

CLAY MINERALOGY, MAJOR ELEMENTS GEOCHEMISTRY AND STRENGTH CHARACTERISTICS OF THREE HIGHWAY SUBGRADE SOILS IN SOUTHWESTERN NIGERIA

MINÉRALOGIE DES ARGILES, PRINCIPAUX ÉLÉMENTS GÉOCHIMIQUES ET CARACTÉRISTIQUES MÉCANIQUES DE TROIS SOLS UTILISÉS EN COUCHE DE FONDATION DE ROUTE EXPRESS DANS LE SUD-OUEST DU NIGERIA

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Abstract

The clay mineralogical assemblage, major elements geochemistry and strength characteristics in terms of the California Bearing Ratio (CBR) of three genetically different residual soils in Southwestern Nigeria were investigated. The study revealed a fairly strong negative correlation of -0.58 between the amount of kaolinite and the silica-sesquioxides of iron and aluminium ratio. It also showed a weak positive correlation of 0.004 between the amount of kaolinite and ferric oxide. The amount of ferric oxide and kaolinite showed positive correlation of 0.24 and 0.29 respectively with the strength (measured in term of CBR) of the studied soils.

The study has stressed the relevance of a knowledge of geological characteristics prior to a rational understanding of some geotechnical properties of residual soils.

Résumé

L'article présente l'étude des minéraux argileux, des principaux éléments géochimiques et des caractéristiques de résistance mécanique mesurées par le C.B.R., de trois sols résiduels génétiquement différents dans le Sud-Ouest du Nigeria. Elle a mis en évidence une corrélation nettement négative ($-0,58$) entre la teneur en kaolinite et le rapport silice/sesquioxydes de fer et d'alumine, ainsi qu'une très faible corrélation positive ($+0,004$) entre la teneur en kaolinite et en oxyde de fer. On note des corrélations positives (respectivement $0,24$ et $0,29$) entre la teneur en oxyde de fer et en kaolinite par rapport à la résistance C.B.R. des sols étudiés. L'étude a montré l'importance de la connaissance des caractéristiques géologiques pour une bonne compréhension de certaines caractéristiques géotechniques des sols résiduels.

Introduction

The influence of geological parameters of clay mineralogy and major elements geochemistry on geotechnical properties of laterite soils have been the subject of investigation and discussion by various workers (e.g. Gidigas, 1976; Balogun, 1982 and Mesida, 1985). Differences in mineralogical, geochemical and hence engineering properties of soils are often caused by pedogenic factors such as parent rock, relief and climate. In this study, the clay mineralogy, major elements geochemistry and geotechnical properties of soils derived from sandstone, migmatite-gneiss and quartz-schist are investigated. The study focusses not only on the relationship between geochemistry and mineralogy but also on the extent to which the geological properties have affected the strength characteristics of the soils studied.

Physical setting and geology of the study areas

The study areas in southwestern Nigeria are shown in Fig. 1. The areas are contiguous to sections of the Lagos – Ibadan highway in Southwestern Nigeria.

The rocks in the study areas are sandstone of the Abeokuta Group (Omatsola and Adegoke, 1981), quartz-schist and migmatite-gneiss both of the Pre-Cambrian Basement Complex. Petrographic studies showed that the mineralogy varies from one rock to another. The sandstone essentially consists of quartz grains coated with iron compounds. The major minerals in the quartz-schist are muscovite, biotite, quartz and feldspars. The migmatite-gneiss contains biotite, hornblende, quartz, feldspar and muscovite. Whereas the migmatite-gneiss shows an intricate 'mixture' of felsic and mafic components, the quartz-schist displays remarkable foliation.

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Table 1 : Amount of ferric oxide and kaolinite in some horizons of the studied soils.

Parent rock	Ferric oxide (%)	Kaolinite (%)
Sandstone	6.53	53.87
	7.66	55.89
	9.08	67.36
	15.59	66.99
Migmatite-Gneiss	14.76	70.97
	15.82	68.03
	16.28	87.63
	13.84	76.66
Quartz-Schist	8.34	87.91
	8.21	94.56
	6.79	89.10
	10.57	91.59

Table 3 : Unsoaked CBR of soils compacted at the OMC of the modified AASHTO level and amount of ferric oxide.

Parent rock	Unsoaked CBR (%)	Amount of ferric oxide (%)
Sandstone	20.0	6.53
	26.0	7.66
	20.0	9.08
	34.0	15.59
Migmatite-Gneiss	38.0	14.76
	12.3	15.82
	54.6	16.28
	59.8	13.84
Quartz-Schist	59.4	8.34
	53.3	8.21
	9.2	6.79
	5.7	10.57

Table 2 : Silica-sesquioxide of iron and aluminium ratios and amount of kaolinite in some horizons of the studied soils.

Parent rock	Silica-Sesquioxide ratio	Kaolinite (%)
Sandstone	1.38	53.87
	1.29	55.89
	1.16	67.36
	0.89	66.99
Migmatite-Gneiss	0.89	70.97
	0.89	68.03
	0.84	87.63
	0.92	70.77
Quartz-Schist	1.02	87.91
	1.02	94.56
	1.01	89.10
	0.96	91.59

x = Sandstone - derived soil
 ● = Migmatite - gneiss - derive soil
 ○ = Quartz - schist - derived soil

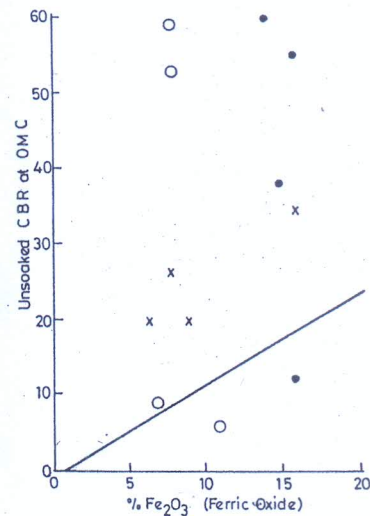


Fig. 4 : Unsoaked CBR at OMC against amount of ferric oxide (modified AASHTO level of compaction).

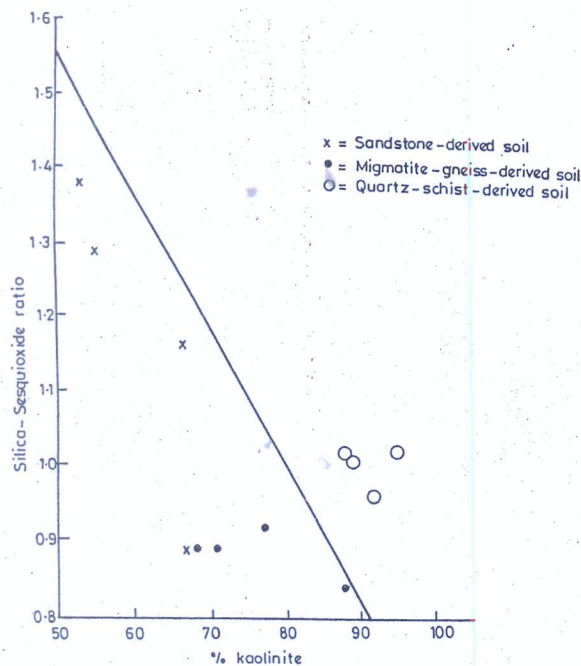


Fig. 3 : Silica-sesquioxide (of iron and aluminium) molar ratio against amount of kaolinite of studied soils.

terkorn *et al.*, cited in Gidigas (1976), to assess the degree of laterisation of tropical soils. The lower the ratio the higher the degree of laterization. Thus the higher the amount of kaolinite in the soils the higher would be the degree of laterization.

CBR and amount of ferric oxide. The California bearing ratio (CBR) of a soil is an indication of its strength. The unsoaked CBR of soils compacted at the optimum moisture content of the modified AASHTO level are shown against the amount of ferric oxide in Table 3. Figure 4 shows the cross-plotting of the parameters. Statistical treatment of the data gives a correlation coefficient of 0.24 between the CBR and amount of ferric oxide. The equation of the regression line is $y = 1.27x + 18.56$ where y and x are the CBR and % ferric oxide respectively. This positive correlation is in agreement with the findings of Madu (1977) who investigated some geotechnical properties of laterite soils in Eastern Nigeria.

Table 4: Unsoaked CBR of soils compacted at the OMC of the modified AASHTO and the amount of kaolinite.

Parent rock	Unsoaked CBR (%)	Amount of kaolinite (%)
Sandstone	20.0	53.87
	26.0	55.89
	20.0	67.36
	34.0	66.99
Migmatite-Gneiss	38.0	70.97
	12.3	68.03
	54.6	87.63
	59.8	76.77
Quartz-Schist	59.4	87.91
	53.3	94.56
	9.2	89.10
	5.7	91.59

Clay mineralogy and strength characteristics: Since kaolinite is the most abundant clay mineral in the soils, establishment of some association between the amount of kaolinite and the strength characteristics (in term of CBR) was made. Table 4 shows the amount of kaolinite and the corresponding CBR while Fig. 5 is the cross-plotting of the parameters. The equation of the regression line for the plot of amount of kaolinite (y) against the unsoaked CBR (x) is given by

$$y = 0.20x + 69.29$$

The correlation coefficient is 0.29. This means that the strength characteristic of the studied soils may be reliably assessed from a knowledge of their clay mineralogical properties.

Conclusions

Soils derived from rocks with widely different textural and mineralogical characteristics have, under similar weathering conditions, given rise to soils with different mineralogical and geochemical characteristics.

A weak positive correlation of 0.004 has been established between the amount of kaolinite and ferric oxide of the soils. However, a fairly strong negative correlation of -0.58 was found between the amount of kaolinite and the silica-sesquioxide of iron and aluminium ratio.

The amount of ferric oxide and kaolinite (the most abundant clay mineral) showed positive correlations of 0.24 and 0.29 respectively with strength (in term of CBR). Thus the strength of the soils may be reliably assessed from a knowledge of their clay mineralogy and major elements geochemistry.

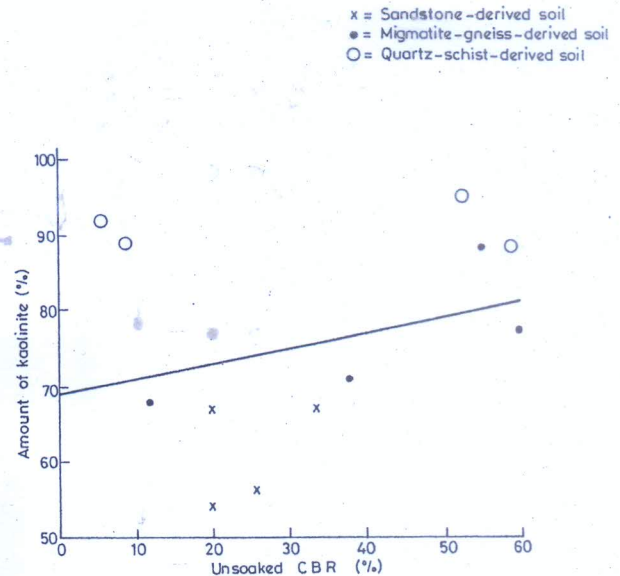


Fig. 5: Amount of kaolinite against Unsoaked CBR at OMC of soils compacted at modified AASHTO level.

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