EVALUATION OF THE EFFECT OF PHYSICAL AND MINERALOGICAL CHARACTERISTICS OF SOME ROCK TYPES ON THEIR MECHANICAL PROPERTIES (A CASE STUDY OF EKITI, ONDO AND KWARA STATE)

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ABSTRACT

The research work studies the effect of physical and mineralogical characteristics of some rock types on their mechanical properties. Samples of rock were collected from six locations, Egbejila and Odore (Kwara State), Ijare and Itaogbolu (Ondo State), Iyin and Awo road, (Ekiti State), in Nigeria. The physical properties (hardness, density and specific gravity), mineralogical properties (X-Ray Diffraction (XRD) and mechanical properties (Uniaxial Compressive Strength (UCS); Point Load Strength and Brittleness) were determined in the laboratory using the required international standard and the equipment used are Impact Testing Machine, Compression Testing machine, Aggregate Impact Value (AIV) machine, Aggregate Crushing Value (ACV) machine, Global Positioning System (GPS), Cut-off Saw Machine, and Petrographic Microscope. From the results of the investigation, it was observed that the concentration of quartz and other minerals as indicated by the X-Ray Diffraction (XRD) have influence on the highest on the mechanical properties of the rocks under study. Ijare with the highest quartz content of 69.4% has the highest UCS of 174.4 MPa while Odore with the lowest quartz content of 33% has the lowest UCS of 120 MPa. Dominance of silica is range of 62.455% – 70.72%). The physical properties (hardness, density and specific gravity) were found to follow the same trend with the mineralogical properties in influencing the mechanical behaviour of rock, most especially the UCS. Denser and harder rock samples were found to have higher UCS. Conclusively, the physical and mineralogical properties of rock were found to correlate strongly with the mechanical properties.

Keyword: Physical, Mineralogical, Uniaxial Compressive Strength, Properties, X-ray Diffraction, Rock

Introduction

The study of the mechanical properties of rocks and their respective mineralogy characteristics are important in determining the rock strength and its capability from failure (Tugrul and Zarif, 1999). The properties of rock are influenced by the mineral composition, texture (grain size and shape). Fabric (arrangement of minerals and voids) and the weathering state (Irfan, 1996.) Mechanical properties of rock materials have a great influence on service like, reliability and resilience of the critical infrastructure research has shown that mechanical properties of rock materials are closely related to textural characterises (Ozturk, Nasuf and Kahraman, 2014). Texture characteristics of rock are influenced by the following six factors; mineral composition, size, shape and spatial distribution of mineral grains, porosity, and inherit micro crack (Liu, *et al*., 2004). Mechanical properties of rock are measured through laboratory mechanical test in terms of unconfined compressive strength, tensile strength, values and impact value. The minerals composition of rock materials can be determined from scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX) micro-analyser (Sun *el al.*, 2015). (Jethro, *et al*., 2012) observed that mineralogical compositions are one of the main properties controlling the rock strength. They added that the variation in quartz and plagioclase contents is the major factor affecting strength properties. These studies evaluate the effect of both physical and mineralogical characteristics on the mechanical properties within three (3) state selected locations in South-Western Nigeria. The mineralogical composition of aggregates also affects their crushing strength, hardness, elastic modulus and soundness, which in turn influence various properties of hardened concretes/mortar (Mehta and Monteiro, 2013). Aggregates can be classified as natural or artificial depending on their sources. Natural aggregates are obtained from quarries processing crushed rocks or form river beds while artificial aggregates are obtained from industrial by product such as blast furnace slag. Natural aggregates are most commonly obtained and are for Ethiopian construction sector since artificial aggregates are hardly produced in the country. It is an accepted fact that the physical and mechanical properties of aggregates are inherited from parent materials, while the properties of the parent material intern depend on its geological formation. Geologically rocks are classified into three major divisions based on their origin, namely igneous, sedimentary and metamorphic (Sidney, *et al*., 2003). It should be noted that physical properties do not only vary from rock to rock, rock location to rock location, but also within the same rock because of heterogeneous nature of rocks and various local geological condition. In addition to the direct properties of the rock and rock masses described above, we have to remember that the natural rock environment can also have a profound effect on the engineering. In general, this is basically governed by the location of engineering, whether a structure is being built in the surface or being created by excavation of the surface rock or is underground (Hoek and Brown, 1988). For the purpose of this research work, the influence of physical and mineralogical characteristics on mechanical properties of granite rock which makes it suitable for engineering application was investigated.

Materials and Methods

Rock samples were used for various tests required for this study.

Study Location

The study areas are located in Kwara States, Ondo and Ekiti, in the South-West region of Nigeria. The locations are as shown in Figures 1 while the locations and the respective coordinates are as shown in Table 1. A total of ten samples of about 5kg each were obtained from six locations for laboratory analysis, with each location having two representative samples. The samples collected are already crushed rock aggregates with sizes of one inch (32-70mm) and three-quarter inch (19-25mm). The description of each sample was based on location name as shown in Table 1.

Methods of Study

This research work is divided into two major aspects. Field work and laboratory work aspects. The field work involves the collection of samples used for the tests and the laboratory work encompasses all the tests carried out in the laboratory from thin section, aggregate crushing value, aggregate impact value, using the ISRM standard. The tests were carried out on different aggregate samples from six locations. The samples from each location was mixed together at the laboratory before being subjected to several tests at the Engineering Geology and Petrology workshop, Federal University of Technology Akure, Ondo State. The tests were carried out on accurate precision to avoid error of measurement, counting and inconsistency also it was in accordance to the standards suggested by ASTM (1986), BS (1990) and ISRM (1981).

Table 1: Location and Coordinates of Studied areas

S/N	LOCATION	STATE	COORDINATES
1.	Egbejila	KWARA	8˚24′43″ N; 004˚32′05.4″ E
2.	Odore	KWARA	8˚24′40.8″ N; 004˚32′02.7″ E
3.	Ijare	ONDO	7˚20′18″ N; 005˚10′10″ E
4.	Itaogbolu	ONDO	7˚21′31″ N; 5˚13′59″ E
5.	Iyin	EKITI	7˚39′30″ N; 5˚09′30″ E
6.	Awo Road, Iyin	EkITI	7˚39′01″ N; 5˚10′03″ E

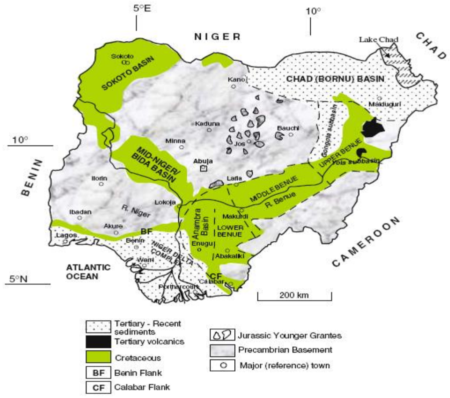

Figure 1: Geological map of Nigeria Showing the Major Rock suites (Obaje, 2009)

Determination of Mineral Composition

This is the laboratory preparation of a rock for use with a microscope. Modal analysis is the study of the dynamic properties of systems in the frequency domain i.e. it shows the frequency distribution of the various minerals that makes up the sample. Fresh samples were trimmed to fit on a glass slide, the trimmed surface is lapped on a glass plate using water and silicon carbide 600grits, this is done so as to have a very smooth surface for bonding with the glass slide; one surface of the glass slide is also lapped and made smooth for bonding with the sample. The sample is then bonded to the glass slide using epoxy A and B on a hot plate, this is allowed to bond for 24hrs, the sample is then trimmed to 50micron on the glass slide using the cut-off saw machine and later transferred to the lapping plate and lapped to 30micron using silicon carbide and water, at 30micron the slide is ready for study under the petrographic microscope. The mineral compositions were estimated by viewing the sections under a polarizing microscope in accordance to (ISRM, 1989). Photomicrographs of the sections are both in Plane Polarized Light (PPL) and Cross Polarized Light (XPL).The results of all thin section of each rock type were collated and the percentage abundance determined for each mineral. The relative abundance of the major and accessory minerals expressed in percentage is the modal analysis for the rock type. The equipment for determination of XRD is Pan Analytical Empyrean PANalytical Empyrean diffractometer was equipped with Pixel detector and fixed slits with Fe filtered Co-Kα radiation, procedure in accordance with (ASTM, 1992). Morphological and qualitative analyses of the samples were performed using high resolution Scanning Electron Microscopy equipped with Energy Dispersed X-ray facilities SEM-EDX in accordance with (ASTM, 1994).

Chemical Composition Determination

Absorption Spectrophotometer (AAS) would be used to determine percentage oxides of elements present in the sample as suggested by (ASTM, 2003). An atomic standard solution, each of the elements was prepared in flask for the determination of the element. Each standard solution was aspirated which the aspiratory tube of the AAS and a range of value were obtained. Appropriate wavelength setting, range setting, slit setting and adjustment were done before analyzing for each element. The test was carried out on these samples at the Petrology and Engineering laboratory of the School of Earth and Mineral Science at Federal University of Technology Akure.

Determination of Specific Gravity

The prepared test sample was placed in the wire basket and immersed in water at a temperature of 20°C with a cover of 50 mm of water above the top of the basket. All the procedure in accordance to (ISRM, 1989) was followed in the determination of the Specific Gravity by Equation 1.

$$Specific\ Gravity = \frac{A}{A-(B-C)}$$

Where,

A is the mass of the saturated surface-dry aggregate in air (g);

B is the apparent mass in water of the basket containing the sample of saturated aggregate (g); and C is the apparent mass in water of the empty basket (g).

Determination of Density

The specimen volume V was calculated from an average of several caliper readings for each dimension. The specimen was dried to constant mass at a temperature of 105°C and allowed to cool for 30 minutes in a desiccator and the mass M was determined. (ISRM, 1989) standard was used to determine the density.

Density was calculated using the following Equation 2.

$$Density\ (\rho) = \frac{M}{V}$$

Where,

M is the mass of the rock sample (Kg); and V is the volume of the sample (m^3)

Determination of Schmidt Rebound Hardness

This method involves the use of Schmidt Impact Hammer for the hardness determination of rocks in accordance to (ISRM, 1989). The test surface of test specimen was ensured to be smooth and flat over the area covered by the plunger. The area and the rock material beneath to a depth of 6 cm were also ensured to be free from rock cracks or any localized discontinuity. The bases of the various samples to be tested were placed on the flat surface to provide firm support. Twenty individual tests were conducted on each sample. Tests that caused cracking or any other visible failure were rejected. The plunger of the hammer was placed against the specimen and depressed into the hammer by pushing the hammer against the specimen. Energy stored in a spring which automatically released at a prescribed energy level and impacts a mass against the plunger. The height of rebound of the mass was measured on a scale as hardness and. The Type L hammer was used with this suggested method. The measured test values for the sample were arranged in descending order. The lower 50% of the values should be discarded and the average obtained of the upper 50% values. The average value was multiplied by the correction factor to obtain the Schmidt Rebound Hardness.

Determination of Uniaxial Compressive Strength

A Riedligen testing machine capable of loading up 3000 kN at rate conforming to the (ISRM, 1989) requirement was used. UCS of the rocks were calculated using Equation 3

$$\sigma_c = \frac{P_{max}}{A} = \frac{P_{max}}{\pi\left(\frac{D}{2}\right)^2}$$

Where,

σ_c is Compressive Strength (MPa); P_{max} is the Maximum Load (kN); A is the cross-sectional Area (mm^2);and D is the diameter (mm)

Determination of Point Load Strength

The Point Load Strength test is intended as an index test for the strength classification of rock materials. It may also be used to predict other strength parameters with which it is correlated, for example uniaxial tensile and compressive strength. The test procedure is in accordance with (ISRM, 1989).

The size-correction Point Load Strength Index $I_s(50)$ is unnecessary because the diametral test were all conducted at 2 D = 50 mm. Point Load (I_s) was calculated using equation 4.

$$I_s = \frac{P}{D_e^2}$$

4

Where,

I_s is Point Load Strength and P is the Failure Load in kN; and$D_e^2$is the equivalent core diameter given by $D_e^2 = D^2$ (for diametral test)

Determination of Tensile Strength

Tensile strength was calculated on the block samples prepared using point load tester. This test was carried out accordance with (ISRM, 1989) and (ASTM, 2001). The units of the point load index are MPa and whereas the test is considered to cause tensile failure it can be converted to compressive strength *(Co)* Equation 5**:**

$$C_O = 30\ Is_{(50)}$$

The general relationship between tensile strength *(T_o)*, the point load strength *(I_s)* and compressive strength *(C_o)* is represented by Equation 6:

$$C_O = 20T_o = 30\ Is_{(50)}$$

3

Determination of Brittleness Value

The determination of brittle fracture is largely empirical. Usually, brittle fracture measures the relative susceptibility of a material to two competing mechanical responses, deformation and fracture; ductile-brittle transition. The used brittle fracture concepts in this study are given below.

(a). The determination of brittle fracture from tensile strength and uniaxial compressive strength was calculated using Equation 7: (Hucka, and Das, 1974).

$$B_1 = \frac{\sigma_c}{\sigma_t}$$

(b). The determination of brittle fractures from tensile strength and uniaxial compressive strength was calculated using Equation 8: (Hucka, and Das, 1974).

$$B_2 = \frac{\sigma_c - \sigma_t}{\sigma_c + \sigma_t}$$

(c). The determination of brittle fracture from the area under the line of $\sigma_c - \sigma_t$ graph, was calculated using Equation 9: (Altindag, 2002).

$$B_3 = \frac{\sigma_c \, x \, \sigma_t}{2}$$

(d). The determination of brittleness concept, B_4 is given by using Equation 10: (Yarali, and Soyer, 2011).

$$B_4 = (\sigma_c \, x \, \sigma_t)^{0.72}$$

Where:

B_1, B_2 $and B_3$ and B_4 $denotes$ are $brittle$ $fracture, \sigma_c$ is $compressi$
and σ_t is $Tensile$ $Strength$ (MPa).

Determination of brittle fracture in rock is very important; gneiss sample are selected in such a way that its average strength will represent the strength of the entire rock in-situ. The act of properly selecting such a sample is called sampling.

Results and Discussion 7

Mineralogical Composition

The mineralogical composition of the selected rocks is as shown in Table 2. The results show that the percentage of quartz, plagioclase and biotite which are predominant minerals are 34%, 17% and 22% for Egbejila; 15%, 25% and 15% for Odore; 33%, 17% and 21% for Ijare; 69.4%, 4.1% and 9.4% for Itogbolu; and 45.6%, 13.1% and 18.1% for Iyin 42.6%, 42.7%, 7.4% and Awo Road Iyin 42.6%, 42.7% and 10.8% respectively. Table 3 shows the average grain sizes of the predominant minerals in the selected rocks under study. Table 4 shows the silica contents of the rock samples. The silica contents are 62.45%, 63.21%, 70.72%, 68.86%, 70.21 and 60.28% respectively for Egbejila, Odore, Ijare, Itogbolu, Iyin, and Awo Road.

Table 2: Mineralogical Composition of Selected Rocks in South-Western Nigeria

Rock type	Quartz	Microcline	Plagioclase	Biotite	Hornblende	Orthoclase	Muscovite	Opaque	Pyroxene	Total
Egbejila	**34**	**17**	**22**	**9**	**14**	**-**	**-**	**4**	**-**	**100**
Odore	**33**	**17**	**21**	**9**	**15**	**-**	**-**	**4**	**-**	**100**
Ijare	**69.4**	**4.1**	**9.4**	**14.1**	**-**	**-**	**0.9**	**0.9**	**-**	**98.8**
Itaogbolu	**45.6**	**13.1**	**18.1**	**16.3**	**-**	**-**	**4.7**	**-**	**-**	**97.8**
Iyin	**42.6**	**42.7**	**-**	**7.4**	**-**	**6.2**	**0.2**	**-**	**-**	**99.1**
Awo Road, Iyin	**43.4**	**40.1**	**-**	**10.8**	**0.7**	**-**	**3.6**	**-**	**3.7**	**98.4**

Table 3: Average Grain Size of Major Minerals

Rock Type	Quartz (mm)	Plagioclase (mm)	Biotite (mm)
Egbejila	3.0	2.00 – 3.00	0.1 – 1.0
Odore	2.5	2.00 – 3.50	0.1 – 1.0
Ijare	2.5 – 3.5	2.50	0.1 – 0.8
Itaogbolu	2.5	2.00	0.6
Iyin	2.8	2.00 - 2.20	0.3
Awo Road, Iyin	2.5 – 3.0	2.00 - 2.50	0.4

Chemical Composition

The chemical composition (gneiss) of the three study areas was presented in Table 4 showing their respective elements.

Table 4: Chemical Composition of the Gneiss Samples

S/N	Compound	Element	Egbejila Conc. (%)	Odore Conc. (%)	Ijare Conc. (%)	Itaogbolu Conc. (%)	Iyin Conc. (%)	Awo Road Conc. (%)
1	SiO_2	Si	63.21	62.45	70.72	70.21	68.86	69.28
2	TiO_2	Ti	0.32	0.41	0.55	0.45	0.62	0.56
3	Al_2O_3	Al	15.31	15.37	16.32	16.79	17.32	16.82
4	MnO	Mn	0.05	0.05	0.05	0.06	0.52	0.05
5	Fe_2O_3	Fe	5.20	5.34	1.86	1.76	4.63	1.48
6	FeO	Fe	3.10	3.15	0.00	0.00	0.00	0.00
7	P_2O_5	P	0.14	0.14	0.14	0.17	0.11	0.13
8	MgO	Mg	3.11	3.12	1.32	1.62	1.21	1.44
9	CaO	Ca	2.35	2.46	1.05	1.08	0.10	1.11
10	Na_2O	Na	3.51	3.65	3.16	3.26	2.60	4.13
11	K_2O	K	3.70	3.86	3.84	4.06	3.18	4.37

Table 5: Silica Content of Selected Rocks in South Western Nigeria

Rock Type	Silica Content (%)
Egbejila	63.21
Odore	62.45
Ijare	70.72
Itaogbolu	70.21
Iyin	68.86
Awo Road, Iyin	69.28

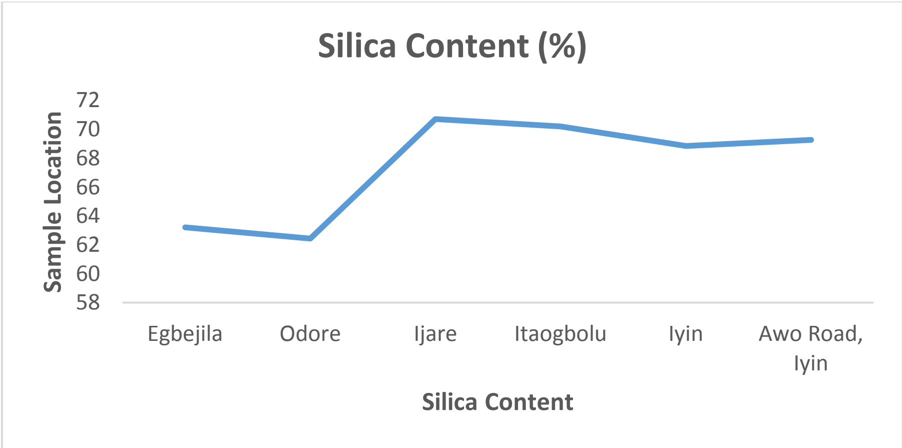

Fig. 2: Silica Content (%)

Fig. 2 and Table 5 show that the silica content granite rock Odore has the highest value of 70.72%, Ijare has the value of 70.21%, Itaogbolu has the value of 68.86%, Awo Road has value of 69.28 % and Egbejila has the least value of 62.45 %.

Physical Properties

The results of the physical properties test are as shown in Table 6 – Table 10. The Hardness, Specific gravity and Density results are presented in Table 6 – Table 10. The Schmidt rebound value result is presented in Table 6. The strength parameter of Schmidt hammer rebounds and their respective strength classifications are presented in Tables 6.

Table 6: Rebound Value of Upper 50%

S/N	Egbejila	Odore	Ijare	Itaogbolu	Iyin	Awo Road
1	58	52	55	53	55	54
2	56	52	53	55	56	54
3	56	52	50	54	58	52
4	54	50	52	51	54	52
5	54	50	51	53	57	52
6	50	50	50	52	54	50
7	50	50	51	55	55	50
8	50	50	49	54	52	50
9	48	48	50	55	51	48
10	48	48	49	51	54	48
Average	**52.4**	**50.2**	**51.0**	**53.3**	**54.6**	**51.0**

From Table 6, the granite rock average Rebound value of Iyin has the highest value of 54.6, Itaogbolu has the value of 53.3, Ijare has the value of 51.0, Awo Road has value of 51.0 and Egbejila 52.4 and Odore has the least value of 50.2.

Table 7 presents the result of the specific gravity test carried out on rock samples collected from the three locations.

Table 7: The Results of the Specific Gravity (Gneiss Samples)

Sample	Egbejila	Odore	Ijare	Itaogbolu	Iyin	Awo Road
1	2.40	2.60	2.63	2.76	2.81	3.30
2	3.30	2.65	2.37	2.58	2.66	2.50
3	2.50	2.33	2.81	3.31	2.70	2.75
4	2.23	2.63	3.11	2.30	2.67	2.55
5	2.54	3.22	2.39	2.41	2.44	2.45
Average	**2.594**	**2.686**	**2.655**	**2.672**	**2.656**	**2.710**

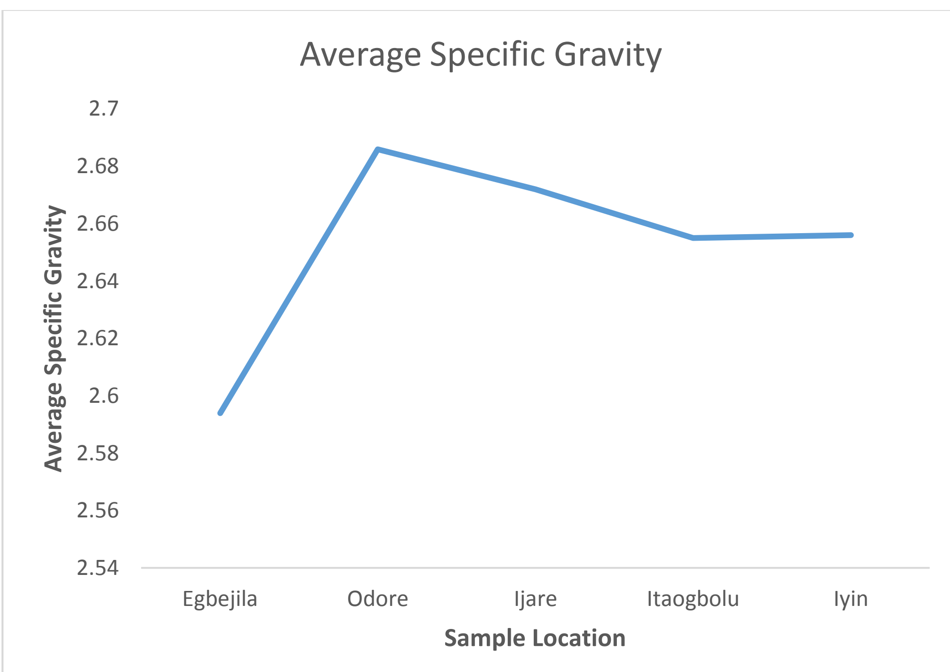

Fig. 3: Average Specific Gravity

Table 7, the specific gravity result shows that Awo has the highest specific gravity of 2.710, Itaogbolu has the specific gravity of 2.672, Odore has the specific gravity of 2.686, and Ijare also has specific gravity of 2.655, Iyin road has the specific gravity of 2.656 and Egbejila has the least specific gravity of 2.594.

Table 8: Results of Rebound Value Conversion

Location	Rebound Value	Density (kN/m^3)	UCS (MPa)
Egbejila	52.4	24.71	125
Odore	50.2	27.04	120
Ijare	51.0	27.43	145
Itaogbolu	53.3	26.33	140
Iyin	54.6	25.96	137
Awo Road	51.0	25.78	139

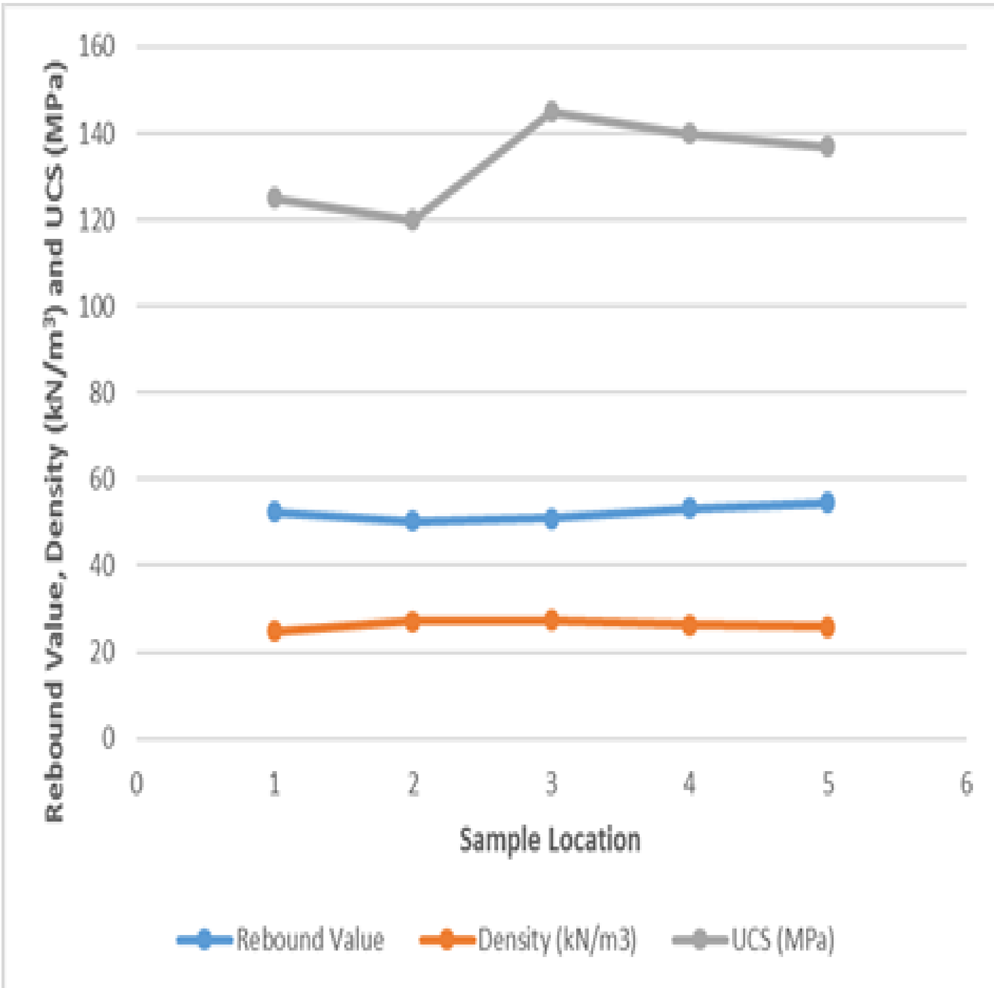

Fig 4: Round Value, Density (kN/m^3) and UCS (MPa)

Table 8 presents the results of the Schmidt rebound hardness value and equivalent compressive strength. The results were arranged in descending of values. The lower 50% of the value were discarded and the average obtained of the upper 50% values for each of the rock samples as Suggested by (ISRM, 1985 and ISRM, 1981). The average of the upper half is taken to represent the average rebound value of their respective hardness.

Table 9: Physical Properties of the Different Rock Samples

Location	Rock Type	Schmidt Hardness	Specific Gravity (Kg/m^3)	Density (Kg/m^3)

Egbejila	Gneiss	52.4	2.594	2.651
Odore	Gneiss	50.2	2.686	2.704
Ijare	Biotite Granite	51.0	2.672	2.743
Itaogbolu	Biotite Granite	53.3	2.655	2.712
Iyin	Granite Gneiss	54.6	2.656	2.703
Awo Road, Iyin	Granodiorite Gnesis	51.0	2.710	2.632

The results of the physical properties tests are as shown in Table 9. The Specific gravity and Density results are 2.594 Kg/m^3 and 2.651 Kg/m^3 for Egbejila; 2.704 Kg/m^3 and 2.686 Kg/m^3 for Odore; 2.672 Kg/m^3 and 2.743 Kg/m^3 for Ijare; 2.655 Kg/m^3 and 2.712 Kg/m^3 for Itagbolu; 2.656 Kg/m^3 and 2.703 Kg/m^3 for Iyin and 2.710 Kg/m^3 and 2.632 Kg/m^3 for Awo Road.

Results of Mechanical Properties

Table 10 shows the mechanical properties of the selected rocks. The results of Point Load Ijare has the highest value 12.34 MPa; Egbejila has point load value of 10.31 MPa, Awo has point load value of 10.56, Odere point load value is 11.98 MPa, Itaogbolu point load value is 10.33 and Iyin has the lowest value of 9.89 MPa.

Point Load Index Test

The results of the point load index are presented in Table 10.

Table 10: Point Load Test for the Locations

Sample	D_1 (mm)	D_2 (mm)	Load (kN)	$D_{AVE.}$ (mm)	D^2 (mm^2)	Point Load (I_s) N/mm^2	Point Load (I_s) MPa
Egbejila	65.8	67.1	45.5	66.45	4415.18	10.31	10.31
Odore	69.6	71.6	59.7	70.59	4983.28	11.98	11.98
Ijare	67.35	72.27	60.1	69.80	4872.04	12.34	12.34
Itaogbolu	79.64	70.52	58.2	75.06	5634.07	10.33	10.33
Iyin	77.4	75.74	57.98	76.57	5862.49	9.89	9.89
Awo Road	71.2	68.1	51.2	69.65	4848.72	10.56	10.56

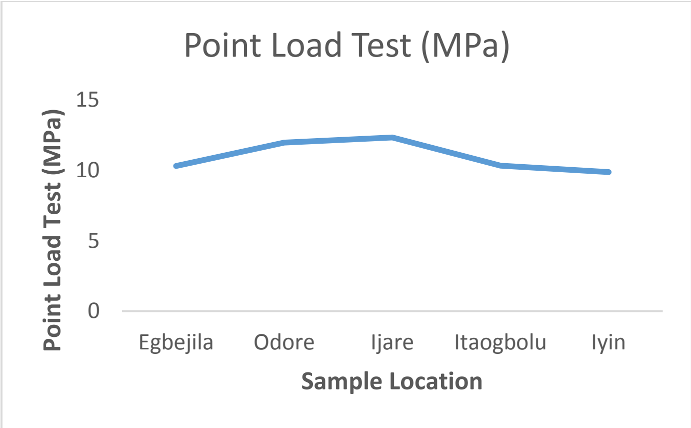

Fig. 5: Point Load Test

Rock Brittleness Index Results

The results obtained from the computation of rock brittleness index are presented in Table 11.

Table 11: Rock Brittleness Index Results

Code	Egbejila	Odore	Ijare	Itaogbolu	Iyin	Awo Road
B_1	23.9	24.1	23.9	24.1	23.3	23.1
B_2	0.92	0.92	0.92	0.92	0.92	0.92
B_3	325.63	299.40	438.63	408.10	402.01	418.39
B_4	106.15	99.92	131.54	124.88	123.55	127.14
B_I	**23.9**	**24.1**	**23.9**	**24.1**	**23.3**	**23.1**

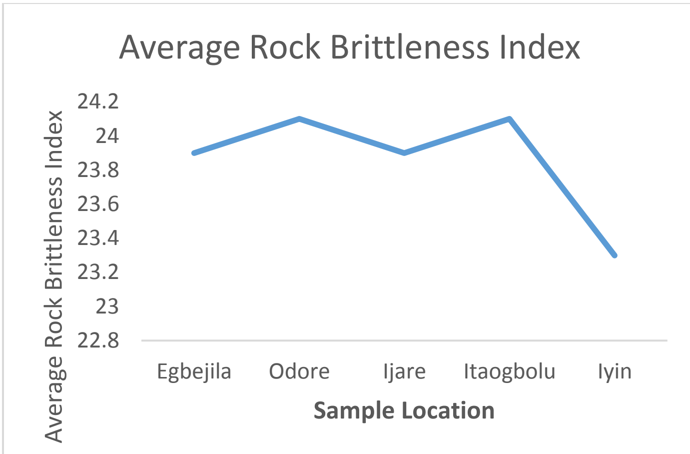

Fig. 6 Average Rock Brittleness Index

Table 12: Mechanical Properties of the Different Rock Samples

Location	Rock Type	Compressive Strength (MPa)	Point Load (MPa)	Tensile Strength (MPa)	Brittleness Value (%)	Rock Classification
Egbejila	Gneiss	125	10.31	5.21	23.9	Very High Strength
Odore	Gneiss	120	11.98	4.99	24.1	Very High Strength
Ijare	Biotite Granite	145	12.34	6.05	23.9	Very High Strength
Itaogbolu	Biotite Granite	140	10.33	5.83	24.1	Very High Strength
Iyin	Granite Gneiss	137	9.89	5.87	23.3	Very High Strength
Awo Road	Granodiorite Gnesis	139	10.56	6.02	23.1	Very High Strength

Table 12 shows the result of the summaries of Uniaxial Compressive Strength, Tensile strength and Brittleness are 125 MPa, 5.21 MPa and 23.9 % for Egbejila; 120 MPa, 4.99 MPa and 24.1 % for Odore; 145 MPa, 6.05 MPa and 23.9 % for Ijare; 137 MPa, 5.83 MPa and 24.1 % for Itaogbolu; 139 MPa, 5.83 MPa and 23.3 % for Iyin and 140 MPa, 6.02 MPa and 23.1 % for Awo Road.

Relationship between Physical, Mineralogy and Mechanical Characteristics of Rocks

Quartz percentage and Physical Properties

The relationship between the quartz percentage and physical characteristics are as shown in Fig. 7 – 9. It was observed that the linear relationship exists between Quartz percentage and Hardness, Specific Gravity and Density. The equations of the relationship are expressed in Equation 11 – 13.

$$Q_c = 4.2819SH - 185.62 \quad 11$$

$$Q_c = 286.86SG - 808.14 \quad 12$$

$$Q_c = 10.275\rho - 222.89 \quad 13$$

Where:

Q_c *is Quartz content* (%); *SH is Schmidt Hardness*; *SG is and* ρ *is the Density* $(\frac{Kg}{m^3})$

Quartz percentage and Mechanical Properties

The relationship between the quartz percentage and physical characteristics are as shown in Fig. 10 – 12. It was observed that the equations connection UCS, Point Load and Brittleness with Quartz percentage are linear. The equations of the relationship are expressed in Equation 14 – 16.

$Q_c = 1.1243\sigma_c - 106.32$ 14

$Q_c = 11.14PL - 76.742$ 15

$Q_c = -37.068Br + 925.11$ 16

Where:

Q_c *is Quartz content* (%); σ_c *is UCS* (MPa); *PL is Point Load* (MPa); *Br is Brittleness*(%)

Silica percentage and Physical Properties

The relationship between the silica percentage and physical characteristics are as shown in Fig. 13 – 15. It was observed that the linear relationship exists between silica percentage and Hardness, Specific Gravity and Density. The equation of the relationship is expressed in Equation 17 – 19.

$S_c = 3.13025SH + 295.88$

$S_c = 73.74SG + 128.94$ 18

$S_c = -2.4325\rho + 131.61$ 19

Where:

S_c *is Silica content* (%); *SH is Schmidt Hardness*; *SG is Specific G*

ρ *is the Density* $(\frac{g}{m^3})$

Silica percentage and Mechanical Properties

The relationship between the silica percentage and physical characteristics are as shown in Fig.16 – 18. It was observed that the linear relationship exists between silica percentage and Hardness, Specific Gravity and Density. The Equations of the relationship are expressed in Equation 20 – 22.

$S_c = 0.3351\sigma_c + 20.82$ 20

$S_c = 11.403PL + 182.28$ 21

$S_c = -5.1235Br + 188.62$ 22

Where: S_c *is Silica content* (%); σ_c *is UCS* (MPa); *PL is Point Load* (MPa); *and Br is Brittleness*(%)

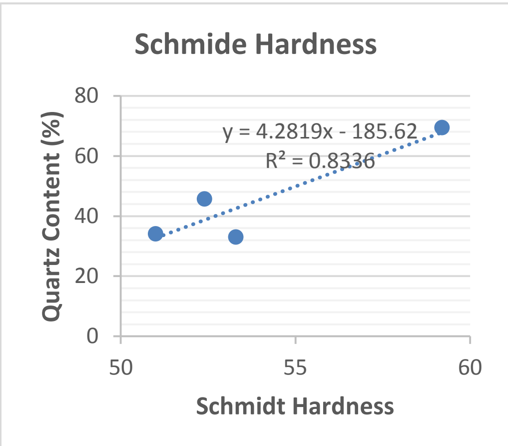

Fig. 7: Plot of Quartz percent against Hardness

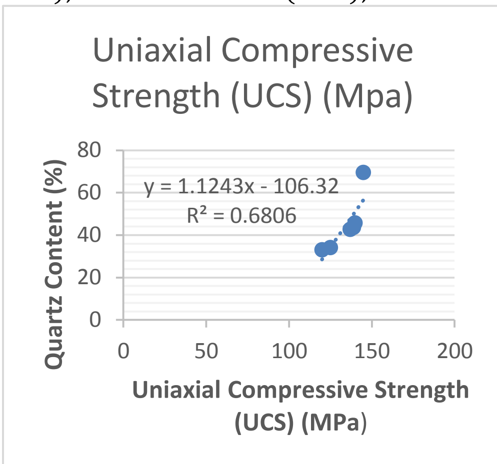

Fig. 10: Plot of Quartz percent against UCS

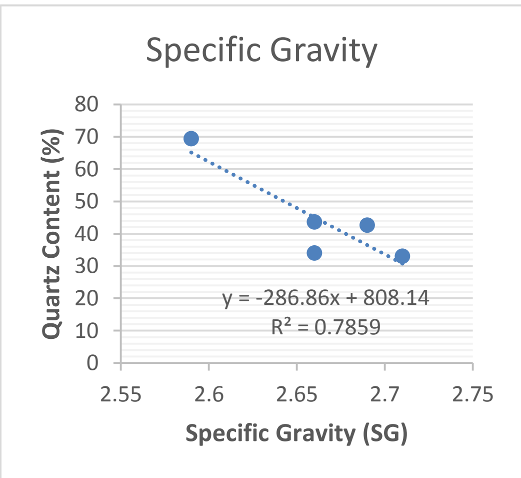

Fig. 8: Plot of Quartz percent against SG

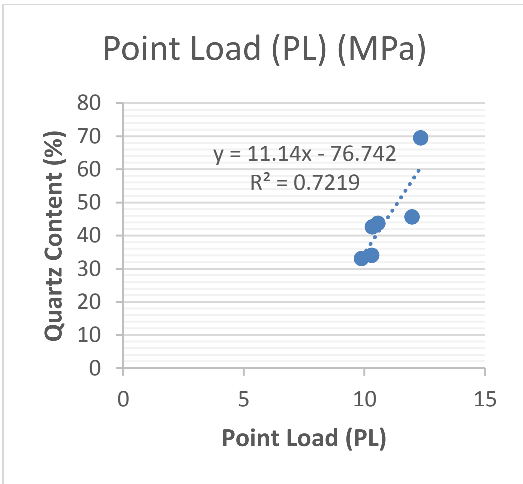

Fig. 11:Plot of Quartz percent against PL

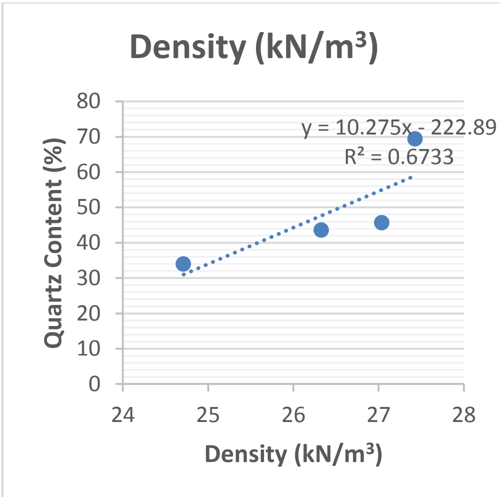

Fig. 9: Plot of Quartz percent against Density

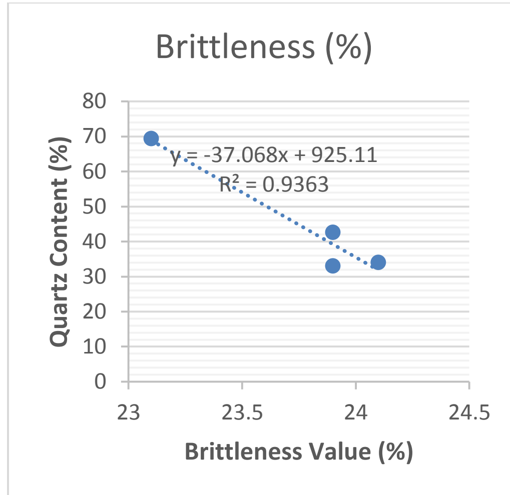

Fig. 12: Plot of Quartz percent against Brittleness

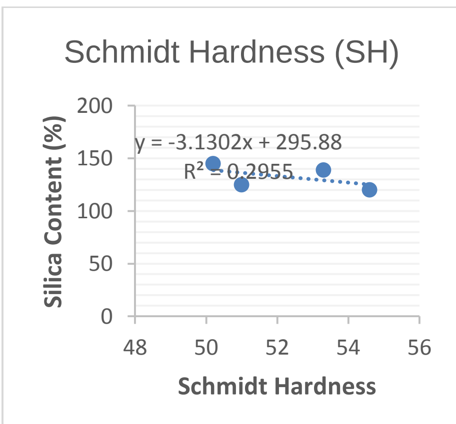

Fig. 13: Plot of Silica percent against Hardness

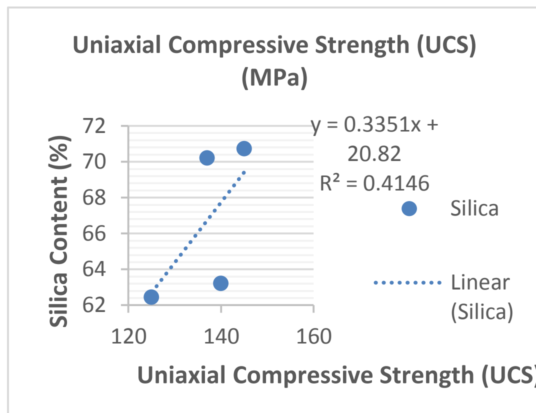

Fig. 16: Plot of Silica percent against UCS

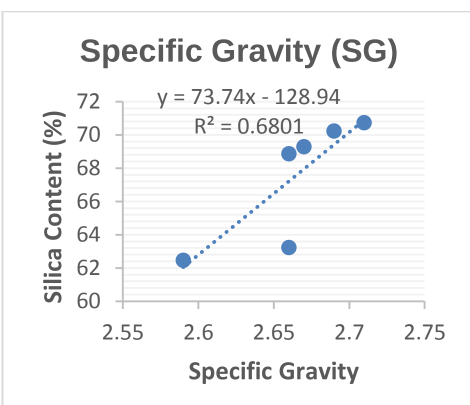

Fig. 14: Plot of Silica percent against SG

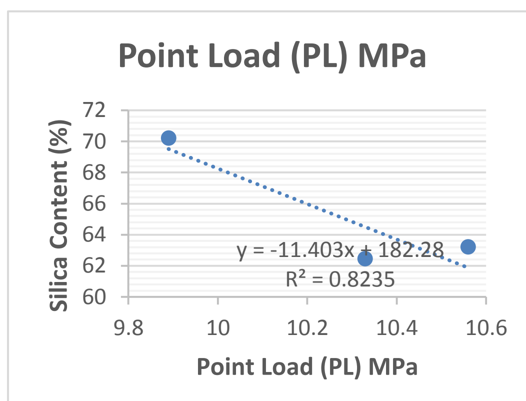

Fig. 17: Plot of Silica percent against PL

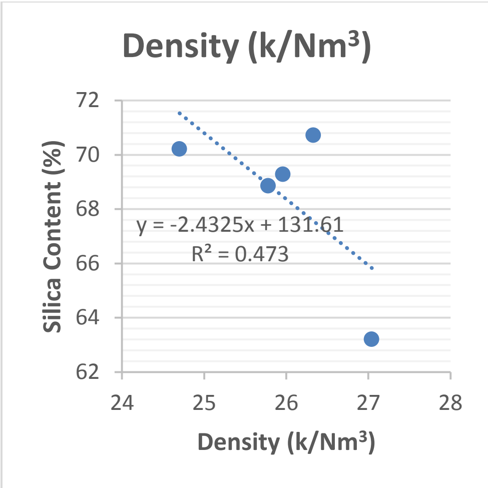

Fig. 15: Plot of Silica percent against Density

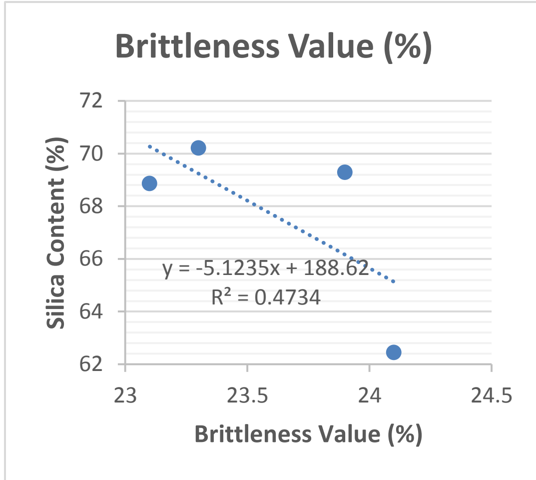

Fig. 18: Plot of Silica percent against Brittleness

Conclusion

The investigating the effects of physical and mineralogical characteristics of rocks on their mechanical properties are important in drilling bit and mining equipment selection. The quartz content of rock is the major determinants of the hardness and strength of rocks. The physical properties were all found to exhibit strong relationship with the Quartz content, Hardness and Density were found to exhibit weak relationship with silica content while Specific gravity was found to exhibit strong relationship with Silica content. The relationship of Uniaxial Compressive Strength and Brittleness with Silica content is weak while that of Point load was observed to be also strong. This implies that the Quartz content has great influence on both the physical and mechanical properties of rock. The relationship of Uniaxial Compressive Strength and Brittleness with Silica content is weak while that of Point load was observed to be strong. It could therefore be inferred that Quartz content has great influence on both physical and mechanical properties of rock.

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