3: Bulk Density Determination

Wt of Mould + Sample (g)	767	771.5
Wt of Mould (g)	189	189
Wt of Sample (g)	578	582.5
Volume of Mould (cm3)	251.4	251.4
Bulk Density (g/cm3)	2.3	2.32
Average Bulk Density	2.31 g/cm3	

Aggregate Impact Value test

Aggregate impact value is a strength value that is determined by performing the aggregate impact test on a rock aggregate. The results of the aggregate impact value test are shown in Table 4. The IS 283-1970 code specifies that aggregate impact value shall not exceed 45% by weight for aggregate used for concrete other than wearing surface and 30% by weight for concrete used for wearing surfaces, such as runways roads and pavement (Amuda *et al*., 2014). Aggregate Impact Value (AIV) above 35% would normally be regarded as too weak for use in road surface (Egesi and Tse, 2012). Average value of the results of Aggregate impact value of the rock sample is 22.79%. Hence, this value certified the rock sample for use as concrete and for wearing surfaces, such as runways roads and pavement.

Table 4. Aggregate Crushing Value test

Wt of Mould +Aggregate (g)	3274
Wt of Mould (g)	2585
Wt of Aggregate (g)	689
Wt of Aggregate retained on 2.36 mm Sieve after test	532
Wt of Aggregate passing through 2.36 mm Sieve after test	157
Aggregate Impact Value	22.79%

Aggregate crushing value is a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. ACV determines the percent of fines produced under a prescribed load. Low values indicate a more resistant rock and a higher quality of pavement. According to Shetty 2005, the crushing value of aggregate is restricted to 30% for concrete used for roads and pavements and 45% may be permitted for other structures. The lower the value, the stronger the aggregate. That is, the greater its ability to resist crushing. Therefore, crushing value of 30 percent and above is not good for road construction. Result of the Aggregate crushing value (ACV) test conducted on the selected samples is 11.17% (Table 5). Hence, the rock sample from the study area is suitable for use as concrete for roads and pavements and for other structures.

Table 5: Aggregate Crushing Value

Wt of Mould +Aggregate (g)	2375
Wt of Mould (g)	1650
Wt of Aggregate (g)	725
Wt of Aggregate passing through 2.36 mm Sieve after test	81
Aggregate Crushing Value	11.17%

Conclusion

The elevation contoured map obtained by contouring the elevations measured at different points on the area shows that the lowest elevation in the study area is 275 m while the highest elevation is 290 m. The 3D model shows that elevation is lowest in the southern part of the study area which corresponds to the quarry face which evolved from previous quarry operation in the study area. The elevation increases northwards from the quarry face to the top of the hill. The elevation contour map was divided into 50 regular grids labelled 1-50. Average Elevation Grid (AEG) for the area of study was obtained from value of the contour line or average value of contour lines (where 2 or more contour lines pass through a grid) passing through each grid. Area of each grid as measured on ground is 5.28 m^{2}The predetermined elevation datum (PED) used for this study is 275 m. This value corresponds to the lowest elevation measured on the area of study. Hence, Reduced Elevation Grid (REG)/ Rock thickness was obtained subtraction. The predetermined elevation datum (PED) from the Average Elevation Grid (AEG). The summation of the Reserve Volume of all Grid Σ(RVG) is 2457.84 m^3 while the Reserve Tonnage is 6660.75 tons. Also, life Span of the Reserve at an adopted exploitation rate of 18.25 ton per day is one year. Hence, the rock is considered unsuitable for mining based on Bell (2008) recommendation of minimum of 20 years life span for their economic viability of quarry. Finally, the quarry is valued at a sum of 26, 643,000.00 ₦ at the cost of 4,000.00 ₦/ton.

The suitability of rock for construction purposes depend on it competence of the rock which in turn depends on the mineralogyand geotechnical characteristics. Specific Gravity (SG) of the rock as determined in the laboratory is 2.71.The specific gravity (SG) of the rock sample tested is higher than the minimum value of 2.60 recommended for rocks that are suitable for construction purposes.The thin section of the rock sample was observed under both plane and cross polarized light and was found to consist of consist of quartz, orthoclase, plagioclase, amphibole, muscovite, biotite and opaque minerals. Mineralogical composition is one of the main properties controlling the rock strength. Most of the minerals present in the aggregates are resistance to weathering and iron-rich and they will impart more on the strength of the aggregates.The average bulk density of the studied sample is 2.31 g/cm3. These values fall below the acceptable limit of greater than 2.60 g/cm3.Average value of the results of Aggregate impact value of the rock sample is 22.79% thus certified the rock sample for use as concrete and for wearing surfaces, such as runways roads and pavement. The IS 283-1970 code specifies that aggregate impact value shall not exceed 45% by weight for aggregate used for concrete other than wearing surface and 30% by weight for concrete used for wearing surfaces, such as runways roads and pavement. Result of the Aggregate crushing value (ACV) test conducted on the selected samples is 11.17%. Hence, the rock sample from the study area is suitable for use as concrete for roads and pavements and for other structures.The crushing value of aggregate is restricted to 30% for concrete used for roads and pavements and 45% may be permitted for other structures. The lower the value, the stronger the aggregate, that is, the greater its ability to resist crushing. Therefore, crushing value of 30 percent and above is not good for road construction.

REFERENCES

Abudulawal, L., Amidu, S. A., Adeagbo, O. A. and Adejumo, S. A. (2017). Overburden Thickness and Potential Tonnage Estimate of Olode-Gbayo Pegmatite Deposit, Southwestern Nigeria, Using Electrical Resistivity Method. *Journal of*

Geography, Environment and Earth Science International, 10(2): 1-12.

Agbede, O. A. and Osuolale, O. M. (2005). Geotechnical Properties of Subgrade Soil in Orire Local Government Area. *Science Focus*, 10(2): 137-14.

Aghamelu O. P. and Okogbue C. O. (2011). Geotechnical Assessment of Road Failures in The Abakaliki Area, Southeastern Nigeria. *International Journal of Civil & Environmental Engineering*, 11(02): 12-19.

Ajibade, A. C. (1988). Structural and Tectonic Evolution of the Nigerian Basement with Special Reference to NW Nigeria.Inter. Conf. on Proterozoic Geology and Tectonics ofHigh-grade Terrain (Ife, Nigeria) p. 45.

Amuda, A. G., Uche, O. A. U. and Amuda, A. K. (2014). Physicomechanical Characterization of Basement Rocks for Construction Aggregate: A Case Study of Kajuru Area, Kaduna, Nigeria. *Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 11(6): 46-51.

Bayewu, O. O., Mosuro, G. O., Oloruntola, M. O. and Oladele , S. J. (2013). Assessment of Economic Viability of a Proposed Quarry Site Using Resistivity Survey in Lewuodo, near Ijebu-Igbo, South-Western Nigeria. *International Journal of Advances in Science and Technology*, 6(5): 24-31.

Bell, F. G (2008). *Engineering Geology*, 2nd Edition, Elsivier, 581p.

Dada, S. S. (2006). Proterozoic evolution of Nigeria. In: Oshi, O. (Ed.) The Basement Complex of Nigeria and Its Mineral Resources (A Tribute to Prof. M. A. O. Rahaman). Akin Jinad & Co. Ibadan. Pp. 29–44.

Egesi, N. and Tse, A. C. (2012). Engineering-Geological Evaluation of Rock Materials from Bansara, Bamenda Massif Southeastern Nigeria asAggregates for Pavement. *Construction Geosciences*, 2(5): 107-111.

Hartman, H. L. and Mutmansky, J. M. (2010). *Introductory Mining Engineering*. John Wiley and Sons, Inc. 570 p.

Krynine, D.P. and Judd, W.R. (1957). *Principals of Engineering Geology and Geotechnics*. McGraw-Hill Book Company, Inc., New York, 707 p.

Mallo, S. J. and Sani, S. D. (2012). Influence of Mineralogy and Fabric on the Engineering Properties of theMiango Granite Porphyry, North Central Nigeria. *International Journal of Modern Engineering Research (IJMER)*, 2(6): 4600-4608.

Nandi, A., Liutkus, C. M. and Whitelaw, M. J. (2009). Geotechnical characterization of Sevier and Rome shale, East Tennessee, Proceedings of the 43rd U.S. Rock Mechanics Symposium and 4thU.S. –Canada Rock Mechanics Symposium, Special Volume. pp. 1-8.

Nigerian Geological Survey Agency, (NGSA) (2006). Geological and Mineral Resources Map of Nigeria.Ministry of Mines and Steel Development, Abuja.Nigeria.

Obaje, N. G., (2009). *Geology and Mineral Resources of Nigeria, Lecture Notes in Earth Sciences 120,* Springer-Verlag Berlin Heidelberg**.** 221 p.

Olasehinde, P. I. (1999). Characteristics of rain, groundwater and surface water in the area of Ilorin, Kwara State, Nigeria. *Zb1. Geol. PalaontTeil*, 1(3-4): 149-158.

Rahaman, M. A. (1988). Recent advances in study of the basement complex of Nigeria. In: Oluyide P. O., Mbonu W. C., Ogezi A. E., Egbunike I. G., Ajibade A. C. Ana-Umeji A. C. (eds) Precambrian geology of Nigeria. Geological survey of Nigeria publication, pp 11-43.

Waqa, I. R. (2004). Geological and Geo-technical Characterisation of Aggregate Source Rocks from Selected Sites in VitiLevu Fiji. M.Sc. Thesis, University of Canterbury (unpubl.).

Yagiz, S. (2001). Overview of classification and engineering properties of shale for design considerations, In: Proceedings of Second Congress on Construction and Materials Issues, American Society of Civil Engineers, Civil Engineering Conference and Expositions, D.E. Hancher (Ed), Pp156-165.

Yahaya, O. Y., Adamu, G.I., Bamidele, O. and Moshood-Oniye, T. (2014). The Impact of Cropping Systems on Fertility Status of Soil in Babanla Rural Area, Nigeria. *Academic Research International,* 5: 181-188.

Table 2: Results of Reserve Tonnage Determination

Grid	AEG	REG=AEG-PED	RVG=A x REG
1	289.0	14.0	73.92
2	288.0	13.0	68.64
3	288.0	13.0	68.64
4	288.0	13.0	68.64
5	288.0	13.0	68.64
6	288.0	13.0	68.64
7	287.0	12.0	63.36
8	285.0	10.0	52.8
9	282.5	7.5	39.6
10	281.0	6.0	31.68
11	288.0	13.0	68.64
12	288.0	13.0	68.64
13	287.0	12.0	63.36
14	286.5	11.5	60.72
15	287.0	12.0	63.36
16	287.5	12.5	66
17	287.0	12.0	63.36
18	287.5	12.5	66
19	281.5	6.5	34.32
20	279.5	4.5	23.76
21	288.0	13.0	68.64
22	287.0	12.0	63.36
23	286.0	11.0	58.08
24	285.0	10.0	52.8
25	284.5	9.5	50.16
26	284.5	9.5	50.16
27	283.5	8.5	44.88
28	283.5	8.5	44.88
29	280.0	5.0	26.4
30	276.5	1.5	7.92
31	287.0	12.0	63.36
32	286.0	11.0	58.08
33	285.0	10.0	52.8
34	284.0	9.0	47.52
35	283.0	8.0	42.24
36	282.0	7.0	36.96
37	282.5	7.5	39.6
38	281.5	6.5	34.32
39	278.5	3.5	18.48
40	278.0	3.0	15.84
41	286.0	11.0	58.08
42	285.5	10.5	55.44
43	284.5	9.5	50.16
44	283.5	8.5	44.88
45	282.5	7.5	39.6
46	281.5	6.5	34.32
47	281.5	6.5	34.32
48	281.0	6.0	31.68
49	279.5	4.5	23.76
50	280.0	5.0	26.4
ΣRVG:			2457.84
Reserve Tonnage (tons)=ΣRVG x SG:			6660.75

AEG-Average Elevation of each Grid
REG-Reduced Elevation Grid / Rock thickness
RVG-The Reserve Volume of each Grid
Area of each grid as measured on ground (A)(m^2)= 2.2 m x 2.4 m=5.28 m^2
The predetermined elevation datum (PED) = 275 m
Specific Gravity (SG) = 2.71