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Investigation into the Suitability of Burrow Pits along Ilaro-Papalanto Road for Road Earthworks

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ABSTRACT

Nine samples of lateritic soils obtained from trial pits dug at depth of 1 metre in three borrow pits along Ilaro – Papalanto highway (6°52'58"N, 3°5'49" E - 6°53'16" N 3°2'55"E) in Ogun State southwestern Nigeria were tested in the laboratory tests to determine their usefulness or otherwise as subgrade or subbase materials for the construction of pavement. The soil natural moisture content, gradation, specific gravity, consistency limits, compaction and California bearing ratio (CBR) characteristics were undertaken. in accordance with BS 1377. The specific gravity results range from 2.52 to 2.64 while the fines (less than 0.075mm) range between 12.70% to 20.96%. The consistency limits results indicate that liquid limit, plastic limit and plasticity index range from 17% to 44%, 14.1% to 26.48% and 2.18 to 22 % respectively. The optimum moisture content and maximum dry density range from 10% - 13.1% and 1.77 Mg/m^3 - 1.97 Mg/m^3 respectively. The un-soaked CBR values range from 20.30% to 59.34%. From the result, the soil can be used as sub-base and subgrade materials since their exhibited properties are fairly similar to the stipulations of the Nigerian Standard Regulations for Roads and Bridges Constructions(FMWH, 2000)..

Keywords: *Borrow pit, geotechnical properties, pavement, subgrade and sub-base*.

Introduction / background Study

Laterite is a product of weathering of parent rocks such as igneous and metamorphic rocks and vary in colour between reddish-brown and brown (Okeke et al., 2013). The formation of laterite is supported mostly by the tropical climate (Adeyemi, 2002). The majority of lateritic soils geotechnical behaviour and performance are determined by factors such as their origin, extent of weathering, morphological traits, chemical and mineral composition, and environmental circumstances. The nature and characteristics of the lateritic soil influence the engineering performance of structures built upon them. However, information provides that the performance of lateritic soils ranges between very good to poor when used as a construction material (Eze et al, 2014). The use of lateritic soils as materials for construction in a number of Civil engineering projects such as buildings, roads, embankments, fill materials and so on cannot be over-emphasized. Engineering structures are constructed with the expectation to stand a test of time therefore must be founded on very good, stable soil to avert structural failure /collapse, (Ademila, 2016). During new road construction, good lateritic soils are often utilized as either the subgrade or the subbase course. The materials are often in short supply along the right-of-way (ROW) hence the need for sourcing at a borrow pit at the shortest of haul distance. A borrow pit is a spot where materials for use in construction projects are abstracted whether soil or sand. Literally, the term borrow pit refers to a pit where resources are borrowed without an intention of returning the materials acquired eventually. (Nwachukwu and Osoro, 2013). A number of borrow pits abandoned by multinational road contractors for unknown reasons are along Ilaro – Papalanto road. These borrow pits are usually being patronized by some local road builders without re-assessing the geotechnical properties of the abstracted materials. However, with the increase in the numbers of road failures being witnessed across the nation many of which Adams and Adetoro, 2014 ascribed to substandard construction materials. With the growing needs to construct new roads with scarce resources, construction materials must be ensured to possess adequate geotechnical features to enhance optimal performance when deployed for road construction purposes either as subgrade or to safeguard against the loss of the huge financial commitment in road construction. It is very common in the tropics, to identify differences in soil properties. Adeyemi and Wahab, 2008 posited that the variations in soil properties can be witnessed over short distances and/or at shallow depths as a result of different formation elements of the resulting soils. Therefore, the need for reassessing the geotechnical features properties of lateritic soils from the old borrow pits before their use in civil engineering works is essential to determine their suitability as a construction material for that particular need. Hence, this paper examines the geotechnical properties of lateritic soils from the three (3) prominent borrow pits at Oteyi, Iganmu, Anglican (Bethel) praying ground which were opened during the construction of Abeokuta-Lagos highway to determine whether the properties conform with the Nigeria General Specification for Roads and Bridges construction, (FMWH, 2000) since the lateritic soils from the borrow pits are either utilized as a subgrade or sub-base material for road construction in areas around the sourced borrow pits.

Methodology

The study area is along Papalanto-Ilaro road covering part of Yewa-South and Ewekoro Local Government Areas, Ogun State, Southwestern Nigeria lying within the following coordinates, Anglican (Bethel) praying ground, latitude 6º53'15" to 6º53'16" N and longitude 3º2'55" to 3º2'58" E), Iganmu, latitude 6º53'3" to 6º53'4" N and longitude 3º4'34" to 3º4'37" E and Oteyi, latitude 6º52'58" to 6º52'59" N and longitude 3º5'48" to 3º5'51" E. The study location is accessible through Papalanto off Abeokuta-Lagos Express Road. Lateritic soils for construction purposes, especially road works, within the region are sourced from these sites. Fig. 1 is the Ogun State map with all local government areas shown while Fig. 2 is the study area extracted from the map of Ogun State.

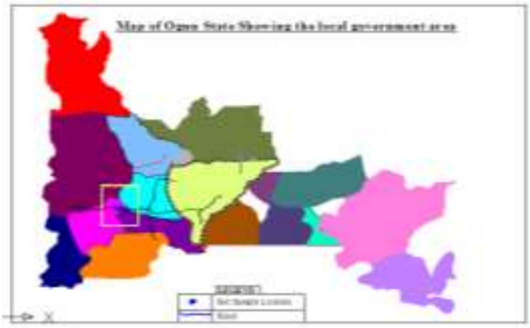

Fig. 1: Ogun State Map showing the Local Government Areas

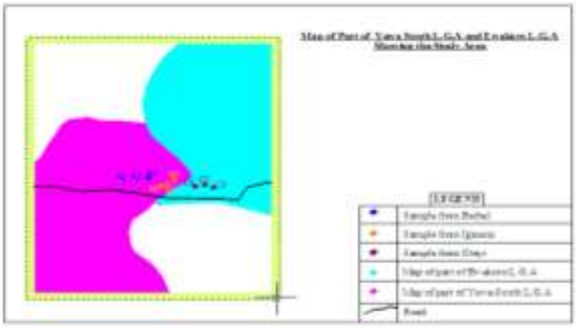

Fig. 2: The Study Area Map

Disturbed samples were obtained from three trial pits within each of the borrow pit at a depth of 1 metre and horizontal spacing of 5 metres apart. The lateritic soils obtained were taken to the Department of Civil Engineering Soil Mechanics laboratory of the Federal Polytechnic, Ilaro for the determination of selected engineering index properties, compaction and CBR characteristic tests. The natural water content determination, specific gravity test, particle size gradation, consistency limits test, compaction test, and unsoaked CBR (Bowles, 1988 and Brian, 1980) were conducted as stipulated in BS 1377 (1990).

Fig 3: Compaction Test in progress

Results and Discussion

The tests results of the samples from the study area are as detailed in Table 1 while Table 2 shows the comparison of the results with Nigeria Standard of Soil classification for Roads and Bridges (FMWH, 2000) specification.

Natural Moisture Content

Soil's natural moisture content is important in either increasing or reducing its densities. Ramamurthy and Sitharam (2005) pointed it out that water content of soils affects the corresponding dry density of soils. According to Mohammed H and Dahunsi B.I.O. (2012), soils with natural moisture contents (NMC) higher than its corresponding optimum moisture contents (OMC) gave low density indices (DI). This is explained by the higher degree of saturation; these soils are unsuitable for use as pavement materials because their moisture content values have dropped to the wet side of the compaction curve (Garber and Hoel, 1999) as the bearing capacity would have been reduced. From the result presented in table 1 below the samples B1, B2, C1 and C2 have their natural water content above the OMC. These soil samples may have poor drainage ability hence susceptible to flood inundation. Pavement built on such subgrade or subbase can failed as result of high compressibility and settlement (consolidation). Materials in these borrow pits can be stabilized by adding coarse materials to increase the soils' ability to drain before being used as building material for roads.

Specific Gravity

The weight of that specific soil in relation to the weight of an equivalent volume of water is known as its specific gravity. It is a sign of the dry, saturated surface state. Additionally, it depends on how many spaces and quartz-like particles there are in the soil. The amount of sand in the soil, as well as its mineral composition and formation process, determine its specific gravity. A good lateritic material should have specific gravity ranging from 2.5 to 2.75 (Alabo, 1987 and FMWH, 2000). The specific gravity for the soil samples vary from 2.52 to 2.64. The specific gravities of samples from the study area are however considered to be acceptably high which may be attributed to high mineral composition of the samples. Lower specific gravity value in number indicates a coarse soil type, while higher value in number indicates a fine- grained soil type. The soil samples are however good materials for road construction. e values are higher than the specific gravity of 2.2 specified by FMWH for roads and bridges. The specific gravity of sandy soil, which is primarily composed of quartz, can be predicted to be roughly 2.6 by the AASHTO standard of soil classification, but it can range from 2.35 to 2.7 for silt and clay soils. These facts support the range of the specific gravity, which confirms the significant proportion of silt or clay, both of which are very advantageous when building roads at the sub-grade and sub-base levels.

Particle Size Analysis

The particle size gradation shows the range and the type of particle sizes represented in the soil sample. According to the Federal Ministry of Work and Housing specification (2000), soil sample to be used for road construction should consist of fines (passing 75-micron sieve) of which the percentage by weight should be less than and not greater than 35% of the weighed sample. Sequel to the above, the samples under investigation are good samples because the percentage by weight passing sieve No. 200 (75 micron) for the soil do not exceed 35% as shown in Table 1. A value of the coefficient of curvature, C_c between 1 and 3 indicates a well graded soil. Aside sample C1 with a C_c of 0.72 all other samples under study exhibit a well graded property hence C1 may be an outlier. For the coefficient of uniformity, C_u, the higher its value, the larger the scope of particles sizes in the soil. Good and well graded soil samples have C_u of 6 and greater.

Consistency Limits

The liquid limit values varied from 17% to 44%, the plastic limit values ranged from 14.1% and 26.48% while the plasticity index varied between 2.18 to 22 (Table 1). According to Whitlow (1995), liquid limit between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity. Any value below 35% is low plasticity. The Federal Ministry of Works and Housing (2000) manual for road works recommend liquid limits of 40% and 50% maximum for subgrade and sub-base/ base materials and plasticity index less than 18%. Since all of the soil samples taken from the research region meet this requirement, they can be used for subgrade (except for samples A1 and B2), sub-base and base materials.

Compaction

A high density of compacted soil is normally required for roads and airfields construction to avert settlement of the foundation soil when subjected to the weight of an embankment or traffic. Ademila, 2017 averred that compaction reduces the detrimental effects of the ingress of water into the embankment (). This test is used to establish a dry density/moisture content relationship of a soil under controlled condition which can form a standard for comparison with field specifications. The maximum dry density for the soil samples varied between 1.77 mg/m^3 and 1.97 mg/m^3 while that of optimum moisture content ranged between 10% and 13.1%. O"Flaherty (1988) in his study suggested the range of values that may be predicted when using the compaction standard proctor laboratory test methods. These values are: for clay, maximum dry density (MDD) may fall between the range of 1.44 mg/m^3 and 1.685 mg/m^3 and optimum moisture content (OMC) may fall between the range of 20-30%. In the case of silty clay, MDD is usually between the range of 1.6 mg/m^3 and 1.845 mg/m^3 and OMC ranged between 15-25%. For sandy clay, MDD usually ranged between 1.76 mg/m^3 and 2.165 mg/m^3 and OMC between 8 and 15%. Thus, looking at the results of the soil samples, it could be observed that they are sandy clay. However, the best and possibly the excellent soil for the construction of foundation is the soil with high maximum dry density (MDD) at low optimum moisture content (OMC) (Jegede, 1999). The essence and importance of compaction is to improve the desirable load bearing capacity (i. e. strength) of pavement structures. Failure of civil engineering structures and road pavements increased when the underlying soils are always soaked with water hence, the foundation of pavement structures must always be compacted above the MDD and OMC to yield maximum strength, prevent ingress of water and distribute wheel loads uniformly into the pavement structures (Ademila, 2017, Mohammed and Dahunsi, 2012).

California Bearing Ratio, CBR

The CBR is a semi empirical test that is often employed in the estimation of the bearing capacity of sub-grade, sub-base and base materials in road and airfield pavement design. The unsoaked CBR values for the tested soil samples range from 20.30% to 59.34%. All the samples lack the required 80% minimum unsoaked CBR value recommended for highway base, some fall within the category of subbase (A2, A3, B3, C1, C2 and C3) while all the samples can be used as subgrade soils according to specification by FMWH (2000). It is observed that the unsoaked CBR values of the study area are low aside location 3 with medium CBR values ranging from 40.63 and 59.93, requiring that soil stabilization would be required for founding stable structures.

Table 1: Summary of Laboratory Results

Parameter	Sample	A1	A2	A3	B1	B2	B3	C1	C2	C3
Water Content	(%)	10.83	10.73	8.44	14.61	12.61	10.55	15.00	15.27	10.86
Specific gravity		2.52	2.53	2.55	2.57	2.56	2.64	2.62	2.59	2.61
Particle size analysis	% Fines	19.9	17.6	20.5	20.96	18.2	19.14	16.94	12.70	19.24
	Cc	1.88	1.89	2.14	2.2	1.81	1.62	0.72	1.69	1.03
	Cu	9.67	8.70	10.38	8.20	8.68	9.19	7.40	11.57	9.23
Consistency Limit	LL (%)	44	30	17	31	44	31	35	31	25
	PL (%)	22	23.08	14.82	14.1	31.8	28	26.48	22.09	19.81
	PI (%)	22	6.92	2.18	16.90	12.2	3	8.52	8.91	5.19
Compaction	OMC (%)	13.1	12	11.4	12	10.2	11.7	11.85	10	12
	MDD (kg/m³)	1770	1935	1895	1883	1970	1925	1830	1900	1950
CBR (%)	Un-Soaked	35.63	28.9	36.22	20.30	38.42	31.21	57.35	59.93	40.63

Table 2: Summary of Test Results in Comparison with the Nigeria Standard of Soil Classification for Roads and Bridges (FMWH, 2000)

Location	1	1	1	2	2	2	3	3	3
Sample	A1	A2	A3	B1	B2	B3	C1	C2	C3
% Fines (≤35%) Comment	19.9	17.6	20.5	20.96	18.2	19.14	16.94	12.7	19.24
	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
L. Limit(≤40%)	44	30	17	31	44	31	35	31	25
Comment	Fail	Pass	Pass	Pass	Fail	Pass	Pass	Pass	Pass
P.I for Sub-base (≤12%)	22	6.92	2.18	16.90	12.2	3	8.52	8.9	5.19
Comment	Fail	Pass	Pass	Fail	Pass	Pass	Pass	Pass	Pass
C.B.R (unsoaked)	35.63	28.9	36.22	20.30	38.42	31.21	57.35	59.93	40.63
Subgrade (≥10%)	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
	Good	Fail	Good	Fail	Pass	Pass	Pass	Pass	Pass
Sub-base (≥30%) Base (≥80%)	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail	Fail
Overall Rating	Sub-base	Subgrade	Sub-base	Subgrade	Subgrade	Sub-base	Sub-base	Sub-base	Sub-base

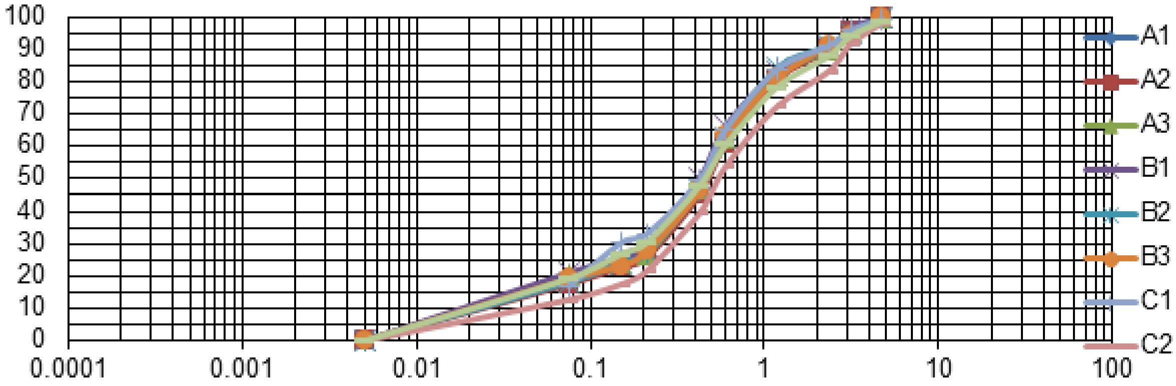

Fig 4: Graph of Sieve Analysis Test for All Samples.

Conclusion

The assessment of geotechnical properties of soils within Ilaro and its environs in South-western Nigeria for road construction has been carried out in compliance with British Standard Methods of Test for Soil for Civil Engineering Purposes (BS 1377: 1990) and the Nigeria General Specification for Roads and Bridges construction, (FMWH, 2000). The result indicates that the soil samples investigated are medium graded clayey sand; the samples A2, A3, B3, C1, C2 and C3 can be utilized fairly as sub-base course material in road projects and all the samples can deployed as subgrade materials because they meet certain index and engineering parameters while they all failed the unsoaked CBR value specified in FMWH (2000) for base course material. However, all the soil samples may have to be modified or stabilized for use as a base. The result obtained from this study could constitute a geotechnical data pool on the properties of soil in the study location.

References

Ademila O. (2012), “Application of geophysical survey for subsurface investigation of an Erected multistory building in southwestern Nigeria,” International Basic and Applied Research Journal, 2(12):1-12, 2016.

Ademila O. (2017). Engineering Evaluation of Lateritic Soils of Failed Highway Sections in Southwestern Nigeria, Geosciences Research, Vol. 2, No. 3, August 2017 https://dx.doi.org/10.22606/gr.2017.23006 pp 210 - 218

Alabo, E. H. and P. Pandy, (1987). Distribution of engineering properties of red soils in the central Lower Niger Delta, Nigeria. Proceeding of the 9th African Reg. Conference Soil Mechanics and Found. Engr., Lagos, pp: 49-55.

American Association of State Highway and Transportation Officials, 1982. AASHTO Materials, part 1, specifications, Washington.

Ashworth G. B., and Overgaard R. T., “Highway planning methods: In highway and traffic engineering in developing countries,” (ed. B. Thagesen) Chapman and Hall, London, 1996.

Banks, J.H., “Introduction to Transportation Engineering”, 2nd edition McGraw-Hill Book Company. New York, 2004.

Bowles, J.E., “engineering properties of soil and their measurement”, McGraw-Hill Book company, New York, 1988.

Brian V. (1980), Laboratory works in civil Engineering, New York, USA, Granada Publishing.

BS 1377, (1990): Methods of test for soils for Civil Engineering purposes, British Standard Institution.

Eze E. O., Adeyemi. G. O. and Fasanmade P. A. (2014). Variability in Some Geotechnical Properties of Three Lateritic Sub-Base Soils Along Ibadan Oyo Road.IOSR Journal of Applied Geology and Geophysics. Vol 2:5, pp 76-81

Federal Ministry of Works and Housing (2000). General Specification for Roads and Bridges, Volume II, Federal Highway Department, FMWH: Lagos, Nigeria, 317 p.

Garber, J.N and Hoel, L.A., “traffic and highway engineering”, Brooks/Cole Publishing company, Pacific Grove, California,1999.

Jegede G. (1999), “Engineering geological significance of the superficial deposits in Carrington Hill area,” Country Conc, Ireland. Nigeria Journal of Sciences, 28:153-158, 1999.

Mohammed H. and Dahunsi B.I.O., 2012, Effects of Natural Moisture Content on Selected Engineering Properties of Soils, Transnational Journal of Science and Technology Vol. 2, No.5, June pp 29-47.

Nwachukwu M.A. and Osoro E. (2013) Assessment of environmental hazards: Linking borrow pits, gully erosion, and road failure; Journal of Civil Engineering and Construction Technology; Vol. 4(6), pp. 199-210, June, 2013 doi:10.5897/ 2013.0270, pp 199-210

Oke, S.A. and Amadi, A.N., 2008, An assessment of the geotechnical properties of the sub-soil of parts of Federal University of Technology, Minna, Gidan Kwano Campus, for foundation design and construction., J. SciEduc Technology., 1(2), 87 – 102.

Okeke, O.C., Ogbunyiba,O.O. and Chukwujekwu, D. (2013).Geotechnical Evaluation of Lateritic Soil Deposits in parts of Abuja (Nigeria), for Road Construction". International Journal of Environmental Issues, vol 10 No. 1, pp. 148-160s

O'Flaherty, C. A., (1988). Highway Engineering. Vol. 2, Edward Amold Publishers, London UK.

Ramamurthy, T.N and Sitharam, T.G., "geotechnical engineering" S. Chand and Company Limited, Ram Nagar, New Delhi.2005

Whitlow R., "Basic soil mechanics," 3rd ed., Edinburgh Gate, Addison Wesley Longman Limited, 1995.