© Volume 1, Issue 1, ***Dec*** 2025 | JATIR

Petrographic And Geochemical Studies of Lateritic Soil in Kwara State Polytechnic, Ilorin, Kwara State

[1]Obaro, R. I., [2]Hammed. A., [3]Agbalajobi. S. A., [4]Obaro, N. T
[1,2,3,4] *Department of Minerals and Petroleum Resources Engineering Technology*
[1,2,3,4] *Kwara State Polytechnic, Ilorin*
obaro.r@kwarastatepolytechnic.edu.ng
http://doi.org/10.64643/JATIRV1I1-140008-001

Abstract - Petrographic and geochemical studies of lateritic soil have been examined in order to determine their suitability for construction purpose. Ten lateritic soils were examined through petrographic studies and X - ray fluorescence to ascertain their suitability for industrial applications. Petrographic studies suggest that the laterites are mostly associated with specific landforms such as mounds and terraces formed through long period of weathering processes and derived from underlying bedrock which often leads to the development of terraces or mounds characterized by small to large-sized nodules or concretions which exhibit varying degrees of hardness and cementation depending on the minerals and chemical constituents distributed throughout the soil matrix. The chemical analysis from X – ray fluorescence of the lateritic soil suggest SiO_2, Al_2O_3, Fe_2O3, K_2O, Na_2O, TiO_2, CaO and MnO. The results agree with petrographic studies which indicate that SiO_2, Al_2O_3, and Fe_2O_3 are the dominant phases in both the parent rock and its derived products. SiO_2 suggest enrichment in the soil while the proportion of alumina (Al_2O_3) reflects the presence of aluminosilicates and its enrichment which can be attributed to the weathering alteration of feldspar to clay mineral, causing leaching of Al_2O_3 by infiltrating acid rain/recharge water into the ground. K_2O, Na_2O, MgO, CaO and P_2O_5 are decreasing due to leaching of the soil. TiO_2 also increases in all the soil samples and it contribute to the soil reddish – brown colour which are mostly formed through weathering of silicate minerals. However, lateritic soil remains one of the best natural materials used in compressed earth bricks because it is a well graded soil that combines both cohesive and cohensionless parts of the soil. It also contains sesquioxides and clay minerals which are very useful in natural binding process as well as in the presence of most chemical binders. Increase in ratio of SiO_2 to Al_2O_3 leads to chemical reactivity known as geopolymerization in the presence of amorphous materials. This enhancement reactivity supports its usage in geopolymer synthesis and as a suitable precursor for geopolymer production.

Index-Terms: Lateritic, Composition, Mineral, Chemical, Industries

I. INTRODUCTION

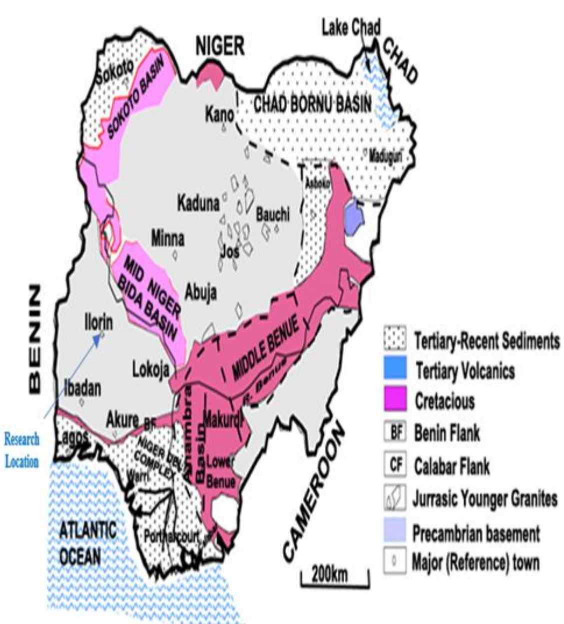
Lateritic soil is highly weathered and altered residual soils formed by the in – situ weathering and decomposition of rocks under tropical condition, which are essentially rich in sesquioxide but may contain appreciable amounts of quartz and kaolinite (Zelalem, 1999). It is formed from the leaching of parent sedimentary rocks, metamorphic rocks and igneous and mineralized ores, which leaves the more insoluble ions predominantly iron and aluminum. The mineralogical and chemical compositions are dependent on their parent rocks and are mostly characterized with low activity value, high bearing capacity, low permeability, intermediate plasticity and non – swelling clay minerals with predominant oxides of Alumina (Al_2O_3), Silica (SiO_2) and Iron oxides (Fe_2O_3) (Bell, 2007). The predominant clay minerals in most laterites and lateritic soils are kaolinite. Occasionally, laterites may contain montmorollitic clay mineral, which may however develop the tendency to swell when in contact water, leading to problem soil. (Gidigasu, 1973; Gromko, 1974). These index properties and qualities of laterite have enhanced the engineering properties and performance particularly as engineering fill materials in construction works. Notably, causes of structural failures around Kwara State Polytechnic and its environs is due to the presence of deformation such as cracks, depression etc. other factors may be due to geological, geotechnical, geomorphological, poor design, construction inadequacies and maintanances. Other factors that may also account for cracks and sudden collapse of structures is the behaviour of residual soil which is a function of mineral compositions and a reflection of properties of host rocks (Akpan, 2005; Amadi *et al.,* 2012). Generally, soil analysis in different part of Nigeria shows variation from one place to another mostly because of the host rock type they are formed from. Lateritic soils are mostly used as a foundation material for all engineering structures like; airfield, low- cost housing and compacted fill in earth embankments (Oke *et al.,* 2009; Kamatchueng *et al.,* 2016). The mineralogical composition of lateritic soil has an effect on the geotechnical parameters such as specific gravity, Atterberg limits, shear strength, swelling potential, bearing capacity and petrographic properties (Amadi *et al.,* 2012). Chemical compositions such as silica, ferrous and alumina sesquioxides depends on weathering and decomposition experienced. The works of several authors like Jegede, (2000); Meshida (2006) and Okoyeh *et al.,* (2017) has provide an insight about the use of lateritic soil as construction materials. Researchers have investigated the geotechnical properties of subsoils to understand the behavior of the soil that has caused significant damage to civil structures and also proffer solutions to the identified problems with either expansive or un expansive soils (Oke *et al.,* 2009). It is therefore pertinent to determine these properties before embarking on any constructions.

II. GEOLOGICAL SETTINGS

The study area is underlain by the Nigerian Basement Complex, a group of igneous and metamorphic rocks of Precambrian age. The basement complex is largely undifferentiated and constitutes about 50% of the bedrock of Nigeria. Large outcrops of granite, augen-gneiss and biotite-gneiss are common. The general trend of the outcrops is SW-NE with a west dip (Fig. 1).

The granite outcrops appear to be intrusions in the gneisses. The soils of the area are laterites consisting of three layers, a basal lateritic clay, a middle laterite gravel and a surface crust. All laterites in this area are over the Precambrian granite gneiss complex.

Laterite crust is a cellular texture and is usually hard to break with a geologists' hammer. Light explosives may be required to excavate this type of laterite. It commonly is found on top of flat-topped hills or as boulders on slope surfaces, and often is encountered while digging foundations of buildings. Laterite gravel may be found below a layer of laterite crust. At some locations, the gravel deposit is only covered by a thin layer of soil. It is usually pisolitic. Lateritic clay is often located below the gravel or the crust, and usually above the weathered basement. It has a very rich reddish-brown colour, with patches of pinkish white material (probably kaolinite). Flakes of micas are visible in hand specimens. It often is used in the construction of earth dams. biotite.



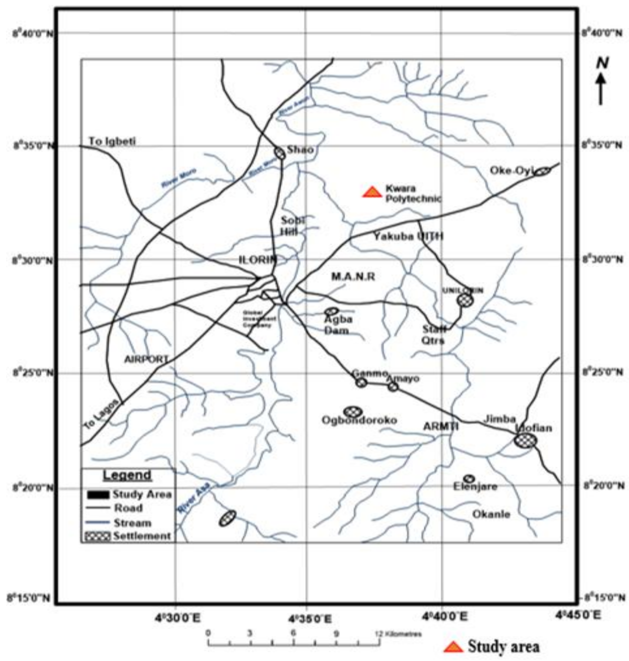


Fig.1: Geological map of Nigeria showing the study area (modified after Obaje et al., 2004)

Fig. 2. Location of the study area (modified after Olasehinde et al., 1998)

III. MATERIALS AND METHOD

This study evaluate the geotechnical properties of Kwara State Polytechnic, lateritic soils and its suitability for construction works. Ten disturbed samples at a depth of 1.5m were taken from ten (10) borrow pits within the campus and were denoted as Sample 1 - 10. Petrographic studies of each of the sample was carried out in – stitu. All the soil samples were labelled and transported in a sealed polythene bags to Afe Babalola University, Ekiti State for X – Ray Fluorescence. However, calculation for silica/sesquioxide of iron and aluminum molar ratio for the classification of soils is shown below.

$$\text{S-S Ratio} = \frac{\text{Mol. Silica } (SiO_2)}{\text{Mol. Sesquioxide } (Al_2O_3 + Fe_2O_3)}$$

IV. RESULTS AND DISCUSSION

Petrographic study

Laterites found in the studied area are considered in situ due to thick layers of soil (1 m to <5 m). The in-situ laterite typically displays distinct layering, which remains largely intact, suggesting a compact structure with minimal mixing with other materials, indicating no significant transportation or redeposition. These laterites are mostly associated with specific landforms such as mounds and terraces, formed through long period of weathering processes and it is connected to the underlying bedrock or parent rock which often leads to the development of terraces or mounds. Laterite in the studied area can also be characterized by small to large-sized nodules or concretions distributed throughout the soil matrix. These nodules typically exhibit varying degrees of hardness and cementation depending on the minerals and chemical constituents. The surrounding matrix can vary in consistency, ranging from loose and porous to compact and hard. Hard matrixes are often black, red, or brown, while loose matrix can appear pink, yellow, or white. Often times poorly sorted fine- to coarse-grained soils. These characteristics imply that the laterite underwent a chemical reaction with a percolating solution leading to the formation of the nodular texture. According to Waikhamnuan *et al.* (2025) correlation between colour intensity and mineral content is also vital in this study. The pale yellowish-pink laterite exhibits significant amounts of kaolinite. The brighter red hues signify a greater presence of hematite. The intensity of red colouring corresponds to the goethite content, with darker brown hues indicating higher levels of hematite. Montmorillonite are detected in the pale yellowish-pink colours.

V. X – RAY FLUORESCENCE

The results from X – Ray Flourescence revealed that the major oxides are SiO_2, Al_2O_3, Fe_2O3, K_2O, Na_2O, TiO_2, CaO and MnO Table 2. Three oxides SiO_2, Al_2O_3, and Fe_2O_3 constitute about 70-80%. Al_2O_3 enrichment increases in the studied samples with the SiO_2 behaving in similar manner (Table 2). The results agree with the petrographic and mineralogical studies which indicated that quartz, alumino-silicates and iron-rich minerals are the dominant phases in both the parent rock and its derived products. Adeyemi (2002) have suggested the use of the silica/sesquioxide of iron and aluminum molar ratio for the classification of soils. Soils with ratio less than 1.33 were classified as true laterites, those with ratio between 1.33 and 2.00 were classified as lateritic soils and soils whose ratio is in excess of 2.00 were decided to be non-lateritic tropical soils. Therefore, with a silica/sesquioxide molar ratio between 1.33 and 1.60 the soils from the study area can thus be described as lateritic soils. The proportion of alumina (Al_2O_3) reflects the presence of aluminosilicates (Darman *et al.,* 2022) and its enrichment can be attributed to the weathering alteration of feldspar to clay mineral (Elueze *et al.,* 2004), causing leaching of Al_2O_3 by infiltrating acid rain/recharge water into the ground. Oxides such as K_2O, Na_2O, MgO, Cao, P_2O_5 are decreasing due to leaching of the soil. TiO_2 also increases in all the soil samples and it contribute to the soil reddish – brown colour and are mostly formed through weathering of silicate minerals. The enrichment of Fe_2O_3 in each sample can be attributed to chemical weathering of mafic mineral composition of the parent rock and ferruginization of Fe bearing minerals. Ferruginised laterite is composed of sediments such as sand, silt, or clay that have been altered by iron oxidation processes, resulting in reddish brown and red colours and high iron content (Bourman and Ollier, 2002). There is also a general increase in Iron III oxide (Fe_2O_3) down the soil horizons. This is evidenced by an increase in the amount of Fe_2O_3 but was subsequently converted to hematite (Fe_2O_3) in the laterite. Chandrakaran and Nambiar (1997) noted that iron III oxide exist as an inert material whereas in the bottom layers, it exists as a cementing material. According to Rao *et al.* (1988), iron oxide present in soils binds individual soil particles into coarser aggregates and contributes to the development of random soil structure. Hence, down the sampled area, there is more cementing of the soil particles, forming coarser aggregates. These coarser aggregates are of concretionary structure (Malomo, 1989), hence engineering properties such as shear strength and unconfined compressive strength reduces as a result of reduction in the constituent iron oxide (Fe_2O_3). This suggest that iron oxide is the main influential varying oxides in the study area.

Table 2. Chemical Composition of all the studied soils

Oxides / **Sample Location**	**SiO_2**	**Al_2O_3**	**CaO**	**Fe_2O_3**	**MgO**	**K_2O**	**Cr_2O_3**	**Na_2O**	**P_2O_5**	**SO_3**	**MnO**	**CuO**	**TiO_2**	**LOI**	**Total**	**S-S Ratio**
SAMPLE 1	55.60	24.44	0.01	10.34	0.32	0.40	0.02	0.42	0.06	0.02	0.08	0.02	2.46	5.81	100.00	**1.60**
SAMPLE 2	45.93	24.97	0.01	11.55	0.40	0.26	0.02	0.37	0.04	0.04	0.03	0.02	9.94	6.42	100.00	**1.26**
SAMPLE 3	49.95	25.27	0.02	12.35	0.39	0.20	0.03	0.39	0.05	0.05	0.07	0.03	3.39	7.76	99.95	**1.33**
SAMPLE 4	49.88	25.11	0.01	11.84	0.37	0.37	0.03	0.38	0.06	0.04	0.05	0.03	5.70	5.81	99.68	**1.35**
SAMPLE 5	51.25	25.60	0.02	8.63	0.36	0.39	0.03	0.37	0.06	0.03	0.03	0.03	3.92	8.55	99.27	**1.50**
SAMPLE 6	47.40	25.32	0.02	13.21	0.35	0.29	0.02	0.39	0.04	0.04	0.09	0.02	5.80	6.85	99.84	**1.38**
SAMPLE 7	51.10	25.59	0.02	11.13	0.39	0.32	0.02	0.35	0.07	0.02	0.03	0.03	3.16	7.76	99.99	**1.40**
SAMPLE 8	49.70	23.30	0.01	12.37	0.33	0.27	0.03	0.37	0.06	0.04	0.07	0.02	4.12	9.29	99.98	**1.39**
SAMPLE 9	53.54	24.13	0.02	9.87	0.41	0.29	0.02	0.41	0.05	0.03	0.08	0.01	3.30	7.79	99.95	**1.57**
SAMPLE 10	48.35	24.32	0.01	10.55	0.35	0.30	0.03	0.42	0.06	0.02	0.09	0.01	3.32	12.13	99.96	**1.39**
Average	50.27	24.81	0.02	11.18	0.37	0.31	0.02	0.39	0.05	0.03	0.06	0.02	4.51	7.82	99.86	**1.42**

VI. INDUSTRIAL APPLICATIONS

Lateritic soil remains one of the best natural materials used in compressed earth bricks because it is well graded soil that combines both cohesive and cohensionless parts of the soil. It also contains sesquioxides and clay minerals which are very useful in natural binding process as well as in the presence of most chemical binders. Manoharan *et al.* (2011) explained that the durability of brick is due to relatively high SiO_2 content in the raw materials. This proportion of this SiO_2 content makes it possible to obtain bricks with a uniform shape after firing. Al_2O_3 content is associated with kaolinite and gibbsite while Fe_2O_3 is related to hematite and goethite. The combined percentage of SiO_2 and Al_2O_3 is greater than 70% for raw materials and constitute a good binder for brick production. Laterite usually has a higher concentration of iron and aluminum oxides compared to red soils. This gives laterite soil its distinctive red or orange colour and contributes to its hardness and durability. Davidovits (1991) stressed that heating laterite soils can convert clay minerals, especially kaolinite into metakaolinite. This transformation allows chemical compounds to dissolve more effectively when mixed with an alkaline activating agent. The resulting geopolymer cement demonstrates excellent physical and mechanical properties. According to Townsend (1970) increase in ratio of SiO_2 to Al_2O_3 leads to chemical reactivity known as geopolymerization in the presence of amorphous materials. This enhancement reactivity makes it promising for use in geopolymer synthesis. The chemical composition of lateritic soil also support the findings of Abomo *et al.* (2023) who identified it as a suitable precursor for geopolymer production.

VII. CONCLUSION

Geochemical analysis of lateritic soil has been carried out in Kwara State Polytechnic, Ilorin. The X – ray diffractogram revealed the presence of kaolinite, quartz while illite, halloysite, goethite, anatase, hematite and montmorillonite has little or insignificant amount in all the studied samples. The X – ray fluorescence suggests significant amount SiO_2 and Al_2O_3 with minor amount of K_2O, Na_2O, MgO, Cao, P_2O_5 which are decreasing due to leaching of the soil.

On industrial application, lateritic soil remains one of the best natural materials used in compressed earth bricks and it is also useful in natural binding process as well as in the presence of most chemical binders. Increase in ratio of SiO_2 to Al_2O_3 known as geopolymerization in the presence of amorphous materials enhance reactivity and makes it for use in geopolymer synthesis and as a suitable precursor for geopolymer production

REFERENCES

[1] Abomo, T., Cyriaque Kaze, R., Cengiz, O., Alomayri, T., Pefuo Wilson, T., Eko Robert, M., Naghizadeh, A., Kamseu, E. (2023). Impact of the Depth of a Lateritic Profile on Physiochemical, Mechanical and Microstructural Properties of Geopolymer Binders. *Constr. Build Mater,* 403, 1333138.

[2] Adeyemi, G. O. (2002). Geotechnical Properties of Lateritic Soil Developed over Quartz schist in Ishara Area, Southwestern Nigeria. *Journal of Min. and Geol*. 38, 65 - 69.

[3] Akpan, O. (2005). Relationship between Road Pavement Failures, Engineering Indices and Underlying Geology in a Tropical Environment. *Glob. J. Geol. Sci*. 3 (2): 99 – 108.

[4] Amadi, A. N., Eze, C. J., Igwe, C. O., Okunlola, I. A. and Okoye, N. O. (2012). Architect's and Geologist's view on the Causes of Building Failures in Nigeria. *Mod Appl. Sci* 6, (6): 31 – 38

[5] Bell, F. G. (1993). Engineering Geology, *Blackwell Scientific Publications, Oxford, London*, 359.

[6] Bell, F. G. (2007). Engineering Geology 2nddition, Butterworth – Heinemann Publishers, Oxford, 581.

[7] Bourman, R. P. & Ollier, C. D. (2002). A Critique of the Schellmann Definition and Classification of 'Laterite'. *CATENA* 47, 117–131

[8] Chandrakaran, S. and Nambiar, M.R.M. (1997). Influence of some Environmental Factors on the Engineering Behaviour of Compacted Lateritic soils. *Publ. Indian highways*, 29-35.

[9] Darman, J. T., Tchouata, J. H. K., Ngon, G. F., Ngapgue, F. Ngakoupain, B. L. and Langollo, Y. T. (2002). Evaluation of Laterite Soils of Mbe for Use as Compressed Earth Bricks (CEB). *www.cell.com/Heliyon*.

[10] Davidovitis, (1991) Geopolymer Inorganic Polymeric New Materials. *Journal Therm. Anal. Calorim.* 37.8, 1633 – 1656.

[11] Elueze, A. A., Ekengele, N. I., & Bolarinwa, A. T. (2004), "Industrial Assessment of the Residual Clay Bodies over Gneisses and Schists of Youndé area, Southern Cameroon", *Journal of Mining and Geology*, 40(1), 9-15.

[12] Gidigasu, M. D. (1973). Review of Identification of Problem Lateritic Soils in Highway Engineering. *Transport Research Board, Washington,* 497

[13] Gromko, G. J. (1974). Review of Expansive Soils, ASCE. *Geotechnical Engineering,* 100 (6), 667 – 686.

[14] Jegede, G. (2000). "Effect of Soil Properties on pavement Failure along F 209. Highway at Ado – Ekiti, Southwestern Nigeria*". Construction and Building Materials*, 14, 311 – 315.

[15] Kamatchueng, B. T., Onana, V. I., Fantong, W. Y., Ueda, A., Ntouala, R. F. D., Wongolo, M. H. D., Ndongo, G. B., Ngo'Oze, A., Kamgang., V. K. B. and Ondoa, J. M. (2016). 'Geotechnical Chemical and Mineralogical Evaluation of Lateritic soils in Humid Tropical Area (Mfou, central Cameroun): Implication for Road Construction". *International Journal of Geo-Engineering* 6, 1

[16] Mahoharan, C., Sutharsan, S., Dhanapandian, R. Venkatachalapathy, R. and Asanulla, R. M. (2011). Analysis of Temperature Effect on Ceramic Brick Production from Alluvial Deposits, Tamilnadu, India. Appl. Clay Sci. 54, 20 – 25

[17] Malomo, S. (1989). Microstructural Investigation on Laterite Soils. *Bulletin of the international Association of engineering Geology, Paris*

[18] Meshida, E.A. (2006). "Highway failure over talc tremolite schist terrain: a case study of the Ife to Ilesha Highway, South Western Nigeria". Bulletin Engineering Geology and Environment 65:457-461.

[19] Obaje, N. G., Wehner, G., Scheeder, G., Abubakar, M. B. & Jauro, A. (2004). Hydrocarbon Prospectivity of Nigeria's Inland Basins: From the Viewpoint of Organic Geochemistry and Organic Petrology. *AAPG Bulletin* 88: 325–353.

[20] Oke, S. A., Okeke, O. E., Amadi, A.N. and Onoduku, U. S. (2009). Geotechnical Properties of the Subsoil for Designing Shallow Foundation in some selected parts of Chanchaga Area, Minna, Nigeria. *Journal of Environmental Science,* 1 (1), 45 – 54.

[21] Okoyeh, E. I., Ejezie, O. E., Ezeh, H. N., and Okeke, H. C. (2017). Journal of Ihlala Laterites for Use as Sub – grade Material in Road Construction. *Journal of Geography, Environment and Earth Science International,* 12 (3): 1 – 9

[22] Olasehinde, P. I., Virbka, P. and Esan, A. (1998). Preliminary Results of Hydrogeological Investigation in Ilorin area, South – western Nigeria – Quality of Hydro-chemical Analysis. *Water Resources Journal,* 9, 51 – 61.

[23] Rao, S. M., Sridharan, A. and Chandrakaran, S. (1978). The Role of Iron Oxide in Tropical Soil Properties. Proceedings 2nd Nat. Conf. on Geo –mechanics in Tropical Soils. *Singapore, 1, 43 – 49.*

[24] Townsend, F. C. (1970). The influence of Sesquioxides on some Physio-chemical and Engineering Properties of a Lateritic Soil, *Oklahoma State University; Stillwater*, OK, USA.

[25] Waikhamnuan, T., Chawchai, S. and & Bissen, R. (2025). Geochemistry of laterite around UNESCO World Heritage Sites in Kamphaeng Phet, Thailand. Heritage science Article https://doi.org/10.1038/s40494-025-01645-7.

[26] Zelalem, A. (1999). Basic Engineering Properties of Lateritic Soils. Addis Ababa