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Influence of mineralogical composition on physico -mechanical properties of selected granite rocks in Ogun State, Nigeria

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Abstract
The influence of mineralogical composition on physico-mechanical properties of some selected granite rocks in Ogun State was investigated. In-situ and laboratory tests were conducted on the granite samples from four different locations – Milatex, CCECC, Jia Bao and CNC within the State. Schmidt hammer was used to carry out in-situ test while mineralogical compositions of the rock samples were determined in the laboratory using modal analysis. The rock samples were prepared for the determination of density, porosity, point load index and uniaxial compressive strength. The percentage microcline present ranged from 28.6 - 36.0 %; biotite present ranged from 7.7 - 23.9 %; hornblende present ranged from 0 - 25.4 %; quartz present ranged from 22.4 - 53.8 %; plagioclase feldspar present ranged from 20.9 – 71.4 %; orthoclase feldspar present ranged from 5.1 - 9.6 %; and 5.1 % mymakite present in CNC only. The average density of granite samples ranged from 2.69 - 2.71 g/cm^3 while average porosity ranged from 2.33 - 3.93 % classified as low porosity. The average uniaxial compressive strength value of granite samples ranged from 52.5 - 172.5 MPa classified having averagely high strength. The average point load index of granite samples 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 granite rock samples from quarries have good engineering properties for the construction of roads, dams, structures and other social amenities.

Keyword: Textural properties, mechanical properties, mineral composition, granite.

Introduction

Granite technically refers to a light-coloured granulose plutonic rock composed of felspars, plagioclase, quartz (felsic minerals) and minor amounts of mafic minerals, such as biotite, hornblende, pyroxene, iron oxides, etc. Rock can equally be defined as mixture of one or more different minerals (Barton *et al*., 1974). It has no definite chemical composition. The author defined rock further as an aggregate of fixed or compressed discreet mineral particles.

Being more resistant to wear and tear as well as weathering, granite is most sought-after stone to be used as building as well as decorative stone. The fascination for granite is due to its taking mirror-like polish, high compressive strength, longevity and beauty. In recent years granite has experienced a marked revival in use, most obviously as external cladding to steel or concrete framed structures. Against this background, there is a growing requirement from construction professionals for an increased understanding of physical, mechanical and durability properties of any granite proposed for use in construction.

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 mass because of the heterogeneous nature of rocks and various local geological condition. In addition to the direct properties of the rock and rock masses as described above, we have to

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remember that the natural rock environment can also have a profound effect on engineering properties of rock. In general, this is basically governed by the location, i.e. whether a structure is being built on the surface or is being created by excavation of the surface rock or is underground (Hoek and Brown, 1988). For the purpose of this project work, the influence of mineralogical composition on physico-mechanical properties of granite rock which makes it suitable for engineering applications is investigated

Description of the Study Area

The study area falls 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.

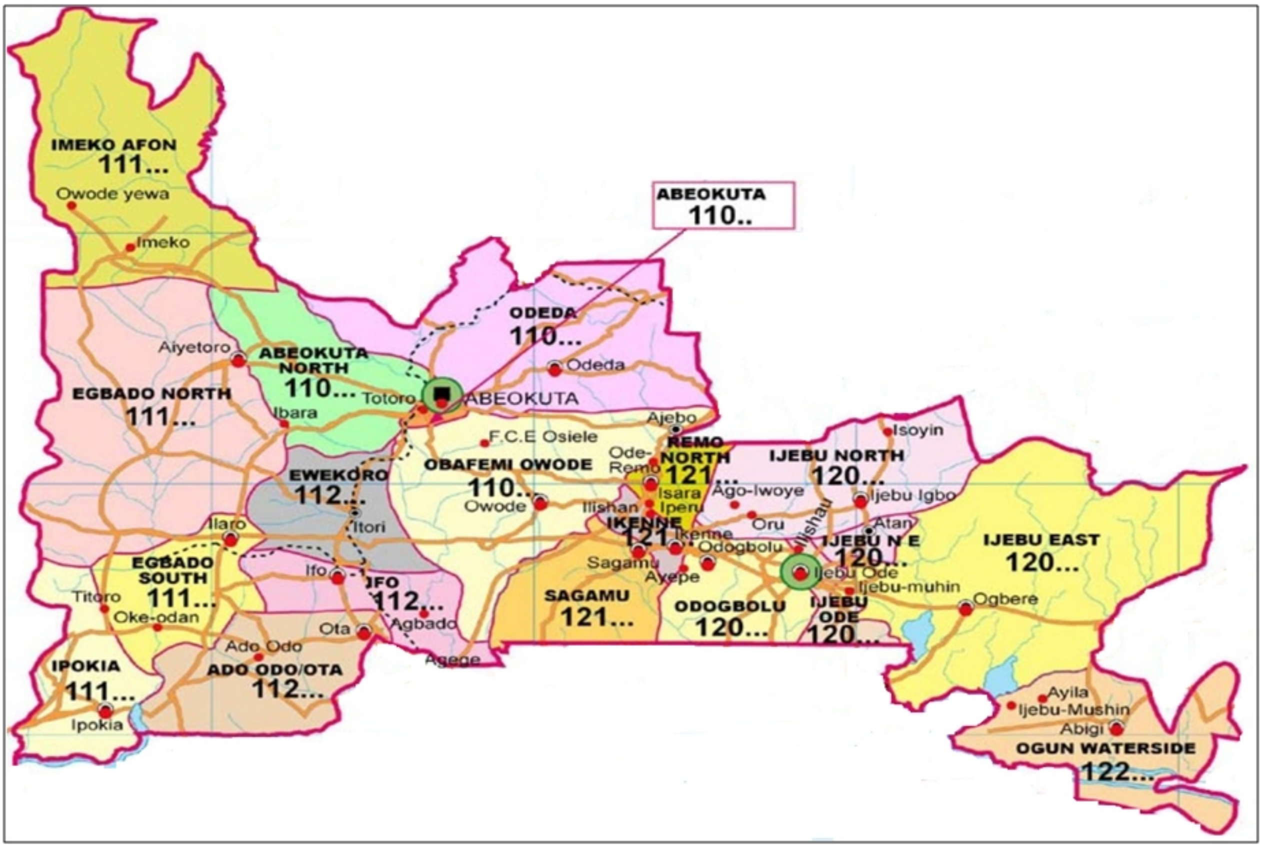

Figure 1: Map of Ogun State showing the study areas (source: NIPOST)

Materials and Methods

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 and the photomicrograph of the samples were taken as presented in Tables 1-4 and Plates 1-4. The mineral composition was determined at the laboratory of Department of Geology, Federal University of Technology, Akure.

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 5.

$$\rho = \frac{M}{\Delta V}(g / cm^3) \qquad ...1$$

Where M is mass in g and ΔV 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 procedure adopted is according to ISRM and ASTM standards. 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: ρ_w 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.

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

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 (ISRM, 1981). The standard method for the Schmidt Hammer test as described by ISRM (1981) and ASTM (1994) was adopted.

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 named after Deere and Miller (1966).

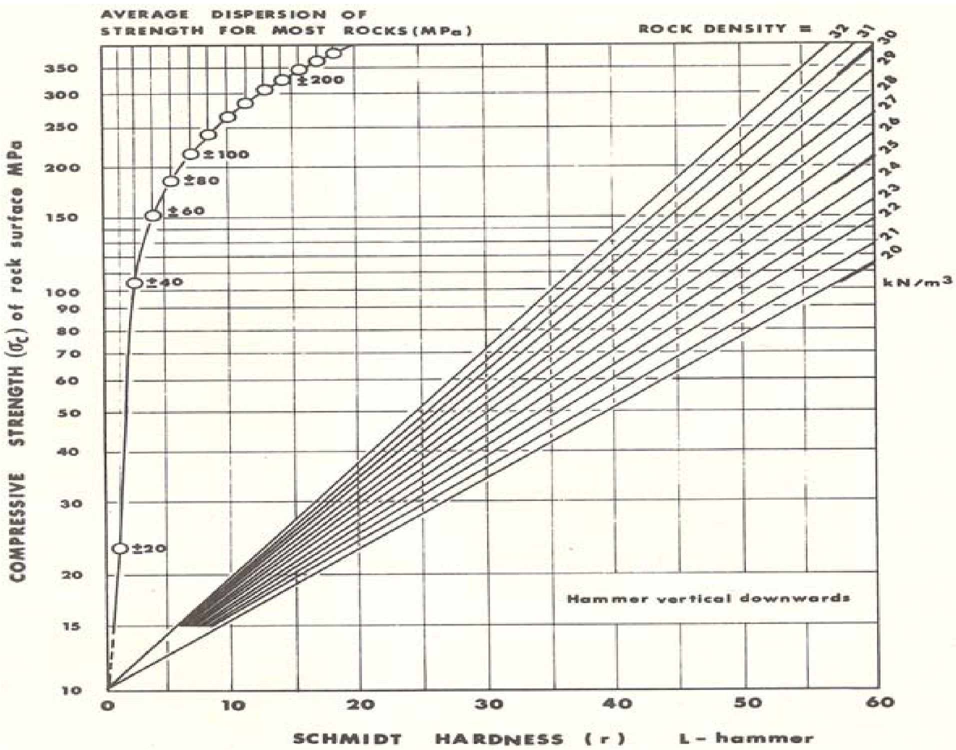

Figure 2: Correlation Chart for Schmidt (L) Hammer, Relating Rock Density, Compressive Strength and Rebound Number (After Deere and Miller, 1966).

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 Broch and Franklin (1972). Load at failure is recorded as P. Uncorrected point load strength, I_s, was calculated as written in Equation 4:

$$I_s = \frac{P}{D_e^2} \quad ...4$$

The uncorrected point load strength index is corrected to the point load strength at equivalent core diameter of 50mm, for $D_e \neq$ 50mm; the size correction factor is given using (ISRM, 1985) in Equation 5:

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

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:

$$T_0 = 1.5I_{s(50)} \quad ...7$$

Results and Discussion

The result of the mineral composition is presented in Table 1 while Tables 2 – 6 present strength parameters. Also, photomicrograph of rock samples was presented in Plates 1 – 4.

Table 1: Mineral Composition of Selected Rocks

Minerals	% Prop. Milatex	% Prop. CCECC	% Prop. Jia Bao	% Prop. CNC
Quartz	0	22.4	53.8	33.3
Biotite	0	23.9	7.7	20.5
Plagioclase	71.4	20.9	28.9	0
Orthoclase	0	7.4	9.6	5.1
Microcline	28.6	0	0	36.0
Hornblende	0	25.4	0	0
Mymakite	0	0	0	5.1

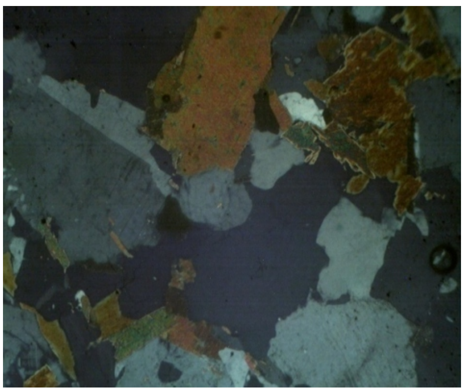

Plate 1: Photomicrograph of Milatex Rock

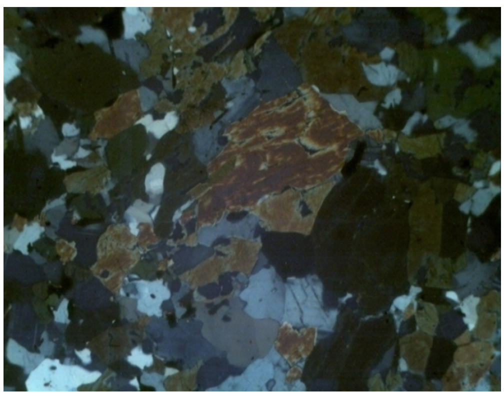

Plate 2: Photomicrograph of CCECC Rock

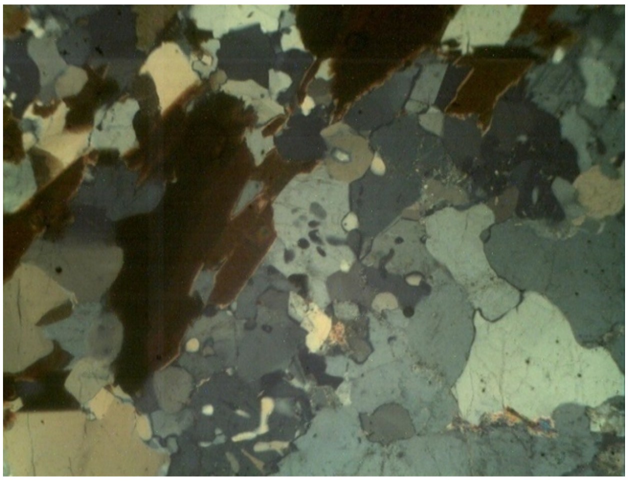

Plate 3: Photomicrograph of Jia Bao Rock

Plate 4: Photomicrograph of CNC Rock

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

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 5: Point Load Index 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 6: Tensile Strength of Selected Rocks

Granite Location	Milatex (MPa)	CCECC (MPa)	Jia Bao (MPa)	CNC (MPa)
Sample 1	1.71	4.01	3.84	3.98
Sample 2	4.10	3.04	1.63	2.40
Sample 3	3.82	6.91	3.40	7.30
Sample 4	3.22	3.54	2.83	3.94
Average	3.21	4.37	2.92	4.40

From Table 1, the results of mineralogical composition of rock samples obtained from four different quarries. Milatex quarry samples have 28.6% microcline and 71.4% plagioclase respectively. CCECC quarry samples have 23.9% biotite, 22.4% quartz, 20.9% plagioclase feldspar, 7.4% orthoclase feldspar and 25.4% hornblende respectively. Jia Bao quarry samples have 7.7% biotite, 53.8% quartz, 28.9% plagioclase feldspar and 9.6% orthoclase feldspar respectively while CNC quarry samples have 36.0% microcline, 20.5% biotite, 33.3% quartz, 5.1% orthoclase feldspar and 5.1% mymakite respectively.

Physical Properties

From Table 2, the results of the density determined from laboratory analysis conducted on the rock samples from Milatex, CCECC, Jia Bao and CNC. The results of the analyses show that the value of density vary from 2.51 - 3.08 g/cm^3, 2.62 - 2.77 g/cm^3, 2.62 - 2.75 g/cm^3 and 2.63 - 2.82 g/cm^3 respectively. From the results obtained, Milatex have the highest density as a result of high feldspar content while Jia Bao, as high quartz content of the rock.

From Table 3, the porosity of the rock samples from Milatex, CCECC, Jia Bao and CNC. The results obtained from the analyses show that the porosity vary from 2.02 - 3.27 %, 2.63 - 3.42%, 3.40 - 4.22% and 2.27 - 2.39% respectively. Jia Bao has highest porosity as a result of low strength of the rock from this study area.

Mechanical Properties

From Table 4, the uniaxial compressive strength values of samples from Milatex, CCECC, Jia Bao and CNC which range from 140 - 220 MPa, 80 - 100 MPa, 35 - 75 MPa and 150 - 190 MPa respectively. It was deduced that the uniaxial compressive strength varies from high to very high strength according to ISRM (1985) classification.

From Table 5, the results of point load index value for samples from Milatex, CCECC, Jia Bao and CNC which varies from 1.14 - 3.33 MPa, 2.03 - 4.61 MPa, 1.08 - 2.56 MPa and 1.60 - 4.87 MPa respectively. It was classified from medium to high strength according to ISRM (1985) classification.

From Table 6, the results of tensile strength determined from point load index using relation generated by Brook (1993) and ISRM (1989). The tensile strength varies from 1.71 - 4.10 MPa, 3.04 - 6.91MPa, 1.63 - 3.84 MPa and 2.40 - 7.30 MPa respectively.

Conclusion

This research work analyzed the influence of mineralogical composition on physico-mechanical properties of selected granite rocks in accordance with ASTM and ISRM standards. In situ and laboratory tests were conducted on the granite samples. In Milatex, CCECC, Jia Bao and CNC, the percentage microcline present ranged from 28.6 - 36.0%, quartz 22.4 - 53.8%, plagioclase feldspar 20.9 - 71.4%, orthoclase feldspar 5.1 - 9.6%. The result of average density shows that granite rock value ranged from 2.69 - 2.71 g/cm^3. The average porosity of granite rock ranged from 2.33 - 3.93%. The result of average porosity indicates low porosity for the four locations. The strength characterization of the granite rock has average uniaxial compressive strength value ranged from 52.5 - 172.5 MPa, classified as high strength. The results of average point load index of granite samples ranged from 1.95 - 2.94 MPa, classified as averagely medium strength. The result of average tensile strength of granite samples ranged from 2.92 - 4.40 MPa classified as high strength. It was concluded that all the rock samples tested have good physical and mechanical properties.

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