GEOTECHNICAL INVESTIGATION OF SOILS: A CASE STUDY OF A PROPOSED RESIDENTIAL DEVELOPMENT AT NO. 7, SAMBO CLOSE, KADUNA, KADUNA STATE, NIGERIA

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ABSTRACT
This Sub-soil geotechnical report, presents detailed information and results of a soil survey which covered five (5) No. Trial pits, manually excavated to a maximum of 2.00M depth maximum for a Proposed Residential Development at No. 7, Sambo Close, behind British Council, Kaduna. Undisturbed soil samples were obtained with core cutters for shear strength determination and bulk samples were also collected identified, labeled, bagged in polythene to prevent moisture loss and transported to the laboratory, Results of the geotechnical investigation show a safe bearing capacity range of 107.28 KN/m^2 in TP 1 – 124.44 KN/m^2 in TP 5, at 1.00m respectively. At 2.00m depths the bearing capacity increased from 145.72 KN/m^2 at TP 2 – 156.72 KN/m^2 in TP1, using a factor of safety of 2.50. Total settlement (Oedometer) values ranged between 0.0006m – 0.0017m. It follows therefore that the proposed structure could be supported on, Isolated Wide Pad Foundation which may be designed at 2.00m depth

Keywords: *Geotechnical, settlement, Sub-soil, foundation, Shear strength*

INTRODUCTION
In engineering practice, generation of data for design purposes for future development is paramount and gaining greater awareness amongst the professional engineers. Civil engineering structures are designed and built on natural soils and there is the need to have a record of the characteristics of the soil upon which these structures are built. Soil can be defined as an unconsolidated material composed of soil particles, produced by the disintegration of rocks. The void spaces between the particles may contain air,

water or both (Arora, 2007). It is however, necessary to use our engineering judgment to predict the future behavior of the soil in order to support the foundation of structures thereby making them serve the functions for which they are built. Greenfield and Shen (1992) defined a foundation as the supporting base of a structure which forms the interface across which the loads are transmitted to the underlying soil or rock.

The proposed residential building at Sambo close, Kaduna is a mega residential building plan. Aside the structural developments coming up, there will be road network construction which in turn requires a viable geotechnical investigation of the soil. These investigations are usually part of the requirements for the approval of high rise building foundation and pavement constructions. This is done so as to prevent collapse of buildings and pavement failure.

One of the biggest problems facing construction industry in Nigeria is lack of qualitative geotechnical investigation to meet the requirements to assist the engineers involved in the design and construction of durable structural foundations. This study entails the investigation of the soil properties to ascertain it's suitability for construction purpose.

In civil engineering constructions, soil play the most important part, this truth cannot be over emphasized, since all engineering (civil) project are *dependent on soil parameters for foundation design* such as shear strength of soils. The shear strength of soils is largely a function of the effective normal stress on the shear plane, which equals the total normal force less the pore water pressure (Atkinson, 1993).Unconfined compressive strength according to Das (2000) consisting of a clayey soil can be determined as follows: 0-25kN/m^2indicates very soft, 25-50kN/$m^2$is soft, 50-100kN/$M^2$is medium soft, and 100-500kN/$m^2$is stiff, 200-400kN/m^2very stiff and greater than 400kN/m^2indicates hard clay

Geotechnical investigations of soil have helped many Civil Engineers in knowing the properties of soil so as to predict on its behavior under various loading conditions. Researchers have carried out investigation on bearing capacity of soils, many researchers like Terzaghi and Hansen are the most widely used particularly Karl Terzaghi equation which is being used successfully in the design of numerous foundations throughout the world in the pass and still in use. Smith et al (1990). Incorrect appraisal of the character of the geological profile and the construction properties of the soil have in the most cases causes excessive deformations of structures and in some cases their destruction. In order to avoid the later from occurring, there is the need for proper Geotechnical investigation of soil before the commencement of construction.

The objectives of this research is based on the fact that the Nigerian construction industry are faced with the problem of lack of data bank for the design of structures as a results, therefore designs were based on assumptions of basic soil parameters which often lead to structural failure or total collapse in some cases as follows:

To conduct Laboratory tests on soil samples from site and to determine the shear Strength, settlement parameters and other geotechnical properties of the sub - soil.

To evaluate the bearing capacity values of the sub-soils for foundation purposes.

To recommend on suitable foundations based on geotechnical analyses of the sub-soils.

To determine the suitability of soil at the proposed residential building for use as construction material.

METHODOLOGY

The subsoil investigations were carried out at the Proposed Residential Development in Kaduna, State of Nigeria Kaduna. Five trial pits were carefully selected within the area as indicated in the map. The methodology adopted in this research involved excavation of five trial pits explored to a maximum of 2.0m depth with soil samples collected at every 1.0m depth. Undisturbed soil samples were obtained with core cutters for shear strength determination and bulk samples were also collected, identified, labeled, bagged in polythene to prevent moisture loss and transported to the Kaduna polytechnic civil engineering laboratory for tests and analyses. The samples obtained were then subjected to the following laboratory tests: Natural moisture content, Atterberg's limit test, Sieve analysis test, Specific gravity test, Unit weight test, Shear box test and Consolidation.

These tests were carried out in accordance to B.S. 1377 (1990) specification. The principle of shear strength determination is based on un-drained shear strength of undisturbed cohesive soil sample when it is subjected to a constant confining pressure and strain controlled axial load. Soil classification by

American Association of State Highway and Transportation Officials (AASHTO) system to show the suitability or otherwise of the soil for road construction was also made. The criteria used for the classification of soil according to Chen, (2000) are;

1. Percentage of gravel, sand, and fines in accordance with grain size
2. Shape of grain size curve for coarse grain soils
3. Plasticity and compressibility characteristics for fine grained soils and organic soils.

RESULTS AND DISCUSSION.

BEARING CAPACITY ANALYSIS.

The bearing pressure imposed by a foundation is a function of the characteristics of the shear strength of the soil as well as the depth and dimension of the foundation. The analytical approach adopted in estimating the bearing capacity is based on the Terzaghi's Equation. The bearing capacity factors are also based on the Terzaghi's bearing capacity coefficients, which are functions of the angle of shearing resistance (Ø) of the soil samples as obtained from the direct shear box test.

The Terzaghi's bearing capacity equation was used and assuming the most wet site condition since ground water was encountered during excavation in some of the five trial pits explored.

$$\mathbf{Q_{(ultimate)} = CN_C + \gamma D\,(Nq-1) + 1/2\ \gamma BN_\gamma}$$

<u>TP 1 @ 1.00m depth</u>

$C = 20.00\ KN/m^2$, $Ø = 14^0$, $\gamma = 19.42\ KN/m^3$, $N_c = 10.40$, $N_q = 3.60$, $N_\gamma = 1.00$, $B = 1.00m$

$Q_{(ultimate)} = CN_C + \gamma D(Nq-1) + 1/2\ \gamma BN_\gamma$

$Q_{(Ultimate)} = 268.20\ KN/m^2$

Using a safety factor of 2.50,

$$Q_{(safe)} = \frac{268.20}{2.50} = 107.28\ KN/m^2$$

PRIMARY CONSOLIDATION SETTLEMENT.

The Laboratory data and test results of the consolidation (Oedometer) test were basically used in estimating the primary consolidation settlement for the 5 No.

trial pits at the 2.00m maximum depth explored on the soil samples collected. These values were based on the increase in the effective pressure induced by loads from the structure. Since the soil from each location is homogenous, thus, the coefficients of volume compressibility (Mv) are used in the analysis.

Hence,

Pc (oedometer) = Mv x $\Delta\delta$ x H

Where

P_c = Total settlement (oedometer)

M_v = Average Coefficient of volume compressibility obtained from the effective pressure increment in the particular layer under consideration

$\Delta\delta$ = Average effective vertical stress imposed on the particular layer resulting from the foundation pressure.

H = Thickness of the particular layer under consideration.

The P.C. (Layer) for TP 1 @ 2.00m depth = 0.0123 x 9.97 x 2.00 **= 0.2453m**

These tests were carefully conducted on selected soil samples in accordance with the provisions of relevant sections of B.S. 1377, 1990. The summary of the test results is presented in Table 4.1 below.

TABLE 3.1: Summary of Laboratory Tests Results.

TEST TYPE	UNIT	MIN.	MAX.
Natural moisture content	%	24.30	**30.78**
Liquid limit	%	41.00	**49.00**
Plastic limit	%	29.98	**31.34**
Plasticity index	%	10.09	**18.10**
Linear shrinkage	%	8.57	**10.71**
Specific gravity	**-**	2.28	**2.55**
Apparent cohesion	KN/m^2	20	**24**
Angle of internal friction	°	14	**15**
Unit weight	KN/m^3	19.04	**19.97**
Coefficient of Consolidation	M^2/yr	5.522	**55.724**

Coefficient of compressibility	M^2/KN	0.0067	**0.0176**
Total settlement(Oedometer)	M	0.0006	**0.0017**
Passing B.S. No. 200	%	66.12	**78.72**
Safe Bearing capacity	**KN/m^2**	**107.28**	**156.72**

TABLE 3.2 Settlement Analysis.

DEPTH (M)	THICHNESS OF LAYER (M)	AVERAGE EFFECTIVE STRESS (kN/M^2)	AVERAGE COEFFICIENT OF COMPRESSIBILITY (M^2/kN)	AVERAGE SETTLEMENT (M)
TP 1 @ 2.00	2.00	9.97	0.0123	0.2453
TP 2 @ 2.00	2.00	9.11	0.0110	0.2004
TP 3 @ 2.00	2.00	9.28	0.0082	0.1522
TP 4 @ 2.00	2.00	9.46	0.0082	0.1551
TP 5 @ 2.00	2.00	9.50	0.0098	0.1862

CONCLUSION.

Results of the geotechnical investigation show a safe bearing capacity range of 107.28 KN/m^2 in TP 1 – 124.44 KN/m^2 in TP 5, at 1.00m respectively. At 2.00m depths the bearing capacity increased from 145.72 KN/m^2 at TP 2 – 156.72 KN/m^2 in TP1, using a factor of safety of 2.50. Total settlement (Oedometer) values ranged between 0.0006m – 0.0017m. It follows therefore that the proposed structure could be supported on, Isolated Wide Pad Foundation which may be designed at 2.00m depth**.**

The sub-soil at the proposed site is underlain by deposits **Reddish Brown fine Lateritic Soil** to a depth of 2.00m depth explored. The soils are of different ranges of strengths and geotechnical properties. The ground was relatively soft during excavation of the trial pits and no ground water was encountered in any of the five trial pits explored. The analytical bearing capacity computations revealed that the bearing pressures of the sub-soil at the site are generally satisfactory for designs at 2.00m depths with 150 KN/m^2 average.

Consistency limits: The liquid limits obtained from the laboratory test vary 41.00% to 49.00%. Plastic limit ranged 29.98% – 31.34%. Plasticity index was determined within the range of 10.09% - 18.10%. These values indicate soils of medium to high plasticity according to the Casagrande plasticity chart. But the linear shrinkage ranged 8.57% to 11.43%, this shows that the soils have potentials for moderate shrinkage during dry season and may slightly swell in the raining season due to high contents of plastic properties.

Existing soil moisture: Though the site exploration was done in the raining periods, the natural moisture content test revealed moderate to high content of moisture in almost all the samples tested. This may mean that the underlying soils have moderate high water holding capacity. Values obtained ranged; 24.30 % to 30.78%.

Particles size distribution: The wet sieve analysis conducted was quite revealing. Materials passing B.S. sieve No. 200 were moderately high. This explains that the greater percentages of the soil constituents are fine grained materials. Values ranged 66.12% – 78.72%.

Settlement analysis: Results of the one-dimensional consolidation test carried out on undisturbed soil samples show that the coefficient of volume compressibility (M_V) varies from 0.0067 m^2/kN to 0.0176 m^2/kN. Total Oedometer settlement ranged 0.0006m to 0.0017m. These values are indicative of soil material of low to moderate to compressibility in place.

RECOMMENDATIONS.

Our recommendations as contained in this report are based on the careful correlation and interpretation of the field and laboratory analyses carried out.

⇔⇔ Results of the geotechnical investigation show a safe bearing capacity range of 107.28 KN/m^2 in TP 1 – 124.44 KN/m^2 in TP 5, at 1.00m respectively. At 2.00m depths the bearing capacity increased from 145.72 KN/m^2 at TP 2 – 156.72 KN/m^2 in TP1, using a factor of safety of 2.50. Total settlement (Oedometer) values ranged between 0.0006m – 0.0017m. It follows therefore that the proposed structure could be supported on, **ISOLATED WIDE PAD FOUNDATION** which may be designed at 2.00m depth below the ordinary ground level for Columns, using a safe bearing pressure of 150 KN/m^2. The foundations may be provided with ground beams for stability.

However, the structural or foundation Engineer may wish to design and adopt any other footing type he/she deems best fit for the proposed development, considering the information provided in this report, financial implications and other relevant factors.

⇔⇔ No static ground water level was encountered in any of the five Trial pits explored, but, adequate measures should be taken during construction and to prevent ingress of moisture into the structure when in service by providing DPM and DPC

⇔⇔ The excavated sides and hard-core level should be properly back filled and well compacted with laterite to a maximum dry density of 2.00 gm/cm^3 at optimum moisture content in order to enhance the strength of the fill material.

⇔⇔ All necessary quality control measures on construction materials must be ensured during construction and supervision must be done by an experienced, qualified and registered civil engineer.

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