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GEOTECHNICAL INVESTIGATION OF BORROW PIT AS A SUBGRADE MATERIAL FOR ROAD CONSTRUCTION AT VICTOR ATTAH INTERNATIONAL AIRPORT, UYO, NIGERIA

BADANIE GEOTECHNICZNE MATERIAŁU Z WYKOPU JAKO PODŁOŻA DO BUDOWY DRÓG NA MIĘDZYNARODOWYM LOTNISKU VICTOR ATTAH, UYO, NIGERIA

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Abstract

One of the mass prompt practices of soils is for engineering projects such as the construction of roads, buildings, dams, and so on. Therefore, suitability of index and mechanical properties needs to be investigated. This study aims to determine the essential quality material required for road construction, thereby poses détente prospect for the disposal of ineffectual atrophy generated on sites. Such materials are classified into index and mechanical properties. Six subgrade samples were taken at the depth to bottom ranging from (1.0-5.0) m and tested. The sample was subdued to the laboratory tests, such as Sieve Analysis, Atterberg limits, compaction, California Bearing Ratio (CBR), and Specific Gravity (SG) respectively. The mechanical analysis which involved particle size distribution revealed that the subgrade was finely grated with a limit of ≤35% for subgrade passing sieve No. 200 (0.075 mm) with 29.1%, with an average Natural Moist Content (NMC) of 13.9%. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were 1.83 mg/m³ and 11.5%. The index analysis involved the liquid and plastic limits determination of Liquid Limit (LL) of 35.8%, Plastic Limit (PL) of 24.0%, and a Plasticity Index (PI) of 12%. California Bearing Ratio (CBR) results were 20.3% (soaked). The SG test results ranged from (2.68-2.94) kg/m³, employing the American Association of State Highway and Transport Officials (AASHTO) system of soil classification. The AASHTO grouped the materials into A-1, subgroups A-1-b and A-2-4 constituting 50% and 29.1%, with significant materials composed of stone fragments and sand rating the subgrade samples as excellent to good materials suitable for road construction.

Keywords: Lateritic, Liquid Limit, Plasticity Index, Subgrade

Streszczenie

Jedną z masowych praktyk związanych z gruntami są projekty inżynieryjne, takie jak budowa dróg, budynków, zapór itp. Dlatego należy zbadać przydatność gruntu i jego właściwości mechaniczne. Niniejsze badanie ma

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na celu określenie niezbędnych właściwości materiału wysokiej jakości wymaganego do budowy dróg, co stwarza perspektywę usunięcia nieefektywnych wykopów generowanych na terenie. Materiały są klasyfikowane według wskaźników i właściwości mechanicznych. Sześć próbek gruntu pobrano z głębokości w zakresie 1,0-5,0 m i poddano badaniom. Próbki zostały poddane testom laboratoryjnym, takim jak analiza sitowa, granice Atterberga, zagęszczenie, kalifornijski wskaźnik nośności (CBR) i ciężar właściwy szkieletu gruntowego (G_S). Analiza rozkładu wielkości cząstek wykazała, że grunt był drobnoziarnisty o uziarnieniu ≤35% dla sita nr 200 (0,075 mm) oraz 29,1%, przy średniej naturalnej wilgotności gruntu (W) wynoszącej 13,9%. Maksymalna gęstość szkieletu gruntowego (ρds) i optymalna zawartość wilgoci (Wopt) wyniosły odpowiednio 1,83 mg/m^3 i 11,5%. Wyznaczono granice płynności i plastyczności: granica płynności (wL) wynosiła 35,8%, a granica plastyczności (wp) 24,0% oraz wskaźnik plastyczności (Ip) na poziomie 12%.

Kalifornijski wskaźnik nośności (CBR) wyniósł 20,3% (po nasiąkliwości). Wyniki badań G_S wahały się od 2,68 do 2,94 kg/m^3, przy zastosowaniu systemu klasyfikacji gruntów AASHTO. Według AASHTO pogrupowano grunty na A-1, podgrupy A-1-b i A-2-4 stanowiące 50% i 29,1%, przy czym materiały składające się z odłamków kamieni i piasku oceniono jako doskonałe lub dobre materiały nadające się na budowy dróg.

Słowa kluczowe: lateryt, granica płynności, wskaźnik plastyczności, grunty

1. INTRODUCTION

Globally, inaccessible to infer suitable data about the index and mechanical properties of the soil and subsoil condition of the region, especially for primary prior engineering projects, antiquated and cause failures on road construction projects (Fidelis et al., 2019; Robert et al., 2020). That is, a failure immediately after the project is commissioned or even before commissioning. It is essential for the engineers, geoscientists, and soil scientists designing road construction projects to have a good knowledge of the geotechnical, index, and mechanical parameters of the subgrade material before any construction commences (Malomo, 1977; Ola, 1978; Adeagbo, et al., 2016). The various properties of subgrade soil are grouped into; index properties and engineering properties (Ramamurthy and Sitharam, 2005; Osinubi et al., 2019). The mechanical properties of subgrade soils are permeability, compressibility, and shear strength while the index properties are particle size distribution, Atterberg limits, density index, and specific gravity of soil particles (Agbede, 1992; Hunt, 2007). These soil properties are mainly used in the identification and classification of soils and help the geotechnical engineer in predicting the suitability of soils as foundation and construction material (Coduto, 2007; Aroka, 2009; Ola, 1978). In this study, selected borrow pits around Ndon Ebom Uruan, Akwa Ibom, Nigeria was investigated and used as the subgrade. These borrowed pits were originally entrenched as a source of road fill material and are nowadays the source of red earth material for nearby construction sites and other civil engineering work (Lancellotta, 2009: Godwin et al., 2020). A borrow pit is a term used in construction for a hole, pit, or excavation that has been dug to remove gravel, clay, and sand used in a construction project such as bridges, dams, and so on (Salter, 1988; Oglesby and Hicks,1992; Ogbuagu and Okeke 2019). Borrow pit site investigations are primarily carried out to establish reliable estimates of the quantity, quality, and processing needs of potential road building materials. These materials suitable for filing surfacing or blending can be removed using earthmoving equipment. A borrow pit can also be referred to as a sandbox, a large hole that has been dug for a particular purpose. Almost all construction projects involve earthwork designed to determine a suitable base for engineering construction (Malomo, 1977; Singh, 2004). A key aspect is to ensure that ground conditions are sound for stable construction through grading and excavation processes. Frequently, constructions crews will dig borrow pits to gather gravel, soil, and sand for use in another location (Opeyemi et al., 2018). The digging of borrow pitfalls under the engineering discipline known as earthworks. Earthworks projects consist of engineering exploits including, the transportation of large amounts of soil or rock from one area to another. Borrow pit construction may seem relatively easy to accomplish, though this type of digging requires an extensive amount of analysis before the original dig (Charkley et al., 2019). Engineers and Geoscientists must be sure that the amount of soil dug from a pit in an area will not disrupt the earth. Before the invention of geotechnical engineers, geoscientists, and other soil scientists needed to calculate the degree to which the earth desired displacement during digging (AASHTO, 2000; Murthy, 2007). As well as the accuracy in the laboratory, modern equipment on quality and sampling techniques was applied and data interpreted. On the other hand, it poses the rationale for the growth and development of the state, and other places around the world as the international airport good road attracts investors globally (Onakunle et al., 2019). Hence, this research aids to provide geotechnical data for engineers, geoscientists, and contractors for use as engineering subgrade and base materials as well as educating the fresh research worker.

2. GEOLOGY AND LOCATION OF THE STUDY

The borrow pit is located at Ndon Ebom Community, Southern Uruan in Uruan Local Government in Akwa Ibom State, Nigeria, about 1500 m away from Victor Attah International Airport, South-South Nigeria. It lies between latitudes 4°90'N and longitudes 8°08'E covering an area of about 449 km^2, as shown in Figure 1.

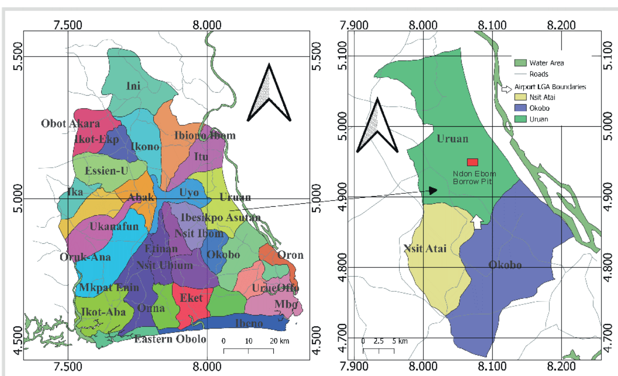

Fig. 1. Location of the study area citing Ndon Ebom (Borrow pit) and Airport

The Borrow pit is sited away from the residential areas and major roads to prevent the environmental hazard. The subsoil material is lateritic in color with an enclosure of coarse particles with conceivably enhanced particle size distribution. The lateritic material possesses clayey properties which influence the acceptability level of compaction for road construction and other engineering projects (Malomo, 1977; Aka et al., 2021). The topography of the area is tabled land with a gentle slope accompanied by natural vegetation consisting of grasses, economic and commercial trees, and shrubs. Geologically, the parent rock materials within the area are mainly sedimentary rocks which have resulted in the prevalence of sandy-clayey soils lithology as shown in Figure 2 (Aka et al., 2020a; Avbovbo, 1978; Aka et al., 2020b).

Fig. 2. Borrow pit formation in Ndon Ebom lithology with a heavy-duty excavator at work

3. MATERIALS AND METHODS

Borrow Pit Sampling

The sampling method covers procedures for recovering soil samples to investigate the soil for use as a borrow pit. The test was carried out in reference to American Society for Testing and Materials (ASTM) International, which is a standard test method for analysis of Soils. The pits were assigned: numbers, names, sites, and locations in consecutive order for filing purposes, and references of the pit.

Apparatus: The apparatus used for the sampling include: Posthole auger with handle extensions of (50 -300) mm in diameter that is capable of extending by adding sections to the handle for boring the marked point on the field into the holes to achieve the desired depth. Accessory Equipment such as Sample tag for identifications of samples, sample bags for collection of samples taken out from auger to the laboratory, shovel for clearing of access way and point of boring, tape for measurements of sample distance, a permanent marker for writing on sample bags.

Procedure: The area was taken out for testing using a grid pattern with number labeling on-site and the location at about 1.0 m intervals for areas where soils vary unpredictably and 2.0 m intervals for areas where soils are reasonably uniform respectively. The hand auger is made boring by turning the auger to a desirable distance, say (1-5) m into the soil, withdrawing the auger, and removing the soil for sampling. The process was repeated for the three sets of data acquired and the samples of each soil type, except topsoil, were taken. Stockpiles were involved in the sample during the stockpiling operation by obtaining characteristic samples using a shovel sampled as specified after the stockpile is complete. Place the sample in the bag and complete the identification tag for the sample, depth to the nearest half afoot, of the top and bottom of the soil strata from which the sample was taken. After sampling is complete the stake bearing the site and location number was reset to mark the location. Then a map is drawn for referencing each location of the site presently being tested to landmarks with the legend indicating the name and number of the pit, district, name of the contractor, type of borrow, contract number, date sampled, names of the sampling crew, and the scale used to draw the map. Lastly, the bagged samples were returned to the laboratory for testing (ASTM D 698, 2012).

4. LABORATORY TESTS

Moisture Content (W)

The moisture content of the soil also referred to as water content, is an indicator of the amount of water present in the soil. It is the ratio of the mass of water contained in the pore spaces of soil to the solid mass of particles in that material, expressed as a percentage. A standard temperature of 110°C ±5°C is used to determine the mass of the sample.

5. SAMPLE PREPARATION FOR MOISTURE CONTENT

Apparatus: The apparatus involved includes: non-corrodible container, and vented thermostatically controlled drying oven that maintains temperatures between 105°C to 115°C, a balance of sufficient sensitivity (sensitive to 0.01 g), and Container handling apparatus.

Procedure: The container was clean, dry, and weighed empty balance, tarred before it is used to measure the weight W_1. The weight of the container and wetness of the soil sample of the specimen in the container was measured as W_2. The container was kept in the oven for 24 hours, drying the specimen to a constant weight, maintaining the temperature between 105°C to 115°C, and recording the final constant weight W_3 of the container with the dried soil sample (Head, 1994a; ASTM D 698, 2012). The moisture content of soil (W)

$$W = \frac{M_w}{M_s} \times 100\% \tag{1}$$

where: M_w = weight of container + wet of soil W_2 – weight of container + dry soil W_3,
M_s = weight of container + dry soil W_3 – weight of container W_1.

6. PARTICLE SIZE ANALYSIS

Mechanical analysis (particle size distribution) is the determination of the size range of sand, silt, and clay present in a soil expressed as a percentage of the total dry weight.

7. SAMPLE PREPARATION FOR PARTICLE SIZE ANALYSIS

Apparatus: The apparatus set up were: Drying oven maintained at 110°C ±5°C, Standard sieves, Sample splitter, Mechanical sieve shaker, and Pans.

Procedure: The procedure consists of the following: drying the soil sample in an oven for 24 hours to get rid of moisture, measuring 500 g of the dry sample, and soaking in water for 24 hours. Record the weight of the sieves and the pan that will be utilized during the analysis. Each sieve should be thoroughly cleaned up before the test. Assemble the sieves in ascending order, by placing those with the larger openings on top. That is, the No. 4 were placed on top and the No. 200 sieve on the bottom of the stack. Place the soil sample into the top sieve and place a cap/lid over it. Place the stack in a mechanical shaker and shake for 10 minutes. After the sieve stack was removed from the shaker and measure the weight of each sieve and that of the pan were placed at the bottom of the stack. Lastly, the weight of the soil retained on each sieve was calculated by subtracting the weight of the empty sieve from the recorded weight of the sieve after the test. The total weights of particles retained were added and compared to the initial weight of the soil sample. A difference lower than 2% was required which is a standard. The percentage retained on each sieve is determined by dividing each weight retained by the initial weight of the soil sample. Subsequently, the total percentage passing from each sieve was calculated by subtracting the cumulative percentage retained in that particular sieve and the ones above it from the totality (ASTM D422, 2007). On the other hand, the grain size distribution curve of medium-fine sand was plotted to calculate the uniformity coefficient (C_u) expresses the variety in particle sizes of soil ratio of D_{60} to D_{10}. The value D_{60} is the grain diameter at which 60% of soil particles are finer and 40% of soil particles are coarser, while D_{10} is the grain diameter at which 10% of particles are finer and 90% of the particles are coarser.

$$C_u = \frac{D_{60}}{D_{10}} \tag{2}$$

when C_u is greater than 4, the soil is classified as well graded; whereas when C_u is less than 4 the soil is classified as poorly graded/uniformly graded (Head, 1994b).

8. COMPACTION

Compaction of soils is a procedure in which soil sustains mechanical stress and is densified. This was carried out to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The mechanical stress may be applied by kneading, or via dynamic or static methods (Didei and Oborie 2018). The degree of compaction is quantified by measuring the change of the soil's dry unit weight (γ_d), as a result of an increase in the strength of soils, and a decrease in incompressibility and permeability of soils.

Apparatus: The apparatus utilized to conduct the test include: a 10-centimeter diameter cylindrical compaction mold equipped with a base and a collar, a Proctor rammer weighing 2.5 kg or 4.5 kg depending on whether the standard of the modified test is conducted, No. 4 Sieve Steel straightedge, Moisture containers, Graduated cylinder, Mixer, Controlled oven, Metallic tray, and a scoop.

Procedure: Four soil samples were obtained and measured at about 3 kg each. 2% of water was added to the first portion and mixed thoroughly. The other was kept in separate cans to determine the weight of both wet and dry samples after 24 hours of placement in the oven to determine the moisture content. The first portion of the sample was compacted and mixed with a proctor mold using a 4.5 kg rammer in 3 layers of 27 blows per layer. The same procedures were taken for the remaining layers and rammed 27 times each. The weight of the compacted wet sample was weighed using a weighing balance and calculates the wet density respectively. The procedure was repeated for the remaining three portions with 4% to 12% volume of water till the value of the compacted soil and mold drops. Finally, the compaction water content (W) of the soil sample was calculated using the average of the three measurements obtained from the top, middle and bottom part of the soil mass along with dry unit weight (γ_d) (ASTM D 698, 2012):

$$\gamma_d = \frac{W - W_m}{(1+w) \times V} \quad (3)$$

where: W = the weight of the mold and the soil mass (kg), W_m = the weight of the mold (kg), W = the water content of the soil (%) and V = the volume of the mold (m^3).

The procedure was repeated four times, for a given selected water content from lower to higher than the optimum. Hence, the calculated dry unit weights were plotted against their corresponding water contents to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) along the Zero Air Voids at a 100% saturation line. On the other hand, the Zero-Voids curve is calculated as follows:

$$\gamma_d = \frac{G_s \times \gamma_w}{1 + W \times G_s} \quad (4)$$

where: G_S – the specific gravity of soil particles, γ_w – the saturated unit weight of the soil (kN/m^3), W – the water content of the soil (%) (Head, 1994a).

9. ATTERBERG LIMIT

The Atterberg limits test is named after the Swedish chemist Albert Atterberg who was the first to develop a classification system to determine the different states and limits of soil consistency. The Atterberg limits test, also known as consistency, is used to determine the moisture content at which a soil changes from solid, semi-solid, plastic, and liquid states (Godwin et al., 2020). It is used to distinguish between silt and clay and determines the shrinkage limit (SL), plastic limit (PL), and liquid limit (LL) of the soil sample. The Atterberg test is performed only on soil fraction that passes through sieve No. 40 (ASTM D 4318, 2010).

Apparatus: The apparatus were: Evaporating dishes to mix specimen to desired moisture content, spatula to mix, form and smooth the soil specimen, aluminum containers for soil moisture samples, mortar and pestle to reduce particle size, digital scale with 0.01 g readability, drying oven for moisture content test, liquid limit test accessory set including liquid limit machine and Casagrande grooving tool, plastic limit test apparatus including plastic limit roller and glass plate, shrinkage limit test apparatus including shrinkage dish, microcrystalline wax, petroleum jelly, fine thread, glass plate, and wax melting pot.

Procedure: 150 g air-dry soil samples passing sieve No. 40 were used. The Moisture was adjusted by adding 20% of water to the soil sample and mixing thoroughly. The samples were allowed to condition for at least 16 hours. For the liquid limit (LL) Test, a small portion of the soil sample was spread in the brass cup of the liquid limit device case grinder. A groove was cut to at least a 2 mm base with a grooving tool, turns the device and notes the number of blows (N) and stop when the groove in the soil closes. Finally, a sample and oven-dry were taken to find the moisture content. The tests were repeated three times and plotted the moisture content against the number of blows to determine LL, PL, and SL (ASTM D 4318, 2010).

10. CALIFORNIA BEARING RATIO (CBR)

The California Bearing Ratio Test (CBR) is a penetration test developed by the California State Highway Department (U.S.A.) for evaluating the bearing capacity of subgrade soil for the design of roads and pavement. The tests are carried out on natural or compacted soils in water-soaked or unsoaked conditions and the results obtained are compared with the curves of the standard test to have an idea of the soil strength of the subgrade soil (Akaolisa et al., 2021).

Apparatus: The apparatus involved are: mold, steel cutting collar, spacer disc, surcharge weights, dial gauges, IS sieves, penetration plunger, and loading machine.

Procedure: Soil samples were measured at about 6 kg, added water to the sample, and mixed thoroughly. Using a 2.5 kg rammer, weight of empty mold, compact the mixed sample into three (3) layers with 61 blows per layer. After compaction, the collar was removed, level the surface, and taken a sample to determine moisture content. Record the weight of mold + compacted specimen respectively. Mold was placed in the soaking tank for four days for soaked and ignored for unsoaked (Ojuri et al., 2017). The process was repeated for another set of samples after four days, measuring the swell reading and finding the percentage swell. After, the mold was removed from the tank and allowed water to drain. Then the soil sample was placed under the penetration piston and placed a surcharge load of 2.5 kg, applied the load, and noted the penetration load values were. Finally, the graph of piston load against penetration was plotted to determine the value of CBR, along with % CBR versus Dry Density to find CBR at the required degree of compaction (ASTM D 4318, 2010).

11. SPECIFIC GRAVITY (SG)

Specific gravity is a fundamental property of soils and other construction materials. It is the ratio of material density to the density of water and is used to calculate soil density, void ratio, saturation, and other soil properties with a dimensionless unit (Akaolisa et al., 2021). It is applicable in the foundation design for structures, calculations for the stability of soil embankments, and estimations of settlement for engineered soil fills.

Apparatus: Two density bottles of 50 ml capacity with stoppers at 27.2°C water bath, vacuum desiccator, oven, capable of maintaining a temperature of 105°C, spatula and weighing balance with an accuracy of 0.001 g.

Procedure: The density bottle along with the stopper was dried to a temperature of 105°C, cooled in the desiccator, and weighed to the nearest 0.001 g (W_1). The sub-sample, which had been oven-dried, was transferred to the density bottle directly from the desiccator for cooling. The bottles and contents together with the stopper were weighed to the nearest 0.001 g (W_2). The soil sample was covered with air-free distilled water from the glass wash bottle and left for a period of 2 hours for soaking. After the water was added to fill half a bottle and entrapped air was removed by heating the density bottle on a water bath, and keep the bottle without the stopper in a vacuum desiccator for about 1hrs until there is no further loss of air. Then the soil was gently stirred in the density bottle with a clean glass rod. The process was repeated till no more air bubbles were observed in the soil mixture and recorded by inserting the stopper in the density bottle, wiping, and weighing it (W_3). Lastly, the bottle was empty, cleaned thoroughly, and filled the density bottle with distilled water at the same temperature. Insert the stopper in the bottle, wipe dry from the outside and weigh it (W_4), (Head, 1994b; Ihekweme et al., 2021). After this process, the density of the soil particles (along with the specific gravity) were calculated as shown:

$$\rho_s = \frac{(W_3 - W_1) \times \rho_w}{(W_2 - W_1) - (W_4 - W_3)} \tag{5}$$

$$G_s = \frac{\rho_s}{\rho_w} \tag{6}$$

where ρ_w is the density of water = 997 kg/m^3.

12. RESULTS AND DISCUSSION

The results of the geotechnical investigation carried out in the laboratory on the soil samples collected from the study area are summarized and presented in Table 1.

Table 1. Summary of Geotechnical properties of the collected soil samples

PROPERTIES / SAMPLES	A	B	C	D	E	F
(1) Index Properties						
Colour	Red sandstone	Reddish-brown	Grey wacke	Reddish-brown	Grey - brown	Grey
(a) Atterberg Limits Test						
Liquid Limit (%)	68.49	63.69	71.88	64.75	41.87	41.69
Plastic Limit (%)	61.23	57.23	63.90	58.86	31.51	28.29
Plasticity Index (%)	7.26	6.46	7.98	5.89	10.36	13.4
Moisture Content (%)	37.5	36.1	35.7	33.9	24.1	23.9
Number of blows	10	18	29	37		
(b) Specify Gravity Test						
Specific Gravity (G_S)	2.41	2.76	2.80	2.94	–	–
Density of the Soil Particle (ρ_s) kg/m³	2.403	2.752	2.792	2.931	–	–
Number of blows	10	18	29	37	–	–
(a) California Bearing Ratio (CBR) Test						
Load (kg)	0.5 1.0	1.5 2.0 2.5	3.0 3.5	4.0 4.5	5.0 5.5 6.0	6.5 7.0
Penetration (mm)	0.06 0.44	0.73 1.04 1.39	1.74 2.06	2.44 2.78	3.42 3.48 3.80	4.12 4.44
% CBR value	11.7			20.3		
(2) Mechanical Properties (a) Compaction Test						
Water Content (%)	7.9	9.6	11.5	12.7	14.1	14.2
Dry Density (mg/m³)	1694	1725	1830	1770	1737	1736
Optimum Results	Maximum Dry Density (MDD) = 1.83 mg/m³			Optimum Moisture Content (OMC) 11.5%		
(b) Sieve Analysis Test						
Percentage Passing (%)	100.0	98.3	86.9	52.7	32.4	29.1
Opening Diameter (mm)	2.36	1.18	0.600	0.300	0.150	0.075
Uniformly Coefficient (C_u)	4.0			8.0		

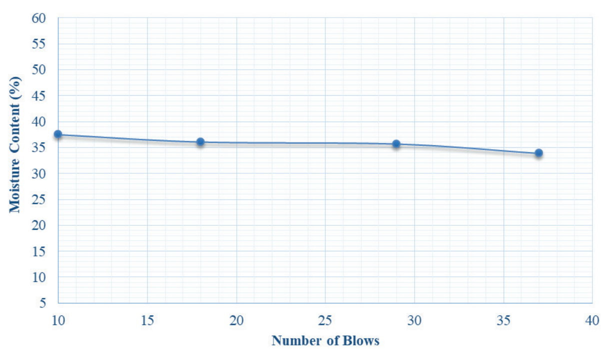

Fig. 3. A plot of moisture content (%) against number of blows on Atterberg limit test

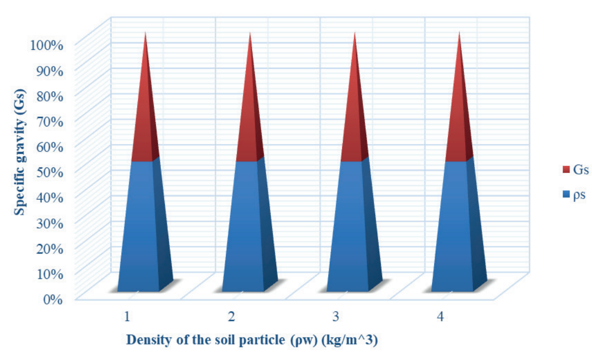

Fig. 5. Variations in specific gravity (G_S) against density of the soil particle (ρ_w) (kg/m³)

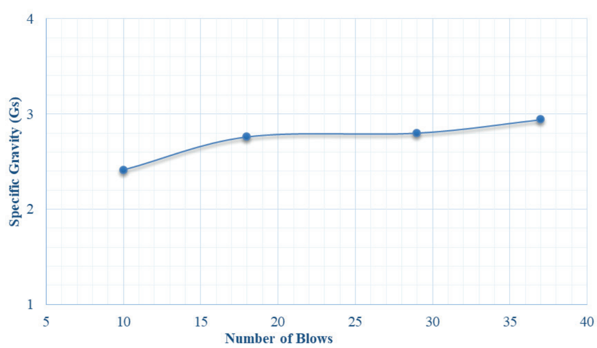

Fig. 4. A plot of specific gravity (G_S) against number of blows

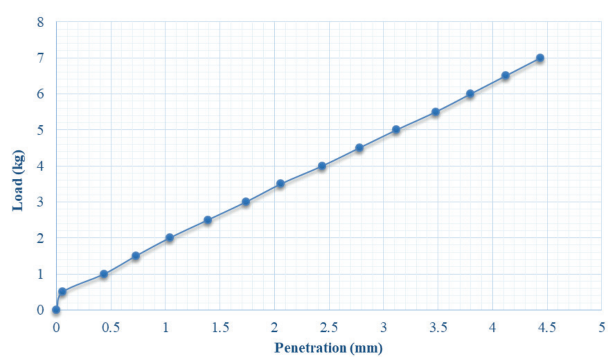

Fig. 6. A plot of load (kg) against penetration (mm) on CBR test

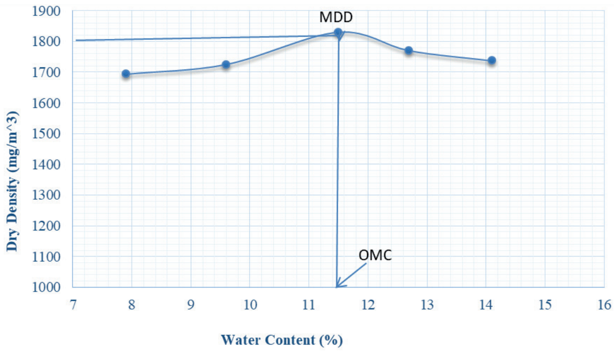

Fig. 7. A plot of dry density (mg/m³) against water content (%) on compaction test

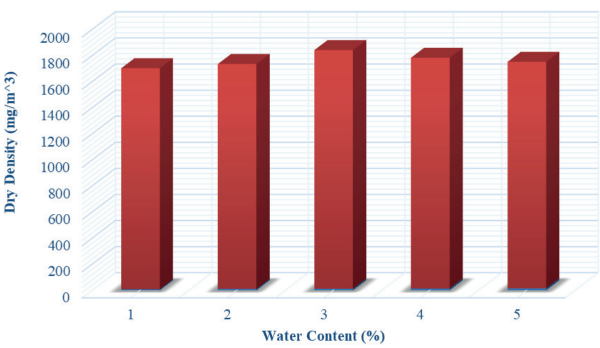

Fig. 8. Variations in dry density (mg/m³) against water content (%)

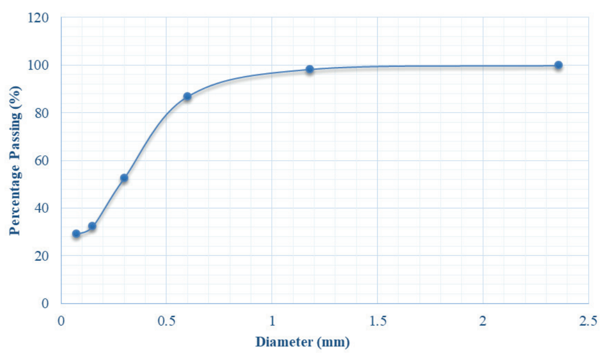

Fig. 9. A plot of the percentage passing (%) against diameter (mm) on sieve analysis test

The result obtained from the geotechnical analysis test was classified based on the AASHTO standard and compared quantitatively by specifications to establish if the material is the same quality throughout and evaluate scattering results errors. The analyzed result was summarized and presented in Table 1. In the Index properties: geologically, the coloration of the samples ranged from red sandstone to reddish-brown, greywacke to greyly brown. Pursuant to (Brady and Weil, 2010), the reddish to brown deposition indicates the presence of iron oxide, and greywacke indicates immature sedimentary sandstone deposition of mud and sand applicable for road construction. The Atterberg limits analysis as depicted in Table 1, shows the plasticity graphical illustration for USCS with a Plastic Limit (PL) average of 24.0%, a Liquid Limit (LL) of 35.8%, and a Plasticity Index (PI) of 12% as shown in Figure 3. This Conform to F.M.W & H specification requirements for LL and PI of not more than 35% and 12%, determined by the American Society for Testing Materials Method (ASTM D422, 2007). Also, attest, the subgrade is suitable to be used in road construction since LL and PI values do not exceed the standard limit of 35% and 12% respectively. However, based on (AASHTO, 2000) and (USCS, 2006) comparison, samples A to D were classified as sandy silt formations whereas E to F were clay formations respectively. The clay is greater than 10% realized in the acquired samples according to a fair to high-rise plasticity index of sampling. This gives an intimation of the prospects to productively restrain dilapidation waged being foot covering during dumpster diving (EPA, 2014). On the other hand, soils with regards to high-rise clarity indulge breathe prone to bulk shrinking (Rowe et al., 1995). Conforming to (Guney et al., 2014), for soil to be potent sheathing substantial, fragment dimensions are requisite to mollify at the minimum of (15-20)% clayed-sized materials with plasticity of greater than 10%. The density of the soil particles was found to range from (2.41-2.94) kg/m³ with an average value of 2.73 kg/m³ across the soil layer of the borrow pit. This exhibits a continuous periodic displacement of particle soil density concerning several blows as shown in Figure 4. Moreover, the comparison of G_S with soil density was done to ascertain its data sets as illustrated in Figure 5. It also shows that the subgrade sample of the borrow pit is primarily of good lateritic material, according to the specification of specific gravity ranging from 2.5 to 2.75. From Table 1, the result revealed a CBR value of 20.3% at 48 hours of soaking. Based on (ASTM D422, 2007) specification requirements, the minimum strength for subgrade should not be less than 10% after at least 48 hours of soaking and not less than 80% un-soaked. Therefore, the 20.3% CBR soaked value obtained is good for road construction as required in the specification. However, Figure 6 shows linear variations of the load (kg) against penetration (mm). This implies an increase in penetration, increasing the load-bearing capacity of the road and its strength. In mechanical properties: the Natural Moisture Content (NMC) of earth materials from the borrowed pit ranges (from

7.9 to 14.1)% with an average of 13.9%. The low value obtained in some areas revealed that NMC loses moisture readily in its natural state. The MDD and OMC values of 1.83 kg/m^3 and 11.5% were depicted as illustrated in Figure 7 with a vertical comparison between dry density water content as shown in Figure 8. This variation in MDD and OMC values of the sample revealed that the subgrade samples are better classified due to their conformity to absorb less water increase on drying which promotes robust construction works. The sieve analysis in Table 1 shows the range and distribution of various sizes of particles. The values range from (0.075-2.36) mm in line with the Federal Ministry of Work and Housing (F.M.W&H) specification requirement for subgrade samples. The percentage base on the limit of ≤35% for subgrade was 29.1% passing sieve No. 200. This required no need for advanced tests on samples, revealing good subgrade samples. The plot of a percent (%) passing sieve analysis in Figure 9, shows that the soil is well-graded, ranging from (0.075-2.36) mm. That is, from fine, medium to coarse particle size. Therefore, the uniform coefficient (C_u) and coefficient of curvature (C_C) assessments of the soil particles range from 8 to 6, and 1. Under the Unified Soil Classification System (USCS, 2006), C_u greater than 4 to 6 classifies the soil as well graded, whereas, C_u less than 4 classifies it as poorly graded soil. Moreover, for the soil to be well graded, the value of C_C must range between 1 and 3. Hence, the samples were classified as well-graded. On the other hand, employing the (AASHTO, 2000) system of soil classification, the inorganic soil sample acquired was grouped into A-1, Subgroups into A-1-B, and A-2-4 constituting 50% and 29.1% significant material, rating the subgrade sample as excellent to good material suitable for construction works.

13. CONCLUSION

The selections of acceptable borrow pits used as subgrade material plays a vital role while designing a road construction. Necessarily, this research evaluated the peculiar suitableness of utilizing borrowed pit soils collected from Ndon Ebom as subgrade materials for road construction at Victor Attach International Airport. Comparing the six subgrade samples to common standard indicated that the soil samples acquired can be energetically applied as well as graded subgrade materials, on account of the suited index and mechanical properties. Comparatively: based on AASHTO and USCS soil classification systems, the subgrade was analyzed and graded as excellent to a good formation for construction works. In addition, the prospective connotations of the current research are awful. It establishes the practicability of borrowing pits as subgrade material for road construction. However, recommendations are made, that adequate laboratory tests be carried out on borrowed pit material before being used as a subgrade for construction works, to know its strength and stability. Hence, subsurface geologists, engineers, and contractors working within the terrain should make use of the inferred laboratory data to construct a road that will stand the test of time. On the other hand, cleaving to the code of standard of the engineering career to sustain best works.

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