Geotechnical Properties of Natural Composite Rock in Ibadan, Nigeria.

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ABSTRACT

The physical property of a rock is a pointer to its suitability for civil engineering works. In this study the suitability of composite rock as construction materials is established. Thirty-four fresh block samples of quartz-schist masses were obtained from three locations in Ibadan, Nigeria. Thin sections were prepared from two representative samples, while others were subjected to standard geotechnical laboratory testing. Regression plots were made to assess the degree of association between pairs of dependent physical parameters of the rock. The results show in thin section that individual quartz crystals of the samples have complexly sutured outlines and mutual interlocking.

Modal analysis reveals quartz as the dominant mineral with subordinate amounts of muscovite. The density (ɣ) is the least variable parameter and ranges between 2600 and 2660 kg/m^3. Water absorption ranges between 0.64 and 3.39 %, indicating good rock materials for construction. Regression analysis shows that approximately 20% of the variation in density and 2% of the void ratio were associated with porosity and water absorption capacity of the rock respectively. These are due to different proportions of quartz and muscovite with voids in the quartz-schist.

(Keywords: quartz-schist, construction materials, geotechnical properties, Ibadan)

INTRODUCTION

Rocks of the Precambrian Basement Complex make up the greater part of South-west Nigeria. The oldest known rocks exposed in the area comprise a Gneiss Complex, whose principal members include quartzite and quartz-schist. These have been established by Jones and Hockey (1964). Although, the gneisses cover the larger part of the area, quartz-schist can also be traced over a wide area for several kilometers (Figure 1). This class of crystalline rocks constitutes more than one rock in a rock. Rocks of multi compositional characteristics are best defined as composite rocks (Mohammed, 2004). Quartz-schist is product of metamorphism of sedimentary to meta-sedimentary rocks.

Okwonko, (1992), Okonkwo and Winhester, (2001), Elueze and Okunlola, (2003), and Okonkwo, (2005) have tremendously contributed to knowledge in the aspects of compositional features and petrotectonic significance of quartzite and quartz-schist. The engineering performance of construction materials is strongly tied to their physical properties (Krynine and Judd, 1998). Like granite and gneiss, the physical properties of such crystalline metamorphosed rocks are of utmost concern in this study as they are also being widely employed for construction purposes.

Studies on the compressive strength of artificial composite rock materials in relation to their moisture content in Malaysia (Mohamed et al., 2009) emphasized probable complex engineering challenges due to variation in the rock composition. Akpokoje, (1992) studies certain rock aggregates for the Nigerian Basement rocks. His findings show that the aggregates are good engineering materials based on both compressive strength and water absorption characteristics. Adebisi and Adeyemi (2010) confirm the exclusive sensitivity of gneisses in South-west Nigeria to moisture content among other properties. However, the studied gneisses are to a greater extent homogeneous and isotropic compared to quartz-schist.

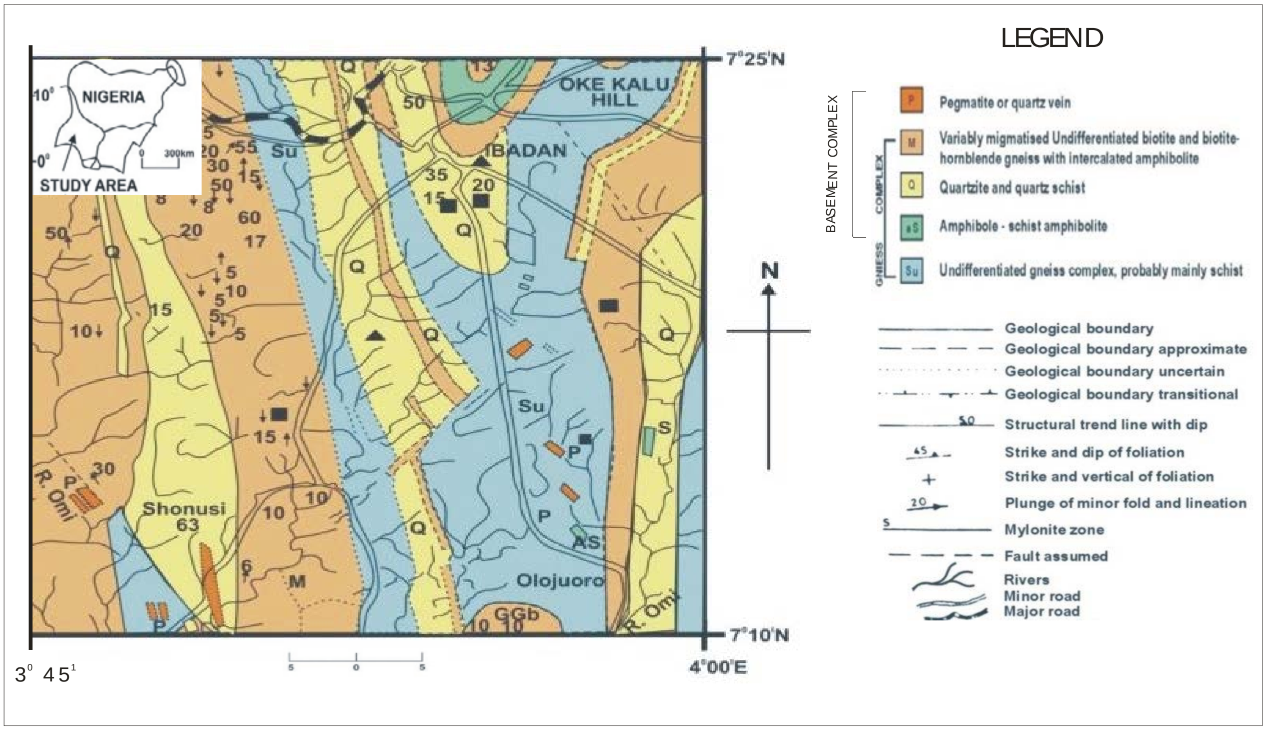


Figure1: Geological map of South-west Nigeria.

The present study tries to employ field disposition, petrography and more importantly, some basic physical properties of the rock to elucidate further the probable geotechnical complexity that may result due to anisotropy and inhomogeneity. It is certain that information regarding physical properties of quartz-schist, taking cognizance of compositional characteristics, will enable better appreciation of geological fundamentals in engineering practice.

MATERIALS AND METHODS

Field Characteristics

Field study revealed that ridges of quartz-schist are distinctive topographic features in certain parts of South-west Nigeria. They strike West of North through Ibadan at a height of about 76m above its immediate surroundings. The quartz-schist is extensively weathered and fractured with well-developed foliation planes. Some quartz-schist ridges can be traced for almost 10km, although the crests are seldom even and there are many breaks where streams have cut through joint directions. The ridges in the area split to the east and west and are straight trending. These rocks form good topographic features, they seldom outcrop well. There are few outcrops, particularly at Mokola and University of Ibadan (Figure 2). The quartz-schist in the area had been folded together with the gneisses and migmatites of the Gneiss Complex.

The quartz-schist is intensively weathered, although the overburden thickness is generally very much less than 5 metres except in some few cases. Road cuts, about 4m thick are common in Queen Elizabeth road, around Mokola area, where civil construction is seriously going on. The soils developed over them are reddish to brown in color, generally loose sandy clay with some gravel near the surface. In a profile, the top soils are humic sandy silty clay generally 0.3m thick, overlying a reddish brown sandy clay which extends to varying depths of 2.3 and 2.8m, which in turn overlie deeply weathered bedrock.

Sampling and Laboratory Testing

Thirty-four block samples were prepared from the fresh pieces recovered in the quartz-schist masses at three locations in South-west Nigeria. Thin sections were prepared from some selected samples by pasting their tiny chips on glass slides with aradite.

a

b

Figure 2: Outcrop of the Studied Rocks - (a) Extensively weathered outcrop of quartz-schist showing well-developed foliation in Mokola, Ibadan. (b) Exposed quartz schist surface at the University of Ibadan, Ibadan.

The slides were observed under transmitted of a petrographic microscope for mineral identification and modal analysis. Other samples had been initially paraffined to avoid loss of moisture.

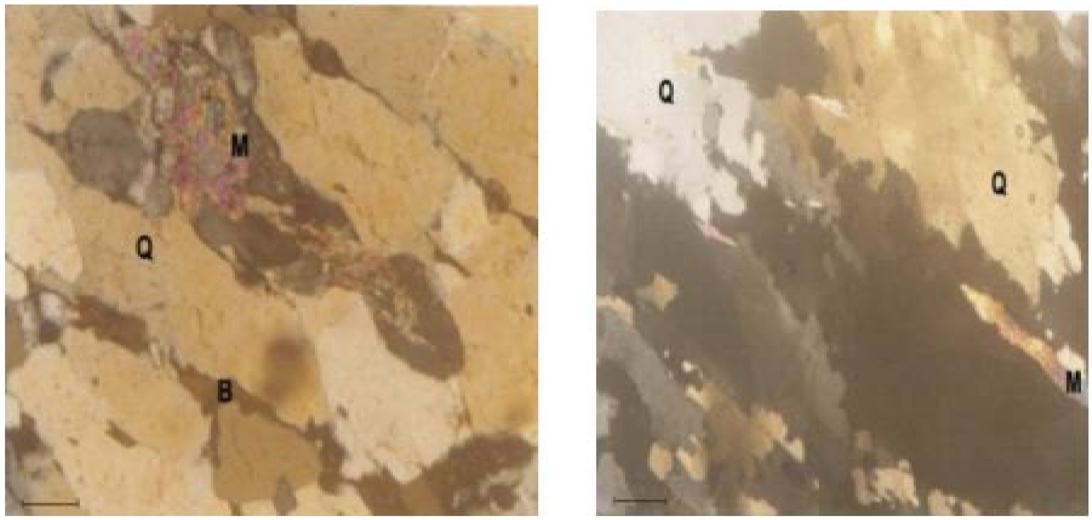
In accordance with ISRM (1991), IS: 2386 – part - 3 and ASTM D – 2216 (1998) physical properties which include; density, porosity, void ratio, moisture content and water absorption of the samples are determined. The paraffin was later pulled off and water content of the mass of the perfectly dry samples was calculated at temperature of 1050C. Porosity was measured by dividing the amount of water filling the pore spaces, deduced from weight of each sample by density of water at room temperature.

Void ratio was calculated based on the dry weight of each rock sample by subtracting one from the product of the sample volume and density, divided by the mass of the sample. Density was estimated from the ratio of bulk mass of each sample to its bulk volume. The mass of each specimen was determined after drying to a constant mass at a temperature of 1050 C for 24 hours, and allowing it to cool in the desiccator for about 30 minutes.

The volume of each sample was measured from its dimension, while water absorption was calculated as percentage by weight of water absorbed in terms of oven-dried weight of each sample. All numerical data obtained from the measured physical properties were subjected to statistical analysis, including regression plots in order to establish how water absorption varies with void ratio and density with porosity.

RESULTS AND DISCUSSION

In thin sections as shown in Figure 3, the individual quartz crystals of the studied rock materials have complexly sutured outlines and are mutually interlocked. Strain-shadows form a marked feature in the section examined, and on rotation of the stage, large proportions extinguished together. Modal composition of representative samples as shown in Table 1 reveals that quartz is the dominant mineral with subordinate amounts of muscovite, while insignificant amount of biotite is present in one of the samples.



a b

Figure 3: Photomicrographs of Quartz Schist in Transmitted Light; Showing Biotite (B), Quartz (Q) and Muscovite (M). (Bar scale = 2.5mm)

Table 1: Physical Properties and Modal Composition of Ibadan Natural Composite Rock Materials.

PHYSICAL PROPERTIES	RANGE	AVERAGE	COEFFICIENT OF VARIATION (CV) %	MODAL ANALYSIS FROM PETROGRAPHICAL STUDY		
Density (ɣ) kg/m^3	2600 – 2660	2630	0.53	**MINERALOGICAL CONSTITUENTS**	**AMOUNT PERCENT (%)**	
Water Absorption (Ab) %	0.8 – 1.95	1.18	27.97	**Quartz**	62	60
Void Ratio (e)	0.0084 – 0.033	0.016	35.6	**Muscovite**	20	18
Moisture Content (Mc) %	0.32 – 1.24	0.60	36.67	**Biotite**	-	4
Porosity (n) %	0.64 – 3.39	1.5	40.40	**Accessory minerals**	8	10

The density (ɣ) of the studied rock ranges between 2600 and 2660 kg/m^3. This is consistent with the determined density of metamorphic rocks (Krynine and Judd, 1998).

The porosity (n) of the rock is the most variable parameter compared to others. It ranges between 0.64 and 3.39 % with an average void ratio (e) of 0.016. The average moisture content of the rocks is 0.60 %. The results obtained are with the recommended limits for good construction materials especially, water absorption which ranges between 0.64 and 3.39 %, (Akpokodje,1992).

In Figure 4, a linear relationship between density and porosity of the studied rock is shown. The line of best fit is $ɣ = 1.270\ n + 2626$, with very low coefficient of correlation ($r = 0.045$). This may be due to composite nature of the studied rocks. It is known that quartz-schist does not have pore spaces but cracks, fissures and joints, unlike sand stone. The coefficient of determination of (r^2) 0.002 between the two properties implies that about 0.2 % of the variation in the density of quartz-schist will always be associated with porosity. This is because they contain different proportions of quartz and muscovite with voids which is responsible for the range of densities.

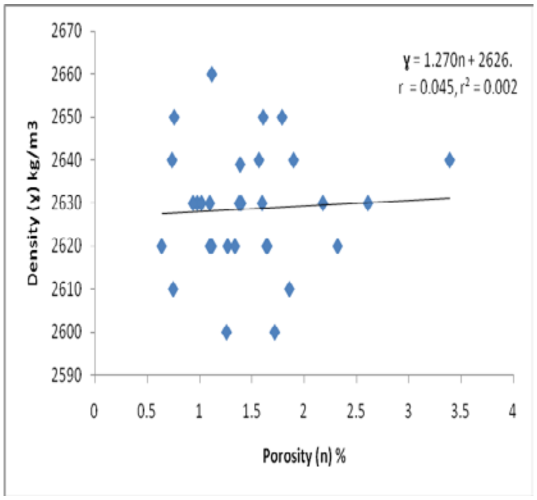


Figure 4: Regression Plot of Density against Porosity.

The water absorption capacity of the studied rocks increases with increasing void ratio as shown in Figure 5. However, a low coefficient of correlation (r = 0.15) exists between the two properties with Ab = 6.628 e + 1.077 as the line of best fit. Approximately 2 % of the variation in the water absorption capacity of quartz-schist is associated with its void ratio. This implies that for quartz-schist, the void ratio cannot be reliably estimated if water absorption is determined.

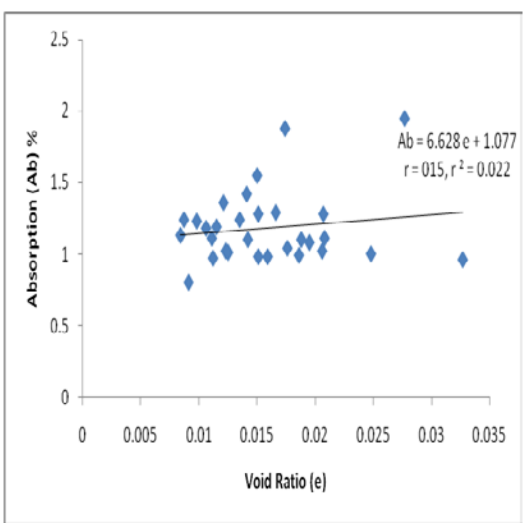


Figure 5: Regression Plot of Absorption against Void Ratio.

Table 2: Geotechnic Properties of Quartz-Schist Rock in Selected Locations in Ibadan.

Porosity %	Density Kg / m^3	Moisture Content %	Void Ratio	Absorption %
1.57	2640	0.54	0.0142	1.1
1.40	2630	0.71	0.0186	0.99
1.60	2630	1.24	0.0327	0.96
3.39	2640	0.57	0.0151	0.98
2.32	2620	0.95	0.0248	1.00
1.12	2620	0.79	0.0208	1.11
1.61	2650	0.6	0.0159	0.98
1.10	2630	0.47	0.0123	1.02
1.39	2639	0.63	0.0166	1.29
1.90	2640	0.78	0.0206	1.02
1.27	2620	0.43	0.0112	0.97
1.26	2600	0.54	0.0141	1.42
1.12	2660	0.47	0.0125	1.01
0.64	2620	0.32	0.0084	1.13
0.74	2640	0.35	0.0091	0.80
1.64	2620	0.67	0.0174	1.88
2.61	2630	1.05	0.0277	1.95
1.79	2650	0.56	0.015	1.55
1.72	2600	0.75	0.0195	1.08
1.86	2610	0.64	0.0176	1.04
0.75	2610	0.37	0.0098	1.23
0.76	2650	0.33	0.0087	1.24
1.38	2630	0.51	0.0135	1.24
1.34	2620	0.58	0.0151	1.28
1.10	2620	0.46	0.0121	1.36
2.18	2630	0.79	0.0207	1.28
0.98	2630	0.44	0.0115	1.19
1.65	2620	0.72	0.0188	1.11
1.02	2630	0.42	0.0111	1.11
0.94	2630	0.4	0.0106	1.18
0.76	2620	1.24	0.0327	1.95

CONCLUSION

The complex geotechnical problem which rocks of varying composition may pose is best assessed through their compositional features and physical properties. In order to achieve this, parameters such as density, moisture content, porosity, void ratio and water absorption were determined. Previous research on strength in relation to moisture content focused on artificial composite rock materials. Evaluation of compositional features further helps to reveal quartz and muscovite as two major mineralogical contents of the, which differ greatly in nature.

On the basis of density and water absorption among others, fresh quartz-schist is to some extent a suitable composite rock material for construction purposes. It is apparent that one physical property of the rock cannot be estimated on the basis of the other. The complexity in the engineering performance of quartz-schist will be due to different proportions of quartz and muscovite with voids that present in it.

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