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Defining Niger Delta Soils: Are They Laterites?

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Abstract
The ambiguity of the use of the term 'laterite' to generally classify tropical soils especially for engineering purposes needed to be addressed. An attempt was made to analyze the silica-sesquioxide ratio of some Niger Delta soils to establish whether these soils which are formed in the tropic are indeed laterites. This ratio is used because it is generally accepted as a parameter in the classification and specification of laterites and can be measured with some degree of accuracy in the laboratory. This study revealed that these soils (except the ferralsols) which were soft when wet and significantly hard when air-dried could not be called laterite soils because of the high silica-sesquioxide ratios. It is envisaged that this study would help the engineers in the region to have a better understanding of the soils which are erroneously acclaimed and handled as laterite soils.
Keywords: Laterite, Niger Delta soils, Silica-sesquioxide ratio

1.1 Introduction

Soil is a broad term used to describe loose deposits which are created from the underlying rocks by physical, chemical and biological processes which vary with time, location and environmental conditions and result in a wide range of soil properties (Mitchell, 1993). The physical weathering causes the disintegration of the rock mass, while the chemical weathering decomposes the rock minerals by oxidation, reduction, hydrolysis, chelation, and carbonation (Little and Nair, 2009). The formed soil can remain in-situ (residual) or transported to other location especially by erosion; which is the most common process in the Niger Delta. Soil is a very complex material because of the continuous weathering forces acting on it. In the analysis of soil for construction purposes more attention is given to physical properties especially on the bearing capacity and the chemical properties are rarely tested; which are the inherent properties that define the soil. The physicochemical property that define laterite soils is the silica-sesquioxde content, however this property is rarely analyzed in the application of the soils for construction purposes.

1.2 Formation of Tropical Soil

Laterite soils are formed in regions of significant hot and wet climates and on a variety of rock types with high iron content which is responsible for the reddish or brownish colour of the soils. Rolling, et al (2002) opined that laterites can be found in almost all the continents of the world, hence the soil is not peculiar to tropical region, though they are widespread in hot, wet tropical regions with an annual rainfall between 750 and 3000mm, (usually in areas with a significant dry season). The authors gave the locations on the earth that characterise these conditions as falling between latitudes 35^o S and 35^o N.

Till date, all reddish or similarly coloured soils form in the tropical regions are termed 'laterite' which is a word used by Buchanan to describe a reddish rock formation in southern India. This rock can be cut into brick-shaped blocks for buildings when dry (Buchanan, 1807). He coined the word 'later' from Latin word meaning 'brick'. Thus the definition was based on the hardening property which was the physical manifestation of the soil. Since Buchanan definition there have been varied definitions of the soils encountered in the tropic region and it is worthy to note that till date there is no universally accepted definition for laterite. The complexity in the formation of laterite soils is clearly reflected in the exhibited physical and engineering properties and performances.

These soils exhibit undeniable variance from the temperate-zone soils which are assumed to be inert and thus not likely to undergo considerable physico-chemical changes when used in construction. Gidigasu (1983) gave the proposition that laterite soils are not inert; they have been known to be subjective to physical, chemical and mineralogical changes during construction and especially under adverse moisture and/or environmental conditions. This causes for caution in the application of temperate-zone specifications for defining laterite or tropical soil properties.

2.0 Some peculiarities of Niger Delta Soil in Construction

Niger Delta is a region of hot and wet climates and decked with both fresh and salt water-bodies. The rainfall extends throughout the year and with high intensity, and some locations are permanently waterlogged because of the flat terrain. Olorunfemi (1984) in his study of geotechnical problems of some Niger Delta soils revealed that extensive leaching out of salt by rainwater and groundwater caused detrimental effect on soil structure. He noted that the rigidity of the soils matrix may become deflocculated when there is leaching out of salt which makes the soil particles to lose their inter-particle attractive forces and results in breaking down of the soil structure. He also opined that this spontaneous dispersion of soils could be related to the pH of the eroding or percolating water and the concentration of cations in both water and soil, and concluded that the engineering problems of the Niger Delta soils are related to the mineralogy and chemistry of the soils and groundwater, and that the chemistry and pH of pore-water have significant effect on soil strength.

Another peculiarity of the Niger Delta soils is that they can be very soft when wet and can be hard when dry, requiring considerable effort to break down (see figures I and II). Akpokodje, 1986 and 1987; Arumala and Akpokodje, 1987; Otoko and Karibo, 2014 reported that many of the Niger Delta soils lack gravel fractions, contain high clay and moisture contents, undergo large volume changes resulting in excessive swelling and shrinkage, have poor compaction characteristics, and generally have low bearing capacities especially when wet; features which are unsuitable in pavement construction. The incessant road failures in the region are proof of these and many other findings.

Figure I: Exposed typical soft subgrade soil in the Niger Delta

Figure II: Air-Dried Niger Delta Soil

2.1 Physicochemical tests – keys to Understanding the Peculiarity of Niger Delta Soils

The formation of Niger Delta soils involve continuous physicochemical processes, and it is especially intense because of the deltaic terrain of the region which causes transportation of the weathered soils. The transportation processes usually cause the mixing of the soils with organic materials, salts and in different concentrations. The application of the physicochemical tests in the analysis of soils for construction purposes is not done conventionally and the reasons are not far-fetched. Some of the tests require special and expensive equipment and expertise to carry out and some can be time consuming. However, in order to understand the peculiarity, in-depth study of the physicochemical properties especially the sesquioxide ratio of the different soil types must be carried out.

Earlier work by Martin and Doyne (1927, 1930) and, Winterkorn and Chandrasekharan (1951) analysed for silica, aluminum, and iron oxides to quantify the silica-sesquioxide ratio and used formula – [SiO_2 / ($A1_2O_3$ + Fe_2O_3)] to group laterites. They classified true laterites as those with ratio less than 1.33; those with ratio between 1.33 and 2.00 were named lateritic soils while those with ratio in excess of 2.00 were classified as non-lateritic tropically weathered soils. However, AFCAP (2013) in the literature review survey on the specifications for laterites in road pavement reported the use of the molecular masses to normalize the individual oxides in the silica-sesquioxide ratio formula (Persons, 1970 after De-Medina (undated); MRWA, 2002), and this was used in this study:

$$\frac{S}{R} = \frac{\frac{SiO_2}{60}}{\frac{Al_2O_3}{102} + \frac{Fe_2O_3}{160}}$$

It will therefore be a worthwhile effort to study this physicochemical property of the soils in addition to the conventional engineering properties in order to have a better understanding of the causative factors of this wet and hard phenomenon especially in their application for construction and of their expected field performances.

3.0 Methodology

The oxides were determined using the X-ray fluorescence Spectro Xepos and USEPA 6200 test method. The spectrometer was first calibrated and the correlation coefficient for the standard curve was 0.990. Then 5g of the milled sample (about 5µm grain size) was used for the analysis.

4.0 Results and Discussion

The results as shown in Table 4.1 revealed that none of the five soils samples investigated could be classified as laterite or lateritic irrespective of the colour. The sesquioxide ratios were all above the specified limit of 2 as generally agreed by various researchers. It is of interest to note that the soils that could be attributed to be laterite based on the reddish or brownish colour have very high sesquioxide ratios: an indication that they are not.

Furthermore, the air-dried samples D and E were physically strong and could not easily break unless some substantial effort was applied, while the individual grains of samples A, B and C were relatively separated and broke easily without much force. An explanation for the hardening tendency in the samples could be deduced also from this analysis. A look at the results in the table showed that the iron, calcium, and magnesium oxides of the latter soils were considerable low when compared with former. These oxides in particular have been known to be responsible for the cementing effects in soil particles as reported by various authors (e.g. Gidigasu, 1976). The results from this analysis thus corroborated with Alexander and Cady (1962) and Gidigasu (1976) findings that the sesquioxides play an important role in the hardening and cementing tendency of soils. Also noted in the results is the high aluminum oxide content over the ferric oxide in all the samples, which is one of the features peculiar with soils formed in a continuously wet climate as reported by Gidigasu (1976). The titanium oxide appeared not to be substantial in the samples generally.

Further searchlight was beamed on the work of other researchers in the region who analyzed for the oxides contents of different types of soils for various research purposes, and the same normalized formula was used to analyze the silica-sesquioxide ratio (see Table 4.2). It was revealed that those soils which were derived from cretaceous and tertiary sedimentary rocks have their silica-sesquioxide greater than the maximum recommended value of 2; hence they could not be classified as laterite soils. While soils (ferralsols) derived from mesozoic (secondary) sedimentary rock have silica-sesquioxide ratio in the range 1.37 – 2.11. Also noted from this investigation is the dominance of Al_2O_3 over Fe_2O_3.

It could be deduced therefore that the process of formation of these soils has played important role in the physical and chemical properties. Abam (2009) reported that the geology of the Niger Delta is generally influenced by the movements of rivers which are all over the region. These rivers in their quest to flow back into the sea, deposited sediments which could be sand, silty clay, and sandy clay. The sandy layer of medium densification usually form the underlying layer and are predominantly medium to coarse grain-sizes, while the silty and sandy – clays form the surface deposits. These surface deposits are subjected to seasonal variations in moisture and could become substantially dried during the dry season, projecting some false enhancement of strength.

Table 4.1: Oxides Content of Niger Delta Soils

	East/West – Nyokuru Link Road Subgrade A	**East/West - Nyokuru Link Road Borrow-pit soil B**	**Kaa-Ataba Link Road Bridge Site Subgrade C**	**Okaka Road Subgrade D**	**Sampou Road Subgrade E**
Sample colour	Deep-brown with mottled greyish patches	Reddish-brown	Dark grey	Light to dark grey	Greyish with pockets of mottled brown silty peaty clay
SiO_2 (%)	74.4	73.1	84.1	78.5	66.5
Fe_2O_3 (%)	2.58	2.94	0.85	3.31	5.29
Al_2O_3 (%)	22.9	24.3	16.7	18.1	25.5
CaO (%)	<0.0014	<0.0014	<0.0014	0.68	0.12
MgO (%)	0.22	0.82	0.26	1.97	1.58
TiO_2 (%)	0.97	1.06	0.76	0.68	1.51
SR	5	5	8	7	4

Table 4.2: Compendium of Silica-Sesquioxide Ratio of Some Soils in the Niger Delta and Environ

Sample	Colour	SiO_2	Al_2O_3	Fe_2O_3	SR - Calculated Using Brazilian formula	Geological Formation	Reference and Method of Analysis
Afikpo shale	Not stated	59.81	21.76	3.02	4.30	Cretaceous	Arua and Onyeoku (1978) Method not stated
Aba soil Umukroshe soil Calabar clay Egamini-Ndele clay Oboburu clay	Not stated	78.40 94.50 64.70 69.90 51.40	8.90 3.52 7.32 10.50 22.60	3.50 1.21 1.90 1.80 10.40	12 37 13 10 2.99	Recent (Holocene) sedimentary rock	Olorunfemi (1984) X-ray fluorescence
Onitsha soil Imo Aiport Okigwe soil	Not stated	56.80 49.50 54.70	17.60 12.30 11.50	6.45 5.98 4.75	4.45 5.22 6.38	Cainozoic (Tertiary) sedimentary rock	Nnadi (1988) Method not stated
Afam clay	Not stated	42.20	26.20	5.10	2.43	Cretaceous	Jubril and Amajor (1991) Method not stated
Mpu shale	Olive-brown and bluish-grey	59.45	21.70	2.00	4.39	Cretaceous	Obrike, et al (2012) AAS
Four different soil sites in Nsukka, Nigeria coded as: HT OPPCG MV IK	Not Stated	45.90 46.80 43.30 37.60	24.00 27.50 27.00 30.00	20.73 20.20 23.90 26.34	2.11 1.97 1.74 1.37	Mesozoic (secondary) sedimentary rock and the derived soils are ferralsols	Obeta and Eze-Uzomaka (2013) X-ray florescence
Okija clay Iyuku clay Ubiaja clay	White and mottled-white clay, light grey with some mottles/pinkish patches	60.42 64.45 55.80	18.62 20.28 27.50	3.42 0.63 3.15	4.93 5.29 3.21	Cretaceous and tertiary sedimentary deposits	Onyeobi, et al (2013) AAS
Aloji clay Ofe-jiji clay Udane Biomi clay Agbenema clay	These soils are basically dirty white clay with stains bands colours of dark-grey, brown, and red.	86.65 78.02 87.75 79.99	10.59 9.62 6.78 9.57	0.24 1.11 1.02 2.06	13.69 12.87 20.31 12.47	Cretaceous in Northern Anambra Basin	Alege, et al (2014) ICP-ES and ICPMS
Chicoco mud	Light to dark grey	30.7	16.15	4.75	2.73	Marine clay	Otoko and Karibo (2014) Method not stated

Conclusion

This study showed the importance of the use of the silica-sesquioxide ratio in defining Niger Delta soils. The phenomenon of softness when wet and considerable hardness when dry is clearly evident in these soils and is synonymous to Buchanan's observation and definition of laterite soils, however many of the Niger Delta soil types cannot be termed laterites based on their high silica-sesquioxide ratio. The exceptional hardness noticed in some of the soils is ephemera, since the geology of the region is under continuous and intense physico-chemical transformation. It is therefore recommended that this chemical test be conducted in addition to engineering tests, which will provide detail information about these soils as at the time of their use for construction purposes. It is also recommended that long time study of the oxides and mineral contents of the soil deposits in the region be carried, in order to monitor and document any transformation especially during seasonal variations.

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