Correlation between Cation Exchange Capacity and Geotechnical Properties of Lateritic Soils

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Abstract

The processes involved in determining the cation exchange capacity (CEC) of lateritic soils are complex and time-consuming, hence the need for its estimation from geotechnical properties. In this study, geotechnical properties of lateritic soils (derived from Gneisses) which are influenced by clay minerals are correlated with CEC. Thin sections of fresh gneisses were prepared for petrographic study, while disturbed and undisturbed soil samples were obtained with the aid of a hand urger, and core cutter respectively from profiles over gneisses, at various depths. Chapman's method was employed in the determination of CEC. Specific gravity (Gs) of the grains was determined using a pycnometer. Hygroscopic moisture content (Hmc), liquid limit (L_L) and plastic limit (L_p) were determined on air-dried soil samples based on ASTM D-4038 and D-4318 respectively. Cohesion (Cu) was determined by means of undrained triaxial compression test on undisturbed samples in accordance with the British standard (BS) 1377. Regression plot of each of Gs, against CEC shows that specific gravity increases with decreasing cation exchange capacity. In adition, inverse correlation also exist between each of L_L Hmc, Ip, and Cu in the order (r = -0.1,-0.19, -0.3, and -0.5). It is noted that the best correlation coefficient (r = -0.5) exists between undrained cohesion and cation exchange capacity with regression line Cu = -2.755CEC + 58.07. The results indicate that undrained cohesion is sufficiently good for the estimation of lateritic soils cation exchange capacity.

Keywords: *Cation exchange capacity, geotechnical properties, lateritic Soils*

1. Introduction

In many areas of geotechnical engineering where compositions of lateritic soils have been studied in Southwestern Nigeria, role clay minerals were found to be of paramount importance (Adeyemi, 1994). The cation exchange capacity of a soil reflects the type of clay minerals present in it (Krynine and Judd, 1958). The study of Yukselen and Kaya (2006) only established relationships between cation exchange capacity (CEC) and index properties of soils. This was done in order to provide a quick method for estimating CEC from various consistency and derived limits. The best correlation was found to exist between CEC and liquid limit. This is important as plasticity reflects the clay mineral in a soil.

Cohesion on the other hand, is an important engineering parameter which also attributes to clay minerals rather than any other property. In a similar development, engineering geological approach to soil properties study need to take cognizance of the parent rock factor. Adeyemi (1992), Adeyemi (1995) and Adebisi (2010) established that parent rock is a dominating factor influencing behavior of lateritic soils. This study is therefore aimed at predicting cation exchange capacity of lateritic soils of Gneiss origin in Southwestern part of Ngeria, from their relevant index and engineering properties.

2. Methods

2.1 Physiography and Geology

The study area covers Southwestern part of Nigeria. Samples were obtained at Idi-Ayunre, Ibadan (Fig. 1), where gneiss is mainly the bed rock. It stretches between longitudes 3^0 50'E and 3^0 52'E, and latitudes 7^0 14'N and 7^0 17'N (topographic maps of Ibadan, sheets 261 SW). The various combinations of pedogenic factors of which tropical climate is prominent, have been shown to cause the disintegration and transformation of the Gneisses into lateritic soils of variable thicknesses (Faniran and Jeje, 1983). The sampling locations were easily accessed through network of footpaths, tarred and gravel roads, which linked other minor and major roads throughout the study area. According to Gbadegesin 1992, the vegetation in the area consists of a complex combination of a variety of plant groups, which include tall grasses, herbs and small trees. Adebisi, 1999 established three major landform units in the scenery of the study area; these are hills, plains and river valleys, with the drainage terrain layout conforming to a dendritic pattern as shown in figure 1.

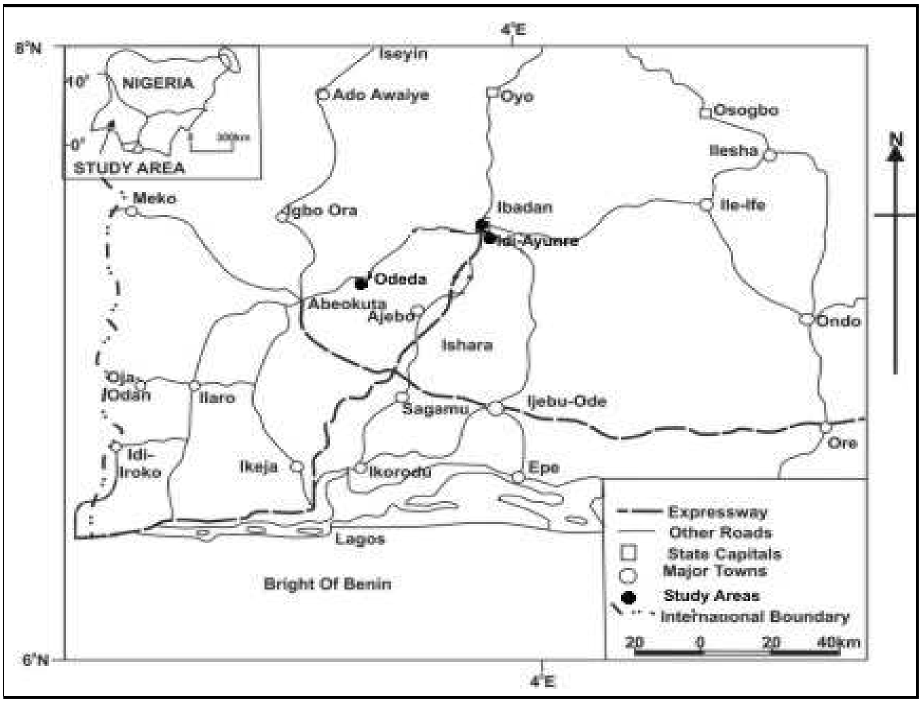


Figure 1. Map of South western Nigeria showing the study area

Geologically, the study area falls within the Basement complex of Southwestern Nigeria. Aspects of the geology of Idi-Ayunre, has been published by Jones and Hockey (1964). Idi-Ayunre is underlain by the variably migmatised undifferentiated gneiss and schist, which constitute part of the Precambrian Basement rocks in the Gneiss complex of Nigeria. Field study revealed that gneisses are more extensive than schist in the area. They occur as well-exposed outcrops and are highly migmatized (Fig 2) and display a considerable variation in degree of banding.

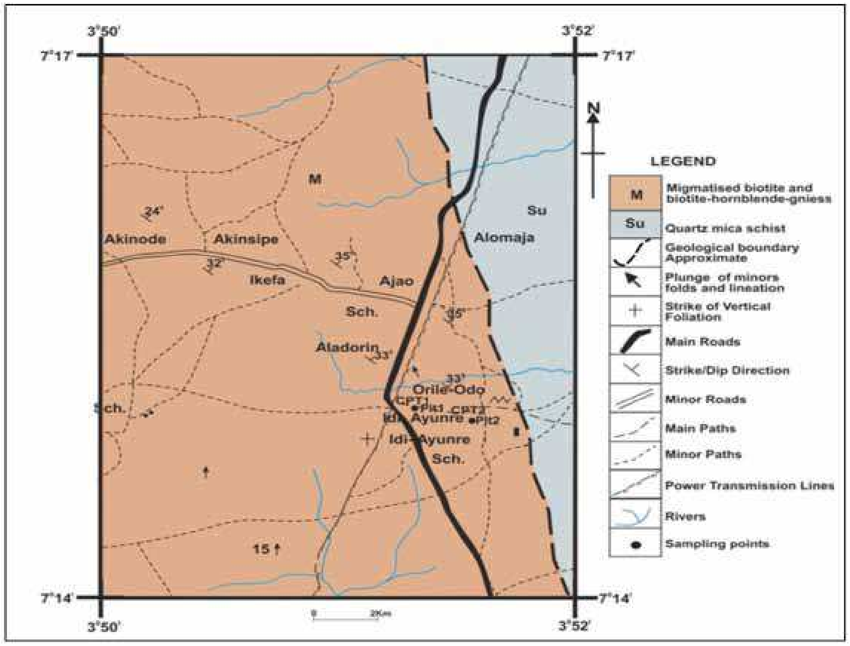
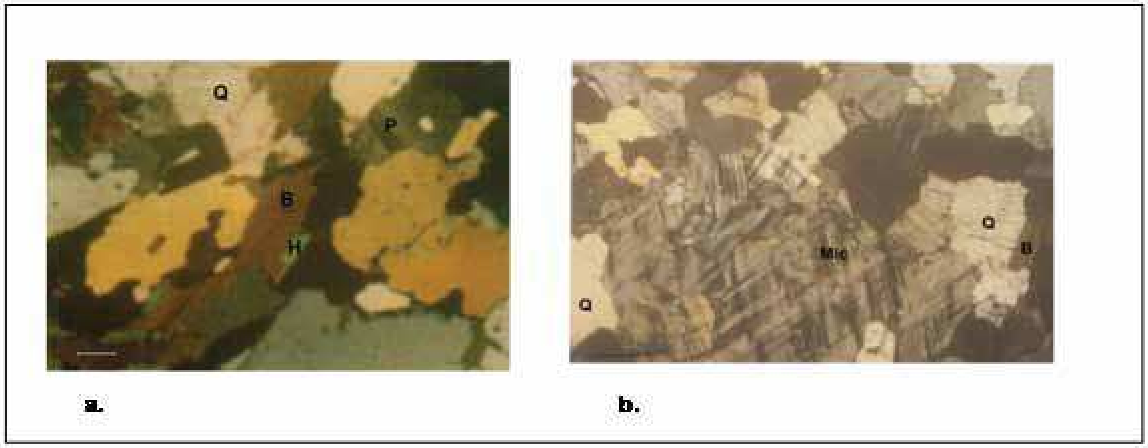


Figure 2. Geological map of the study area

The minerals present in the studied gneisses, as seen from thin sections under transmitted light (Fig 3a and b) are essentially quartz, plagioclase (alkali feldspars), orthoclase and biotite. The gneisses at WETTIP quarry and other areas around Idi-Ayunre town are overlain by thick overburden. The exposed overburden measured between 4 m to 5 m, an evidence of deep weathering. Their weathered profiles at two locations (Fig 4a and b) which form pits 1 and 2, revealed that the top soil is 0.2 m to 0.3 m thick, and underlain by reddish brown sandy silty clay about 0.8 m thick, which grade into mottled reddish brown and brownish color.



Figures 3a & b. Photomicrograph of banded gneiss in transmitted light; showing plagioclase (P), Hornblende (H), quartz (Q), Mirocline (Mic) and biotite (B); (Bar scale = 2.5mm)

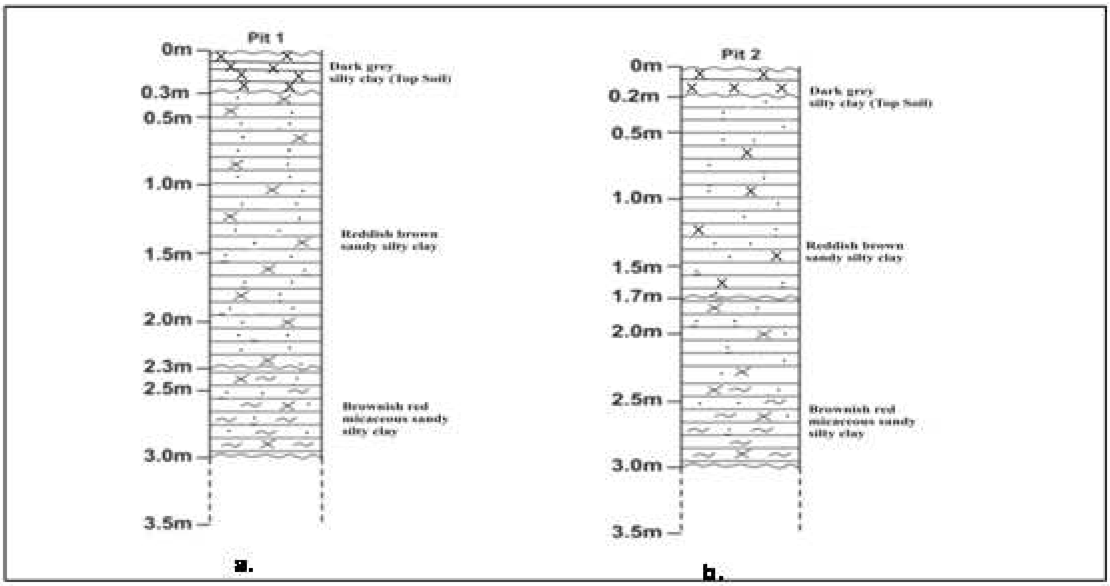


Figure 4a & b. Profiles of soils developed over gneiss in Idi-Ayunre form Pits 1 & 2

2.2 Method of Study

Thin slices of fresh gneisses were cut with a diamond saw and attached to a thin glass using aradite for petrographic study. Twelve samples each of disturbed and undisturbed soil were obtained with the aid of a hand urger, and a core cutter respectively, from profiles over gneisses, at various depths. Experimental cation exchange capacity values were determined following the method of Chapman, (1965), while hygroscopic moisture content of the studied soils were determined by air-drying method. The specific gravity (Gs) of the samples was determined using pycnometer. Liquid limit (L_L) and plastic limit (L_p) were determined on air-dried soil samples which passed through the British standard sieve no. 40 following ASTM (1991) D-4038 and D-4318 respectively. This facilitates calculation of the soil's plasticity index (Ip). Cohesion (Cu) was determined by means of undrained triaxial compression test on undisturbed samples in accordance with the British standard (BS) 1377 (1990).

2. Results and Discussion

Grain specific gravity of the soils ranges between 2.62 and 2.71 with a maximum plasticity index below 50 %. This indicates cohesive soils, which according to Mitchel (1993) is devoid of montmorillonite. Soils with CEC below 3 meq/100 g are sandy, while soils with CEC above 20 meq/100 g are clayey (Chi and Richard, 1999). It follows that the higher the CEC, the more clayey a soils would be. All the studied soils have CEC values greater than 3 meq /100 g but very much less than 30 meq/100 g indicating that, the soils are weakly clayey. Hygroscopic moisture content (Hmc) is desirable for soil assessment in the sense that it is not affected by seasonal changes. For the studied soils, it ranges between 0.27 and 0.57. This is consistent with the established variations in the Hmc values obtained for soils by Shah and Sigh (2005).

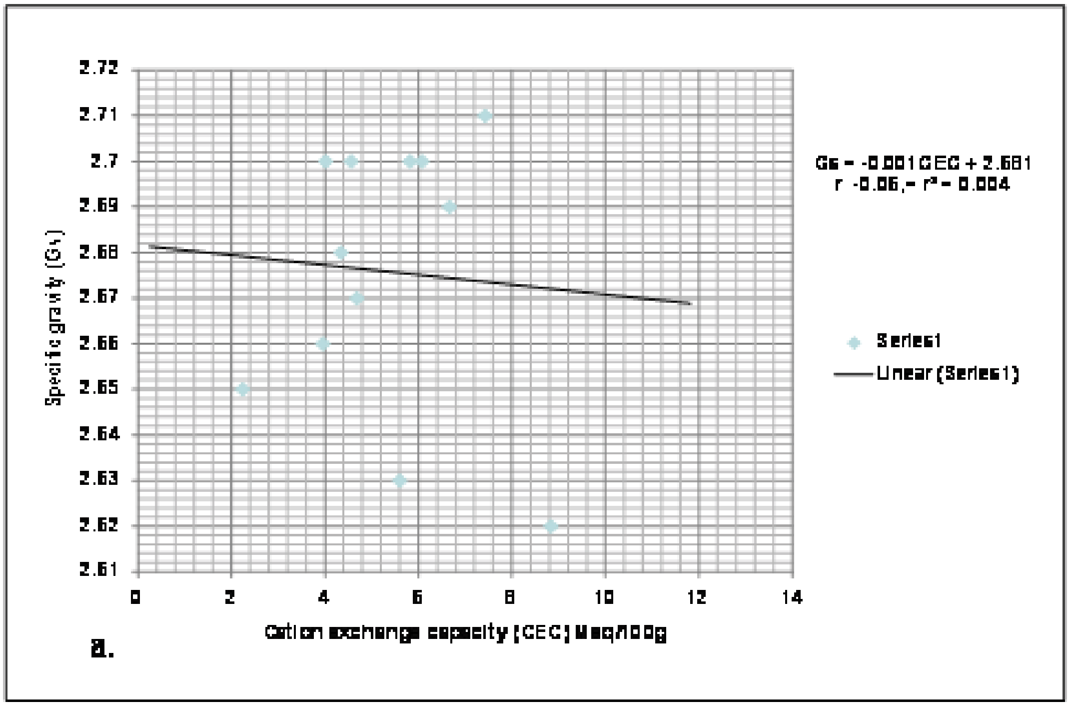


Figure 5a. Regression plot of specific gravity against cation exchange

Correlation of CEC with geotechnical properties of engineering soil will definitely, permit a complete preliminary design estimate. Regression plot of each of Gs, against CEC (Fig. 5a) shows that specific gravity increases with decreasing cation exchange capacity. This is in agreement with the findings of Krynine and Judd, (1958). In figures 5b – e, inverse correlation also exist between each of L_L, Hmc, Ip, and Cu in the order (r = -0.1,-0.19, -0.3, and -0.5). It is noted that the best correlation coefficient (r = -0.5) exists between undrained cohesion and cation exchange capacity with regression line Cu = -2.755 CEC + 58.07. This shows that undrained cohesion is sufficiently good for the estimation of lateritic soils cation exchange capacity.

4. Conclusions

Cation exchange capacity of a soil increases with decreasing specific gravity, hygroscopic moisture content, liquid limit, plasticity index and cohesive strength of a lateritic soil. This implies that the more clayey a soil is the less its specific gravity, hygroscopic moisture content, liquid limit, plasticity index and cohesive strength. Statistical analysis revealed that CEC of the lateritic soils depended much strongly on the cohesive strength, rather than any of the index properties and hygroscopic moisture content.

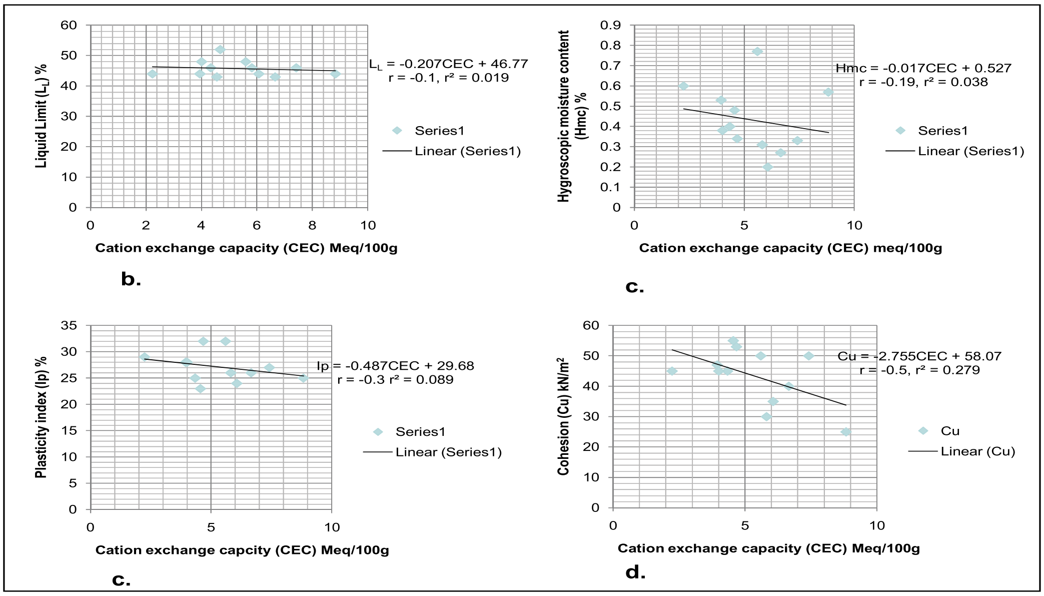


Figure 5b-e. Respective regression plots of liquid limit, hygroscopic moisture content, plasticity index and undrained cohesion against cation exchange capacity

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