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Geotechnical Characteristics of Tropical Residual Lateritic Soils – A Review

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ABSTRACT: Unlike transported soils, residual soils originate from the in-situ weathering and decomposition of parent rocks. The red coloured lateritic soils found in the tropical and sub-tropical regions are also residual soils, mainly derived from metamorphic and igneous rocks. Local climatic conditions as well as topography are very important in the formation of lateritic soils, combined with so many other factors that define their geotechnical characteristics. Hence the lateritic soils formed in different regions of the world vary significantly in their physical, chemical and mineralogical properties. The engineering properties namely permeability, compressibility and shear strength of soils, that define the suitability of the soil for any of its specific practical engineering application, also are site specific and greatly variant in nature. To understand the trend in their basic geotechnical characteristics i.e. the index and engineering properties, a review study is conducted here from available literature on the topic.

KEYWORDS: Lateritic soils, Formation, Index properties, Permeability, Compressibility, Shear strength etc.

I. INTRODUCTION

Unlike transported soils, residual soils are formed in-situ. Being formed in-situ, these soils have their peculiar characteristics that distinguish them from other soils formed by normal depositional processes. Lateritic soils, also called as red soils, are residual soils found in the tropical and sub-tropical regions. In tropics, such soils are widely used in construction especially in pavement construction as subgrade, sub-base or base-course, in earthen embankments or in the form of laterite blocks for building construction purpose. The tropical regions are characterised for their typical warm-humid climatic conditions that create the natural environment for the origin of such deep and wide lateritic profiles, which are having a stable structural form with porous surficial horizon; which on extensive weathering leads to the formation of residual lateritic soils. The occurrence of periodical wet and dry seasons is mandatory for the origin of lateritic soils. Therefore their formation and characteristics at a particular region are significantly affected by the regional climatic and topographical conditions and hence the lateritic soils formed in different regions of the world vary significantly in their physical, chemical and mineralogical properties.

The engineering properties namely permeability, compressibility and shear strength of soils, that define the suitability of the soil for any of its specific practical engineering application, also are site specific and greatly variant in nature. These are influenced by many factors and hence comparison of properties in residual soils is really difficult. But to understand the trend in their basic geotechnical characteristics i.e. the index and engineering properties, a review study is conducted here choosing appropriate literature.

II. OBJECTIVE

The lateritic soils are very important to a geotechnical engineer, as they are widely used in construction practices in tropical and sub-tropical regions. But to ensure the quality of the material, the properties and the behaviour of such soils under different practical situations must be known in depth, as their properties are observed highly variant in nature and are affected by a number of parameters. The objective of this research review paper is to study the general behaviour of lateritic soils by reviewing the various available research projects carried out so far on lateritic soils pertaining to their basic geotechnical characteristics and to better understand their index and engineering properties.



III. FORMATION OF LATERITIC SOILS

Laterite materials cover a large succession of reddish tropically weathered materials, varying from earthy to rocky materials. The parent rock may be igneous, sedimentary or metamorphic in origin, but should have high amount of iron content. From literature study, the optimum conditions required for the formation of laterites include (1) high seasonal rainfall and high temperature causing intense chemical weathering and subsequent severe leaching, (2) strong acidic and oxidising environment, (3) sustained long duration weathering (4) a chemically unstable parent rock, (5) good internal drainage and (6) continuous supply of freshly formed sesquioxides of iron either from the underlying parent material or from an adjacent area of similar petrological environment. The process of formation of laterites is called 'laterisation'. This commences with the formation of cracks in the parent rock, as a result of prolonged cyclic processes of heating and cooling by rain and sun. The cracked parent rock will gradually undergo upper facial decomposition under the fundamental conditions that are requisite for the chemical and mineralogical alterations to happen, which ultimately results in laterisation which may be controlled by a variety of local conditions of weathering and other factors. The major factors influencing their formation are properties of the parent rock material, climate, topography, vegetation and time.

IV. GEOTECHNICAL CHARACTERISTICS OF LATERITIC SOILS

The widely varying complex mineral composition and the extreme climatic conditions of their native tropical regions (i.e. alternate heavy rain fall and hot conditions) make the situation quite challenging for the geotechnical engineers to arrive at the exact engineering behaviour of such soils under the working environment. Hence to find out their suitability as quality assured construction materials, it is imperative to do the testing of such soils to know the engineering behaviour of the same prior to its usage at site, the lack of which may affect the durability of the structure. Tuncer(1976) has stated that the basic index property laboratory tests upon which the soil classification are based, are not always reproducible for lateritic soils. As lateritic soils are sensitive to oven drying, the classification properties are to be obtained on air dried samples only.

1. Particle Size Distribution

The grain size classification results are important due to the fact that particle size and measure of plasticity are widely used as basis for engineering soil classification. In lateritic soils also, the sieve analysis method is used for the coarser fraction i.e. for particles greater than 0.075 mm in size, and pipette analysis method or hydrometer method for the finer fractions i.e. for particles less than 0.075 mm. Lateritic gravels are composed of pieces of rock of varying hardness, whose size generally ranges from 2 to 20 mm and they remain stable in presence of water without losing their structure. Lateritic sands are composed of mineral particles, whose size ranges generally from 0.06 to 2 mm and they are also stable in presence of water. Though they don't have the cohesive forces holding the particles together, they have got a higher value of angle of internal friction, as expected normally. Lateritic silts are made up of particles of size ranging generally from 0.002 to 0.06 mm; their cohesion is almost nil when dry, but display slight cohesion when wet. Lateritic clays with size less than 0.002 mm, are the finest among the different particle sizes of lateritic soil. In case of lateritic soils also, well graded soils are expected to be better in their engineering properties than uniformly graded soils (Oyelami, 2017).

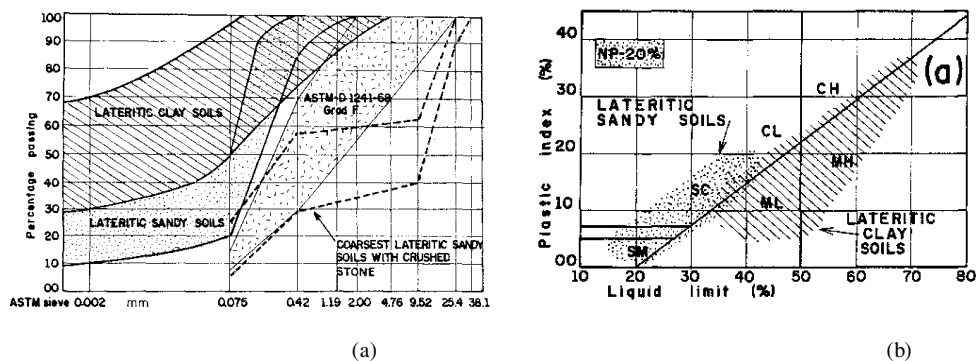


Fig 1. (a) Grading Envelopes for Lateritic Soils (Nogami and Villibor, 1991) (b) Lateritic Soils on Plasticity Chart (Nogami and Villibor, 1991)

2. Natural Moisture Content, Density and Void Ratio

As the lateritic soils show variations in their characteristics depending on many factors, the generalization of properties is practically difficult. The natural moisture content of lateritic soils varies from 3% for the lateritic rocks to 200% for the volcanic red lateritic clays. For problematic lateritic soils, the natural moisture contents are generally high, being far above the plastic limit and in many cases it can be even above the liquid limit, but at the same time remaining in their natural undisturbed state exhibiting the solid characteristics externally, rather than of a plastic or liquid mass. The in-situ dry density of lateritic soils is highly variant having pretty good values, ranging from 2082 to 2563 kg/m³ for homogeneous lateritic rocks, to as low as 320 to 961 kg/m³ for the volcanic red lateritic clays. As a result of leaching of materials, lateritic soils will usually have a porous structure, which can trap air and water in their voids between the porous micro aggregations. When depth increases, the void ratio decreases, reflecting the degree of weathering. Topmost layers will have more void ratio and lesser density. As depth increases, the porosity and void ratio decreases and hence the density increases. The void ratio ranges for lateritic soils is observed as 0.3 to 0.7 for dense soils, 0.7 to 1.1 for medium soils and 1.1 to 1.5 for low dense soils.

3. Plasticity Characteristics

Plasticity is an important index property of the fine grained soils, which is the ability of a soil to undergo deformation without cracking or fracturing. Liquid limit of some of the lateritic soils is above 50%. These soils have wide range of shear strength from poor to excellent. According to the plasticity chart, lateritic soils can fall above or below A-Line. Most of the fine grained lateritic soils fall in CH, MH or OH category. Gidigasu(1976) pointed out that the lateritic soils which fall below the A-line category needs to be well taken care of regarding their engineering properties when the soils are used for any construction purposes. The greater the plastic limit, the greater will be the compressibility and swell (volume change), when the soil comes in contact with water, finally leading to a decrease in the compressive strength. Hence a careful study according to the soil’s plasticity index, liquid limit and the percentage of clay fraction is very imperative.

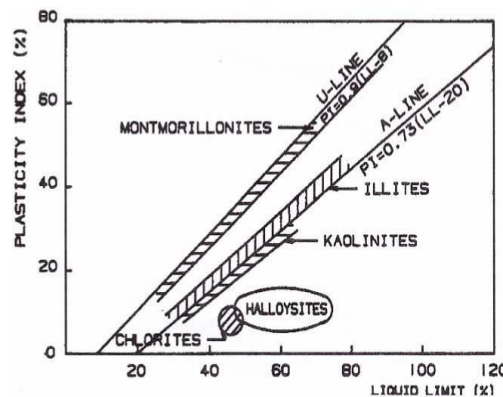


Fig.2.Location of Common Clay Minerals present in Lateritic Soils on Plasticity Chart(Morin and Todor, 1976)

According to Zelalem, A. (2005), when some laterite soils are tested after oven drying at temperature of 105°C, they exhibit lower Atterberg limit values. This is because when laterites dry, the hydrated oxides of iron and aluminium become less plastic as the dehydration of the sesquioxides creates a stronger bond between the particles upon drying. The process cannot be reversed by re-wetting. The effect takes place during air drying also but becomes more predominant on oven drying at higher temperatures. Hence lateritic soils are air dried only, instead of oven drying.

4. Specific Gravity

The specific gravity of lateritic soil generally falls within a range of 2.5 to 3.6, and is dependent on the particle size and iron content. A greater degree of ferruginization produces a higher specific gravity soil. Also the larger the clay fraction and alumina concentration, the lower will be the specific gravity. High specific gravity test value is attributed to its high iron content. It is observed that the iron content of high specific gravity minerals increases with age of formation and hence the specific gravity of lateritic soils should increase with increasing degree of weathering. size of samples, position of samples in soil profiles, grading characteristics, mineralogical composition of parent rock materials, amount



of iron content and accumulation of ferrous materials. In a well graded lateritic soil, the coarser particles will be having a higher value of specific gravity than the finer particles. Tuncer (1976) has given a table compiling the values of specific gravity of different clay minerals present in lateritic soils. Table 1 shows the values.

Table 1: Specific Gravity Values for Clay Minerals in Lateritic Soils, after Tuncer (1976)

Primary Minerals	Specific Gravity	Secondary Minerals	Specific Gravity
Quartz	2.65	Kaolinite	2.2 - 2.6
Orthoclase feldspars	2.5 - 2.6	Gibbsite	2.4
Plagioclase feldspars	2.61 - 2.75	Hematite	4.9 - 5.3
Augite	3.3 - 3.6	Goethite	3.3 - 3.5
Hornblende	2.9 - 3.3	-	-
Serpentine	2.5 - 2.8	-	-

5. Compaction Characteristics

Compaction increases the dry density of a soil, thereby leading to an increase in soil’s shear strength and bearing capacity, while it reduces the compressibility, volume change, permeability and susceptibility to frost action. There occurs usually wide variations of compaction characteristics in the case of lateritic soils due to their heterogeneity, degree of weathering, sensitivity to moulding water content, effect of sample preparation etc. The moisture density relationship in lateritic soils is affected by particular factors like degree of weathering, crushing strength of the gravelly materials formed, grading pattern, the amount and type of the prevailing clay mineral formed, placement condition of the material formed etc. Gidigas (1976) identified the factors affecting compaction of lateritic soils as nature of the soil, particle size gradation, mineralogical composition, specific gravity, plasticity and amount of clay size content present.

Lateritic soils comprise of concretionary particles. Weak particles break down with increase in the compactive effort whereas hard particles adds up to the strength of the soil mass. The higher the content of iron oxide, the harder they are. Many researchers noticed significant variations in the moisture-density relationships in lateritic soils when compaction is carried out from wet to dry and from dry to wet conditions of testing. If the natural moisture content is less than Optimum Moisture Content (OMC), we are adding water to get the maximum dry density value at OMC. But if the natural water content is greater than OMC, we have to dry up the soil initially and then gradually increase the water content to get the maximum dry density at OMC. But this value of maximum dry density is found to be lower than the former case, for the same compactive effort. It is observed that higher the compactive effort, the higher will be the reduction in strength with increase in water content. The degree of field compaction is directly related to the particle size distribution and field moisture content. The results of field compaction, rather than laboratory compaction test results, form a more useful basis for accepting or rejecting lateritic earthworks, due to the fact that for such soils the laboratory test results are sometimes not reproducible under field conditions. From the available literature reviewed, it is observed that the optimum moisture content of lateritic soils varies between 9% - 19% whereas the maximum dry density varies between 1.3 g/cc - 2.4 g/cc.

6. Shear Strength Characteristics

Within a lateritic profile, the shear strength characteristics vary considerably with the depth of the water table, nature of parent rock, topography, degree of decomposition etc. Lateritic soils have relatively high to very high cohesion and internal friction angle. As the lateritic soils are mainly kaolinitic in composition, they have got enough effective cohesion intercept, that hold the particles together and adds up strength to the shear forces. The cementation process which is taking place among the individual soil grains by the binding action of sesquioxides, imparts more resistance additionally. It imparts good interparticle friction also. Well graded lateritic soils have good interlocking properties at the macro and micro level. With the increase in the number of wet and dry cycles, the shear strength is observed to increase. This happens because, with the increase in wetting and drying, the cementation and aggregation increases which again increases this intrinsic effective stress.

A well graded lateritic soil has considerably enhanced shear strength properties when compacted close to the Proctor density, due to the excellent interlock between grains and internal cementation. With a decrease in void ratio, as we move down in the profile, the C value increases and the Φ value also increases. Hence we can observe a reverse

relationship between the degree of weathering and shear strength, down along a lateritic profile. However the value of effective cohesion C' decreases with a decrease in weathering due to the reduction in fines content but the effective angle of internal friction Φ' increases with a decrease in degree of weathering, as the concrete particles increases. The magnitude of Φ' depends on the texture, size and distribution of soil particles which in turn are greatly influenced by the degree of weathering. If the kaolinite content is high, C value will be high. If the sesquioxide content increases, the value of Φ will be increasing.

Decreasing moisture content usually causes an increase both in cohesion and internal friction angle. This behaviour is attributed to the variation in soil structure with varying moisture content. As the soil dries out, a part of the hydrated colloidal iron and aluminium oxides dehydrates and forms strong bonds among certain soil grains which in turn causes an increase in shear strength. The observed shear parameter values compiled by Ogunsanwo (1998) is given below in table 2.

Table 2. Values of Shear Strength Parameters for Compacted Lateritic Soils

Parent Material	Value of Φ (in degrees)	Value of C (in kPa)	Value of Φ' (in degrees)	Value of C' (in kPa)
Quartz Schist	22	43	31	15
Mica Schist	26	70	31	35
Granite Gniess	22	28	30	15
Amphibolites	17	92	27	45
Benin Sands	17	58	26	26

7. Compressibility Characteristics

The compressibility of compacted lateritic soils is generally in 'medium to low' range and the settlement is within the elastic zone. When lateritic soil sample was tested for the compressibility characteristics, it was observed that the values of both compression index and total settlement were obtained much smaller than that for pure kaolinitic clay sample, indicating that the compressibility of lateritic kaolinite soils is much lesser than pure kaolinite.

This property of lateritic soils is attributed to the presence of the sesquioxide compounds that coat the normal scale-shaped planar kaolinitic structure, which restricts their easy bending and sliding under compressive forces. The settlement value remained same for both the standard duration test and the extra duration test, clearly indicating that these sesquioxide bonds that bind and cover the particles are not affected by soaking for a longer time, under laboratory conditions.

Collapse of lateritic soils occur, under fully saturated conditions at high applied pressure which are compacted at dry of optimum. This is attributed to the probable loss of suction. When lateritic soils are compacted at dry of optimum, they deform gradually under the applied vertical pressure to some extent, till a critical pressure is reached, beyond which there occurs a rapid deformation or collapse.

8. Permeability Characteristics

As the degree of weathering increases while moving down the profile, the value of coefficient of permeability decreases, due to the presence of cemented aggregates subsequent to the fines filling up the voids, leaving the soil mass less permeable for water flow. Hence it can be stated that the value of coefficient of permeability decreases when the depth increases. Compaction also decreases the permeability of lateritic soils. The increase in the compactive effort results in decrease in permeability values. The brittleness of compacted lateritic soils has much to do with its natural soil structure through compaction or desiccation. The compaction at lower moisture content or excessive compactive effort can generate brittleness of the core, leading to increased tensile cracking within the soil mass, thereby increasing the permeability and reducing the shear strength and stability on other end.

The permeability of compacted lateritic soils is determined in the laboratory usually at 95% of its maximum dry density. The values obtained for selected lateritic soils in the falling head permeability test for the standard and modified



Proctor tests were 2.3×10^{-7} cm/s and 1.5×10^{-7} cm/s respectively, which are sufficiently low in maintaining a relatively impermeable cohesive core.

9. Shrinkage and Swelling Characteristics

Lateritic soils show very less shrinkage and swelling properties. The presence of the clay mineral montmorillonite is responsible for imparting the swelling as well as shrinkage properties to the cohesive soils. If montmorillonite is present in soil, as in black cotton soils, it provides the soil the tendency to swell upon wetting and shrink upon drying and hence generally called as expansive soils. Lateritic soils are not expansive soils. Though lateritic soil is a mixture of both cohesive and cohesionless soil fractions, the predominant clay mineral present in lateritic clays is kaolinite, instead of montmorillonite. But soils possessing low degree of laterization may possess comparatively pronounced swelling characteristics as well as shrinkage characteristics. Hence it is always suggested to do the mineralogical analysis of lateritic clays for the presence of any expansive clay minerals. If present in high quantities, precautions need be taken accordingly.

As per the papers referred, the maximum value of volumetric shrinkage strain for the materials to be considered for possible use as liners in waste containment facilities is limited to 4% only, to avoid the possibility of any shrinkage crack. A value of linear shrinkage between 6 to 7% is suggested for accepting lateritic clayey soils as base-course materials in pavement construction. The value of linear shrinkage permitted for sub-base is 12-13%. For lateritic gravels it is 3.3 to 5% for base-courses. High values of colloidal activity also indicate that the soil contains highly active clay minerals that can cause expansion or shrinkage. For most of the lateritic soils, the colloidal activity is in the low range only i.e. between 0.4 and 1.0 for residual lateritic soils and greater than 1.0 for the alluvial and tropical black clays.

V. CONCLUSIONS

The conclusions of this research review study, regarding the important geotechnical characteristics of lateritic soils, can be summarised as below:

- The formation of lateritic soils depends upon so many factors like nature of the parent rock material, climate, rainfall, topography, vegetation, age of the deposit etc; each factor having its own impact on the soil formation.
- Though lot of clay minerals are present, kaolinite is the main mineral constituent in lateritic soils, which imparts the binding property to the soil. At the same time, they tend to be silica poor, for silica is leached out by waters passing through the soil. For most of the lateritic soils, their colloidal activity is ranging from 0.4 to 1.0, which is comparatively low.
- The strength and hardness of laterites depend greatly on the amount of iron minerals present and the dense crystalline packing of these minerals within the soil structure. The percentage of iron content and percentage of clay fraction define the geotechnical properties of lateritic soils.
- Specific gravity of lateritic soils can vary within a wide range of about 2.40 to 3.50. Higher range of specific gravity value is attributed to its high iron content. Higher the iron content, harder they are.
- Lateritic soil has a good representation of both cohesive (i.e. fine grained) and cohesionless (i.e. coarse grained) portions of its particle sizes. The fine grained portion may contain lateritic silt or lateritic clay, whereas the coarse grain portion may contain lateritic gravel or lateritic sand. But majority of lateritic soils contain less clay fraction, but more silts, sands and gravels. A well graded lateritic soil comprising of different sizes of particles, has more strength as expected.
- The natural moisture content of lateritic soils can vary from 3% for the lateritic rocks to 200% for the volcanic red lateritic clays. The in-situ dry density of lateritic soils is highly variant, having pretty good values ranging from 2082 to 2563 kg/m³ for homogeneous lateritic rocks, to as low as 320 to 961 kg/m³ for the volcanic red lateritic clays. As lateritic soils usually have a porous structure, the void ratio ranges for lateritic soils is observed as 0.3 to 0.7 for dense soils, 0.7 to 1.1 for medium dense soils and 1.1 to 1.5 for loose soils.
- According to the plasticity chart, lateritic soils can fall above or below the A-Line. Most of them fall below the A-line generally. The Atterberg limit values for lateritic soils have proved misleading many times as the tests may not yield reproducible results.
- The factors affecting compaction characteristics of the lateritic soils are the heterogeneity of the soil, particle size gradation, mineralogical composition, the specific gravity and the amount of clay size content present. The lateritic soils show significant variations in their moisture-density relationships. The optimum moisture content



of lateritic soils generally varies between 9% - 19% whereas the maximum dry density varies between 1.3g/cc - 2.4 g/cc.

- Lateritic soils show very less shrinkage and swelling properties, as their main mineral constituent is kaolinite instead of the expansion causing-montmorillonite. For their acceptance as the base-course material for pavements, the value of linear shrinkage is limited to 6-7 % and for their use as sub-base material, the range is from 12-13%, as per earlier researches. The permissible value of volumetric shrinkage is limited to 4%, for using them as the liner material for waste containment facilities like landfills.
- Laterites are porous in nature, with pretty good permeability characteristics, but while moving down in a lateritic profile, the value of coefficient of permeability seems decreasing, due to the presence of cemented aggregates subsequent to the fines filling up the voids, leaving the soil mass less permeable. The value of the coefficient of permeability for laboratory compacted lateritic soils varies from 10^{-6} to 10^{-7} cm/s. The maximum value of field permeability observed in the in-situ permeability test lies in the range of 10^{-3} to 10^{-4} cm/s.
- The compressibility of compacted lateritic soils lies generally in the 'medium to low' range and the settlement is within the elastic zone. The compressibility of lateritic soils is always much lesser than that of pure kaolinite.
- Shear parameters appear to be generally higher for fine grained lateritic soils, and are observed to depend to a greater extent on the type of parent rock, degree of weathering, degree of saturation etc. Lateritic soils usually have relatively high to very high values of cohesion and internal friction angle, due to the cementation taking place among the individual soil grains by the binding action of sesquioxides.
- The shear strength behaviour of lateritic soils is observed to be very much dependent on the saturation of the soil. The major problem associated with lateritic soils is the loss of shear strength and subsequent failure upon inundation, which is visible in the form of landslides or soil collapse. This can be arrested by adopting proper ground improvement techniques well suited to specific site characteristics.
- Lateritic soils are very good choice, as an eco-friendly sustainable construction material, if we are able to carry out detailed geotechnical investigations for their proper characterisation, and thereby adopting suitable remedial measures wherever required.

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REFERENCES

- [1] Aginam, C. H. et.al. "Geotechnical Properties of Lateritic Soils Northern Zone of Anambra State, Nigeria", International Journal of Engineering Research and Development, Vol. 10, No. 12, pp:23-29, 2014.
- [2] Alhassan M. et.al. "Influence of Clay Mineralogy on Plasticity of Lateritic Soils", IOSR Journal of Mechanical and Civil Engineering, Vol. 11, No. 3, pp. 18-21, 2014.
- [3] Elarabi H. et.al. "Some Geological and Geotechnical Properties of Lateritic Soils from Muglad Basin Located in the South-Western Part of Sudan", Research Journal of Environmental and Earth Sciences Vol.5, No. 6, pp: 291-294, 2013.
- [4] Eze E.O. et.al. "Characterisation of Index Properties of Lateritic Soils in Ado Ekiti South Western, Nigeria", International Journal of Science and Research, Volume 6, Issue 8, pp: 308-312, 2017.
- [5] Ghosh, S. and Guchhait, S. K. "Characterization and Evolution of Laterites in West Bengal: Implication on the Geology of Northwest Bengal Basin", Transactions, Vol. 37, No.1, pp. 94-119, 2015.
- [6] Gidigas, M.D., "Laterite Soil Engineering-Pedogenesis and Engineering Principles", Elsevier, Amsterdam, Netherlands, 1976.
- [7] Hegde R.A., and Daware S.N., "Effect of Alternate Wetting and Drying on Laterite and Their Engineering Behaviour", Proceedings of the Indian Geotechnical Conference, at IIT Mumbai, December 16-18, 2010, pp: 321-324, 2010.
- [8] Kasthurba, A.K., Santhanam, M., and Achyuthan, H. "Investigation of Laterite Stones for Building Purpose from Malabar Region, Kerala, SW India - Chemical Analysis and Microstructure Studies", 2008. doi:10.1016/j.conbuildmat.2006.12.003.
- [9] Nogami, J.S. and Villibor D.F., "Use of Lateritic Fine-Grained Soils in Road Pavement Base Courses", Geotechnical and Geological Engineering, Vol.9, No.6, pp. 167-182, 1991.



- [10] Ogunsanwo O., “CBR and Shear Strength of Compacted Lateritic Soils from South Western Nigeria”, Quarterly Journal, Engineering Geology, London, Vol.22, pp: 317-328, 1989.
- [11] Osuji O.S and Akinwamide J.T., “Engineering Properties of Lateritic Soils in Ado-Ekiti, South Western Nigeria”, American Journal of Engineering Research, Vol.7, No.1, pp-353-360, 2018.
- [12] Oyelami C. A., “Suitability of Lateritic Soils as Construction Material in Sustainable Housing Development in Africa: A Geological Perspective”, Thesis Report, Doctor of Philosophy in Engineering and Environmental Geology, Department of Geology, University of Pretoria, 2017.
- [13] Sherman, G.D., “Factors Influencing the Development of Laterites and Lateritic Soils in Hawaiian Islands”, Pacific Science, Vol.3, No.8, pp. 307-314, 1949.
- [14] Shivashankar R., Thomas, B.C., “Laterites and Lateritic Soils : Geology, Engineering Properties and Problems”, Lowland Technology International, Vol. 21, Issue 4, pp: 205-214, 2020.
- [15] Tuncer, E. R., “Engineering Behaviour and Classification of Lateritic Soils in Relation to Soil Genesis”, Thesis Report, Iowa State University Retrospective Theses and Dissertations, 1976.
- [16] Zelalem, A., “Basic Engineering Properties of Lateritic Soils found in Nejo-Mendi Road Construction Area, Welega, Thesis Report for Master of Sciences in Civil Engineering”, Addis Ababa University, Addis Ababa, 2005.



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