Contents list available at Journal of e-Science Letters

Journal of e-Science Letters

journal homepage: http://scienceletters.researchfloor.org/

In-Situ Assessment of California Bearing Ratio Reduction Coefficient of Three Genetically Different Lateritic Derived Soils

Ikubuwaje, C.O.*, Fakode, R.O. and Bosikun, K.S

Department of Mineral and Petroleum Resources Engineering Technology, the Federal Polytechnic, Ado Ekiti, Nigeria
Department of Geology, Kansas State University, USA

ARTICLE INFO

Article History:
Received 28 July 2022
Revised 26 September 2022
Accepted 19 November 2022
Available Online 22 November 2022

Keywords:
in-situ assessment,
lithology,
CBR Coefficient and Dynamic cone penetration (DCP).

ABSTRACT

This study on in-situ assessment of three genetically different lateritic derived soil was carried out to investigate the strength reduction rate of different lithological derived lateritic soils. The in-situ (DCP) sounding was performed at thirty-seven investigation points and soil samples were collected along soil's profile for moisture content analysis. The studied route was underlain mainly by porphyritic granite (OGp), medium to coarse grained granite (OGe) and charnockite (Ch). The mean moisture content values ranged from 13.67 - 24.96%, 7.52 - 15.67% and 11.38 - 17.21% for Ch, OGp and OGe derived soils respectively, with corresponding FCBR values of 7 - 19%, 13 - 53% and 7 - 37% for Ch, OGp and OGe respectively. The results of the CBR reduction coefficient was were 1.85, 1.47 and 1.67 for Ch, OGp and OGe derived soils respectively. This implies that all the derived soils are susceptible to ingress of water with the consequential reduction in strength, which is the characteristic of the lateritic soils. Meanwhile, the degree of CBR reduction is an expression of the lithological differences in the three rock types. Geological factor such as lithology should be taken into consideration whenever lateritic soils are being considered for construction.

1. Introduction

The primary task of any foundation engineering study is to generate reliable geotechnical data to arrive at a safe design in order to avoid conflict of interest (Osammor, 2009). Hence, it is very crucial to obtain comprehensive information that reflect the true nature of the subgrade soil properties and ground conditions. This is more important especially in the design and construction of highways, where the sub-grade soils play an important role in imparting structural stability to the pavement structure as it receives loads imposed upon it by road traffic. However, their strength values is greatly influenced by the moisture content. The higher the moisture content, the lower the strength of the soils. This behavior is attributed to the variation in soil structure with varying moisture content. Gerrard (2000) affirms that bedrock influences soils through weathering process and afterward through the weathered materials. Adeyemi (1992) and Adebisi (2003) in their works all described the various degrees of weathering processes experienced by the parent rocks through the influence of water and other agents to form laterized profiles of soils with diverse thicknesses. According to Adeyemi (1995), textural and mineralogical characteristics of parent materials could be responsible for behavioral differences in the engineering properties of soils derived from genetically different parent rock material. CBR being sensitive to many parameters such as moisture content, grain size, density, soil types among others, IRC: SP 72(2015) recommends the use of dynamic cone penetration test (DCPT) to evaluate the subgrade for its in-situ CBR.

The Study Area

The study area covers parts of the F209 road within the northern environs of Akure, southwestern Nigeria. It stretches between Latitude 07°16.00'N-7°28.00'N and Longitude 005°10.00'E-005°17.00'E. It is bounded in the North by Iju/Ita-Ogbolu Local Government and in

*Corresponding Author: Ikubuwaje, C.O.
E-mailAddress: cikubuwaje@gmail.com ; bosikunkehinde@gmail.com
http://dx.doi.org/10.46890/SL.2022.v03i05.002

the South by Akure South Local Government both in Ondo State. The road passes through Iju/Ita-ogbolu Local Government. The study area contains brownish to reddish residual soils with fine to coarse grained texture. The route is characterized with potholes, wavy and extensive surface failure. The texture is found to be fine to coarse grain. The laterite is sticky and well compacted together. The geological setting of the highway is underlain by rocks of the Precambrian basement complex which vary in type, colour, nature, structure, mineralogical composition and texture (Fig.1). The variation in properties of these rocks is primarily due to the effect of various orogenic and deformational episodes on the rocks at different times during their evolutionary history (Ademeso, 2010). Detailed geological mapping revealed the presence of ~~that~~ rocks such as coarse-grained charnockite, medium-to-coarse-grained granite, porphyritic granite. The rocks have also undergone various degree of weathering.

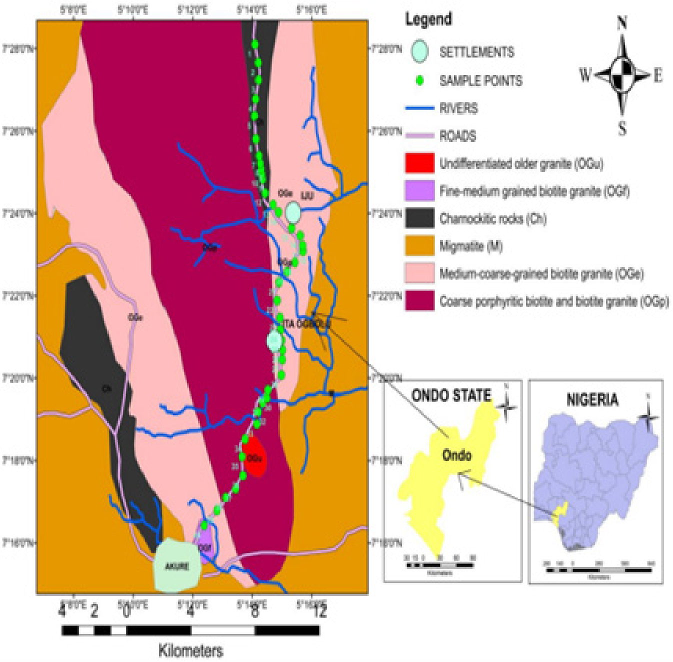

Fig.1: Geological map of the study area (modified after Olarewaju, 1987)

Methods

In-situ geotechnical investigation for subgrade characterization was performed using Dynamic cone penetration test (DCPT) as designated in ASTM D6951 / D6951M-09, (2015). This was performed at an average interval of 500m along the entire route since almost the whole road pavement had failed. A total of thirty seven (37) test pits were established and dug for collection of soil samples. Soil samples were taken at an interval of 450mm, 650mm and 900mm respectively down the profile to examine moisture content variations and its effect along the profile especially on the strength parameter (CBR). The collected soil samples were kept in polythene bags labelled, sealed and brought to the laboratory for analysis. DCP readings are interpreted using DCP software package. The software uses an equation that relates Penetration Index with CBR. These tests were performed during the month of March, before the full onset of the rainy season.

The effect of moisture content conditions on strength parameter was examined by applying the modified equation of reduction in CBR/increase in moisture content equations 1 and 2 (Adeyemi, 2022). The modified formulae make use of the highest and lowest CBR with their respective moisture content to derive co-efficient of reduction properties instead of optimal moisture content and natural moisture content.

$$\%\ \text{Reduction in CBR} = \frac{\text{Unsoaked CBR} - \text{Soaked CBR}}{\text{Unsoaked CBR}} \times 100\% \quad \ldots\ldots 1$$

$$\%\ \text{Increase in MC} = \frac{\text{Moisture content of unsoaked sample} - \text{OMC}}{\text{OMC}} \times 100\% \quad \ldots\ldots 2$$

Results And Discussion

The properties of lateritic soil deposits vary from place to place because of the differences in the geological arrangements, prevailing climatic conditions and the type of mineral present (Adnan *et al.,* 1994). However, the degree of change (reduction) in the CBR values is directly proportional to the amount of moisture content absorption. The result of moisture content variations on FCBR values and co-efficient of reduction of studied soils are presented in Table 1 and Table 2 respectively. The mean moisture content values ranged from 13.67 - 24.96%, 7.52 - 15.67% and 11.38 - 17.21% for Ch, OGp and OGe derived soils respectively. while the mean FCBR values ranged from 7 - 19%, 13 - 53% and 7 - 37% for Ch, OGp and OGe investigation points respectively. Generally, Ch derived soils give rise to soil with the highest moisture content and lowest FCBR, OGp derived soils give rise to soil with the lowest moisture content with the highest FCBR and OGe derived soils give rise to soil with the intermediate moisture content with corresponding FCBR values. This may be attributed to the percentage of fines, amount of clay content and types of clay minerals of the derived soils. However, the results of the ratio values range from 0.71 to 6.15 with an average of 1.85 for Ch derived soils, from 0.27 to 2.78 with an average of 1.47 for OGp derived soils and 0.67 to 6.36 with an average of 1.67 for OGe derived soils. This implies that all the derived soils are susceptible to ingress of water with the consequential reduction in strength which is the characteristics of the lateritic soils. Meanwhile, the degree of susceptibility differed. The result showed that Ch derived soils have the highest reduction rate, next by OGe derived soils and OGp derived soils have the lowest reduction properties. This is because the water absorbing capacity of the Ch derived soil is greater than that of the kaolinite dominated granite derived soils. Rate of loss of shear strength could contribute to the failure observed along the entire derived soil section along the study area. A good subgrade or sub-base soil should not suffer high reduction in CBR as a result of soaking. The co-efficient of reduction in strength parameter values of the derived soils differ on account of the type of mineral present and textural composition. The results showed that increase or decrease in the moisture content values give rise to decrease or increase in the CBR values respectively, either vertically along the soil's profiles or laterally across the soil's horizons.

Table 1: Moisture Content Variations on FCBR values of Studied Soils

S/N	Parameter	45mm	65mm	90mm	Rock types	S/N	45mm	65mm	90mm	Parameter
1	MC	18	24	26	Ch	6	16	19	20	MC
1	CBR	13.7	6.9	5.7	Ch	6	26	13.4	12.6	CBR
2	MC	25	23	24	Ch	7	16.19	17.49	17.06	MC
2	CBR	10.5	11.4	10	Ch	7	17.4	14.1	15.2	CBR
3	MC	21	21.3	22	Ch	8	16.32	17.48	17.62	MC
3	CBR	12.4	13.4	15.2	Ch	8	13	13.5	11	CBR
4	MC	17.5	22	21	Ch	9	14.9	15.82	24.99	MC
4	CBR	28.4	14.1	15.6	Ch	9	12.6	9.6	6.5	CBR
5	MC	18	21.3	22.5	Ch	10	27.69	20.65	17.31	MC
5	CBR	25.4	9.6	6.9	Ch	10	3.8	5.4	10.8	CBR
	MC				Ch	11	10	14.98	16.04	MC
	CBR				Ch	11	25	13.4	12	CBR
12	MC	7.62	8.95	**8.3**	OGp	18	4	6.97	11.58	MC
12	CBR	53	44.9	**48.1**	OGp	18	71.8	48.1	34.9	CBR
13	MC	15.7	15.61	**15.70**	OGp	19	8.5	9.7	**9.7**	MC
13	CBR	12.5	12.5	**13.4**	OGp	19	56	52	**52**	CBR
14	MC	7.74	6.72	**7.75**	OGp	20	14.75	14	**14.70**	MC
14	CBR	33	36.9	**33.0**	OGp	20	18.10	18.7	18.10	CBR
15	MC	10.8	10.07	**12.08**	OGp	21	14.27	14.69	**14.09**	MC
15	CBR	33	36.9	**27.2**	OGp	21	14.1	14.8	**15.6**	CBR
16	MC	9.7	**8**	**7.9**	OGp	22	7.89	8	**8.4**	MC
16	CBR	27.2	**34.9**	**34.9**	OGp	22	48.1	48.1	**40.5**	CBR
17	MC	6.88	11.9	**13.88**	OGp	23	9.35	11.7	11.7	MC
17	CBR	48.1	34.9	**22.2**	OGp	23	34.9	27.2	27.2	CBR
24	MC	9	9	7.79	OGe	31	11.7	13.87	14.1	MC
24	CBR	26	25.6	41.8	OGe	31	16	11.2	11.15	CBR
25	MC	9	11	16.41	OGe	32	5.14	10.19	12.95	MC
25	CBR	34.9	27.2	12.5	OGe	32	50	34.9	22.2	CBR

Continued..

26	MC	6.83	6.45	10.98	OGe	33	12	13.06	14.19	MC
26	CBR	36.9	36.9	12.5	OGe	33	15.1	12.5	11.19	CBR
27	MC	11.04	11.27	11.54	OGe	34	17	18	20	MC
27	CBR	34.9	36	34.9	OGe	34	10.2	7.3	7.0	CBR
28	MC	9.69	8.18	12.7	OGe	35	15.3	17.76	18.58	MC
28	CBR	41.8	48.1	21.4	OGe	35	16.5	10	9.3	CBR
29	MC	**6.9**	**11.3**	**12.7**	OGe	36	15.27	14.89	15.04	MC
29	CBR	**48.1**	**27.2**	**22.2**	OGe	36	17	19.3	17.5	CBR
30	MC	15.6	16.06	16.2	OGe	37	15.8	16.96	15.47	MC
30	CBR	16	13.1	13	OGe	37	7	5.4	7.3	CBR

Table 2: Rate of Reduction in CBR and Increase in MC of Studied Soils

S/N	HCBR	LCBR	Reduction in CBR(RCBR)	HMC	LMC	Increase in MC (IMC)	RCBR/IMC	Rock Type
1	11.7	5.7	51.28	26	24	8.33	6.15	Ch
2	13.2	10	24.24	24	19	26.32	0.92	Ch
3	15.2	7.4	51.32	24	21	14.29	3.59	Ch
4	28.4	14.1	50.35	22	17.5	25.71	1.96	Ch
5	25.4	6.9	72.83	22.5	18	25.00	2.91	Ch
6	26	12.6	51.54	20	16	25.00	2.06	Ch
7	17.4	14.1	18.97	17.5	16.2	8.02	2.36	Ch
8	13	11	15.38	17.6	16.3	7.98	1.93	Ch
9	12.6	6.5	48.41	24.99	14.9	67.72	0.71	Ch
10	10.8	3.8	64.81	17.69	16.00	10.56	6.14	Ch
11	25	12	52.00	16.04	10	60.40	0.86	Ch
Average			45.56			24.63	1.85	1.26
12	53	44.9	15.28	8.95	7.62	17.45	0.88	OGp
13	13.4	12.5	6.72	15.7	15.01	4.60	1.46	OGp
14	33	18.1	45.15	12.75	7.74	64.73	0.70	OGp
15	36.9	27.2	26.29	12.08	10.8	11.85	2.22	OGp
16	34.9	27.2	22.06	9.7	7.9	22.78	0.97	OGp
17	48.1	22.2	53.85	13.88	6.88	7.83	0.53	OGp
18	71.8	34.9	51.39	11.58	4	12.85	0.27	OGp
19	56	52	7.14	9.7	8.5	14.12	0.51	OGp
20	36.9	31.4	14.91	14.75	14	5.36	2.78	OGp
21	15.6	14.1	9.62	14.9	14.27	4.41	2.18	OGp
22	48.1	40.5	15.80	8.4	7.89	6.46	2.44	OGp
23	34.9	27.2	22.06	11.7	9.35	25.13	0.88	OGp
Average			24.19		0.27-2.78	16.46	1.47	1.0
24	41.8	25.6	38.76	9	7.79	15.53	2.50	OGe
25	34.9	12.5	64.18	16.41	12	36.75	1.75	OGe
26	36.9	12.5	66.12	10.98	8.45	30.00	0.94	OGe
27	36	34.9	3.06	11.54	11.04	4.53	0.67	OGe
28	48.1	21.4	55.51	12.7	8.18	55.26	1.00	OGe
29	48.1	22.2	53.85	12.7	8.9	42.06	1.28	OGe
30	16	13	18.75	16.06	15.6	2.95	6.36	OGe
31	16	11.15	30.31	14.1	11.7	20.51	1.48	OGe
32	50	22.2	55.60	12.95	9.14	41.68	0.68	OGe
33	15.1	11.19	25.89	14.19	12	18.25	1.42	OGe

34	10.2	7.3	28.43	16	14	14.29	1.99	OGe
35	16.5	9.3	43.64	18.58	15.3	21.44	2.04	OGe
36	19.3	17	11.92	15.27	14.89	2.55	4.67	OGe
37	7.3	5.4	26.03	16.96	15.8	7.34	3.55	OGe
Average			37.29		0.67- 6.4	22.37	1.67	1.14

HCBR=highest CBR, HMC= highest MC   LCBR = lowest CBR, LMC= lowest MC

Conclusion

This study gives insight into the influence of moisture content variations on the California bearing ratio with respect to local geology characteristics of sub-grade soils. The study areas was underlain mainly by charnockites and granites. The variations in mineralogical composition of the rocks give rise to the difference in the mineralogical and textural properties of their derived soils and the corresponding engineering characteristics of the soils in the study area. The granites derived soils have kaolinite as predominant clay mineral while Charnockites derived soils have vermiculite and kaolinite as predominant clay minerals. This give rise to different water absorption characteristics of the derived soils in study area. Ch derived soils have highest moisture content while OGp derived soils have the lowest moisture content.

The results revealed that Ch derived soils have the highest Penetration Index values, followed by OGe derived soils and OGp derived soils have the least value.The indicates that Ch derived soils have the lowest strength properties, followed by OGe derived soils and OGp derived soils have the highest strength properties. This may be attributed to the percentage of fines content and types of clay minerals of the derived soils which depend on the parent rocks. The results further showed that increase or decrease in the moisture content values give rise to decrease or increase in the CBR values respectively. The degree of change (reduction) in the CBR values is directly proportional to the amount of moisture content absorption.

Results of co-efficient of reduction of the CBR values revealed that Ch derived soils are more susceptible to ingress of water and high reduction in strength characteristics in comparison with OGe and OGp derived soils respectively of the lateritic soils.

Recommendations

Geological factors such as lithological and water content conditions should be taken into consideration whenever structural infrastructures such as dam and road are being considered. Also in-situ studies of the soils can be carried out at different climatic conditions to further elucidate the effect of seasonal variations on the soil engineering properties.

References

[1.] Adams J.O. and Adetoro A.E (2014) analysis of road pavement failure caused by soil properties along Ado ekiti - Akure Road, *Nigeria International Journal of Novel Research in Engineering and Applied Sciences*

[2.] Adeyemi G. O. (1992). Highway Geotechnical Properties of Laterised Residual Soils In The Ajebo-Ishara Geological Transition Zone Of Southwestern Nigeria (Unpublished doctoral thesis, O.A.U., Ile-Ife, Nigeria).

[3.] Adeyemi, G. O. (1994). Clay Mineralogy, Major Element Geochemistry And Strength Characteristics Of Three Highway Subgrade Soils In Southwestern Nigeria. Bulletin of Engineering Geology and Environment, 50(1), 5-8. http://dx.doi.org/10.1007/BF02594951

[4.] Adeyemi, G. O. (1995). The Influence of Parent Rock Factor on Some Engineering Index Properties Of Three Residual Laterised Soils In Southwestern Nigeria. *Bull.* Association of Engineering Geology., *Paris, 52*, 3-8.

[5.] Ademeso, O. A (2010). Field and petrographic relationships between the charnockitic and associated Granitic Rock, Akure Area, Southwestern Nigeria. International Journal Environment and Earth Science (2) :8–89

[6.] Adeyemi, G. O., (2022). Application of integrated Geosciences and Geotechnical in Preconstruction Investigations for sustainable Buildings and

Highways. Lead paper presented at the 3rd IAEG Africa Regional Congress and 7th NAEGE Annual International Conference on Engineering Geology: Imperative for Infrastructural Development and sustainability of Cities in Africa. Lagos 2022, Nigeria.

[7.] Adnan, B. A., Al-Homoud Azm. S. and Al-Tabari Emad Y. (1994). *Effect of Methods of Drying on the Engineering Behavior of Clays*. Applied Clay Science, 9 (3): 151-164.

[8.] Akinlolu S. O and Adetoro A. E (2018) International Journal of Trend in Scientific Research and development Analyses of some Engineering Properties of Ado – Ekiti to Ilawe – Ekiti Road Soil, Southwestern Nigeria 2(5) pp 725 – 729.

[9.] Indian Roads Congress (IRC) (2015). Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads. IRC-SP-72-2015, New Delhi.

[10.] Gerrard, J. (2000). Fundamentals of Soils. London: Routledge/Taylor & Francis.

[11.] Jegede, G. (2000). Effect of soil properties on pavement failures along the F209 highway at Ado Ekiti, south-western Nigeria. *Construction and Building Materials, Vol. 14*(67), 311-315.

[12.] Meshida E.A. (2006). Highway failure over talc–tremolite schist terrain: a case study of the Ife to Ilesha Highway, Southwestern Nigeria. *Bulletin of Engineering Geology and Environment* 65:457–461.

[13.] Obaje S. O (2017) International Journal of Geology And Earth Sciences Appraisal of Pavement Failures on Ado-Ekiti – Ogbagi Road, South-Western Nigeria 3(2) pp 1– 9.

[14.] Osammor J, (2009). Geotechnical assessment of foundation soils from coastal plainsand areas in the Niger delta. *Unpublished PhD thesis University of Ibadan, Ibadan*, 341p.

[15.] Olarewaju, V. O. (1987). Charnockite – granite association in SW, Nigeria: Rapakivi granite type and charnockitic plutonism in Nigeria? *Journal of African Earth Sciences, 6*(1), 67-77.

