International Journal of Novel Researches in Science, Technology & Engineering
Vol. 5 No. 1 March, 2023
ISSN 2141 825X
www.oasisinternationaljournal.org

Evaluation of Some Engineering Properties of Rocks in Selected Quarries for Construction Works in Kwara State

Obaro Reuben[1], Agbalajobi, S. A.[2], Oyathelemi E.O[3]. and Obaro, N.T[4],
[1, 2] Department of Mineral and Petroleum Resources Engineering
Kwara State Polytechnic, Ilorin

[3]Department of Mineral and Petroleum Resources Engineering Technology,
Auchi Polytechnic, Auchi, Edo State, Nigeria

[4]Department of Geology and Mineral Sciences
University of Ilorin, Nigeria

Abstract
Evaluation of some engineering properties of rocks was carried out from selected quarries in Kwara State to determine their suitability for construction works. Representative samples from each quarry were subjected to Aggregate Abrasion Value, Aggregate crushing Value and Aggregate Impact Value and Water Absorption Value. The results of Aggregate Abrasion Value range from 28% to 42% with an average of 34.75%. The Aggregate Crushing Value ranges from 30.4% to 43.4% with an average of 35.57%. Aggregate Impact Value (AIV) ranges from 21.20% to 27.30% with an average of 24.25% while the Water Absorption rate ranges from 1% to 4% with an average of 2.5%. The results of the engineering analysis revealed that all the rocks are good to excellent for construction purpose and they all attained the required satisfactory standard in accordance to with standard specification for aggregates in British Standard, ASTM, and AASHTO.

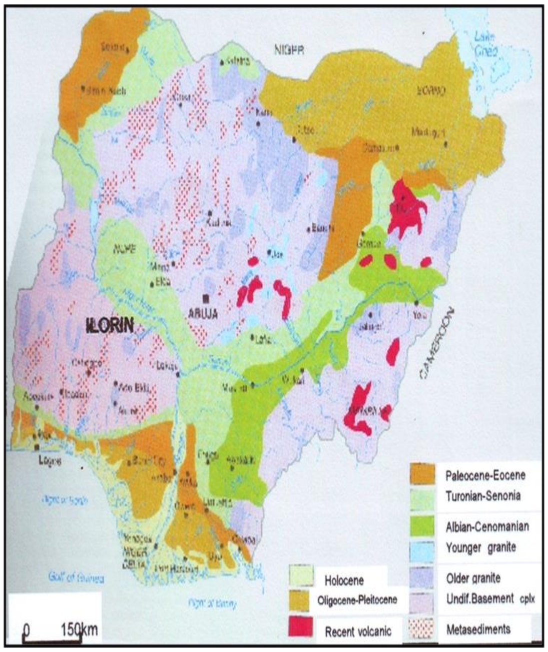
Keywords: Engineering Properties, Aggregates, Rock Strength, Construction works

Introduction
Construction aggregate is one of the major and most abundant natural resources and one of the most widely used for design and other engineering construction works. The high rates of demand for rushed granite rocks as construction material have led to the establishment of rock aggregates. Aggregates are important not only as a foundation for pavements, but also constitute the cement that makes the construction itself when a construction work is concluded (NGSA, 2006). Selecting the appropriate aggregate material is imperative to overcome the frequent problem of building collapse, pavement failure and so on. Intact rock strength is a major rock property of rock mass to force field of its physical environment. These properties will need to be tested and assured before construction. Granite rock, before been turned to an aggregate

might have witnessed some actions before blasting behavior besides the characteristics of rock. Rock fragmentation can be desired as the extent to which rock is broken into pieces by blasting or any other means. The geological factors that affect rock fragmentation are variable and non-controllable; these may also affect the engineering performances of the rock when used for construction (Ukaegbu and Okonny, 2003). Therefore, selecting an aggregate with the necessary characteristics for a particular construction is vital because 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 (Dada, 2006). It is also important to note that the quarrying project may be capital intensive but it is important to assess the engineering property of the materials to avoid the investors from wasting money too early only to realize later that the quality of material at the quarrying sites are unsuitable and quantity insufficient for some desired purpose. Current production of crushed granite aggregate is utilized mainly in preparation of concretes for foundation loads, buildings and airfield pavement. In the past, some work has been carried out on the assessment of the engineering properties of granitic rocks for construction purposes (Rahaman, 1976; Dada, 2006 and Bale, 2010).

The paper seeks to provide useful information on the strength of the rocks at different quarries in Kwara State area, indicating possible responsibility of the rock fragments before they can be used as sub-base during road construction and as foundation materials in a humid tropical environment with frequent alternation of the wet and dry seasons using combination of physical and engineering tests on rock samples from four quarries. This is however imperative since pre-failure and post - failure characteristics could be easily detected from either one or combination of the tests.

Location of the study area
The study areas are Kamwire quarry with located within latitude N08^0 33^1.18.2^{11} and longitude E004^0 45^1 33.0^{11}; Bellison quarry of latitude N08^0 36^1.47.0^{11} and longitude E004^0 35^1 00.7^{11}; Chinese quarry of N 08^0 31^1.50.1^1 and Longitude E004^0 34^1 44.6^{11}; with Mount Olive quarry of latitude N08^0 31^1.52.6^{11} and longitude E004^0 34^1 38.4^{11}. Geologically, the area lies in the Precambrian Basement complex of north central Nigeria and is underlain by rock of metamorphic and igneous type (Figure 1). However, migmatite predominantly underlies the rocks in the area while other principal rocks include granites and gneisses which are emplaced by Precambrian time and have overtime subjected to tectonic activities characterized by large changes on temperature and resulting in folding and fractures such as joints, faults and fractures within the basement complex rock (Ibrahim *et al*., 2012). The mineralogical compositions in these rocks include quartz, feldspar, mica (muscovite and biotite), hornblende.



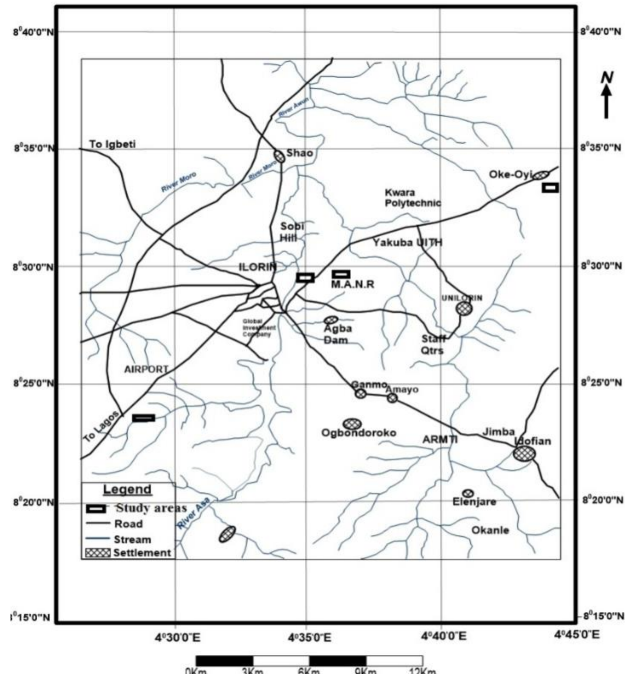


Figure 1: Geological Map of Nigeria (Modified from Africa Atlases, 2007)

Figure 2: Location Map of the study area (Modified after Olasehinde *et al.*, 1998)

Materials and Methods

Geological mapping was conducted and fresh samples of granitic rocks were randomly selected and prepared for strength tests according to International Society of Rock Mechanics Commission (ISRM, 1989). All the rocks were subjected to mechanical (LAAV, ACV and AIV) and physical (water absorption and specific gravity) tests which were carried out on all the samples in accordance to standard specifications. The analyses were carried out at the Civil Engineering Laboratory University of Ilorin, Nigeria.

Aggregate Abrasion Value (AAV) Determination

The Los Angeles machine with twelve (12) balls were used to determine the Aggregate Abrasion Value determination.500g of the sample retained on the 1.80mm sieve were poured in a large rotating drum of Los Angeles with twelve (12) balls and allowed to rotate 500 revolutions at the speed of 30 – 35 revolutions per minute. The materials were later extracted and separated into materials passing 1.80mm. The retained materials were then weighed and compare to the original sample weight. The difference in weight is recorded as a percent of original weight. The British standard recommends that rock materials with Aggregate Abrasion Value below 30% are regarded as strong while those above 35% would normally be regarded as too weak for use in road surface.

Aggregate Crushing Value (ACV) Determination

The Aggregate Crushing Value (ACV) determination is the ability of rock material to resist crushing under gradually applied compressive load (a California Bearing Ratio (CBR) machine or Concrete Crushing apparatus) over a period of 10 minutes, after passing through sieve 14.0 mm and retained on 10mm sieve. The retained materials were poured into a mould in three layers and tamped for 25 minutes in each layer. After compression, the fire materials (materials passing through the sieve number 2.36mm) produced, expressed as a percentage of the original mass is the Aggregate Crushing Value (ACV) and the lower the value (finer particles), the stronger the aggregate that is the greater the ability to resist crushing, 30 percent and above as crushing value is not good for road construction.

Aggregate Impact Value (AIV) Determination

The Aggregate Impact Value (AIV) measures the resistance of aggregates to gradual disintegration due to impact. Oven dried aggregate that pass through 13.2mm and are retained on 9.5mm. British standard sieves were used for the test. A cylindrical cup of known weight is filled with the aggregates in 3 layers with each layer receiving 25 gentle blows using the tampering rod. The weight of the cup and sample is noted after which the aggregates are transferred to the impact mould in one layer and then placed firmly in position of the base of the impact machine. The samples are then given 15 blows using the impact machine rammer. The crushed materials are removed from the mould and passed through 2.36mm sieve. The fraction passing through 2.36mm sieve is weighed and readings noted. The impact value is calculated as the ratio of the weight of the fraction passing 2.36mm sieve to the weight of the sample expressed in percentage. The procedure is repeated a second time and the average is taken.

Water Absorption Value (WAV) Determination

Water Absorption Value determines the amount of water an aggregate can absorb. It tends to be an excellent indicator to determine the strength or weakness of the aggregates. Sample of a retained 1.75mm aggregate was immersed in water for approximately 24 hours to essentially fill the pores. It is then in both saturated surface dry condition, submerged in water and oven dried conditions. Strong aggregate will have a very low absorption value that is below 1.0 percent. Therefore, the aggregate moisture content will affect the water content (and thus impact the water cement ratio) and the water content affects aggregate proportioning because it contributes to aggregate weight.

Results and Discussion

Table 1, depicts the results of the quantitative tests from rocks in various study areas.

Table 1 and Table 2: Results of Strength of Rocks

S/N	Different Quarries	Aggregate Abrasion Value (AAV %)	Aggregate Crushing Value (ACV %)	Aggregates Impact Value (AIV %)	Water Absorption Value (WAV %)
1.	Kamwire Quarries	28.00	30.40	21.20	3.00
2.	Bellison Quarries	42.00	33.60	27.30	2.00
3.	Chinese Quarries	35.00	43.40	23.40	1.00
4.	Mount – Olive Quarries	34.00	34.90	25.10	4.00
Standard Specification for Aggregates British Standard, ASTM, AASHTO		**< 30%**	**< 35%**	**< 30%**	**< 1.0%**

Aggregate Abrasion Value (AAV)
One of the fundamental aspects in assessing aggregate resistance to wearing is the determination of aggregate abrasion value (Aweda *et al*., 2019). The aggregate abrasion value for the four quarries ranges from 28% to 42% with an average of 34.75% (Table 1). These suggest that it does not attain the required standard specification for wearing course but it can be used for concrete and pavement construction. This is according to IS 383-1970 that stipulate that the abrasion value should not be more than 30% for wearing surface and not more than 50% for concrete other than wearing surface. However, it is important to note that aggregates from Kamwire quarries attain 28% (Figure 3) which is good for wearing and fragmentation course (Shetty, 2005).

Aggregate Crushing Value (ACV)
Summer, (2000), the relative measure of resistance to crushing under standard reading indicates that the lower the value, the stronger the aggregate hence the greater is its ability to resist crushing. Ajagbe *et al*. (2015), similarly disclose that the relative capacity of aggregates when subjected to compressive forces will take the same trend of positive correlation as the aggregate impact value. The results of aggregate crushing value for the four quarries (Table 1) ranges from 30.4% to 43.4% with an average of 35.57%. Comparing these values with the acceptable standards from British, ASTM and AASHTO value of < 35% suggest an excellent aggregate for road and air – field pavement construction (Figure 4). The aggregate crushing values for rock in Chinese quarry indicate higher value of 43.40%. Although it falls within the acceptable limit of aggregate crushing value which is ≤ 45% for concrete works as stipulated in the specification standards for materials and workmanship, 1997 by Federal Ministry of Works, Nigeria.

Aggregate Impact Value (AIV)
The Aggregate Impact Value (AIV) can be defined as the ability of an aggregate to resist impact or sudden shock which determines its toughness. According to standard specification by Thuro

and Plinninger (2001), as presented in Table 2 indicate that aggregates tested provides a method for measuring strength in construction industries.

Table 2: Standard Classification of Aggregate Impact Value (after Thuro and Plinninger, 2001)

Aggregate Impact Value (AIV) %	Quality of Aggregates
< 10	Exceptionally strong
10 – 20	Strong
20 – 30	Satisfactory for road surface
> 35	Weak for road surfacing

The results of Aggregate Impact Value (AIV) of four quarries ranges from 21.20% to 27.30% with an average of 24.25%. In accordance to standard classification of Thuro and Plinninger (2001), all the rocks from different quarries attained the required satisfactory standard for aggregate impact values (Figure 4). In addition, from the results obtained the rocks from the four quarries investigated are within the limits of 20% to 30% (Table 2) which is strong and satisfactory for road surface.

Water Absorption (WA)

The results of water absorption rate ranges from 1% to 4% with an average of 2.5%. This gives a higher value for all the rock types (Table 1). This is a pointer of lower strength. Sajid and Arif (2014), noted in Egesi and Tse (2012), that rocks with greater strength possess lower water absorption values than rock with higher absorption values. The water absorption for all the rocks is much higher other than rocks from Chinese quarry that is relatively lower and the value is very close to the standard classification of AASHTO, ASTM and British Standards which indicate that the rocks can be used for concrete embankments and foundations. Sajid and Arif (2014), stated that the degree of recrystallization is also an important factor that must be considered as it greatly influences the water absorption capacity of rocks. In addition to this, there are also micro - cracks and fractures though insignificant but it tends to absorb more water. Hence, the rocks are categorized as very low strength rock materials with corresponding mineral compositions and tectonic events which have occurred in rock.

Conclusion

Construction aggregates are important index materials and detailed assessment of its properties will go a long way in designing and establishing a high quality structures in construction works. However, the low abrasion, high crushing and impact values with high water absorption values are all within the allowable limits of AASHTO, ASTM and BS standards for optimum use in construction industries.

References

Africa Atlases (2007). Atlas of Nigeria. 2nd Edition. P. 156.

Ajagbe, W. O., Tijani M. A. and Oyediran I. A. (*2015).* Engineering and Geological

Evaluation of Rocks for Concrete Production. *Lautech Journal of Engineering and Technology 9 (2): 67- 79*

American Association of State Highway and Transportation Official, AASHTO, (2001). Specific Gravity and Absorption of Coarse Aggregate. Washington DC. Technical specification. No. T85.

ASTM, (2003). Standard Test Methods for Chemical Analysis of Hydraulic Cement, Annual Book of ASTM Standards, Vol.04.01. C114 – 03. pp. 111-120.

ASTM, (2005). Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. C136, P. 5

Aweda, A. K., Mohammed A., Ige, O.O. and Bitrus, S. A. (2019). Engineering Characterization of Rocks from the Minna Granitic Formation as Pavement Construction Aggregates. *Journal of Geography and Earth Sciences.* Vol. 7, No. 1, pp. 27 - 32

BIS (Bureau of Indian Standard), (1970). “Indian Standard Specification for Coarse and Fine Aggregates from Natural Sources for Concrete.” *IS 383,* New Delhi 110002, 2nd revision, 9th Reprint September 1993.

Bolen, A. (2005). Influence of Natural Coarse Aggregate, *Journal of Rock Mechanics Pergamon Press*, Washington, pp. 21 – 26.

British Standard Institute BS 812, Part 2, (1975). Specific Gravity and Absorption of Coarse Aggregate.

British Standard Institute BS 812, Part 3, (1975). Method of Determining Aggregate Crushing Value for civil Engineering Structures.

British Standard Institute BS. (1981). British Standard Code of Practice for Site Investigation, BS 5930 (formerly CP 2001), London. P.140

British Standard 1377 (1990). Methods of Testing of Soils for Civil Engineering Purposes.

Federal Ministry of Works (2013). Specification Limits for Materials and Workmanship, Revised 1997 Volume III”, *FMW, Nigeria.*

ISRM (1989). Rock Characterization and Monitoring, International Society for Rock Mechanics Suggested Methods. Brown E.T. (Ed), Pergamon Press. Oxford, P. 211.

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

Olasehinde, P. I., Virbka, P., Esan, A. (1998). Preliminary Result of Hydrogeological Investigations in Ilorin Area, Southwestern Nigeria-Quality of Hydro Chemical Analysis. *Water Resources*. *NAH,* 9, pp. 51-61.

Ramamurthy T. (2010). Engineering in Rocks for Slopes, Foundations and Tunnels, Second Edition, PHI Learning Pvt Ltd, New Delhi.ISBN: 8120341686, 9788120341685.

Shetty, M. S. (2005). Concrete Technology Theory and Practice, 6th Ed. Chand and Company Limited, New Delhi

Sajid M. and Arif M. (2014). "Reliance of Physico- Mechanical Properties on Petrographic Characteristics: Consequences from the Study of Utla Granites, North - west Pakistan." *Bull Eng Geol Environ* DOI 10.1007/s10064-014-0690-9

Summers C. J. (2000). The idiot's Guide to highways maintenances. www.highwaymaintenance.com

Thuro, K. and Plinninger, R. J. (2001). Scale Effects in Rocks Strength Properties Part Point load and Point Load Strength Index. Rock Mechanics – A Challenge for Society, Sarkka Eloranta (Eds.). Swets and Zeitlinger Lisse.

Ukaegbu V.U. and Okonny, I.P. (2003). Introduction to Igneous and Metamorphic Petrology, *Josany Publishing*, Port-Harcourt Nigeria, First edition. 189p.

Appendix

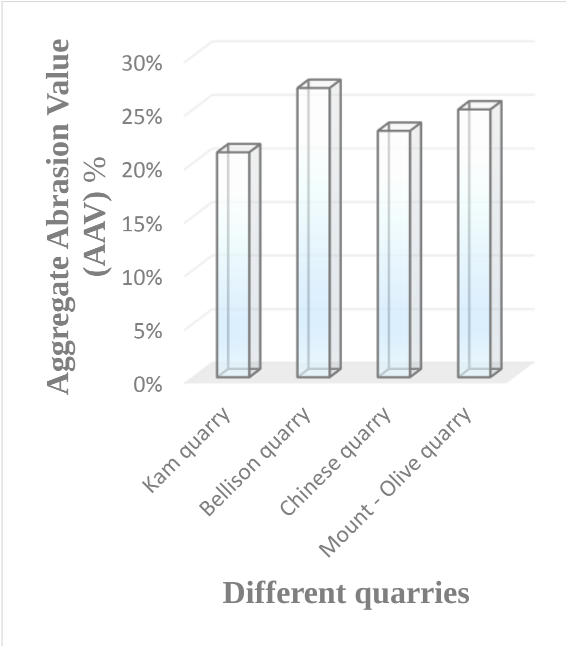


Figure 3: Plots of Different quarries against Aggregate Abrasion Value (AAV)%

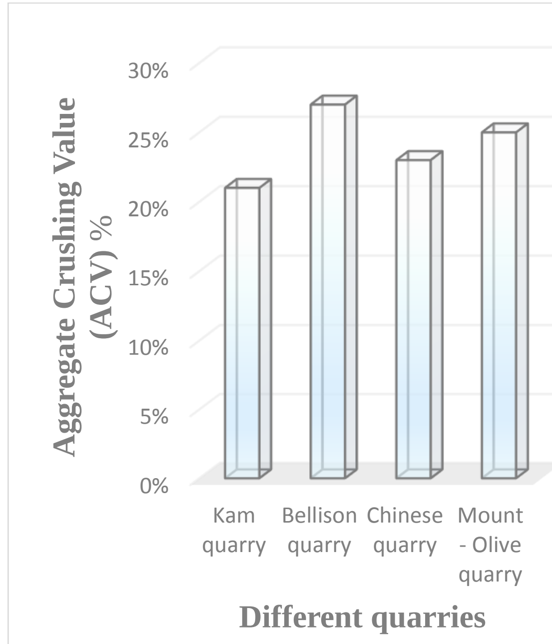


Figure 4: Plots of Different quarries against Aggregate Crushing Value (ACV)%

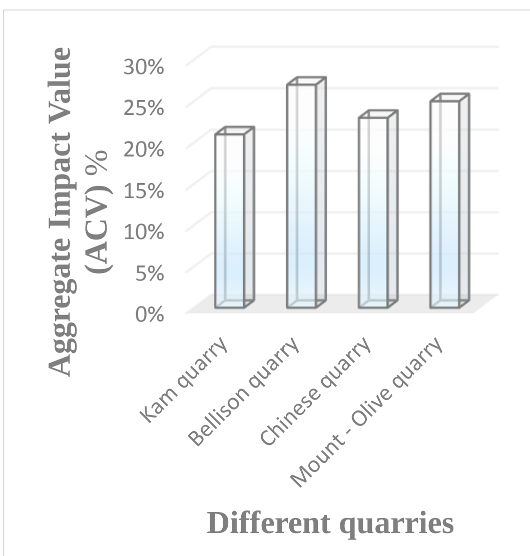


Figure 3: Plots of Different quarries against Aggregate Abrasion Value (AAV)%

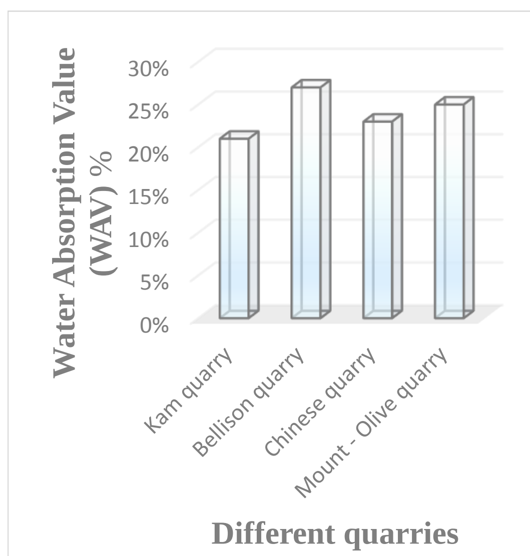


Figure 4: Plots of Different quarries against Aggregate Crushing Value (ACV)%