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Sub-Soil Investigation of a Proposed Construction Site at Kyami District, Abuja, Nigeria

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Abstract: *Sub-soil investigation of a proposed construction site located at Kyami district of the Federal Capital Territory (F.C.T.) Abuja, Nigeria, was carried out to determine the suitability of the soil to host civil engineering structures. The investigation involved excavation of trial pits and obtaining both disturbed and undisturbed samples for laboratory analysis. Classification tests carried out showed that about half of the soil samples analysed is composed mainly of clayey sand (SC), with the remaining half composed of silty sand (SM) and non-plastic sand respectively; each occurring inalmost equal proportion. Analysis showed that the soil has low plasticity characteristics. This implies that the potential for swelling and shrinking when wet and dry that could have negative impact on the stability of structures placed on them is low.The soils therefore have fair to good engineering characteristics necessary for construction work and with a mean allowable bearing capacity of 137.8KPa the soils have moderate strength capable of carrying normal civil engineering structures.*
Keywords: *plasticity, potential, strength, stability, suitability*

I. Introduction

Engineering structures such as buildings are constructed on and or within the earth surface.The nature of the sub-surface soil within such construction sites is of paramount concern to engineers because it determines to a large extent the suitability of the site for the intended construction project and modifications to be made on such site if the need arises. Site investigation is therefore an integral part of major construction projects. It involves exploring the ground conditions at and below the surface and sampling of strata likely to be significantly affected by the structural load; it is a prerequisite for the successful and economic design of engineering structures and earthworks (Anon, 1999). Exploration of the subsurface is done using borings and other techniques, which help in recovering samples for testing and evaluation (Coduto, 2001).The goal of the subsurface investigation is to obtain a detailed understanding of the engineering and geologic properties of the soil and rock strata and groundwater conditions that could impact the foundation (Day, 2006).A site investigation should attempt to foresee and provide against difficulties that may arise during construction because of ground and/or other local conditions (Anon, 1999). One of the earliest soil works carried out within Abuja by Malomo, et al, 1983, indicates that residual soils composed of concretized laterite can be found in most parts of the capital.Soil investigation was therefore carried out at a proposed construction site covering an estimated area of about eighteen (18) hectare located within the newly commissioned Kyami district of the Federal capital Territory (F.C.T.) Abuja, Nigeria (Fig.1 and 2).The aim of this sub-soil investigation wasto determine the engineering properties of the soils underlying the proposed construction site and its load bearing capacityrequired for foundation design of structures expected to be placed on them by subjecting recovered soil samples from the proposed construction site to laboratory analysis.

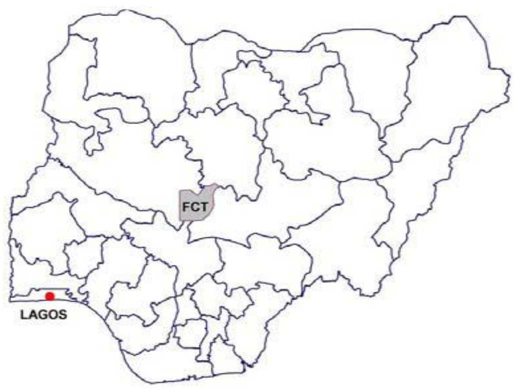

Figure 1: Map of Nigeria Showing Location Of The Federal Capital Territory, (AGIS, 2006) (Modified after Jibril, 2009)

Figure 2: Google Earth mapshowing approximate area of investigation

II. Geology And Soil Types

Two broad geological regions with each one having similar structural and lithological characteristics are recognized within the Federal Capital Territory (FCT): these regions comprise the Pre-Cambrian Basement Complex and sedimentary rocks, and they both have very strong influence on the morphological characteristics of the local soil (Ola, 2001).A number of local soils that have been identified within the F.C.T. are the alluvial soils, Luvisols and Entisols.

III. Materials And Method

A total of sixteen (16) trial pits were randomly established and manually dug to a depth of 1.5 meters. Undisturbed samples were obtained with the aid of core-cutters. Samples were transported to the laboratory for testing. Classification and Atterberg limit tests were carried out on the soil samples recovered from the trial pits to determine the engineering suitability of the subsoil for the proposed project. Shear Box test was carried out to deduce the cohesion (c) and angle of internal friction (ø) of the soil which forms an integral part of the soil's strength from which the bearing capacity was calculated. All test procedures were in accordance with BS1377 PART 9. Natural moisture content of the samples was also determined in the laboratory.

IV. Results And Discussion

4.1 IN-SITU Soil Description

The natural state of the soil in all the excavated trial pits could best be described as compacted and cohesive, with colours varying within shades of reddish-brown. Hardpan or concretized conglomerate was encountered in some of the trial pits;excavation time in such pits was much longer than others without it. Ground water was not encountered in any of the trial pits and as such, the soil appeared to be in firm and moist condition.

4.2 Classification

The unified soil classification system (ASTM, 2005) was adopted in this work. The sieve analysis showed that all the sub-soil materials from the trial pits except trial pit 12 (table) within the area under investigation is characterized by coarse-grained soil, i.e. more than 50% total weight of soil sieved was retained on sieve No. 200. Of this, only trial pit 11 had more than 15% gravel fraction sufficient enough to be included in the group name (Table 1). The rest of the soil is made-up mainly of sand fraction. And within the sand fractions that dominate the soil of the area, fine sand forms the bulk of the total weight of the soil spectrum. This could be the reason for the low-to-moderate angle of shearing resistance (ø) observed in most of the samples from the shear box test results.

Table 1: summary of classification results (Unified Soil Classification System)

Trial pit no	% Retained on No. 4 sieve	% passing sieve no 4	% passing sieve No. 200	Liquid limit LL (%)	Plastic limit PL (%)	Plasticity index PI (%)	Group symbol
1	13.0	61.7	25.3	22.0	11.0	11.0	SC
2	-	74.2	25.8	NA	NA	NA	Non-plastic sand
3	10.0	57.6	32.4	35.4	18.0	18.0	SC
4	-	60.0	40.0	31.6	20.0	12.0	SC
5	-	57.2	42.8	39.3	19.0	20.0	SC
6	-	52.4	47.6	43.8	31.0	13	SM
7	11.8	67.1	21.1	NA	NA	NA	Non-plastic sand
8	-	58.0	42.0	43.0	27.0	16.0	SM
9	-	63.4	36.6	45.8	22.0	22.0	SC
10	7.3	59.3	33.4	41.6	26.0	16.0	SM
11	19.1	49.3	31.6	NA	NA	NA	Non-plastic gravelly sand (SG)
12	-	47.9	52.1	50.0	26.0	24.0	SCH
13	-	61.5	38.5	35.0	11.0	24.0	SC
14	10.0	52.0	38.0	34.2	19.0	15.0	SC
15	-	72.5	27.5	NA	NA	NA	Non-plastic sand
16	12.6	50.7	36.7	34.8	26.0	9.0	SM

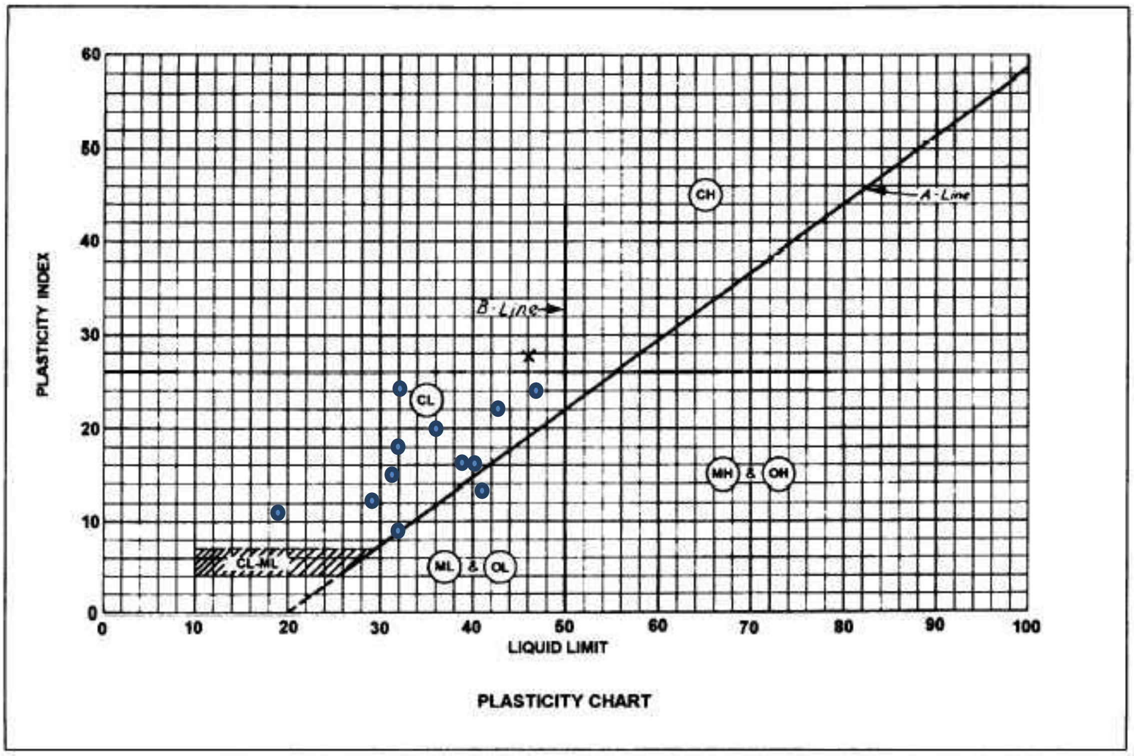

Figure 3: Casagrande (1948)plasticity chart showing relative positions of samples

Atterberg limit tests results showed that the liquid limit of the soil samples varies between 22.0% and 50%; plastic limit varies between 11% and 31% while the plasticity index varies between 11% and 24% (Table 1). More than 75% of the soils' fines plot above the "A" line on the Casagrande plasticity chart (Fig. 3), an indication that the fines are composed majorly of clay with a small fraction composed of silt. The plasticity index of samples 2,7,11 and 15 (Table 1) could not be determined:this is due primarily to the non-plastic nature of the fines in these soil samples and as such, theyare regarded as non-plastic sands. From the sieve analysis and Atterberg results obtained the proposed construction site is underlainby clayey sand (SC),silty sand (SM) and non-plastic sandrespectively; with clayey sand covering about half of the investigated site, while silty sand and non-plastic sand each occurring in almost equal proportion make up the remaining half of the entire site. According to Wagner, 1957, the soil is rated as a good to fair foundation material capable of supporting normal civil engineering structures. In addition, with liquid limit of less than 50% and the relative position on the plasticity chart (Fig. 3) the soils therefore are characterized by clay and silt with low plasticity. This implies that the potential for swelling and shrinking which could alter the stability of structures that would be founded on them is low.

4.3 Strength Parameters Leading To The Calculation Of Bearing Capacity

Depending on the type of soil under consideration the strength of a soil is a function of either the cohesion (c) or friction angle (ϕ) or a combination of both. Shear box tests on the soil samples showed that the cohesion of the soil varies from 8.9 KPa to 26.6 KPa with a mean value of 18.7 KPa, while the friction angle values varies from 8.6 ϕ to 24.8 ϕ with a mean value of 14.7 ϕ (Table2).

Table 2: summary of shear box test and bearing capacity

Trial pit no	Depth	Angle of shearing resistance (ϕ)	Cohesion C (KPa)	Ultimate bearing capacity KPa	Allowable bearing capacity KPa
1	1.5	14.4	26.6	471	157
2	1.5	10.1	11.7	203	67
3	1.5	24.8	12.5	640	213
4	1.5	12.8	21.5	348	116
5	1.5	11.6	24.8	391	130
6	1.5	8.5	23.9	314	105
7	1.5	8.6	18.6	260	87
8	1.5	12.1	22.1	351	117
9	1.5	11.9	22.1	359	120
10	1.5	22.1	18.4	666	222
11	1.5	24.1	15.3	711	237
12	1.5	17.5	26.4	621	207
13	1.5	13.5	17.0	342	114
14	1.5	13.7	15.6	328	108
15	1.5	14.6	8.9	252	84
16	1.5	15.5	14.2	359	120

The moderate cohesion values obtained from the shear test results reflects the type of clay content present in the subsoil. With a mean value of 36% of soil passing sieve No. 200 the soil is considered having considerable quantity of fines sufficient to constitute the binders needed to increase the non-frictional strength of the soil. However, the moderate cohesion values obtained is attributed to the low plasticity of the clay and silt fraction that constitute the fines content of the soil. The ultimate bearing capacity of the soil was computed using Terzaghi's equations for shallow foundations:

$$q_u = 1.3CN_c + \gamma DN_q + 0.4\gamma BN_\gamma \quad (1)$$

Where:

q_u is ultimate bearing capacity

C is cohesion (KN/m^2)

γ is unit Weight (KN/m^3)

Z is depth of footing (m)

B is width of footing (m)

Nc, Nq and Nγ are constants which depend on angle of shearing resistance of the soil deduced from Shear Box Test.

Allowable bearing capacity:

$$q_{all} = q_u/F.S \quad (2)$$

Where:

F.S. is factor of safety = 3.0

The ultimate bearing capacity of the soil varies from 203KPa to 711KPa, with a mean value of 413.5KPa, while the allowable bearing capacity varies from 67KPa to 237KPa, with a mean value of 137.8KPa. The ultimate and safe bearing capacity values of the subsoil derived from (1)and (2) indicate that the subsoil within the area of investigation is characterized by fair to good foundation material capable of supporting normal civil engineering structures and as such, shallow foundation footings such as pad or combined footings could be considered for the design of the structure.

V. Conclusion And Recommendation

Sub-soil investigation was successfully carried out at a proposed construction site located at Kyami district of Nigeria's federal capital, Abuja. The information obtained from the investigation showed that the residual soil, composed mainly of clayey sand and silty sand with low plasticity has moderate allowable bearing capacity capable of supporting normal civil engineering structures. In addition to the immediate application of the results for construction works findings of this investigation would also add to the baseline information of the area that could be used as reconnaissance for subsequent soil investigation work within the district. For heavy civil engineering projects such as multi-storey buildings however, the following recommendations are advised:

- Detailed geotechnical investigation using Standard Penetration Test (SPT) to explore the state of the soil at depth corresponding to the depth of influence for such proposed structure
- Detailed geophysical investigation using either electrical or electromagnetic technique to properly delineate weak sections of the subsurface such as clay and fractures that could compromise the stability of such heavy structures and also to guide the proper placement of Standard Penetration Test (SPT) drill holes
- Additional laboratory tests such as consolidation test to determine the behaviour of the soil to imposed stress from heavy structures, and
- Where the foundation of such structure would be placed on the basement rock, rock coring to determine extent and degree of weathering of the rock and its strength should be carried out

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