International Conference on Applied Energy 2019
Aug 12-15, 2019, Västerås, Sweden
Paper ID: 1159

GEOTECHNICAL ANALYSIS OF LATERITE AS A SUSTAINABLE AND ADEQUATE SUB-BASE AND BASE MATERIAL FOR HIGHWAY CONSTRUCTION.

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ABSTRACT

The wrong application of laterite is one of the major causes of road failure in Nigeria, some road infrastructures in Nigeria are not sustainable and durable owing to the fact that the lateritic materials used as backfill material were not adequate enough to sustain the road over a considerable period of time, this, therefore, affects the durability of the road. In this study, the author has analyzed lateritic soil obtained from Awgu local government area in Enugu state, South East Nigeria, using basic prominent geotechnical laboratory tests. According to the results obtained, the sample in consideration had less than 35% by weight of sample passing through sieve 85,120,150,170 and 240. The sample had a liquid limit of 60%, plastic limit of 44.15%, plasticity index of 15.85%, a specific gravity of 2.49 and average moisture content of 12%. The California bearing ratio ranged from 29% to 77%. All the results above were analyzed according to the Federal Ministry of works specifications. This study has shown that the soil in consideration here is a good backfill material for sub-base and base material for highway construction, however, it is recommended that little improvement should be made on the soil in other to upgrade its ability to remain sustainable and durable over a considerable period of time.

Keywords: advanced geo-energy technologies, geotechnical engineering, highway construction, environment and climate change.

1. INTRODUCTION

Laterite is a major important component used in highway construction in Nigeria. Lateritic soil is a flexible and dynamic highway construction material which can be used in various forms, for instance, it can easily be compacted by mechanical means which helps to improve its strength, it can also be stabilized using foreign materials to improve on its characteristics. Layade Gideon Oluyinka & Ogunkaya Charles Olubunmi, 2018 in their study opined that lateritic soil is easy to handle during construction and they are made up of natural stable grading with an adequate property which acts as binders. It is interesting to note that one of the main causes of road dilapidation in Nigeria is the wrong application of lateritic soil especially during backfilling of the sub-grade & sub-base. In highway construction, the strength of the sub-base is an important factor that should be put into consideration of which laterite is a major component. Lateritic soils are usually formed in tropical regions of the world, they are usually stiff and can gain strength when wetted and dried. There is no specific definition of laterite at the moment however laterite can better be described by its characteristics, (Indraratna. B & Nutalaya. P, 1991). Lateritic soil can be improved upon to meet up with the required geotechnical engineering specifications through stabilization as earlier stated above. (Latifi et al, 2016) as stated by (Ahmad.S et al, 2019) opined that laterite can also be described as an extremely weathered and modified soil that is formed by an on site weathering and decomposition of rocks under tropical condition. Lateritic soil can also be described as a subtropical –

residual - soil material which is made up of varying properties of particles sizes,(Oyelami, C.A & Van, J.L 2016). It is usually formed when there is a breakdown of silicate material which can be kaolinite which leads to the generation of hydrous oxides of iron & aluminum. The soil appears in red or dark brown in color because iron oxides are dominant which allows the lateritic soil to have a rare chemical, physical and engineering properties (Madu, 1976). Joel Fabrice et al, 2019 opined that laterites from volcanic rocks are slightly finer, more plastic and possess low bearing capacity than laterite from sedimentary rock. In other to mitigate environmental pollution, waste generation and biological changes the use lateritic soil should be encouraged for all infrastructural construction in civil engineering as this does not harm the environment when likened to other construction materials,

(Bachar et al, 2014). According to (Adalbert 1996 & Morel et al 2001) the construction industry has been reported to be one of the major contributors of environmental contaminant during the processing and movement of construction materials. As the world begins to pay more attention to the environment and its sustainability, environmentally friendly and energy efficient construction materials has become the center of attraction as this will reduce the effect of construction materials on the earth. Based on the facts above, it has become of great significance and imperative to study the sustainability and adequacy of laterite as a sub-base and base material for highway construction. In this study, several geotechnical tests will be employed to analyze the lateritic sample which was obtained from Awgu LGA of Enugu state, South East Nigeria. The geotechnical tests employed in this study were the basic prominent tests like the sieve analysis, California bearing ratio, compaction, moisture content, and atterberg limit tests. The test results will be discussed in relation to the sustainability and adequacy of lateritic soil from South East, Nigeria as a sub-base and base material in highway construction.

1.1 REVIEW OF APPLIED ENERGY ON LATERITE

According to various research, lateritic soil has been found to contain minerals obtained from leaching which occur from decaying organic materials in the environment. Lateritic nikel ores are generated by heavy tropical weathering of olivine-rich ultramafic rocks. The two types of lateritic nickel ore which are limonite and silicate laterites are immensely enriched in iron because of the strong leaching of magnesium and silica. The silicate laterites on the other hand are formed under the limonite zone. They both contain a good amount of nickel. Various energy related research have been performed on laterite , J.MA & C.A. Pickles, 2013 performed a study on the use of microwave to segregate nickleferious silicate laterites. They submitted that nickel segregation can be done using electrical energy as main source of heat.

2. AIM

To study the sustainability and adequacy of laterite from Awgu, Enugu State, South Eastern Nigeria as a sub-base and base material for highway construction employing several prominent laboratory geotechnical tests.

2.1 Material and methods

The sample used for this study was collected in Awgu LGA in South East Nigeria, at a depth of 1meter from an already dug hole, and it was placed in a plastic, covered and transported to the laboratory for analysis. The moisture content test was conducted after which the sample was allowed to air dry at room temperature for two days. The sieve analysis was conducted by staking sieves of various diameters on a sieve shaker after which 500g of the sample was placed on the staked sieve on the sieve shaker and the experiment was conducted as the sample separated into various sizes in the various sieves. The optimum moisture content was obtained by performing the compaction test which was done by placing 6000g of the sample in a tray, after which the sample was mixed with a minimum percentage of water, the mixed sample was now divided into five different portions, each portion of the sample was placed in the mold and compacted 25 blows each after which it was weighed and the weight recorded, this process continued until the sample failed, the OMC obtained here enabled the calculation of quantity of water to be used for the CBR test. The CBR test was conducted by employing the same procedure used in obtaining the OMC however the compaction test was performed only ones and the sample was not allowed to fail, after the compaction, the sample was taken to the CBR machine to obtain the CBR value. The atterberg limit test which consists of plastic limit and liquid limit was conducted, for the plastic limit, a small amount of the sample was placed on a tray and allowed to lose moisture, after which the sample was mixed with little amount of water which enabled it to be formed, the sample was rolled into a thread until it started to crack, the sample was then cracked into four different portions, placed in a moisture can and the weight recorded, then it was placed in an oven and allowed to dry for 24hours after which the weight of the dried sample was recorded. The liquid limit test was conducted by placing the sample in a Casagranda apparatus, with the use of grooving tool, a path was created in between the sample inside the Casagranda apparatus. The Casagranda apparatus was moved up and down till the sample converged in the created path and moisture content of the converged sample was obtained. The specific gravity test was also performed using the specific gravity density bottles, the sample was placed inside the bottles and recorded both at dry state and wet state.

2.2 Results

Sieve No	Wt Retained In(Gm)	Percentage Wt Retained (%)	Cumulative Percentage Retained (%)	Percentage Wt Passing (%)
8	85	28.3	28.3	71.7
10	10	3.3	31.6	68.4
12	6	2.0	33.6	66.4
22	33	11.0	44.6	55.4
36	18	6.0	50.6	49.4
44	23	7.7	58.3	41.7
60	13	4.3	62.6	37.4
85	42	14.0	76.6	23.4
120	50	16.7	93.3	6.7
150	14	4.6	97.9	2.1
170	2	0.7	98.6	1.4
240	2	0.7	99.3	0.7
TRAY	2	0.7	100	

Table 1: This table represents the particle size analysis of the sample

Index property	Experimental Value
L.L	60.00 %
P.L	44.15 %
P.I	15.85 %
S.G	2.49
Average moisture content	12 %

Table 2: This table represents the index properties of the tested soil sample.

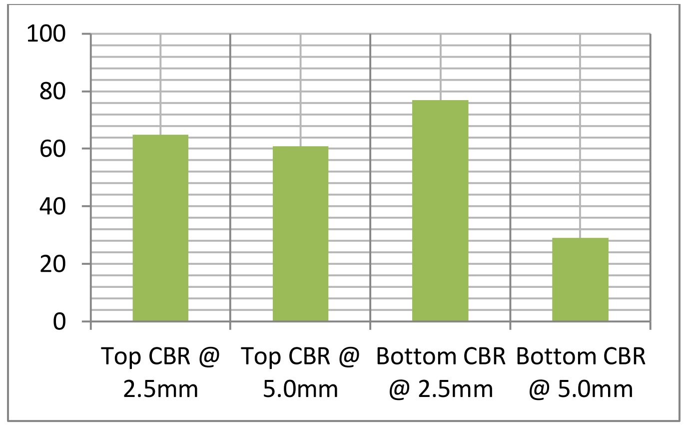

Fig 1: This figure represents the bar chart of various CBR values.

2.3 Validation of Methods & Discussion

Results from table one represents the results obtained from the sieve analysis test which was performed on the sample, table two represents the index properties of the sample, L.L (liquid limit), P.L(plastic limit), P.I(plasticity index),S.G (specific gravity) and the average moisture content while figure one represents California bearing ratio values of the samples. All the test procedures were explained in materials and methods section.

The table 1 represents the grading of the particles in the sample, from the table, it showed that the last five sieves, 85,120,150,170 and 240 had percentage by weight passing (%) of less than 35%. The last two sieves (170 & 240) had 1.4% and 0.7% of samples passing which means that less than 35% of the sample passed through and the sample contained less clay. Therefore, consequent upon the above observations, the sample is sustainable and adequate for use as a sub-base and base material for highway construction. However, the soil sample might need some improvement which will elevate its qualities and make it even more sustainable and adequate for highway construction.

The table 2 represents various experimental values of the samples in percentage (%), in agreement with the Federal Ministry of work specifications which states that for a soil sample to be considered adequate for highway construction the desired liquid limit should be ⩽50%, however at extreme cases the specified liquid limit of ⩽80% can be considered. For the plasticity index (PI) the desired (PI) according to the Federal Ministry of works specification is ⩽30% while at extreme cases a plasticity index (PI) of ≤55% may be considered. For a lateritic soil to be considered as a good material for highway construction, the specific gravity should be within the range of 2.5 – 2.75. The sample in consideration here met all the above-stated requirements however the liquid limit fell above the desired liquid limit of ≤50% but was within the specified liquid limit of ≤80%. This means that the soil sample in consideration here is a good material for sub base and base backfill in highway construction though little improvement might be needed. The above specifications are also in accordance with the works of (sowers & sowers, 1970). Furthermore, soil with plasticity - index >35 can be referred to as highly - plastic soil, such soil has the capability to keep water within its layers and they are highly compressible (seed & woodward, 1964).

The figure 1 represents the various CBR values for both top & bottom, the CBR values in un-soaked condition ranged from 29% to 77%. According to the Federal Ministry of works, the CBR value of a good base material for highway construction should be ≤80%, while for sub-base material the CBR should be ≤30%. This implies that the sample in consideration is a good base material however for the sample to be used as sub-base material; little improvement on its characteristics might be needed.

2.4 Conclusions

The geotechnical properties of soil in Awgu LGA of Enugu state, South East, Nigeria has been analyzed in agreement with the Federal Ministry of Works specifications. The sample analyzed here proved to be cohesive in nature with a low average moisture content of 12%, the results obtained from the particle size distribution test showed that sieves 85,120,150,170 and 240 had percentage by weight passing (%) of less than 35%, this shows that the sample had less clay which means it's a good sub-base and base material for highway construction. The sample met most of the specifications required of a good sub-base and base material however, improvement might be needed on the soil in other to improve its ability to remain sustainable and durable over a considerable period of time. This study will enable highway Engineers in making better material choices especially during highway construction within Awgu local government area.

ACKNOWLEDGEMENT

A special Thanks goes to Michael Igwebuike who gathered data for this study and to Professor Fidelis Okafor for supervising this research, also to my PHD supervisor and co-author Professor Clinton Aigbavboa. God bless you all.

REFERENCE

1. Adalberth,K. Energy demand during the life cycle of a building. CIB symposium Energy mass and flow in the life cycle of building, Vienna, (1996).
2. Bachar, M, Azzouz, L, Rabehi,M, Mezghiche, B. Characterization of a stabilized earth concrete and the effect of incorporation of aggregates of cork on its thermo – mechanical properties: experimental study and modeling. Constr. Build. Mater. (2014).
3. Federal Ministry of works and housing general specification for roads and bridges, volume II, Federal highway Department, FMWH, Lagos, Nigeria, 317p. (1997).
4. Joel Fabrice, N.B, Onana, V.L, Ndzie Mvindi, A.T, Ngo'o Ze,A, Ohandja, N.H , Eko, R.M. Assessment of the determination of California bearing ratio of laterites with contrasted geotechnical properties from simple physical paramters, 2019. Journal of Transportation Geotechnics.
5. Madu, R.M. An investigation into the geotechnical and engineering properties of some laterites of Eastern Nigeria, 1976. Engineering geology, 11:101 – 125.
6. Morel,J.C, Mesbar,A, Oggero,M, Walker,P. Building houses with local materials: means to drastically reduce the environmental impact of construction, 2001. Build. Environ 36,1119 – 1126. http://dx.doi.org/10.1016/50360 - 1323(00) 00054 - 8.
7. Oyelami C.A , Van Rooy J.L. A review of the use of lateritic soils in the construction/ development of sustainable housing in Africa: A geological perspective, 2016. Journal of African Earth sciences.
8. Oluyinka L.G & Olubunmi O.C. Geotechnical properties of lateritic soil as sub grade and sub base material for road construction in Abeokuta, South West Nigeria, 2018. International Journal of Advanced Geosciences.

9. Seed, H.B, Woodward, R.J. Fundamental aspects of atterberg limits. J. soil mech found. Div, Proceedings of ASCE, 90,SM6,P. 75. (1964).
10. Sower, G.B, Sower, G.F, Introductory soil mechanics and foundations. Macmillan, Newyork. P. 556. (1970).
11. Indraratna, B & Nutalaya, P. Some engineering characteristics of a compacted lateritic residual soil, 1991.
12. Latifi N, Horpibulsuk S, Meehan CL, Majid AZA, Tahir MMd, Mohamad ET (2016a) Improvement of problematic soils with biopolymer—an environmentally friendly soil stabilizer. J Mater Civ Eng 29(2):04016204
13. J.MA & C.A. Pickles. Microwave segregation process for nickeliferous silicate laterite. The Canadian Journal of metallurgy and materials science, (2013).