International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.6, Nov-Dec. 2012 pp-4600-4608 ISSN: 2249-6645

Influence of Mineralogy and Fabric on the Engineering Properties of the Miango Granite Porphyry, North Central Nigeria

Stephen J. Mallo, [1] Sunday Daku Sani[2]
[1,2]*Department of Geology and Mining, University of Jos, Nigeria*

Abstract: The major problem associated with the use of rock aggregates in engineering construction, is the difficulty of predicting their probable field performance. This is mainly due to the inadequate understanding of the decisive factors that control their engineering behavior. The mineralogy and fabric of the Miango granite porphyry was studied to assess their influence on engineering properties. The uniaxial compressive strength and aggregate crushing values show that the rocks are weak while other tests such as aggregate impact strength, water absorption, and absorption under saturation, soundness and specific gravity values are fairly good. However, thin section studies revealed three distinctive features which greatly influence the physico-mechanical properties: (a) abundant fractures of varying sizes (b) Sericitization of the orthoclase and or plagioclase feldspars (c) intergrowth of quartz and or orthoclase feldspars. The quartz grains shows extensive cracking which further reduces their mechanical strength. The strength loss of the granite porphyry could be attributed to the presence of the fractures on the quartz grains and the sericitization of the orthoclase and plagioclase feldspars. Geotechnical characterization of the rocks shows that they can be utilized as roadstone or could be polished and used as facing stones because of their non disintegration to sulphate attack and the large feldspar phenocrysts in the rock.

Key Words: Aggregate Impact Value Tests; Aggregate Crushing Value; Water Absorption; Crushing Load

I. Introduction

The study area is located in Bassa Local Government Area (L.G.A) of Plateau State North Central Nigeria. It is between latitudes 9˚ 49’ 02’’N and 9˚ 52’ 36’’N and longitudes 8˚ 39’ 06’’E and 8˚ 43’ 18’’E (Fig.1.1). The area falls under the basement complex of Nigeria (Wright, 1971; Jacobson, 1971) with some parts having relatively high relief while others have low relief and show extensive weathering and erosion thus, the ease with which the rocks are quarried for use as foundation stones and building.

The study on the influence of petrology and fabric on the Engineering properties of concretionary laterite aggregates and rocks in Nigeria have been carried out by Akpokodje and Hudec (1991), and Akpokodje (1992) and recommended that the mineralogy, petrology and fabric of commonly used laterite gravel aggregate in Nigeria should always be studied to assess their influence on engineering properties. Result of thin section studies by Akpokodje and Hudec revealed two characteristics feature which greatly influence the physico-mechanical properties: (a) abundant voids and fissures of varying sizes and (b) varying degree of iron oxide impregnation. For Akpokodje, the pyroclastic aggregates exhibited high expansions (greater than critical value of 0.07%) when immersed in hot IN NaOH due to alkali carbonate reactivity. This constitutes serious durability problem for concretes produced with pyroclastic aggregates. The granite and granite gneiss aggregates generally showed lower and permissible-expansion although, some varieties show values that are higher than the critical expansion, depending on geochemistry.

Ogunsanwo (1994) studied the significance of geochemistry and mineralogy on the optimum geotechnical utilization of some laterite sorts from four Basement Complex rocks and a Sedimentary formation form South-Western Nigeria. Some geotechnical properties of these soils namely compaction, consolidation, permeability and shear strength were investigated in addition to the classification test in the laboratory. The results obtained show that the soils generally possess very favorable geotechnical properties.

From these studies it follows that successful exploitation and use of any rock for engineering purpose requires proper understanding of the physical, structural, mineralogical and strength characteristics of the rock. This is important because rocks like other solids, fail when subjected to load beyond their strength. The failure takes place under compression, tension and shear forces at different values.

The Miango granite porphry is underlain by Precambrian rocks of the Nigeria Basement Complex. Here, the rocks vary in mineralogical composition, texture, color and some other physico-mechanical properties (Macleod and Berridge 1971). Over the years, rocks have usually been quarried and used with or without the knowledge of their engineering properties, as only private construction companies always bother to test for the strength characteristics before they are used for civil engineering construction. Therefore, there is insufficient information on the engineering properties of the abundant rocks on the Plateau particularly the younger and older granites. The significance or influence of mineralogy and fabric (texture) on the Miango granite porphyry in relation to the engineering properties of the rocks has been studied by petrographically indentifying the constituent minerals of the rocks, their arrangement, texture and their role on the engineering properties of the rocks.

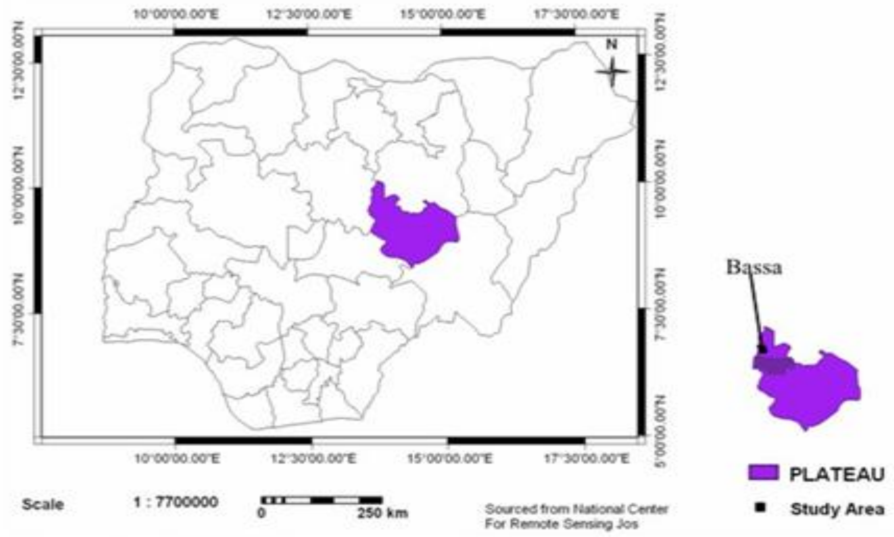

Figure 1.1: Location map of study area

II. Materials and Methods

The main thrust of the research is to determine the engineering properties of the Miango granite porphyry in relation to their mineralogy and fabric (texture). Geological data were gathered from secondary data. Primary data were generated through a systematic method of sampling from where twenty (20) representative samples (Fig.1.2) were collected and subjected to various geo-technical tests (Water Absorption, Specific gravity, Uniaxial Compressive Test, Aggregate Crushing Value Test (ACV),Aggregate Impact Value (AIV) Test, Thin Section Preparation and oundness test) as well as petrographic studies. Equipments and materials deployed for the study include the Global Positioning System (GPS), sampling equipments, digital cameras, and ILWIS 3.0 Academic, Surfer 8.0 and Grapher 5.0 Soft wares.

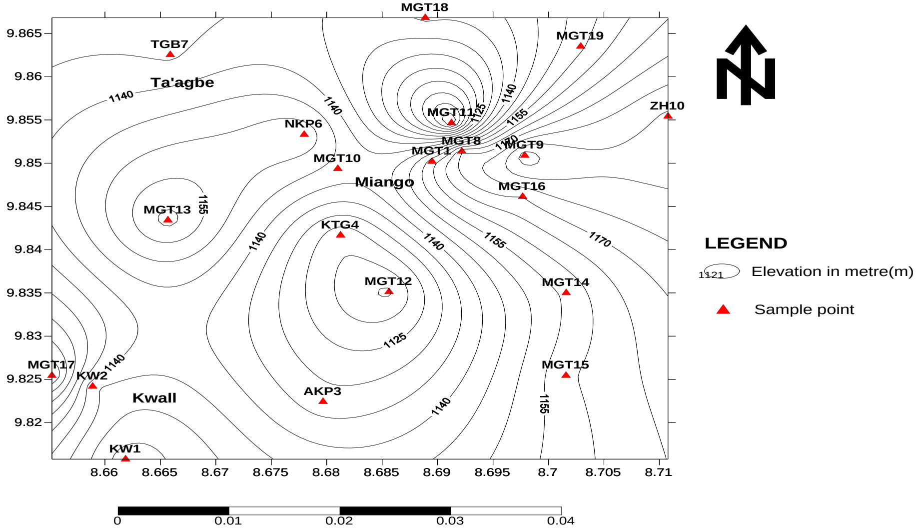

Fig. 1.2: Samples Location Map of the Study Area

III. Structural Geology

Structures of the Miango granite porphyry are the imprints of deformation on rocks which include joints, dykes, foliations, veins, folds etc. Such structural features exhibit variable trends in conformity with the general fracture pattern recorded in the Basement and Younger Granite province of Nigeria. These structures are believed to have resulted from intense regional tectonism that preceded and accompanied the emplacement of the Older Granites during the Pan-African Orogeny which produced a well defined and extensive N-S trend in North Central Nigeria including the Miango area (Macleod and Turner, 1971). The origin of these structures cannot be totally related to tectonism and accompanying deformations, but they may have been due to tensional forces set up as a result of cooling.

The structural setting in the study area has greatly controlled the geological setting, relief, drainage, geological boundaries and trend of younger rocks (Fig.1.3).

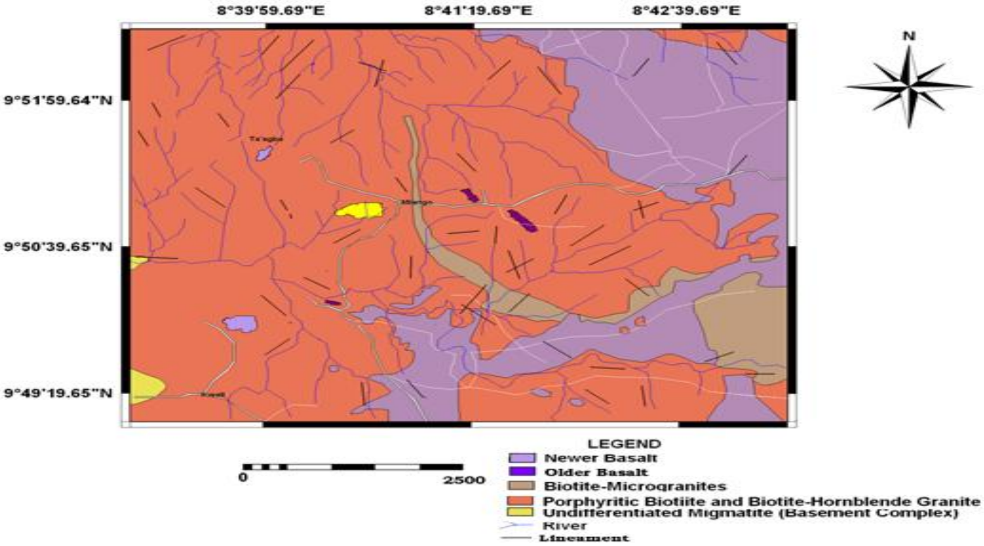

Fig. 1.3: Modified Geological Map of Study Area

Generally, the nature and extent of structures depends on the duration and intensity of deformation.

IV. Field Observation

Fractures and Joints: Fractures represent any break in a rock whether or not it causes displacement due to mechanical failure by stress. It includes cracks, joints and faults. Joints on the other hand are fractures on rocks in the study area in which there is no relative movement along the fracture planes. They are linear structural features resulting from the fracturing of brittle rocks. They are the most common structural features observed within the study area (Plate 1).

Plate1: Joints on the porphyritic biotite granite

Foliation: The term foliation is a general term sometimes used as essentially synonymous with cleavage, but it is applied most generally to mineral alignment in metamorphic rocks and sometimes in igneous rocks (older granites). Thus, salty "cleavage" and "schistosity" are special types of metamorphic foliation characterized by the types of fabric or mineral arrangement commonly found in slates and schists. Foliation is mostly used for metamorphic fabric like migmatite gneiss.

Foliation is formed as a result of static pressure that act on the pre-existing rock changing the platy mineral such as mica and amphiboles contained in the rock structurally to a new form. The presence and degree of foliation in a rock helps in knowing the rock type and condition under which the rock was formed.

Plate 2: Foliation on the Migmatite

Veins: These are tabular or sheet like bodies of mineralization which were introduced into fissures and joints within the study area. They are brought about by the infilling of fractures by mineral fluid before recrystallization. Most of the veins are quartz veins, although, some are fine grained felsic materials. In some places the size of the quartz vein is as thick as 17cm. Plate 3 shows a typical quartz vein within the study area.

Plate 3: Quartz Vein on porphyritic biotite granite

Sampling: Samples were collected using the systematic sampling method using the grid map at an average of 2km per sample. However, because of non total coverage of the study area by granite porphyry some samples were taken at intervals exceeding 2km.

V. Presentation Geotechnical Result

A summary of the geotechnical test carried out which include; soundness or durability test, water absorption, specific gravity, uniaxial compressive test. Aggregate crushing value and aggregate impact value tests are presented in Table 1. Individually the results are graphically presented in Figures. 1.4 to 1.9 below.

Table 1 Summary of Rock Test of the Representative Samples

S/No	Sample No	Specific Gravity	Water Absorption	Water Absorption Under Saturation	Crushing Load(KN)	Crushing Strength (N/mm^2)	Aggregate Crushing Value ACV(%)	Aggregate Impact Value AIV(%)	Soundness Test(%)
1	AKP3	2.46	0.98	1.00	50	21.83	23.44	20.60	5.00
2	KW2	2.59	0.88	0.92	55	24.01	22.69	20.00	4.50
3	MGT9	2.60	0.95	0.98	62	27.07	22.27	19.70	4.40
4	MGT8	2.48	0.98	1.00	51	22.26	22.87	20.80	4.70
5	NKP6	2.60	0.95	0.99	60	26.19	21.57	17.72	5.70
6	KW1	2.29	0.89	0.94	47	20.52	24.33	18.40	4.90
7	MGT1	2.62	0.90	0.93	64	27.94	19.18	20.00	4.20

8	KTG4	2.55	0.95	0.99	52	22.70	21.80	22.22	4.50
9	ZH10	2.49	0.95	0.97	49	21.39	23.20	20.00	4.10
10	TGB7	2.41	0.85	0.90	43	18.77	24.80	22.00	4.90
11	MGT10	2.54	0.91	0.94	48	20.96	24.50	22.80	5.00
12	MGT11	2.50	0.98	1.00	53	23.14	20.30	23.00	4.40
13	MGT12	2.53	0.98	1.00	43	18.77	25.40	18.00	5.35
14	MGT13	2.27	0.97	1.00	40	17.46	23.30	22.00	4.80
15	MGT14	2.31	0.89	0.93	45	19.65	23.81	21.30	5.50
16	MGT15	2.45	0.94	0.96	50	21.83	24.36	22.60	4.40
17	MGT16	2.48	0.93	0.95	50	21.83	22.86	20.00	3.90
18	MGT17	2.51	0.90	0.93	55	24.00	21.64	23.10	4.20
19	MGT18	2.52	0.89	0.93	55	24.00	23.00	22.20	4.20
20	MGT19	2.58	0.94	0.97	59	25.76	24.88	19.70	4.85

The Soundness Test is to simulate weathering characteristics of an aggregate, or more precisely its ability to resist weathering. The particular aggregate being tested is subject to a number of immersions (twelve) in an aggressive solution of magnesium or sodium sulphate to hasten the degrading process the environment has on the aggregate.

After the aggregate has been subjected to the testing regime the remaining weight of the aggregate is expressed as a percentage of the original weight. Aggregate soundness tends to be related to the water absorption of an aggregate i.e. an aggregate with a high moisture absorption value tends to have a low soundness value.

Although, all the twenty rock samples have a soundness value within the acceptable range, (BS 812, Part 2) which should be below 12%, some samples tend to have relatively high water absorption. This could be attributed to the coarse nature of the rock samples and the gradual sericitization of the orthoclase/plagioclase feldspars in some of the rock samples. Samples MGT17 and MGT18 have good soundness value while AKP3 (South western part of the study area) have the highest soundness value which by interpretation is least good particularly for road surface.

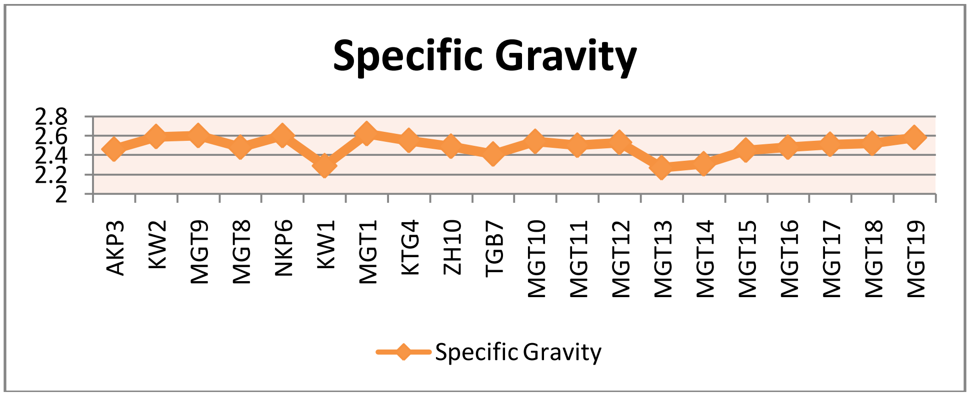

Fig.1.4 Specific Gravity of samples

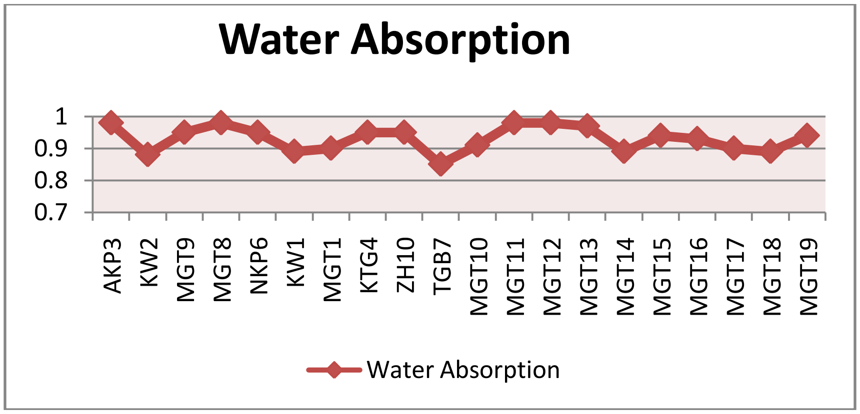

Fig. 1.5 Water Absorption of samples

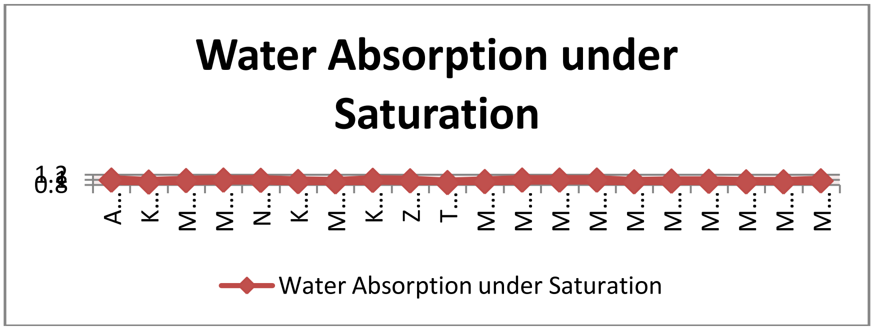

Fig. 1.6 Water Absorption under saturation

Only samples MGT1, NKP 6, MGT9 and MGT19 have compressive strength of above 25 MPa while the remaining samples have compressive strength ranging from 18-24.04 MPa. This then implies that 80% of the samples are likely to yield ambiguous results in civil engineering construction.

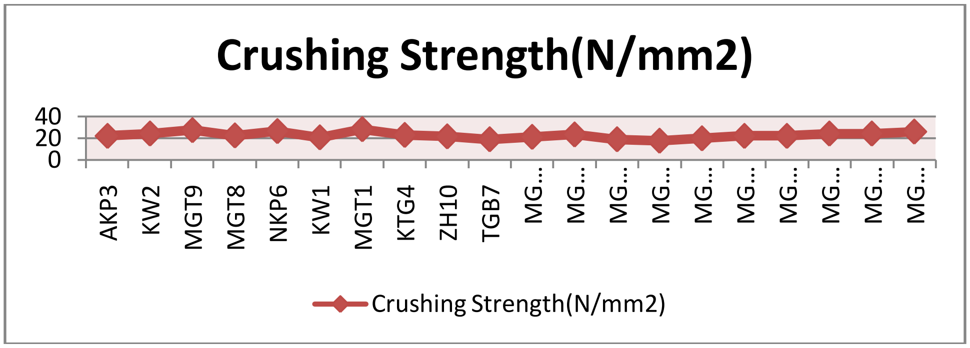

Fig.1.7. Crushing Strength of samples

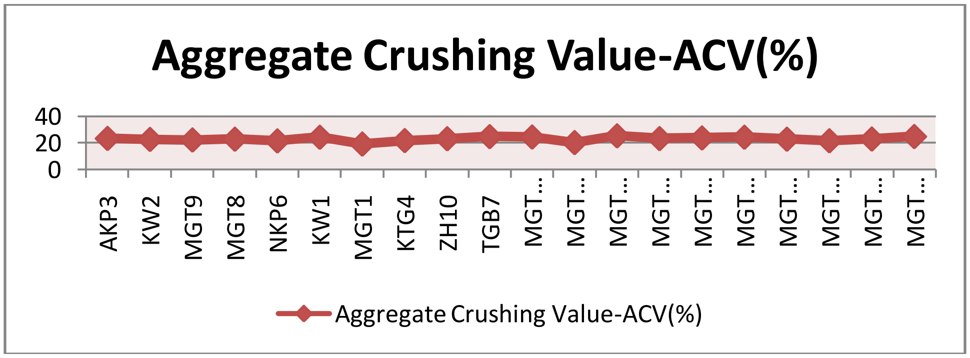

Fig.1.8. Aggregate crushing value of samples

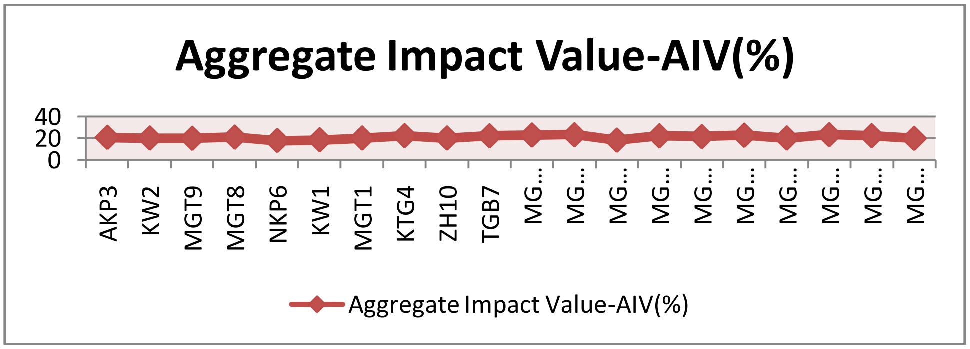

Fig. 1.9 Aggregate impact value of samples

VI. Discussion

This is a test to simulate weathering characteristics of an aggregate, or more precisely its ability to resist weathering. The particular aggregate being tested is subject to a number of immersions (twelve) in an aggressive solution of magnesium or sodium sulphate to hasten the degrading process the environment has on the aggregate.

After the aggregate has been subjected to the testing regime the remaining weight of the aggregate is expressed as a percentage of the original weight. Aggregate soundness tends to be related to the water absorption of an aggregate i.e. an aggregate with a high moisture absorption value tends to have a low soundness value.

Although, all the twenty rock samples have a soundness value within the acceptable range, (BS 812, Part 2) which should be below 12%, some samples tend to have relatively high water absorption. This could be attributed to the coarse nature of the rock samples and the gradual sericitization of the orthoclase/plagioclase feldspars in some of the rock samples. Samples MGT17 and MGT18 have good soundness value while AKP3 (South western part of the study area) have the highest soundness value which by interpretation is least good particularly for road surface.

The specific gravity is defined as the weight per unit volume of a substance, in this case a rock. The unit weight of a rock depends on the constituent minerals of the rock, porosity and on the amount of water in the pores. It has been observed that of the three main categories of rocks (Igneous, metamorphic and sedimentary), sedimentary rocks usually have lower specific gravities, followed by metamorphic and igneous rocks. Rocks containing heavy metals posses high densities (4.5 and above) whereas the ranges of densities for sedimentary, metamorphic and igneous rocks vary from 2.63 to 2.86 (Mallo, 2010).

Almost all the rock samples analyzed have low to moderate specific gravities according to (Anon, 1979). This is attributable to the dominant constituent minerals in the rock. Sample number KW1 has the least specific gravity of 2.29 and is the coarsest of all samples in hand specimen while samples MGT1 has the highest specific gravity of 2.62 and is relatively fine in hand specimen. The implication of these is that the rocks have medium-low porosity whereas higher the porosity, the faster the weathering. Hence, their utilization for engineering construction is hampered Mallo, 2011).

The rate of water absorption of any rock depends on its porosity. The porosity in turn depends on the mineral composition, grain size distribution, degree of packing and the cementing materials in case of sedimentary rocks. The utilization of highly porous construction materials is not advisable as a result of buoyancy effect, because the weight of porous materials decreases due to buoyancy, to the detriment of the carrying capacity (Mallo, 2010). Also, the samples analysed have water absorption of less than 1% which is good for most construction work.

Under normal conditions water fills only a certain portion of the total volume of pores. The degree of saturation is the ratio of the volume of pores filled with water to the total volume of pores. The degree of saturation and water absorption by rocks can affect the bearing capacities of foundation materials of civil engineering structures. Samples AKP3, MGT8, MGT11, MGT12 and MGT13 have a water absorption under saturation of 1% which means that they cannot be used in logged areas as foundations materials, while the other samples have water absorption under saturation of less 1% which mean that the can be considered as foundation materials. A reason could be advanced for the relatively high rate of water absorption under saturation of samples AKP3, MGT8, MGT11, MGT12 and MGT13 to the micro fractures in the samples and the high orthoclase quartz ratio in the sample.

Generally, the compressive strength of rocks is influenced by its texture. The compressive strength of igneous rocks depends on porosity. The more compact the porphyry, the higher the compressive strength. This argument is also true for metamorphic rocks (Mallo, 2010). The cementing materials and presence of fractures or fissures and the degree of saturation affects the compressive strength of most rocks. Consequently, as percentage sorption of rocks increases, the compressive strength decreases.

The classification of rocks based on compressive strength and field estimate of strength by Brown 1981 indicates that only samples MGT1, NKP 6, MGT9 and MGT19 have compressive strength of above 25 MPa while the remaining samples have compressive strength ranging from 18-24.04 MPa. This then implies that 80% of the samples are likely to yield ambiguous results in civil engineering construction in line with dry density and porosity (Anon, 1979).

The aggregate crushing value is a value which indicates the ability of an aggregate to resist crushing. The lower the crushing values the stronger the aggregate and the greater its ability to resist crushing. Crushing strength is related to porosity and grain size, the higher the porosity and the larger the grain size, the lower the crushing strength. On the other hand, with increasing content of altered minerals in a rock, the lower the crushing strength. Some of the samples which have their orthoclase/plagioclase feldspars sericitized have low crushing strength.

Based on the aggregate crushing value of some rocks given by Bell (2007) all the rock samples have low crushing strength as none have aggregate crushing strength of less than 20%. The implication of this is that the rock material cannot be used as wearing course in roads because of low crushing strength and altered form.

Aggregate impact value is a strength value that is determined by performing the aggregate impact test on a rock aggregate. Basically, the aggregate impact value is the percentage fines produced from the aggregate samples after subjecting it to a standard amount of impact. Aggregate impact values and aggregate crushing values are often numerically very similar and indicate similar aggregate strength properties.

The principal tests carried out in order to assess the value of a roadstone are aggregate crushing test, the aggregate impact test, the aggregate abrasion test and the test for the assessment of the polished stone value. Other tests of consequence are those of water absorption, specific gravity and density and the aggregate shape tests (Anon, 1975a).

Of the twenty rock samples analysed for aggregate impact strength, all are satisfactorily for road surfacing because their AIV ranges from 18%-23% for MGT12 which has the highest lowest value, by implication the strongest to 23.10% for MGT18 which is “weakest”. Based on table 5.3 the rock samples are satisfactory for road surfacing. This is because most roads are more susceptible to crushing than to impact.

VII. Characterization Based on Geo-Technical Test.

Crushed rock is produced for a number of purposes, and principally for concrete and road aggregate .Most volume of concrete consist of aggregate, therefore its properties have significant influence on the engineering behavior of concrete. An attempt is made here to characterize the Miango Granite Porphyry with respect to their suitability and utilization for construction works based on the laboratory analyses carried out on them.

Aggregate with compressive strength below 25MPa are likely to yield ambiguous results in engineering construction (Brown, 1981). Those with aggregate crushing strength of more than 20% are considered weak. Conversely, aggregates with aggregate impact strength of 20%-30% are considered satisfactorily for road surfacing. The average compressive strength of the Miango Granite porphyry is 20MPa, aggregate crushing strength of 23% and aggregate impact strength of 22%.

Aggregates used for roads have to bear the main stresses imposed by traffic such as slow-crushing loads and rapid-impact loads have to resist wears (Bell, 2007). Based on the above, the aggregates produced from the Miango Granite porphyry can be utilized as road metal.

The unit weight of a rock depends on the constituent minerals of the rock, porosity and the amount of water in pores of the rock. The BS acceptance limits for water absorption is < 3%, bulk density of >2.60g/cm3 and aggregate impact of 30% (Akpokodje, 1992). The twenty rock samples analysed have water absorption and water absorption under saturation of < 3% and an average specific gravity of 2.45. Based on the results, the Miango Granite porphyry tends to be of high quality however, their compressive strength is low. Therefore, they can utilized as roadstone because are more prone to impact than to crushing loads.

Soundness also known as durability test, measures a rock resistance to weathering, freeze-thaw, sulphate and moisture attack. The acceptable standard for durability test according to BS 812 part 2 is < 12%. All the twenty samples analysed have soundness value of less than 6%. This implies that the rocks can withstand harsh climatic conditions but because of their low crushing and compressive strength, they can be polished and used as facing stone because of their beautiful large feldspar phenocrysts.

VIII. Summary

The influence of mineralogy and fabric of the Miango Granite porphyry, North- Central Nigeria was carried out. The study area lies within the Jos Plateau characterized by an undulating topography with a hybrid of drainage pattern and various rock types. The Miango area is underlain mainly by the Younger Granite suite which composed essentially of Granite, syenites, rhyolite and basalts, and localized occurrences of basement rocks which are mainly migmatites and granite gneiss.

Geological, geotechnical data were acquired and used to ascertain the engineering properties of the Granite porphyry. The geological mapping was mainly from existing geological maps and surface mapping which revealed most outcrops in the study area and of particular interest the Granite porphyry. The geotechnical laboratory analyses carried out include those of specific gravity, water absorption, water absorption under saturation, soundness test, aggregate crushing test, aggregate impact test and uniaxial compressive test of the twenty rock samples from different locations in the study area. Also, thin section and petrographic studies of the twenty samples was carried out to determine the mineral grain orientation and the extent of deformation of the rock samples.

The results of geotechnical analyses were interpreted with the aid of some standards. The results showed that based on (BS 812 part 2) all the twenty rock samples have a soundness value within the acceptable range which is below 12%, none of the rock samples have a soundness value of up to 6%. Almost all the rock samples analysed have low to moderate specific gravities according to (Anon, 1979). This is attributable to the dominant constituent minerals in the rock. Sample KW1 (Zarama Kwall) has the least specific gravity of 2.29 and is the coarsest of all in hand specimen and is the coarsest of all samples while MGT1 (Miango adjacent ECWA Goodnews) has the highest specific gravity of 2.62 and is relatively fine in hand specimen. The implication of this is that the rocks have medium-low porosity. The samples analysed have water absorption of less than 1% which is good for most construction. Samples AKP3, (Akpene Kwall road), MGT8 (Miango Town), MGT 11 (Miango environs) have a water absorption under saturation of 1% which means that they cannot be used in water logged areas as foundation materials while the other samples that have water absorption under salivation of less 1% can be considered as foundation materials. According to Brown, (1981) only samples MGT1, (Miango Adjacent ECWA Goodnews), NKP6 (Nkepru Miango), MGT16 (Miango and environs) have compressive strength of 25MPa while the remaining samples have compressive strength of 18-24 MPa. This means that 80% of the samples are likely to yield ambiguous results in civil engineering construction. Based on Bell, (2007) granites should have an aggregate crushing value of 17%, however, none of the rocks have aggregate crusting values of less than 20% which means that the rocks cannot be used as wearing course in roads because of low aggregate crushing strength. According to IS 383 rocks with aggregate impact value of 20-30% are satisfactorily for road surfacing. Twenty of the rock samples analyzed for aggregate impact strength shows that they have AIV range of 18-23% which implies that they can be used satisfactorily for road surfacing that would not be subject to crushing load.

IX. Conclusion

The need for rock aggregates of high quality in engineering construction is of great importance as its demand is on the increases daily. As this study demonstrates however, it is possible to adopt a scientific approach to determine the quality of the rock aggregates for specific engineering works. This study has been able to show that the geotechnical competence of a rock depends more on the texture and spatial arrangement of the mineral grains than on the mineralogy of the rock (granite porphry). The fine to medium- grained rocks tend to have more engineering strength than the course grained rocks with the same mineralogy therefore, the following conclusion can be drawn from the studies.

The rock samples analysed have poor values for uniaxial compressive strength and aggregate crushing strength which are tests of significance in aggregates for use in heavy engineering works. However, the soundness (durability), aggregate impact, specific gravity, water absorption under saturation values are good which implies that the rocks can be utilized as road surface course were wearing and crushing effects are less.

The orthoclase and or the plagioclase feldspars in 80% of the rock samples have been hydrothermally altered to sericite and also have intergrowth of quartz and orthoclase or plagioclase thereby reducing the strength of the rocks.

The presence of micro fractures on 80% of the rock samples analyzed can hampered their use for engineering construction.

References

[1] Akpokodje, E.G. and Hudec, P.P (1991): The influence of petrology and fabric on the Engineering properties of concretionary Laterite Aggregates. Journal of The Nigerian Mining and Geosciences Society, abstract Vol. 29.

[2] Akpokodje, E.G. (1992): Properties of Some Nigerian Rock Aggregates and Concretes. Jour Min. and Geol. Vol. 28 (2), Pp. 185-190.

[3] Anon. (1975). Methods for Sampling and testing Mineral Aggregates, Sands and Fillers. British Standards Institutions, London.

[4] Anon (1979): Classification of Rocks and Soils for Engineering Geological Mapping, Part 1- Rock and Soil Materials. Report of the Commission of Engineering Geological Mapping, Bulletin International Association of Engineering Geology Vol. 19, pp. 364-371.

[5] Bell, F. G. (2007): Engineering Geology, 2nd Ed. Elsevier Ltd. India. pp 294-296.

[6] Brown, S.F. (1981): Soil Mechanics in Pavement Engineering Geotechnique, Vol. 46 pp. 383-426.

[7] Indian Standard Specification for Course and Fine Aggregates from Natural Sources, I.S. 383, Indian Standard Institution.

[8] Jacobson, R.R. E., Macleod, M.N, and Black, R. (1964): Ring Complexes in the Younger Granite Province of Northern Nigeria. Memoir No. 1, Geological Society of London pp. 65-66.

[9] Macleod, W.N, and Berridge, N.G. (1971): Geology of the Jos Plateau. Bulletin 32, Vol. 2, Geological Survey of Nigeria.

[10] Macleod, W.N. and Turner, D.C. (1971): Geology of Jos Plateau. Geological Survey of Nigeria. Bulletin 32, Vol. 1, pp. 12-47.

[11] Mallo, S. J. (2010): Unpublished M.Sc. Lecture Notes on Rock Mechanics.

[12] Mallo S.J. (2011): Fundamentals of Geotechnical Engineering (unpublished).

[13] Ogunsanwo, O. (1994): Influence of Schist city on the Strength and Wave Velocity Characteristics of a Mica Schist Coprolite. Jour. Min. and Geol. Vol.27 (2) pp. 135-138.

[14] Ogunsanwo, O. (1994): Influence of Geochemistry and Mineralogy on the Optimum Geotechnical Utilization of some Laterite Soils from S.W. Nigeria. Jour. Min. and Geol. Vol. 31 (2), pp. 183-188.

[15] Turner, D.C. (1989): Structures and Petrology of the Younger Granite Ring Complexes. In Geology of Nigeria (Kogbe, C.A. ed), Rock View Nig. Ltd., Jos, Nigeria pp. 175-189.

[16] Wright, E.P. (1971): The Basement Complex, Bulletin *32*, Vol. 1, Geological Society of Nigeria pp. 12-41.