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The Influence of Clay Minerals on the Geotechnical Behaviour of Some Red Tropical Soils from Dunde and Environ, Northeastern Nigeria

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ABSTRACT:

The properties of clay that influence the soil geotechnical behaviour are fundamentally determined by the physio-chemical characteristics of the composite minerals and the relative proportion in which the minerals are present. It requires a number of sophisticated laboratory equipment and time to determine these characteristics. However, an alternative and all-encompassing method which combines simple and normal laboratory tests that gives a quantitative measure of the composite effect of all the basic properties of clay, termed Clay Colloidal Activity was used in this study. It is an index property, the ratio of plasticity index to clay fractions that combines the Atterberg Limits and the particle size distribution, computed by using the normal routine laboratory tests. In this study, the Clay Colloidal Activity of soil samples collected from Dunde, Belel and Sorau in Maiha Local Government Area of Adamawa State, Northeastern Nigeria were tested. The moisture content of the soils ranged from 10.3% to 12.6%. Plasticity Index for the soils studied ranges from 16 to 25, while the ratio of Moisture Content to Liquid Limit was from 0.21 and 0.35. These values suggested low risk of liquefaction thereby mitigating the possibilities of danger and associated unfavorable engineering issues. Dunde has Colloidal Activity value of 0.80, Sorau has 1.25 and Bele has 1.09. All of them were found to have clay of moderate values of Clay Colloidal Activity, and are considered normal clays that may not pose danger to engineering projects.

Key words: Clay, physicochemical, composite effect, clay colloidal activity, Atterberg Limits.

Authors' Contributions

A.E. Utsalo was involved in the conceptualization of the idea, data acquisition, and analysis. K.O. Ejairu was involved in the interpretation, drafting, proofreading, and revising the manuscript for publication. Both authors have consented to the submission, and subsequent publication of the article.

INTRODUCTION

Red tropical Soils are among the major construction materials needed for infrastructure projects in Nigeria. They exist naturally, abundant, assessable and relatively cheap. However, they are problematic and exhibit performance issue (Okagbue and Onyeobi, 1999; Utsalo *et al*., 2023). Mechanical instability and thermal instability are some of the associated problems identified. These have been linked to their mode of formation and mineralogy; and as such, the soils have been found to deviate in terms of engineering behaviour, from expectations of standard soil mechanics (Malomo, 1977). Despite these problems, dangers associated with the soils can be averted if the physico-chemical characteristics of the constituent minerals of the soils, which can be determined is tested and known prior to construction works.

Difficulties have been found to associate with the evaluation of the geotechnical behaviour of these soils, because the laboratory equipment needed for the analysis of their physicochemical parameters cannot easily be assessed,

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but with the clay colloidal activity, such difficulties and associated time factor are mitigated. The presence of active or problem clays that may pose danger in construction may be indicated by high values of clay colloidal activity. With the information obtained, catastrophe can be averted by taking well guided decisions.

Location of Study Area

The study area is delineated by latitudes 09^0 37' 00'' N and 09^0 40' 00'' N; and longitude 13^0 23' 00'' E and 13^0 15' 0" E 9 (Figure 1); and is located in Maiha Local Government Area of Adamawa State, Northeastern Nigeria. Specifically, Dunde, Sorau and Belel from where the test samples used for the work were collected experience warm savannah tropical climate, with two well defined seasons (rainy and dry seasons). The rainy season stretches from May to October while the dry season occupies the period from November to April and having a mean annual rainfall of 900 mm to 1,500 mm (Adzandeh *et al*., 2024). The climate gives an idea of the environmental conditions under which the basement rocks weather to form the red tropical soils under investigation. Coordinates of the sample locations are presented in table 1.

Table 1: Sample Locations, coordinates and Geological Settings

SAMPLE	LOCATION	LOCAL GOVT. AREA	COORDINATES N	E	GEOLOGIC SETTING
DU	Dunde	Maiha	$9^0$37'60"	$13^0$23'60"	Basement
SO	Sorau	Maiha	$9^0$45'0"	$13^0$15'0"	Basement
BE	Belel	Maiha	$9^0$39'30"	$13^0$13'31"	Basement

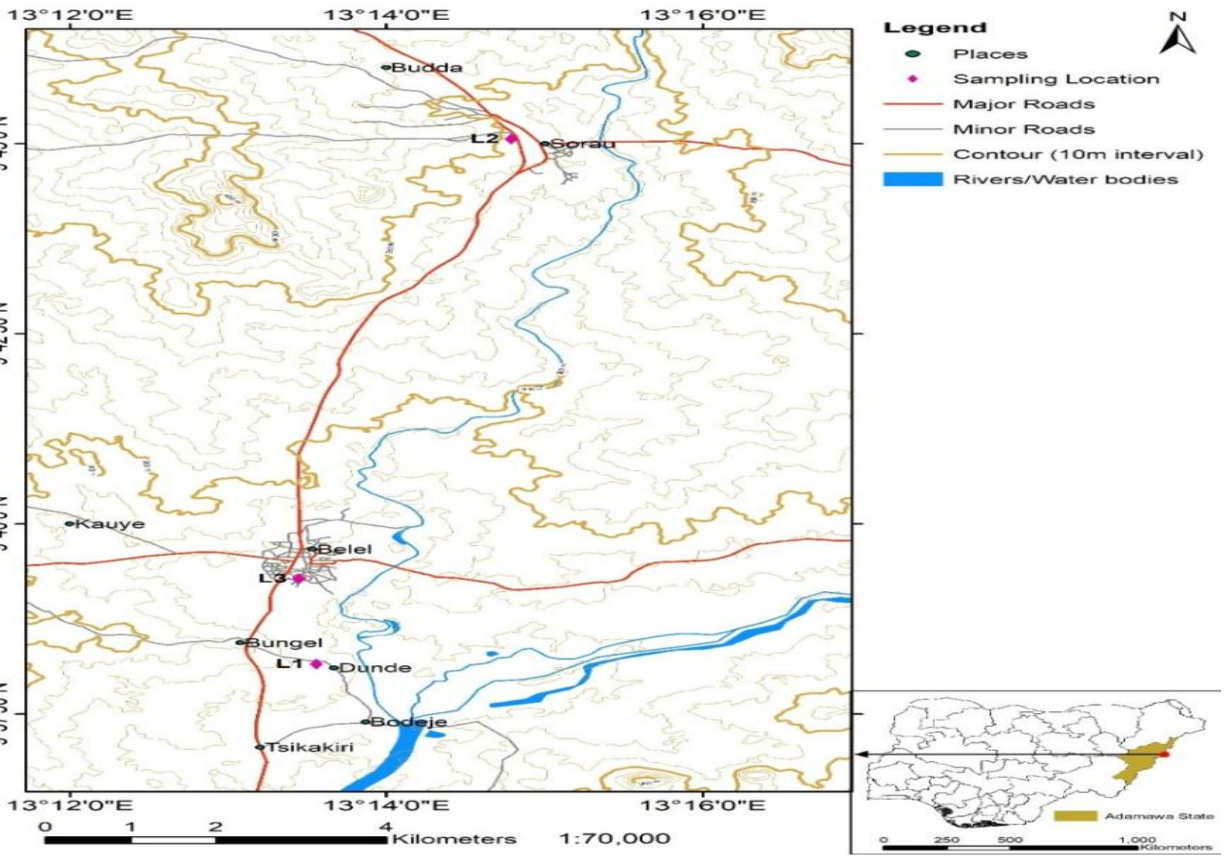

Figure 1: Map of Nigeria Showing Sampling Points, indicated as L1, L2, and L3.

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Geological Setting

Adamawa State is situated partly on the basement of Northern Nigeria (undifferentiated granites) and partly on the sedimentary basin of the Benue trough composed of sandstone, clay and clayey sand. The sample locations are sited on the older granite of the basement area overlained mainly by red tropical soils. The lithologic profiles in the three sampled locations were similar. At Dunde, about 100m from the bank of Mayo Pandi, a seasonal stream that flows through Dunde village (on the Cameroon side), the test pit dug through the overburden intercepted fairly weathered basement rock at 2m depth and exposed fractured flesh colour porphyritic granite. The fairly weathered granite is expected to rest on the fresh basement rocks also expected to be the continuation of an underlying porphyritic granite.

Evidences from the test pits, borrow pits and outcrops reveal that the basement rocks here are mainly varieties of granite overlain with red tropical soils and weathered basement materials. The general lithologic profile exhibits reddish brown top humus soil, reddish grey coarse gritty clayey soil, weathered flesh colour porphyritic granite and fresh flesh colour porphyritic granite (Figure 2). This is replicated in other locations studied. Soils here are generally coarse grained with pebbles of quartz and feldspar; and are slightly clayey.

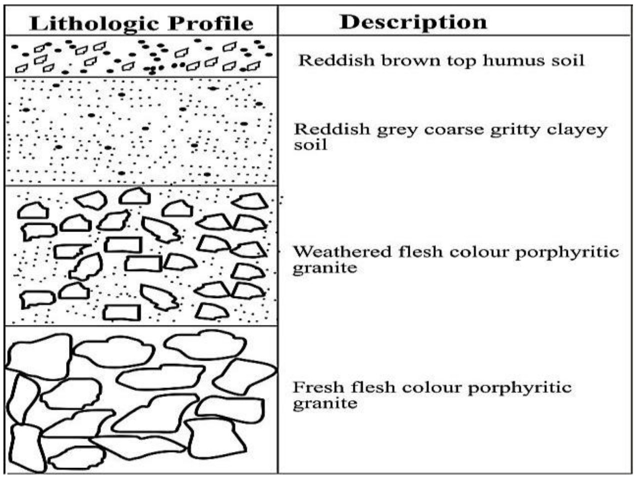

Figure 2: The General Lithologic Profile of Dunde and Environ

In some other locations, it is possible that the flesh colour porphyritic granite could be replaced with any other basement crystalline rock.

MATERIALS AND METHOD

The investigation involved both field and laboratory works.

Field Work

The field work entailed the taking of in-situ speedy moisture content test, and the study and analysis of the geologic conditions of outcrops, borrow pits and lithologic profiles as seen from fresh test pits; and collection of fresh soil samples from test pits for appropriate laboratory tests and analyses. Disturbed samples collected were packed in polythene bags, sealed, well labeled, location and field names accurately inscribed and transported to the laboratory.

Laboratory Studies

Disturbed samples collected were subjected to classification, mechanical and engineering tests in the laboratory in line with established standards; British Standards Institution (1990, 1981), to improve on the field identification, classification and nomenclature. The tests conducted include wet sieving, hydrometer and Atterberg Limits tests. Prior to wet sieving, the samples were air dried and treated with sodium hexametaphosphate solution to disperse the clay fraction from the coarser soil grains. Each sample was spread on a sample tray, soaked with the dispersant solution and stirred for adequate dispersion of the clay size particles.

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RESULTS AND DISCUSSION

Moisture Content

Moisture Content of the lithologies sampled were tested in the field using the speedy moisture tester. The moisture content of the soils ranged from 10.3% to 12.6% (Table 2). The test was conducted in June when the rainy season was just setting in, thus the increase in the natural moisture content of the soils.

Table 2: Ratio of Moisture Content to Liquid Limit

SAMPLE	MC	LL	MC/LL	
	(%)	(%)		
DU	12.6	36	0.35	
SO	10.3	49	0.21	
BE	11.5	44	0.26	

Clayey soil's susceptibility to liquefaction was indicated by the ratio of Moisture Content to Liquid Limit (MC/LL). At MC/LL = or > 0.85, the soil has the tendency to liquefy; and this phenomenon reduces the shear strength of the soil and subsequent structural failure.

Atterberg Limits

Atterberg Limits comprises Liquid and Plastic Limits from which the Plasticity Index was computed. The Plastic Index is a major parameter used in the computation of clay colloidal activity used in predicting the geotechnical behaviour of the soils. The Atterberg Limits influence the geotechnical behaviour based on the variation in the moisture content of the soil. The Plasticity Index is an indicator of soil's potential to resist liquefaction. The Liquid Limit, Plastic Limit and Plasticity Index values of the soils are presented in Table 3.

Table 3: Atterberg Limits of the Soils Studied

SAMPLE	LL (%)	PL (%)	PI
DU	36	20.0	16
SO	49	24.0	25
BE	44	20.0	24

At the Plasticity Index of PI = or < 12 and MC/LL = or > 0.85, liquefaction becomes imminent. Plasticity Index for the soils studied ranges from 16 to 25 while the ratio of MC/LL is 0.21 to 0.35 suggestive of low risk of liquefaction thereby mitigating the possibilities of danger and associated unfavorable engineering issues. Moses *et al*. (2006) reported the possibility of the occurrence of liquefaction in depths hidden from the surface which can cause structural failure of projects located within or above the substratum directly involved.

Swelling, Compressibility, Consolidation and Plasticity Potentials

The soils have intermediate Plasticity and Compressibility as shown on the Casagrande chart, Figure 3. This indicates that the risk of excessive swelling and contraction is not high. DU, BE and SO contain inorganic clays of intermediate plasticity.

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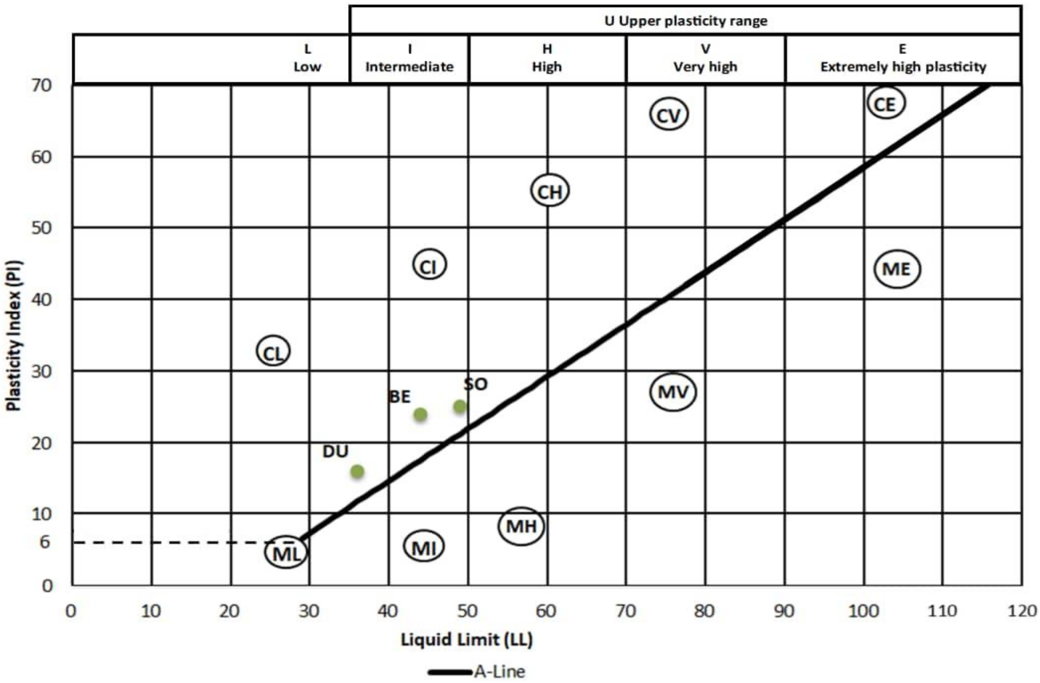

Figure 3: Plasticity of the Soils

Clay Colloidal Activity

Clay colloidal activity of the soils studied was determined by the ratio of the Plasticity Index to clay fraction. This parameter categorizes clayey soils as containing active, normal and inactive clays.

$$Clay\ Colloidal\ Activity = \frac{Plasticity\ index}{Clay\ fraction}$$

With this, the clays are classified into three classes as,

Inactive clays - Activity < 0.75

Normal clays - Activity 0.75 - 1.25s

Active clays - Activity > 1.25

Clay Colloidal Activity

All the soils Studied have normal clays. DU has Colloidal Activity value of 0.80, SO has 1.25 and BE has 1.09. This information is contained in Table 4.

Table 4: Clay Colloidal Activity of the soils

SOIL	CLAY FRACTION (%)	PI	CLAY COLLOIDAL ACTIVITY	CLASS TYPE
DU	20	16	0.80	Normal
SO	20	25	1.25	Normal
BE	22	24	1.09	Normal

The clay colloidal activity values obtained for the soils corroborate the presence of kaolinite as normal clay in red tropical soils and major mineral as reported by Adewole *et al*., (2020), Ajayi and Agagu, (1981). If a soil exhibits high values of clay colloidal activity, it may require further investigation by XRD (clay mineralogical

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analysis) as recommended by Utsalo *et al*. (2023) to ascertain if sensitive and problematic clays are involved or if it is just because of soil geologic history and cohesion (Skempton, 1984; Skempton, 1953) which may not pose much danger. The soils studied also do not have clay of too low colloidal activity (less than 0.75). This suggests that taking satisfactory undisturbed samples in deep clay beds may not be too difficult.

CONCLUSION

The soils studied are made up principally of clays with moderate values of clay colloidal activity, which suggests that they will likely exhibit normal clay behaviour.

Their plasticity and Compressibility figures are intermediate. This indicates that the soils are unexpected to react adversely to moisture or dry conditions. This alleviates the possibility of excessive expansion, contraction or fluidity connected with problem clays.

The results indicated that the soils might not constitute significant dangers when used for civil engineering/construction works, on the ground that they are used within competence and best practices. Soil stabilization using chemical additives such as lime; with dosages ranging from 2% to 8% (Etim *et al.,* 2021) may be considered in circumstances requiring additional soil strength for the intermediate to high plasticity clays in the studied areas.

REFERENCES

1. Adewole, J.A., Adeyemi, M.O and Omojola, D.I. (2020): Geochemical and Mineralogical Characteristics of Clay Deposits at Ijesha–Ijebu and its Environs, South Western Nigeria. Global Journal of Pure and Applied Sciences. Vol 26, 2020, P119 – 130
2. Adzandeh, A.E., Hamid-Masoku, I.A., Ayodele, E.G., Olayinka-Dosunmu, D.N., Badejo, O.T and Okolie, C.J. (2024): Integrating GIS and AHP for Multi-Criteria Flood Vulnerability Assessment in the Benue River Basin, Nigeria. Dutse Journal of Pure and Applied Sciences. 10(3b): 106 - 123.
3. Ajayi, J.O and Agagu, O.K. (1981): Mineralogy of Primary Clay Deposits in the Basement Complex Areas of Nigeria. Journal of Mining and Geology. Vol. 1. 18 Pp, 27-30
4. British Standards Institution (1990): Methods of Testing Soils for Civil Engineering Purposes, BS1377.
5. British Standards Institution (1981): Plasticity Chart for the Classification of Soils. British System, BS5930.
6. Malomo, S.S. (1977): The Nature and Engineering Properties of Some Red Soils from North East of Brazil. PhD Thesis, Dept. of Civil Engineering, the University of Leeds, England, 292 Pp.
7. Etim, R.K., Attah, I.C., Ekpo, D.U. *et al.* Evaluation on Stabilization Role of Lime and Cement in Expansive Black Clay–Oyster Shell Ash Composite. *Transp. Infrastruct. Geotech.* 9, 729–763 (2022). https://doi.org/10.1007/s40515-021-00196-1
8. Moses, R.E.S., Seed, R.B., Kayen, R.E., Stewart, J.P, and Der Kiureghian, A. (2006): CPT - Based Probabilistic Assessment of Seismic Liquefaction Initiation. A report on research sponsored by California Department of Transformation (Caltrans), California Energy Commission (CEC) and Pacific Gas and Electricity Company (PG and E) through the Pacific Earthquake Engineering Research Center (PEER) Lifeline Program, Task 3D02
9. Okagbue, C.O. and Onyeobi, T.U.S. (1999): Potential of Marble Dust to Stabilize Red Tropical Soils for Road Construction. Engineering Geology 53(S 3-4): 371 – 380, DOI: 10.1016/S0013 – 7952 (99) 00036-8.
10. Skempton, A.W. (1953): The Colloidal Activity of Clays. Proceedings of the 3rd International Conference on Soil Mech. and Foundation Engineering, Vol. 1, 57 – 62
11. Skempton, A.W. (1984): Slope Stability of Cuttings in Brown London Clay Imperial College, University of London. Online (2015): DOI: 10.1680/SPOSM.02050.0021. Pp 241 - 250
12. Utsalo, A.E., Ighodaro, E.J. and Komolafe, N.P. (2023): Clay Colloidal Activity in Red Tropical Soils: Geotechnical Insights from South-West and South-South Nigeria. Western Delta University Journal of Natural and Applied Sciences (WDUJNAS). Vol. 3(1). Pp.18-25.