Geotechnical Site Investigation for Proposed Minna City Centre Development in Niger State

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Abstract—This study was carried out to investigate and determine the geotechnical parameters required for adequate design and positioning of structures and facilities of the proposed Minna City Centre, at Minna the capital of Niger state. The soil samples used for the study were obtained from 10 SPT boreholes at 0.6, 2.1 and 3.6 m depths and all laboratory tests were conducted in accordance with BS 1377. Results show that soil particle sizes increases with boring depth up to the basement complex and values of cohesion and angle of internal friction show that the shear resistance and bearing capacity of soils will be relatively high and favourable for the intended structures. Average allowable bearing capacity values in the range of 100 – 300 kN/m² are recommended for use in the study area with embedment depth between 1 – 3m.

Keywords—Atterberg limits, Bearing capacity, Density, Shear strength parameters, Site investigation

1. INTRODUCTION

This study presents a description of field activities and results of in-situ and laboratory tests carried out with a view of determining the geotechnical parameters of the sub-soil material required for the design of the proposed City centre development at Minna, the capital of Niger state. As a pre-requisite for the development of the site, a physical development master plan for the site is required; this includes the geotechnical investigations of the site among others.

According to Holubec (2010), good planning for and management of a geotechnical site investigation is the key to obtaining sufficient and correct site information for designing a structure in a timely manner and with minimum cost for the effort needed. It should be noted that knowledge of the ground conditions depends on the extent and quality of the geotechnical investigations. Such knowledge and the control of workmanship are usually more significant to fulfilling the fundamental requirements than is precision in the calculation of model parameters (Schuppler, 2008).

Some Nigerian soils are problematic and adversely affect foundations of structures thereby compromise the stability of the structures. These soil problems have resulted in excessive settlement, tilting and collapse of many buildings not only in Nigeria but also around the world (Salahudeen and Sadeeq, 2017). Bearing capacity and settlement are the major considerations in designing shallow foundations on granular soils. The designers try to ensure sufficient safety factor against bearing capacity failure and to limit the settlement within a tolerable value (Salahudeen, 2017; 2018). Several techniques based on stress characteristics, and on upper- and lower-bound theorems of limit analysis, have been used to calculate the bearing capacity for structural footings. Niger State is covered by two major rock formations, the sedimentary and basement complex rocks. Minna occupies the central portion of the Nigerian basement complex (Sadeeq and Salahudeen, 2017).

The Minna area comprises of meta-sedimentary and meta-igneous rocks which have undergone polyphase deformation and metamorphism (Ola, 1983). These rocks have been intruded by granitic rocks of Pan-African age. Five litho-stratigraphic units have been recognized in Minna area: The schist occurs as a flat laying narrow southwest-northeast belt at the central part of Minna with small quartzite ridge parallel to it, the gneiss occurs as a small suite(s) at the northern and southern part of the area forming a contact with the granite (Sadeeq and Salahudeen, 2016a; 2016b; 2016c). Feldspathic rich pegmatite is bounded to the east, with average width of 65 m and 100 m long, the pegmatite host tourmaline. Granitic rocks dominate the rock types in the area and vary in texture and composition (Salahudeen, 2017).

The site is located between longitude 6025°E and 6045°E and latitude 9024”N and 9048”N. It is an abandoned local market, about 1.2 km2, which is generally flat in topography. This study was carried out to investigate the subsoil conditions at the site through lab tests on soil samples taken from the site, to make precise engineering decisions on the type of foundations suitable for the proposed structures, to determine the depths of foundation embedment and best locations for different utilities.

2. MATERIAL AND METHODS

2.1 Material

Soil: The soil samples used for this study were obtained by Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils (ASTM D 1586) from 10 (SPT) boreholes at 0.6, 2.1 and 3.6 m depths. All soil samples are disturbed.

2.2 Methods

Index properties: Laboratory tests of sieve analysis, natural moisture content, Atterberg limits and density were performed to determine the index properties of the soil samples. All laboratory tests were conducted in accordance with BS 1377 (1990).

Strength tests: Direct shear test was performed to determine the strength properties (cohesion and angle of internal friction) of the soil samples. These parameters were used to determine the allowable bearing capacities.

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for square footings (2 m by 2 m by 0.5 m for length, breadth and depth, respectively) based on safety factor of 3 using the Terzaghi’s method. It should be noted that all results presented herein are from laboratory tests conducted on soil samples recovered from the SPT and the SPT N-values were not used at all.

**Standard penetration test:** The standard penetration test (SPT) was used in this study only to obtain soil samples for laboratory tests. SPT consists of driving a standard split barrel sampler a distance of 460 mm into the soil at the bottom of the boring, counting the number of blows to drive the sampler the last two 150 mm distances (to obtain the N number) using a 63.5 kg driving hammer falling free from a height of 760 mm (Bowles, 1996). The boring log shows refusal if 50 blows are required for any 150 mm penetration, 100 blows are obtained for a 300 mm penetration or 10 successive drops of the hammer produce no advance in penetration.

The SPT was conducted in accordance with ASTM D-1586-99 (2001). The standard split tube sampler has an inside diameter of 34.93 mm and an outside diameter of 50.8 mm. The numbers of blows required for a spoon penetration of three 150 mm intervals are recorded. The sampler is then withdrawn, and the shoe and coupling are removed. Finally, the soil sample recovered from the tube is placed in polythene bag and transported to the soil laboratory of the Department of Civil Engineering, Ahmadu Bello University (ABU) Zaria. Samples are generally taken at intervals of 1.5 m.

**3. RESULTS AND DISCUSSION**

**3.1 Sieve Analysis**

Particle size distribution curves of soils obtained from ten boreholes at three different depths of 0.6, 2.1 and 3.6 m respectively are shown in Figures 1 – 3. Generally, the percentage fines decreased with increase in boring depth and the curves are closely packed indicating homogeneity. This could be as a result of overburden that has subjected the soil below to compression overtime thereby forming larger particles with stronger bonds. With increase in boring depth, the quantity of free silt and clay progressively reduced and coarser materials were formed. This observation is in agreement with Sadeeq et al. (2016), Sadeeq and Salahudeen (2016a; 2017), Salahudeen et al. (2017).

**3.2 Natural Moisture Content**

Variation of natural moisture contents of the soil samples from the ten boreholes are shown in Figure 4. The general decrease in the natural moisture contents values with boring depth is not unconnected with the fact that the soils in higher depths are more naturally compacted with lower voids for moisture occupation than those above.
### 3.3 Atterberg Limits

The variations of liquid limit, plastic limit and plasticity indices are shown in Figures 5 – 7 respectively. It was observed that the plasticity indices values, though decreased with increase in boring depth, are on the high side. Soils with high values of plasticity indices are normally associated with high content of fines which are in turn associable with high compressibility, consolidation settlement and sometimes, low values of bearing capacity. Structural footings that are to be founded on such soils should be carefully designed taking into serious consideration, the ground water profile, compressibility characteristics and possible bearing capacity failure.

![Fig. 5: Variation of liquid limit with boring depth](image)

![Fig. 6: Variation of plastic limit with boring depth](image)

![Fig. 7: Variation of plasticity index with boring depth](image)

### 3.4 Density

Density is a measure of compaction of non-cohesive soils naturally compacted as a result of geological processes. The values are approximate, primarily because the effective overburden pressure and the stress history of the soil significantly influence the values in sand. Due to its formulation, density is prone to large errors. The relationships between relative density and field tests (mainly SPT and CPT) are not unique and are strongly influenced by other parameters such as fines content, grain size and grain shape, grading and grading curve shape, effective vertical or horizontal stresses, mineralogy, compressibility and crushability, cementation, over consolidation and age (Hamidi et al. 2013). Variations of bulk and dry densities with boring depths are shown in Figures 8 and 9. It was observed that density generally increased with increase in boring depth. Soil with higher density is always associated with higher mobilised angle of shearing resistance (Bolton and Gui, 1993). Relative density has a significant effect on penetration resistance and can be correlated (Salahudeen and Sadeeq, 2016; 2017).

![Fig. 8: Variation of bulk density with boring depth](image)
3.5 Shear Strength Parameters

3.5.1 Cohesion and Angle of Internal Friction

Variations of the cohesion and angle of internal friction with boring depth are shown in Figures 10 and 11. The shear strength of a soil mass is the internal resistance per unit area that the soil mass can offer to resist failure along any plane inside it. When this resistance is exceeded failure occurs. Shear strength within a soil matrix is due to cohesive and frictional forces between adjacent particles (Adunoye, 2014; Salahudeen et al., 2016). Therefore, cohesion and angle of internal friction are the most important parameters of soil strength. Angle of internal friction could be described as a measure of the ability of a unit of soil to withstand a shear stress. Cohesion, which is the mutual attraction among the soil particles without the application of any external force, is used to measure the shearing resistance (of fine grain soils) and bearing capacity of soils. The two parameters are found in this study to be highly variable indicating that the site under investigation has a highly variable geology. This is an indication that the bearing capacity and settlement of the soils in the study area will vary from one point to another. In this case, care must be taken in designing the structural footings since there is likelihood of differential settlement.

3.5.2 Allowable Bearing Capacity

Based on field test results, the bearing capacities of shallow foundations are determined in terms of the allowable bearing pressures. For the allowable bearing pressures of shallow foundations, footing plan dimensions of 2 m by 2 m by 0.5 m for length, breadth and depth, respectively were assumed with safety factor of 3. Variation of allowable bearing capacity with boring depth is shown in Figures 12. Based on the method proposed by Meyerhof (1974) used in this study, allowable bearing capacity values in the range of 100 – 300 kN/m² were proposed for use in the study area within the depths considered.
4. CONCLUSION AND
Based on the results of this study, the following conclusions were made:
1. The plasticity index values are high indicating high content of fines and consequently high compressibility values.
2. Values of cohesion and angle of internal friction show that the shearing resistance and bearing capacity of soils will be relatively high and the site has a highly variable geology.
3. Allowable bearing capacity values in the range of 100 – 300 kN/m² are adequate for use in the study area with embedment depth between 1 – 3 m.

5. RECOMMENDATION
Based on the results of this study, we recommend that:
1. The structural footings that are to be founded on soils of this study area should be carefully designed taking into serious consideration the compressibility characteristics and possible differential settlement.
2. The refusals met, which could be rocks should be cored before high rise buildings are founded on them.

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