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Investigation of Geotechnical Properties of Soil (Case Study: Amonunag Ini L.G.A. Akwa Ibom State)

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Abstract: This research work was carried out to determine the geotechnical properties of soil samples from Annanmong-Ebo road at Ini L.G.A., Akwa Ibom State. The investigation was carried out to ascertain the sub-soil conditions which were expected to support the proposed infrastructure. The brief of the investigation was carried out on six (6) samples bored to a depth of 1.0m below the existing ground level after top soil. Results and interpretations contained in this report were based on the six bored samples positioned within the site at CH 0 + 000, CH 0 + 500, CH 1 + 250, CH 1 + 900, CH 2 + 500 and CH 3 + 450. The Litho-stratigraphy of the site revealed moderately soft to moderately stiff light brownish sandy-clay lateritic soil from top down to 1.0m. Groundwater was not encountered during the boring, the critical laboratory results of the soil samples presented average value for moisture content of 18.5%; average liquid limit of 27%. The Unconfined compressive strength was 57KN/m2 and the shear strength was 28.5KN/m2. To support any proposed structure sited in this location, the results, analysis and interpretations of the tests as contained in this report will be found useful in designing the foundation of such infrastructure. Estimated settlement is expected within permissible limits.

INTRODUCTION

Soil tests is one of the most important part of project design but due to the complexity and variability of soil conditions, accurate testing and analysis are crucial for ensuring the stability and safety of the project. This report presents the results of the soil test activities, analysis and interpretations. It also contains a factual record of the work based on the results of the borehole drilling and laboratory tests. The sample selected for this report is the sample with most critical parameters.

Problem Statement/Justification

Justification for the Research

Field soil exploration and investigation takes time and resources and sometimes the consultancy Engineer may not have time at his disposal to carry out these tests before design especially when the design have tight deadline submission. Based on these and other factors, the findings of this research work will be beneficial to any construction stakeholders who may not have the time and resources required to carried out these soil tests in that area. It will be part of academic research references and can formed a bedrock for further soil exploration and investigation in that area.

Objective (s) of the Study

Aim

The aim of this research is to investigation the geotechnical properties of Soil (Case study Annanmong – Ebo Road, Ini L.G.A, Akwa Ibom State). The investigation specifically aimed at providing the necessary engineering (Geotechnical) data needed for the design of any infrastructure in that area.

Objectives of the Study

To achieve the aim of this research, the following objectives are set out as a guide;

Ascertain the index properties (Specific gravity, Attaberg Limits, grain distribution index and moisture content) of the soil samples. Classification of the soil based on AASHTO (American Association of State Highway and Transportation Official) and USCS (Unified Soil Classification System).

Ascertain the geotechnical properties of the soil samples such as bulk unit weight, dry unit weight, Unconfined Compressive Strength (UCS), Shear strength and Soaked CBR (California Bearing Ratio).

Literature Review

The proposed subsoil investigation was carried out along Annanmong-Ebo Road, Ini L.G.A., Akwa Ibom State. This location is within the southeastern Niger Delta, the area have a mix of lowlands, hills and valleys. The area lies within a sub-horizontal geomorphologic terrain with a measure of undulations arising from uneven surface area erosion. Ground elevation ranges between 29 meters above mean sea level. The local geology is mostly tropical rainy forest land, which has a geology characteristic of shales, sandstones and claystones, reflecting the delta's progressive growth into the Gulf of Guinea. These consist of extensive thickness of light brownish, medium to fine sand with subordinate silt and clay. The area is associated with canals, freshwater groove and vegetation typical of a tropical rainforest. Mean annual rainfall ranges between 2000mm to 3000mm with high temperature and evaporation.

The project location rests on the basement complex and is part of Anambra-Imo Basin with the sedimentary rock (shales, sandstones, sands and clays) characterized the development of the southern sedimentary basin. The detailed geology of the area has been described by Udo and Mode (2013), lithostratigraphically, the rocks here are divided into the Ameki Formation which consist of Nanka sand and Nsugbe Formation (Estuarine, early to middle Eocene). The wells and boreholes tap water from the overlaying Ameki Formation. This formation comprises of tidal facies and backshores facies whose thicknesses are variable. The Ameki Formation has lithology consisting of sands, silts and clayey intercalations.

Methodology

Materials and Methods

Materials

The materials used in this research work are;

Soil Samples: The soil samples were collected at 1.0m depth below the earth surface, this is to dead organic particles. The samples were collected at CH 0 + 000, CH 0 + 500, CH 1 + 250, CH 1 + 900, CH 2 + 500 and CH 3 + 450 chainages. The soil was collected with help of soil auguar and preserved in an air tight polymer bag. The soil was taken to soil laboratory of Department of Civil Engineering Technology, Federal Polytechnic, Ukana, Akwa Ibom State for tests and analysis.

The equipment used for the testing and analysis were;

Set of sieves and sieve shaker.

Thermostat Electric Oven.

Electronic Weighing Balance.

Set of bowls.

Cassagrande Apparatus.

Proctor Compaction Mould and 2.5kg Rammer.

CBR mould and Machine.

UCS machine and cylinder.

Record Book and other stationary.

Laptop computer and data analysis software.

Methods

The tests were carried out following the methods below;

MOISTURE CONTENT

The moisture content was determined by dying selected moist soil materials for at least 12hours to a constant mass in an 110oc drying oven. Difference in mass of material when wet and when dry was taken. The mass of materials remaining after drying was used as the mass of the solid particles. The ratio of the mass of water to measured mass of the solid particles was the moisture content of the materials. This ratio can exceed I (or 100%) Ref: BC 1377: part 2:1990.

ATTERBERG LIMITS

Atterberg Limits were determined on the soil specimens with a particle size of less than 0.425mm. The Atterberg limits refer to arbitrary defined boundaries between the liquid limit (LL) and plastic states and between the plastic limit (PL) and brittle states of fine-grained soils. They are expressed as water contents, in percentage. The liquid limit (LL) is the water content at which a part of soil placed in a standard cup and cut by groove of standard dimensions flows together at the base of the groove, when the cup is subjected to 275 standard shocks. The one-point liquid test was carried out. Distilled water was added during soil mixing to achieve the required consistency. The plastic limit (PL) is the water content at which a soil can no longer be deformed by rolling into 3mm diameter threads without crumbling. The range of water content over which a soil behaves plastically is the plasticity index (IP). This is the difference between the liquid limit and the plastic limit, (LL-PL). Ref: BS13377; part 2: 1990.

iii. PARTICLE SIZE ANALYSIS

Particle size analysis was performed by means of sieving. Dry sieving is presented on logarithmic scale so that two soils having the same degree of uniformity are represented by curves of the same shape regardless of their positions on the particle size distributions plot. The general slope of the distribution curve may be described by the coefficient of uniformity Cu, where $Cu = D60\ D10/$ and the coefficient of curvature CC, Where $Cc = (D30)\ 2\ (D60 \times D10)$ are effective particles size indicating that given effective size. Reference test standard: BS 1377; part 2 1990.

COMPACTION TEST

The objective of the compaction test is to obtain the moisture content – dry density relationship for a soil and hence to determine the optimum moisture content and maximum dry density. This test is conducted on soil passing a 2.00 mm test sieve compacted in a specified manner over a

range of moisture contents. The range includes the optimum moisture content at which the maximum dry density for this degree of compaction is obtained. In this test a 2.5 kg rammer falling through a height of 300 mm is used to compact the soil with 26 blows each in three layers into a 942cm3 compaction mould. The test was carried out in accordance to BS 1377-4:1990 Clause 3.

CALIFORNIA BEARING RATIO TEST

The objective of the California Bearing Ratio test is to determine the CBR value for a soil under consideration as a pavement foundation. This value is a percentage comparison with the standard crushed rock from California. This test covers the laboratory determination of the California Bearing Ration (CBR) of a compacted soaked sample of soil. The principle is to determine the relationship between force and penetration when a cylindrical plunger of a standard cross-sectional area is made to penetrate the soil at a given rate. At certain values of penetration (2.5mm and 5.0mm) the ratio of the applied force to a standard force, expressed as a percentage, is defined as the California Bearing Ratio (CBR). The CBR test was carried out on material passing the 2.0 mm test sieve prepared as described in clause 7.6.5 of BS 1377-1:1990. The samples were thoroughly mixed using the Optimum Moisture Content (OMC) obtained in the compaction test, sealed and stored for 24hours before compaction into the test mould. The compacted sample in the mould was soaked for 48hours before the CBR test. The soaked CBR was selected because the critical behavior of the soil is always when under water (Saturated). The test was carried out in accordance to BS 1377-4:1990 Clause 7.2.

UNCONFINED COMPRESSIVE STRENGTH (UCS)

This was performed on re-moulded sample of cohesive soils. Depending on the consistency of the cohesive material, the test specimen was prepared and trimming the sample or by pushing UCS cylindrical mould into the sample. A latex membrane with thickness of approximately 0.2mm was placed around the specimen. A lateral confining pressure was applied on the specimen until it resists the applied load and fails, the load at which there was resistance and failure becomes the compression loading of the specimen. The area of the cylinder was determined using its diameter and height. The compression load was divided by the area to gives the UCS value of the soil sample in KN/m2.

SHEAR STRENGTH (s)

The shear strength of the soil sample was determined by taking half the unconfined Compressive strength (Arora, 2014). That, shear strength S equals UCS (qu) divided by 2.

UNIT WEIGHT

The unit weight was determined from measurements of mass and volume of the soil. The unit weight γ (KN/m2) refers to the weight of the soil at the sampled water content. The dry unit Wight γd was determined from the mass of oven dried soil and the initial volume. Reference test standard BS 1377; part 2:1990.

EQUATIONS USED FOR CALCULATIONS

1. The dry unit weight $\gamma d = \rho d \times g$ i.
2. Bulk Unit Weight $\gamma = \rho b \times g$ ii.
3. $Plastic\ Index\ PL = LL - PL$ iii
4. $Liquidity\ Index\ LI = (w-PL)\ (LL-PL)$ iv
5. $GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.1(F - 15)(PI - 10)$ v.
6. To plot the zero air void curve $\rho dth. = G\rho(100-Va)\ 100(1+wG-w)$ vi.
7. Unconfined Compressive Strength (qu) $qu = P/A$ vii.

8. Shear Strength (s) $s = qu/2$ viii.

Where

G = specific gravity of the soil (G =2.67)

w = moisture Content (%)

LL = Liquid Limit (%)

PL = Plastic Limit (%)

PI = Plastic Index

GI = Group Index of the soil

F = Percentage passing through sieve number 200 (0.075mm)

ρw = density 1.0 g/cm3

$\rho d = Dry\ Density\ of\ soil$

$\rho b = Wet\ Density\ of\ soil$

$\gamma = Bulk\ unit\ Weight\ of\ soil$

$\gamma d = Dry\ unit\ Weight\ of\ soil$

$Va = Percentage\ of\ void$

$\rho dth = Dry\ Density\ of\ soil\ at\ a\ given\ void$

$g = Acceleration\ due\ to\ gravity$ $(9.81 m/s2)$

$qu = UCS\ or\ Bearing\ capacity$ $(KN/m2)$

$P = Applied\ load\ or\ Force$

$A = Area\ of\ the\ sanple$

$s = Shearstrength$ $(KN/m2)$

Results

SUMMARY OF GEOTECHNICAL PROPERTIES OF SOIL

Summary of Test Result –Subgrade Material

The geotechnical characteristics and the engineering parameters of the soil encountered are presented below:

TEST PARAMETER	**AVERAGE**
Moisture Content (%)	18.5
Liquid Limited (%)	27
Plastic Limited (%)	16
Plasticity Index (%)	11
Liquidity Index (LI)	0.23
Group Index (GI) of the soil	3
Bulk Unit weight (KN/m3)	26.50
Dry unit weight (KN/m3)	19.72
UCS (KN/ m2)	57.00
Shear Strength (KN/m2)	28.50

Soaked CBR (%) 4.20

DISCUSSION

The soil investigation was carried out primarily to ascertain the sub-soil conditions at the location, obtain some engineering parameters of the soil for the design and ultimate construction of the foundation to support the proposed structure. Prior to the investigation, the anticipated loading of the proposed structure was not available. Therefore, our recommendations are based only on the results of the field work and laboratory tests of the soil samples collected. The results obtained were discussed as follows:

Moisture Content Test Analysis:

The result of the natural moisture content test revels that as at the time the test was carried out, the soil has a natural moisture content of 18.5%.

Soil Classification Analysis:

The result of the Sieve analysis shows that less than 35% of the sample passed the No. 200 sieve. Based on the Liquid limit, Plastic Limit, Plasticity Index and Group Index of the Subgrade Material are as follows:

a. AASHTO Soil Classification System: The soil belong to A-3 group.

b. USCS Soil Classification System: SP-SM (Sand Silt with gravel).

Conclusively, from AASHTO and USCS system of soil classification, this falls under group A-3, thus, the soil is Sand Silt with gravel Materials.

Compaction and California Bearing Test

The Density plots for the soils indicate an optimum moisture content (OMC) and maximum dry density (MDD) of the soil sample were 13.6% and 2.01g/cm3. The soil offered some resistance to loading when soaked with water with an average CBR value of 4.2%. A soaked CBR value of greater than 5% is required at formation for flexible and flexible composite pavements which is not in this case.

3. RECOMMENDATIONS AND CONCLUSION

i. From laboratory analysis, the earth materials presented average moisture content of 18.5%, Plasticity Index of 11% and shear strength of 28.5KN/m2.

ii. Since the soaked CBR value (4.2%) of subgrade soil is less than 5%, capping is required of sufficient thickness to improve the strength and stiffness at formation.

iii. Estimated soil settlement is within permissible limits.

iv. This investigation was carried out in accordance with accepted geotechnical engineering practice.

Recommendation and conclusion reached in this report are based on the data obtained from the field work and laboratory analysis of the soil samples from the project site.

NB: It should also be noted that it is not anticipated that the soil conditions will vary significantly from those described. However, should the soil conditions during actual construction vary, it would be necessary to evaluate the engineering significance of such variation which could result in further geotechnical investigation and supplementary.

Work Plan/Time Frame

Activity	Sep 2024	Oct 2024	Nov 2024	Dec 2024	Jan 2025	Feb 2025
1. Literature Review and Conceptual Framework Development	■					
2. Data Collection		■				
a. Surveys and Questionnaires			■			
b. Document Analysis				■		
3. Data Analysis				■		
4. Development of Digital library Service and Patronage Conceptual Framework				■		
5. Pilot Testing of Framework				■		
6. Evaluation					■	
7. Reporting and Dissemination						■

Budget (Provide a budget break-down by activity/line item)

References

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