Petrography and some geotechnical properties of granite in Imeke, Edo State, Southwestern Nigeria

Abade M.

Department of Geology, Faculty of Science, Delta State University, Abraka, Nigeria.
E-mail: melodyabade22@gmail.com. Tel: +2348164941220.

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The petrography and geotechnical properties of the granite in Imeke were evaluated with a view to determine its utility potential for construction purposes. The samples used in this study were obtained from Imeke for the petrological analysis and from Setraco Nigeria Limited, Imeke, Auchi, Edo State, for the geotechnical analysis. The sample was subjected to some geotechnical analysis having an average aggregate crushing value (ACV) of 31.2%, Los Angeles abrasion value (LAAV) of 29.6%, specific gravity (SG) of 2.67, (WA) water absorption of 0.1%, flakiness index (FI) of 20.9% and elongation index (EI) of 19.8%, respectively. The result of the geotechnical properties indicates that the granite is suitable for decoration, stone and road construction when compared with British Standard Institution (BSI) and Federal Ministry of Work (FMW) Standards. The granite has a petrographic average modal composition of plagioclase feldspar (15%), orthoclase feldspar (30%), biotite mica (22%), quartz (23%), and accessory mineral (10%). The result of the petrological and geotechnical analysis was compared and the relationship between them was established.

Key words: Petrography, geotechnical properties, British Standard Institute (BSI), Federal Ministry of Work (FMW), photomicrograph.

INTRODUCTION

Rocks are important sources of construction materials worldwide. Crushed or blasted quarry aggregates are commonly used as coarse aggregate in civil engineering construction works including road base construction, concrete mix for building and pavements. A construction aggregate is defined as being a hard, granular material which is suitable for use either on its own or with the addition of cement, lime or a bituminous binder in construction. Aggregates may be regarded as coarse (with a size greater than 5 mm), fine (a size less than 5 mm), and all-in-varieties (comprising both fine and coarse aggregates) (Dhir and Jackson, 1980). The properties of the aggregate depend on the properties of the parent rock, and the petrographic characteristics are a major determinant for proper utilization of the rock aggregate. Neville (2011) also noted that many properties of the aggregate such as, chemical and mineral composition, petrological characteristics, hardness, strength, specific gravity, physical and chemical stability, pore structure, and colour, depend entirely on properties of parent rock for the reason that all aggregate particles originally formed a part of a larger mass and may have been fragmented by natural process of weathering or artificially by crushing. Rock aggregates are used as concrete mix during construction, concrete consists of cement, fine aggregate (sand), coarse aggregate (gravel or crushed rock) and water in a certain prescribed proportion.

Muhammad et al. (2017) noted that coarse aggregates are the main component in concrete and responsible for the adequate strength of concrete. The suitability and utility potential of the rock aggregate for construction as concrete mix depend on the petrographic and geotechnical properties of the rock. Lindqvist et al. (2007) stated that the engineering properties of rocks can be accessed through their intrinsic properties, including texture and mineralogy.

Sajid and Arif (2014) concluded that variations in the mechanical properties of rocks are largely associated with differences in their textures and modal mineralogical compositions. In this study, the petrographic and engineering properties of coarse aggregates were carried out. Different aggregate size sourced from Setraco Nigeria limited quarry site in Imeke were selected, investigated and compared with National (FMW) and International standards (BSI) to determine the utility potential of the granite (rock) in Southwestern Nigeria Basement Complex in Imeke, hence the relationship between the petrography and geotechnical properties was established.

Location, geomorphology, and geologic setting of the study area

Imeke is located in Estako West Local Government Area of Edo State, Southwestern Nigeria. It lies between Latitudes 7° 8' 21" N and 7° 4' 0" N and Longitude 6° 14' 18.3" E and 6° 16' 0" E (Figure 1). The area is naturally endowed with rocks attracting granite quarry investors. Ojeifo et al. (2013) identify the area to be situated in the humid tropical region of Nigeria, which is characterized by wet and dry season. The vegetation is that of the Guinea Savanna, there is no well-defined direction of drainage (surface run off). The surface granite rocks often obstructing drainage in the area and the elevation above mean sea level is about 214 m.

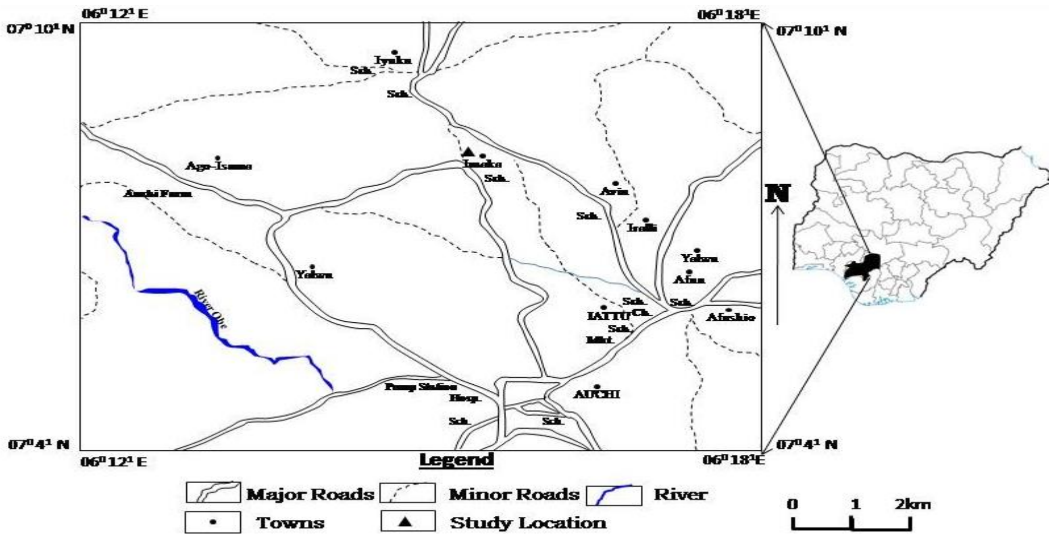

Figure 1. Location map of the study area in Edo State, SW Nigeria.

The Basement Complex forms a part of the Pan-African mobile belt and lies between West African and Congo Cratons, and south of the Tuareg Shield (Black, 1980). The granite rocks are part of the Southwestern Precambrian Basement Complex of Nigeria and shows evidence of polyphase deformation with the plutonic episode of the Pan African event being the most pervasive (Rahaman 1998). Sedimentary and Crystalline Basement Complex rocks are in occurrence in Imeke. This is associated with a Cretaceous sandstone deposits belonging to the Lokoja-Basange Formation. In Imeke, an extensive igneous rocks (Granite and Pegmatite), whose surface expression is circular to elliptical is in occurrence (Figure 3).

MATERIALS AND METHODS

Fresh samples were taken with the aid of a sledge hammer, from the study area for the petrographic analysis, and aggregate of already crushed sample of different coarse aggregate (1, ½, ¾ and 3/8 inches) were collected from the processing plant of Setraco Nigeria Limited Quarry, Imeke, Edo State for the geotechnical analysis.

Laboratory analysis

Petrography

Petrographic preparation of the rock was done at Geology laboratory in University of Ibadan. The process involves cutting of the rock into small rectangular pellet of 3 mm by a cutoff saw, and it is mounted on a glass slide using araldite. The optical study of the rock was done at Geology laboratory in Delta State University. The rock slide was studied under a petrological microscope (Leica DMRX Model) to determine the physical and optical properties of the mineral in both plane polarized light and cross nikols, thereby inferring the modal composition of each mineral present. Photomicrographs of important sections were taken by the combined use of the petrographic microscope and digital camera.

Geotechnical

The geotechnical properties of the rock sample such as the aggregate crushing value, Los Angeles abrasion value, flakiness index, elongation index, specific gravity and water absorption test were carried out at Julius Berger Nigeria Limited laboratory, Port-Harcourt, River State, Nigeria, using aggregate of already crushed sample of different coarse aggregate sizes (1, ½, ¾ and 3/8 inches) from the quarry. The elongation and flakiness indexes test was carried out to determine the particle shape of the aggregate and each particle shape being preferred under specific conditions; the Aggregate crushing value (ACV) was carried out to determine the percentage of wearing due to static load, and to give a relative measure of the resistance of an aggregate crushing under gradually applied compressive load and the Los Angeles Abrasion test (LAAV) was carried out to determine the percentage of wearing due to repetitive load. The water absorption and specific gravity tests were carried out to determine the relative density (that is, specific gravity of all these tests were carried out adopting the standard procedures specified by BS 812, 1990.

RESULTS AND DISCUSSION

Petrography

The petrographic study of the rock includes megascopic and microscopic description.

Megascopic description (Hand specimen)

The granite is dominantly composed of alumino-silicates minerals, although light and dark colored minerals were identified, the dark coloured mineral is less than 33%, hence the rock is leucocratic in terms of color index. Pink, white and dark colours were prominent; the bulk essential mineral composition of the granite observable is quartz, feldspars and mica. The rock is an intrusive igneous rock with Holocrystalline texture, composed of medium grained size and the grain shape is Subhedral (Figure 2). The grain sizes are visible to the naked eyes, that is, they are phaneritic. The crystals of the mineral constituent are Equigranular and they are also interlocked.

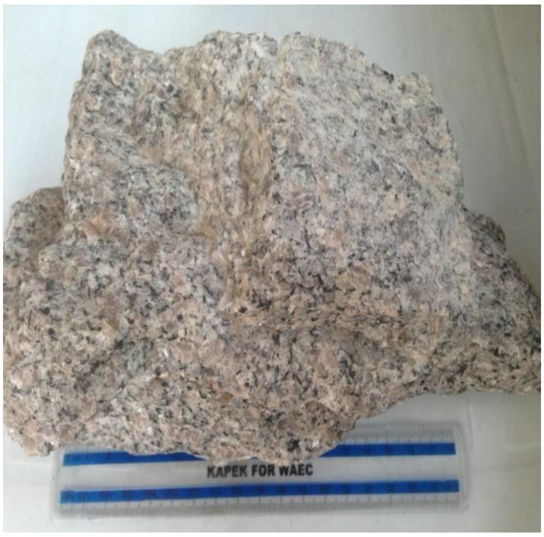

Figure 2. Hand specimen of the granite in the study area.

Figure 3. Granite outcrop around Imeke.

Microscopic description (Thin section)

The prepared thin section was examined and studied under plane polarized light (PPL) and cross polarized light (XPL). Photomicrographs of five important sections (L1-L5) were analyzed from the thin section (Table 1). The minerals are recognized in plane polarized light view by lack of alteration and in cross polarized light view by their interference colour (Mackenzie et al., 1982).

Table 1. Estimated modal composition of the granitic rock of the study area (Photomicrograph L1-L5).

Mineral	Petrographic study of the rock (%)				
	L1	L2	L3	L4	L5
Orthoclase feldspar	20	29	27	31	40
Plagioclase feldspar	10	15	13	16	20
Quartz	14	28	17	30	23
Biotite mica	35	22	23	13	15
Accessory minerals	21	6	20	10	2

In the thin section (Figures 4 to 8), the mineral Quartz, Orthoclase feldspar, Plagioclase feldspar, and Biotite mica were the major rock forming minerals based on their various characteristics. The quartz is colourless under PPL, with low relief, pleochroism is absent and its grain shape is anhedral. It has an undulose (wavy) extinction when the stage is rotated and forms intergrowth with feldspar and biotite at view L1, L3 and L5 which is visible under XPL. Orthoclase and Plagioclase feldspars were distinguished by their cloudy pale brown appearance under PPL, with low relief, pleochroism is also absent and the grain size is anhedral. Orthoclase feldspar was identified by their microcline twinning which occurs as cross hatched twinning while the Plagioclase feldspar is identified by albite twinning which gives a series of fine lamellae under XPL; they both have parallel 'a' extinction. The biotite Mica is brownish in colour and stands out with high relief, showing pleochroism under PPL, it shows a platy grain shape, with one directional cleavage. The biotite Mica has an oblique extinction under XPL. Generally, other properties such as zoning, alteration and inclusions are absent. The average modal composition in percentage includes: orthoclase feldspar 30%, plagioclase feldspar 15%, quartz 23%, biotite mica 21%, and accessory minerals 11% (Table 2).

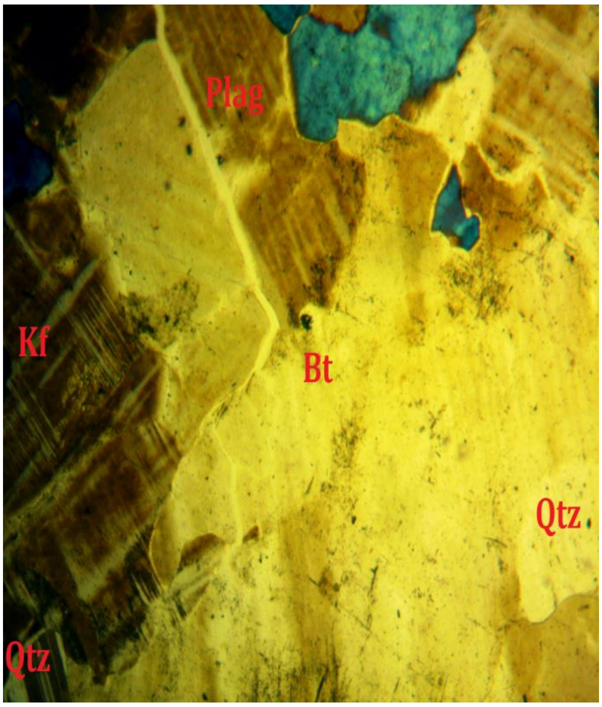

Figure 4. Photomicrograph of the sample under cross polarized light-L2. Bt= Biotite, Qtz=Quartz, Kf=Orthoclase feldspar, Plag=Plagioclase feldspar; magnification:×60.

Geotechnical

The result of granite aggregate was established with specifications and permissible limit according to British Standard (BSI) 1990 and Federal Ministry of Work Nigeria revised 1997 (FMW) 2013 Standard of coarse aggregate for concrete in any construction work.

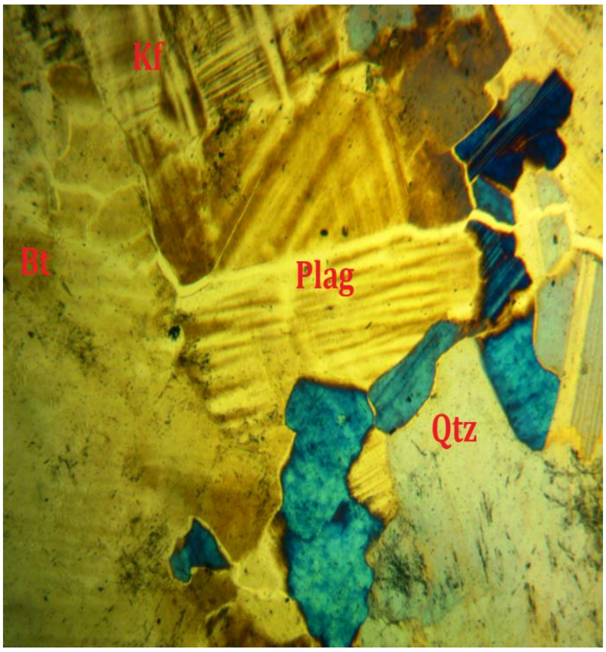

Figure 5. Photomicrograph of the sample under cross polarized light-L3. Bt=Biotite, Qtz=Quartz, Kf=Orthoclase feldspar, Plag=Plagioclase feldspar; magnification:×60.

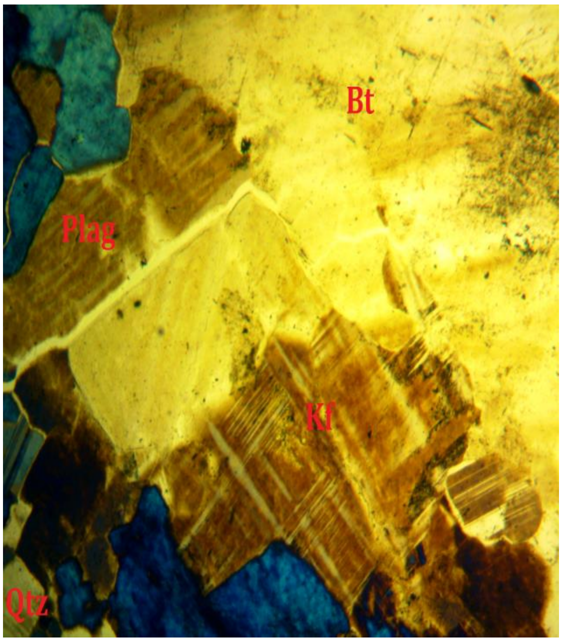

Figure 7. Photomicrograph of the sample under cross polarized light-L1. Bt=Biotite, Qtz=Quartz, Kf=Orthoclase feldspar, Plag=Plagioclase feldspar; magnification:×60.

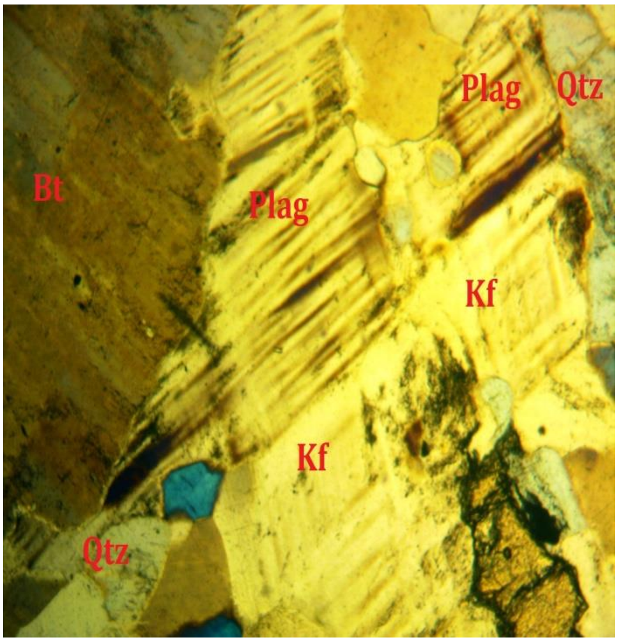

Figure 6. Photomicrograph of the sample under cross polarized light-L5. Bt=Biotite, Qtz=Quartz, Kf=Orthoclase feldspar, Plag=Plagioclase feldspar; magnification:×60.

Aggregate crushing value (ACV)

On the test result (Table 3), the average aggregate crushing value of granite rock is 31.2%. The BSI 1990 and FMW 2013 specified maximum aggregate crushing value for any construction work is 30% permissive limit. The granite exceeds the 30% permissive limit on British and Federal Ministry of Works Standard, but it can still be utilized for construction. To properly utilize the granite in Imeke, it is advisable that when this aggregate is used for construction, more asphaltic bituminous should be used (Jethro et al., 2014).

Los Angeles abrasion value (LAAV)

The result for Los Angeles abrasion test of granite is 29.6% (Table 3). According to British standard, Los Angeles abrasion value should not exceed 35%. The Los Angeles abrasion test of granite in Imeke is within the permissive limit for any construction work. Rock materials with aggregate abrasion values below 30% are regarded as strong and can be used for bituminous mixes (Omowumi, 2019). The granite also has a low LAAV and is useful and suitable for bituminous mixes for road stone construction and decoration for buildings and tiles making (Jethro et al., 2014).

Water absorption

Water absorption of an aggregate is usually accepted as a measure of its porosity. Porosity and water absorption affect the water-cement ratio and the workability of concrete for construction purposes (Indira et al., 2015). The average water absorption test result of granite is

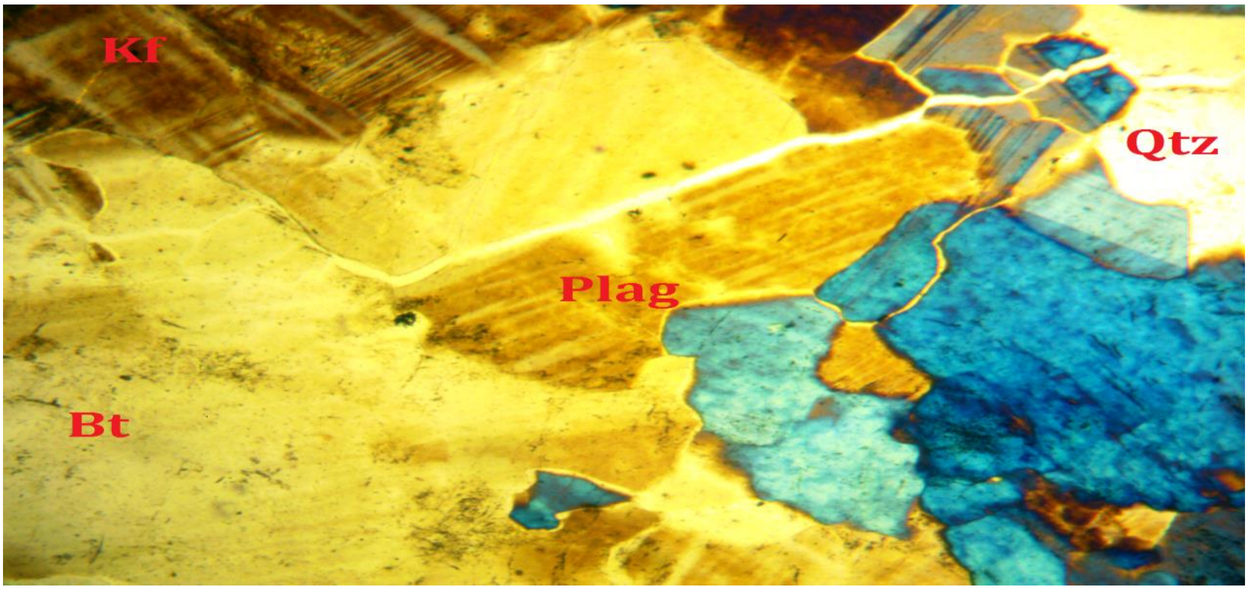

Figure 8. Photomicrograph of the sample under cross polarized light-L3. Bt=Biotite, Qtz=Quartz, Kf=Orthoclase feldspar, Plag=Plagioclase feldspar; magnification:×60.

Table 2. Average modal composition of the granite.

Mineral	Petrographic study of the rock (%)
Orthoclase feldspar	30
Plagioclase feldspar	15
Quartz	23
Biotite mica	22
Accessory minerals	11

0.1% (Table 3). According to the specification of British standard BSI 1990, water absorption value should not be less than 0.3%. The analyzed aggregate of granite is 0.1% which is within the permissive limit of 0.3% by BSI 1990. Sajid and Arif (2014) reported that granites with greater construction strength possess lower water absorption value. The granite in Imeke has a perfect low water absorption value which makes it useful for any construction work.

Specific gravity

This is the property that impacts strength and durability to concrete. The higher the specific gravity, the stronger the aggregates (Omowumi, 2019). The average result for specific gravity of granite is 2.67 (Table 3), though the permissible limit of specific gravity is not specified. Kosmatka et al. (2003) agreed that most natural aggregates have relative density between 2.4 and 2.9 with corresponding particle mass density of 2400 and 2900 kg/m^3. Shetty (2005) reported that rock aggregate still falls within normal weight aggregate as average specific gravity of rocks vary from 2.6 to 2.8. The granite is within the permissible limit as recorded by Shetty (2005). The granite in Imeke can be utilized in heavy construction work, and as mix for cement paste, because the smaller the amount of pores, the higher the specific gravity which is needed for construction.

Flakiness and elongation indexes

The average result of flakiness index is 20.9% and that of elongation index is 19.8%. The British standard 1990 specification limit for flakiness index and elongation index is 40% max while the Federal Ministry of Works (2013) specification limit is 30% (Table 3). The flakiness and elongation indexes are within the permissive limit of concrete construction both on British standard and Federal Ministry of Works Nigeria, thus, the

Table 3. Test and permissible limit of some geotechnical properties of the granite coarse aggregate in Imeke when compared with BSI and FMW Standards.

Geotechnical test	Result (%)	Average result (%)	Permissible limits	Standards
Aggregate crushing value (ACV)	30.8 31.6	31.2	30% max	BSI 1990 and FMW 2013
Los Angeles abrasion value (LAAV)	29.6	29.6	35% max	BSI 1990
Specific gravity	2.68 2.66 2.67 2.66	2.67	Some handbooks give a useful range of 2.5-2.9 SG	Not specified
Water absorption	0.1 0.2 0.1 0.1	0.1	0.3% max	BSI 1990
Elongation index	0.0 14.8 15.0 46.3 21.7 25.7	19.8	30%/40% max	BSI 1990 and FMW 2013
Flakiness index	19.6 42.7 14.7 4.8 18.5 16.3	20.9	40%/30% max	BSI 1990 and FMW 2013

granite in Imeke can be on concrete as bituminous mix for road construction, and this may impair a long-term durability.

The relationship between the petrography and geotechnical properties of the Imeke granite

The petrographic characteristics must be correctly known to understand the performance of the rocks to be used under specific environmental conditions and to avoid inaccurate applications (Sousa, 2012).

The average modal composition of the orthoclase feldspar is 30% and that of the plagioclase feldspar is 15% (Table 2). It is important to note that feldspars are unstable in certain environmental conditions, as it can undergo weathering easily. Ayfer (2018) stated that feldspar and feldspathoids which are found in the composition of many rocks can be very dangerous for engineering work and the higher the percentage of feldspar, the higher the ACV and LAAV. This is because they can be decomposed by some environmental factors, thereby leading to road failure or collapse of any engineering work as weathering takes place simultaneously.

The total feldspar content is 45%; these caused an increase in the ACV of the granite to 31.2% above the BSI and FMW standards (Table 2) which is not advisable to be used in any engineering work. In such cases, more asphaltic bituminous should be added to the aggregate to decrease the ACV (Jethro et al., 2014).

The average modal composition of quartz is 23% (Table 2). Quartz has good engineering properties as it is very stable in any environmental conditions and it does not undergo weathering easily. High concentration of physically strong minerals (quartz) adds strength to rocks, making it durable for any engineering work. Ajagbe et al. (2015), also state the higher the percentage of quartz, the lower the ACV and LAAV. The percentage of quartz caused a decrease in the LAAC especially to about 29.6% which is below BSI and FMW standards (Table 3). This made the rock suitable and durable to resist crushing under compressive load for any engineering work.

The average modal composition is biotite mica 22% (Table 2). The composition of the mica (flaky mineral) contributed to the flakiness and elongation indexes of 20.9 and 19.8%, respectively (Table 3), which fall perfectly within the permissive limit of BSI and FMW. Flaky mineral also is not too stable in specific environmental conditions, but in this case, it is not dominant in the rock, hence rock can be utilized for any construction work.

The mineral grains as observed in the thin section (Figures 4 to 8) are interlocked due to crystallization from molten state and this which decreases the water absorption rate and in turn decreases the pore spaces in the granite. This petrological property of the granite enhances the strength and durability of the granite when used for any engineering work.

Ajagbe et al. (2015) reported that low water absorption rate gives low ACV and LAAC, which is an indication of higher strength.

Amuda et al. (2014) also added that, in the relationship between specific gravity and water absorption, aggregate of high porosity exhibits high water absorption rate and low specific gravity while intact aggregate has low water absorption rate and high specific gravity. The petrographic analysis infer that the rock is medium grained in texture and rocks that are fine to medium grained tend to yield better technical properties than coarse grained rock such as low LAAC and ACV (Ajagbe et al., 2015). The relationship between the petrography and geotechnical properties of the granite shows that it can be utilized for concrete mix in any engineering construction work.

Conclusion

The petrographic and geotechnical property result of the granitic rock obtained from Imeke, Edo State, reveals that the granite can be properly utilized as its falls within the specified standard; also none of the petrographic and geotechnical parameters independently control the strength and utilization potential of the granite rock, thus the relationship of the petrography and geotechnical properties shows that the granite rock in Imeke can be utilized as concrete mix for normal construction base course, like road construction, paving of wearing surfaces, concrete embankment and foundation building.

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