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A Study of Petrographic Properties of some Selected Granite Rocks in Ogun State, Nigeria to Determine Its Suitability for Construction Purposes

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ABSTRACT: Petrographic properties of some selected granite rocks in Ogun state, south western Nigeria were used to predict rock strength index based on mineral constituent. In-situ test was carried out on the rock samples using Schmidt hammer to evaluate its rebound hardness. The rock sample mineralogy was determined in the laboratory using modal analysis. The rock samples were prepared in accordance with International Standard for Rock Mechanism (ISRM) guidelines for the determination of density, porosity, point load index, uniaxial compressive strength and equivalent quartz content. The percentage mineral composition present ranged from 23.4 – 33 % microcline; 32.4 - 53.8 % quartz; 7.7 – 20.5 % biotite; and 20.9 – 31.3 % plagioclase feldspar. The average density of granite samples ranged from 2.69 - 2.71 g/cm^3 while their average porosity ranged from 2.33 - 3.93 % classified as low porosity. The average uniaxial compressive strength value ranged from 52.5 - 172.5 MPa classified as averagely high strength, average point load index ranged from 1.95 - 2.94 MPa classified as averagely medium strength, while average tensile strength ranged from 2.92 - 4.40 MPa which falls under high strength. The equivalent quartz content value ranged from 55.96 – 79.65 %. The statistical mathematical model equation relating petrographic strength of the rock constituent was developed. The equivalent quartz content for Jia Bao, Milatex, CNC, and CCECC was satisfactory indicating high percentage of quartz in the mineral constituent of the granite rock making it suitable for construction works.

Keyword: Petrographic properties, rock strength, equivalent quartz content, model.

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INTRODUCTION

Granite rocks are used extensively as engineering materials, including aggregates for road construction, concrete and railway ballast as well as dimension stone for production of slabs, tiles, ornaments and furniture etc. Granite rocks have a wide range of petrologic characteristics (mineralogical composition, texture – size grains – structure – arrangement of the minerals and voids) and weathering state. Thus, the main issue of the present study consists of a comprehensive characterization (both from mechanical and physical points of view) of a set of granite litho-types selected taking into account these parameters (Vasconcelos *et al.,* 2010). Comparative analysis of rocks properties involves thorough, detail and comprehensive examination of already determined value for the properties of the rocks under consideration. Mathematical techniques such as correlation and regression play a very vital role in this analysis. (Daemen, 1983)

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The performance of any rock under the action of load, water, temperature and tectonic of the earth crust depends on the physical and mechanical properties (strength) of those materials. Application of rock mechanics principles in Mining Engineering therefore involves the selection of a tentative design and prediction of expected behaviour. Hence, the validity of this prediction is not greater than the validity of the physical and mechanical properties which is used (Cristescu and Hunsche, 1998).

In this research, the prediction of petrographic (rock) strength from the rock mineral constituent is investigated. The following selected rock properties are required variables: uniaxial compressive strength and porosity evaluating the rock strength using equivalent quartz content helps to provides information useful to quarry operators on drill tools selection.

MATERIALS AND METHODS

Description of the Study Area

The study areas fall within the south west of Nigeria. Milatex Genework Company Limited is located in Ijebu East Local Government Area, CCECC Limited is located in Ijebu North Local Government Area, Jia Bao Quarry Limited is located in Obafemi/Owode Local Government Area, while CNC Engineering Company Limited is located in Odeda Local Government Area all in Ogun State. The map of Ogun state showing the study locations is presented in Figure 1.

The geology of study areas falls within the basement complex of Nigeria. All the four quarries (Milatex Genework Company Limited, CCECC Limited, Jia Bao Quarry Limited, and CNC Engineering Company Limited) principal rock was classified according to its petrographic description as Biotite-gneiss while minor rock

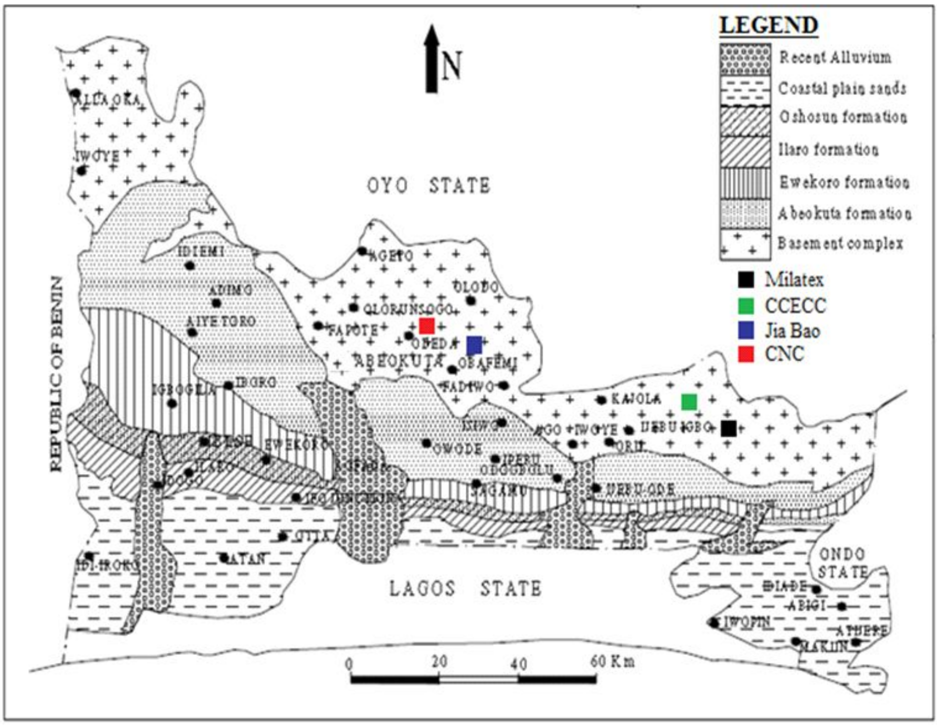

Figure 1: The Geological Map of Ogun State showing the Study Areas (Adapted from Olukayode *et al.*, 2012)

classified as Porphyritic granite (Milatex Genework Company Limited only).

Determination of Mineral Composition

The thin sections prepared from the rock samples were viewed under a polarizing microscope. A modal analysis was used to determine and estimate the mineral composition of the rock samples in accordance with procedure suggested by ISRM (1989). The photomicrograph of the samples was taken as presented in Table 1 and Plates 1-4.

Determination of Density

The densities for the rock samples were obtained from the samples weighed and recorded. Water was poured inside the cylinder and the volume was noted as V_1 (cm^3) and the sample was dropped in the water in the cylinder and the volume were recorded as V_2 (cm^3). The change in volume was calculated as ($V_2 - V_1$) cm^3.The density was calculated from Eq. (1) as shown in Table 2.

$$\rho = \frac{M}{\Delta V}\left({}^{g}\!/_{cm^3} \right) \qquad (1)$$

Where M is the mass in g and "V is the change in volume in cm^3.

Determination of Porosity

Porosity was determined using saturation and buoyancy technique as suggested by ISRM (1989). The representative samples comprising at least 4 lumps of irregular geometry, each having a mass of at least 50g was prepared. The sample was saturated by water immersion in a bath with periodic agitation to remove trapped air for a period of at least 24 hours. The samples are dried to a constant mass at a temperature of 105°C in an oven and cooled for 30 min in a desiccator, and the dry mass M_s is measured. The pore volume and porosity were determined using Equations 2 and 3.

$$\text{Pore Volume, } V_v = \frac{M_{Sat} - M_s}{\rho w} \qquad (2)$$

Where ρw is the density of water in g/cm^3, M_{sat} is the mass of saturated sample in g and M_s is the mass of dry sample in g.

$$\text{Porosity, } \phi = \frac{100 V_v}{V} \% \qquad (3)$$

Where: V_v is the pore volume in cm^3 and V is the bulk volume in cm^3.

Determination of Hardness

Hardness test involves the use of Schmidt Hammer of type L for the determination of the hardness of *in situ* rock. The rebound value of the Schmidt Hammer is used as an index value for the intact strength of rock material, but it is also used to give an indication of the compressive strength of rock material in accordance with ISRM (1981) and ASTM (1994).

Determination of Uniaxial Compressive Strength (UCS)

The uniaxial compressive strength test is most widely used measure of the strength, deformation and fracture characteristics of the rock. The UCS values were estimated by using the chart suggested by ISRM, (1985) presented in Figure 2.

Determination of Point Load Strength

The point load testing machine was used for the strength determination of rock samples. The samples used were of irregular shapes. Since the sample tested do not have a diameter of 50mm, the point load index has to be corrected to standard strength indices as proposed by Brook (1985). Load at failure is recorded as P. Uncorrected point load strength, I_s, was calculated as written in Equation 4:

$$I_s = {}^{P}\!/_{D_e^2} \qquad (4)$$

The uncorrected point load strength index is corrected to the point load strength at equivalent core diameter of 50mm, for D_e "" 50mm; the size

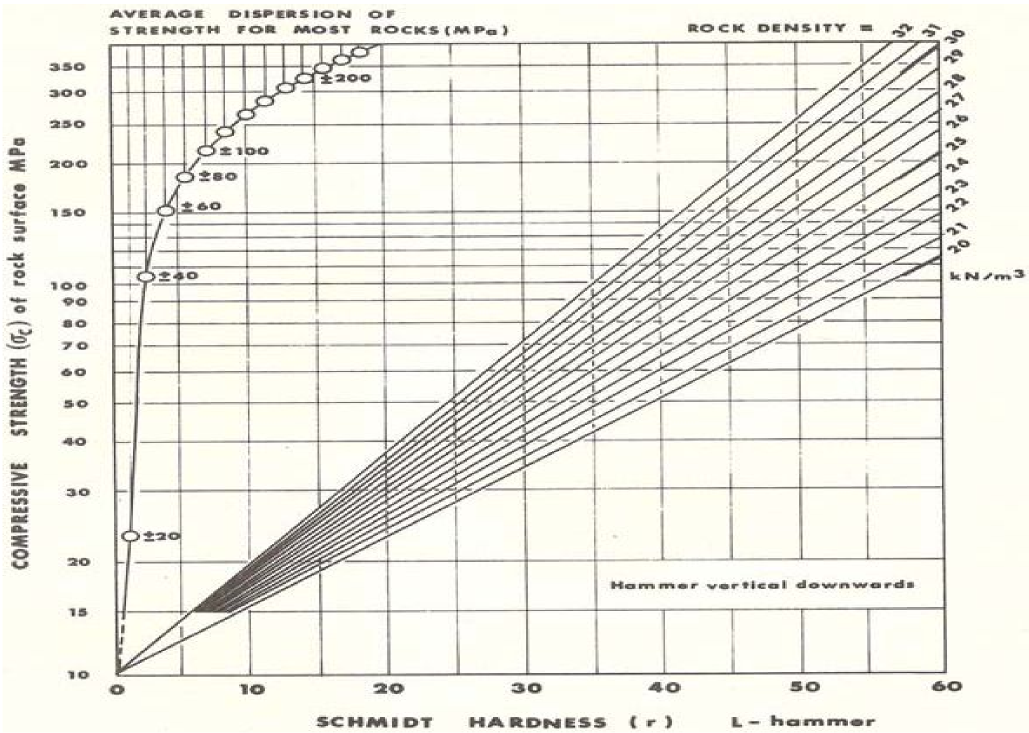

Figure 2: Correlation Chart for Schmidt (L) Hammer, Relating Rock Density, Compressive Strength and Rebound Number (ISRM, 1985)

correction factor is given using (ISRM, 1985) in Equation 5:

$$F = \left(\frac{D_4}{50}\right)^{0.45} \quad (5)$$

F is the size correction factor, P is the load at failure in kN, $I_{s(50)}$ is the point load index value for a standard core diameter (D) of 50mm in MPa and D_e is the equivalent core diameter in mm. The corrected point load strength index, $I_{s(50)}$ is calculated as stated in Equation 6:

$$I_{s(50)} = FI_s \quad (6)$$

Determination of Tensile Strength

The tensile strength can be determined from the relationship between the point load strength ($I_{s(50)}$) and tensile strength (T_o) according to Brook (1993) and ISRM (1989) as shown in Equation 7:

$$T_o = 1.5I_{s(50)} \quad (7)$$

Determination of Equivalent Quartz Content

The equivalent quartz content (EQC) of the rock samples was determined in accordance with Thuro (1997). The equivalent quartz content was determined in thin sections by modal analysis – meaning the entire mineral content referring to the abrasiveness or hardness of quartz. Therefore, each mineral amount is multiplied with its relative Rosiwal abrasiveness to quartz (with quartz 100 %) using Equation 8.

$$\mathrm{EQC} = \sum_{i=1}^{n} \mathrm{Ai} * \mathrm{Ri} \quad (8)$$

Where: EQC is the equivalent quartz content (%); Ai is the mineral amount (%); Ri is the Rosiwal abrasiveness (%); and n is the number of all minerals.

RESULTS AND DISCUSSION

Mineral Composition Result

The result of the mineral composition is presented in Table 1 while Tables 2 – 7 present rock parameters. Also, photomicrograph of rock samples are presented in Plates 1 – 4.

From Table 1 and Plate 1 – 4, the petrographic description of the four locations indicates its principal rock as a biotite-gneiss while minor rock was porphyritic granite (for Milatex only), from result obtained through photomicrograph. The mineral in the thin sections include majorly Q - quartz, B - biotite, M - microcline, O - orthoclase, P - plagioclase and accessory minerals.

Density Result

From Table 2, Milatex have the highest density as a result of high plagioclase feldspar content while CCECC and Jia Bao have the least. Finally, the degree of grain distribution and compactness is a significant factor in density determination.

Table 1: Mineral Composition of Selected Rocks

Minerals	% Prop. Milatex	% Prop. CCECC	% Prop. Jia Bao	% Prop. CNC
Quartz	45.3	32.4	53.8	36.3
Biotite	0	13.9	7.7	20.5
Plagioclase	31.3	20.9	28.9	0
Orthoclase	0	7.4	9.6	5.1
Microcline	23.4	0	0	33.0
Hornblende	0	25.4	0	0
Accessory mineral	0	0	0	5.1

Table 2: Density of Selected Rocks

Granite Location	Density (kg/m^3) Milatex	Density (kg/m^3) CCECC	Density (kg/m^3) Jia Bao	Density (kg/m^3) CNC
Sample 1	3.08	2.77	2.69	2.69
Sample 2	2.67	2.62	2.75	2.63
Sample 3	2.56	2.73	2.62	2.82
Sample 4	2.51	2.62	2.69	2.65
Average	2.71	2.69	2.69	2.70

Table 3: Porosity of Selected Rocks

Granite Location	Porosity (%) Milatex	Porosity (%) CCECC	Porosity (%) Jia Bao	Porosity (%) CNC
Sample 1	2.81	3.40	3.40	2.27
Sample 2	3.27	2.63	4.22	2.39
Sample 3	2.42	3.42	4.04	2.37
Sample 4	2.02	2.78	4.04	2.29
Average	2.61	3.06	3.93	2.33

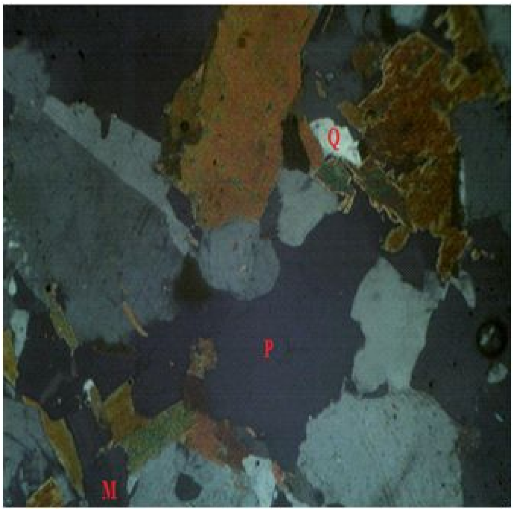

Plate 1: Photomicrograph of Milatex Rock

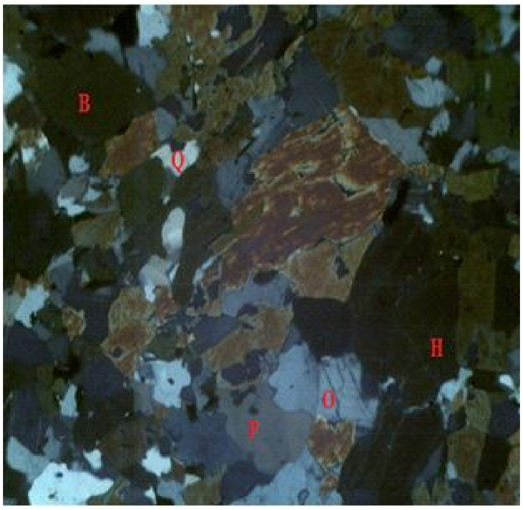

Plate 2: Photomicrograph of CCECC Rock

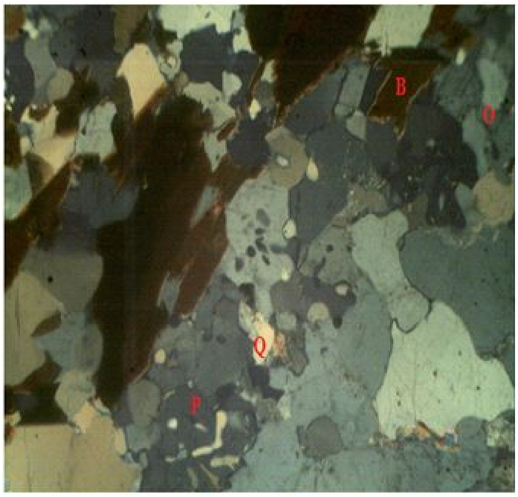

Plate 3: Photomicrograph of Jia Bao Rock

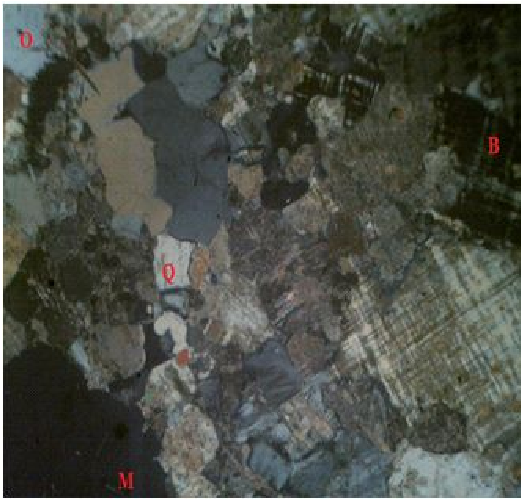

Plate 4: Photomicrograph of CNC Rock

Porosity Result

From Table 3, Porosity is one of the governing factors for the permeability. It provides the void for water to flow through in a rock material. Two locations (CCECC and Jia Bao) have low density but with high porosity indicating low strength while Milatex and CNC have high strength.

Rock Strength

From Tables 4 – 6, the uniaxial compressive strength for the four locations was classified as high to very high strength; the point load index was classified as medium to high strength; and tensile strength classified as medium to high strength. All the strength characterization was in accordance with ISRM (1985) classification.

From Table 7, the result of equivalent quartz content was evaluated in accordance with Thuro (1997). The evaluated values ranged from 55.96 – 79.65 % respectively. Jia Bao has the highest while the lowest is recorded to CCECC. In rock drilling, bit wear rises mainly with increasing

Table 4: Uniaxial Compressive Strength of Selected Rocks

Granite Location	UCS (MPa) Milatex	UCS (MPa) CCECC	UCS (MPa) Jia Bao	UCS (MPa) CNC
Sample 1	220	80	75	190
Sample 2	150	100	55	150
Sample 3	180	80	35	170
Sample 4	140	90	45	150
Average	172.5	87.5	52.5	165

Table 6: Tensile Strength of Selected Rocks

Granite Location	Milatex (MPa)	CCECC (MPa)	Jia Bao (MPa)	CNC (MPa)
Sample 1	1.14	2.67	2.56	2.66
Sample 2	3.33	2.03	1.08	1.60
Sample 3	2.55	4.61	2.26	4.87
Sample 4	2.15	2.36	1.88	2.63
Average	2.29	2.92	1.95	2.94

Table 7: Equivalent Quartz Content of Selected Rocks

Minerals	Rosiwal Value	Equivalent Quartz Content (%)			
		Milatex	CCECC	Jia Bao	CNC
Quartz	120	54.36	38.88	64.56	43.56
Biotite	11	-	1.53	0.85	2.26
Plagioclase	37	11.58	7.73	10.69	-
Orthoclase	37		2.74	3.55	1.89
Microcline	37	8.66	-	-	12.21
Hornblende	20	-	5.08	-	-
Accessory Minerals	4.5	-	-	-	0.23
Total		74.6	55.96	79.65	60.15

equivalent quartz content. This could be used to evaluate bit deterioration based on percentage quartz content.

The relationship of equivalent quartz content with regression standardized predicted value is shown in Figure 3.

From Figure 3, the line of best-fit shown in the graph represents approximately the average value of the equivalent quartz content in relation to rock parameters. The correlation model for equivalent quartz content of the granite deposit increases with increase in regression standardized predicted value (porosity and uniaxial compressive strength) as expressed in Equation 9;

$$EQC = -118.941 + 44.373POR + 0.454UCS \quad (9)$$

Where: EQC is the equivalent quartz content - dependent variable; predictor variables includes POR is the porosity (%); and UCS is the uniaxial compressive strength (MPa).

A linear trend line for the relationship curve with corresponding equation 9 gave a value of multiple correlation coefficient $R^2 = 0.996$ (99 %). The multiple correlation coefficient value obtained exhibit a large correlation which is positive. It was deduced that higher quartz content in the rock composition results to its strength characterisation.

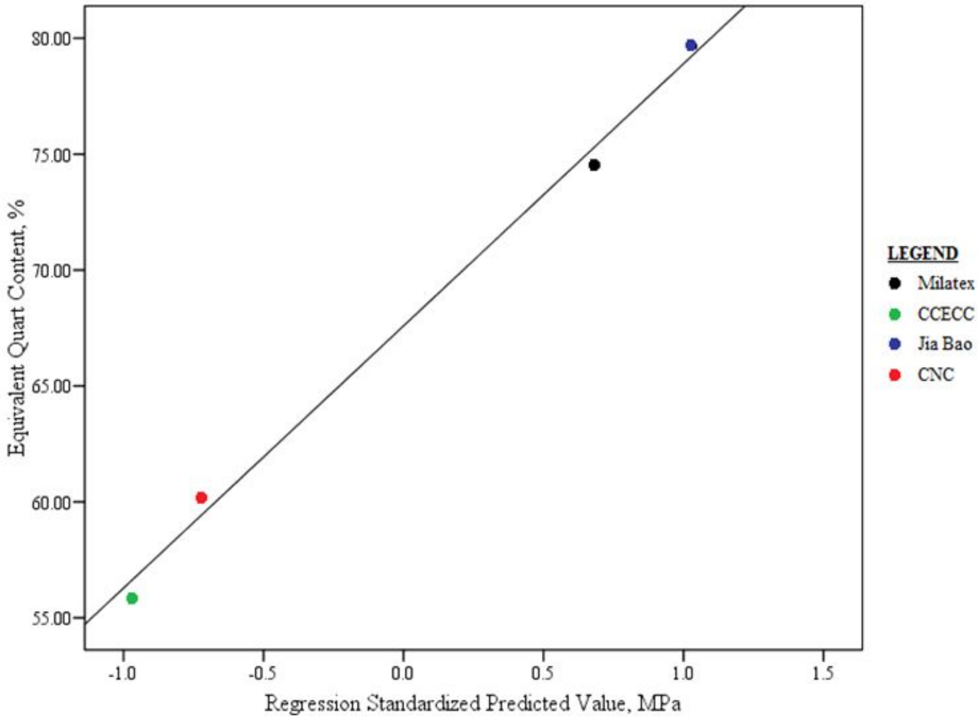

Figure 3: Equivalent Quartz Content against Regression Standardized Predicted Value

CONCLUSION

This research work satisfies the allowable standard in accordance to ASTM and ISRM. In-situ and laboratory tests were conducted on the granite samples. The petrographic properties of rocks in the four locations which include Milatex, CCECC, Jia Bao, and CNC, have the following percentage present: 23.4 – 33 % microcline, 32.4 – 53.8 % quartz, 20.9 – 31.3 % plagioclase feldspar, and 5.1 – 9.6 % orthoclase feldspar. The average density, porosity, uniaxial compressive strength, point load index tensile strength and equivalent quartz content for the four locations are 2.69 g/cm^3, 2.98 %, 119.38 MPa, 2.53 MPa, 3.73 MPa, and 67.59 % respectively. Low porosity was deduced while the strength characterization classified the rock from medium to high strength.

Finally, a mathematical model equation was generated to predict the percentage of quartz present in the rock constituent once the predictor variables such as porosity and uniaxial compressive strength values are supplied. The relationship of equivalent quartz content with regression standardized predicted value indicates a large multiple correlation coefficient which is positive. It serves as a tool to predict the rock strength based on petrographic properties of rock in questioned. Quarry operator would benefit from the research in the area of drilling technology. It also serves as a basis for the determination of rock aggregates strength used for construction purposes.

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