Original Research Article

Geoelectrical and Geotechnical Investigations for Development of Superstructures at Nkpologwu Proposed Judiciary Site, Anambra Basin, Southeastern Nigeria

ABSTRACT

Geophysical and Geotechnical surveys were integrally carried out at a proposed Judiciary site for civil development of superstructures in Nkpologwu, Anambra Basin, southeastern Nigeria. Nkpologwu falls within 7˚06' '40 " E to 7˚08 ' longitudes and 5˚56' 76 " N to 5˚57' 78 " N latitudes at about 320 m above the mean sea level. The study is ai interpreting the lithology of the subsurface at shallow depths in order to accentuate the competence of soil formations at the foundation depths of the site. Vertical Electrical Sounding (VES) data were acquired in the geophysical survey while various geotechnical tests were carried out to ascertain the bearing capacity of the site's subsoil. The registered data from the VES survey were processed with *WINGLET* software hence, geoelectric models of at least four layers were obtained. Characterized by apparent resistivity values in the range of about 1524 to 96,561 Ωm. Geotechnical results showed values of 10.4% to 12.4% OMC, 1.95 to 2.01g/cm^3 MDD, 30.0 to 39.0% CBR, 21.0 to 30.5% particle size distribution, <12% PI and <35% LL Atterberg limit for soil samples within foundation depths at the site. Combined interpretation of the surveys showed that at foundation depths at the site were predominantly sand, laterite and sandstones delineated and these were found to meet the required standard of the Federal Ministry of works and housing for construction of superstructures. Therefore, the study provides the knowledge of the lithology and soil competence at foundation depths for future civil construction works at the site.

Comment [R1]: Upper case Southeastern

Keywords: *Geoelectric models, geotechnical, soil competence, foundation depths, superstructure*

1. INTRODUCTION

The suitability of soils for engineering purposes depends largely on their ability to remain in place and to support either permanent or transient loads that may be placed on them [1,12]. Generally, most problems of structural failures of superstructures are often associated with improper knowledge of subsurface materials at foundation depths and poor quality of building materials [7]. The understanding of swelling and shrinkage characteristics of soils is very important in solving engineering problems commonly associated with the construction of buildings, dams and high ways [2]. Hence, site investigations are usually conducted to determine the physical properties of the soil at the particular location and ascertain their ability to support superstructures emplaced on them [8]. Geoelectrical resistivity technique has been affirmed to be very efficient and applicable in various contexts such as groundwater exploration, engineering site investigations, agronomy, and determination of compaction and soil horizon thickness, archaeological prospecting, assessment of soil hydrological properties and foundation stability assessment [3, 9]. Geotechnical investigations such as boring, drilling, Dutch cone penetrating test (CPT), standard penetrating test (SPT) and several laboratory tests (including Atterberg limits, moisture contents, quick undrained triaxial and Oedometer consolidation tests) are designed within a site to understand the engineering characteristics and bearing capacity of the subsurface geomaterials in the site [11]. The information from both geoelectrical and geotechnical investigations of subsurface geomaterials can be used to determine the kind of building design, foundation type, settlement rate and subsoil bearing capacity for a particular site prior to building construction work [4,10]. Therefore, the study is aimed at using a combination of geoelectrical resistivity survey and geotechnical investigation results to obtain a plausible interpretation of the lithology of the subsurface at depths. Hence the in the competence of soil formations at the foundation depths of the site might be accentuated.

Comment [R2]: Improve the phrase as if there is a missing word to complete its meaning

2 The Study Area

Nkpologwu town is in Aguata Local government of Anambra State, Southeastern Nigeria (Figure 1). The topography of the study area is relatively flat and it falls within the Anambra Basin which is one of the energy-rich inland sedimentary Basins in Nigeria; it is bounded to the south by the Niger Delta Basin hinge line [13, 14]..

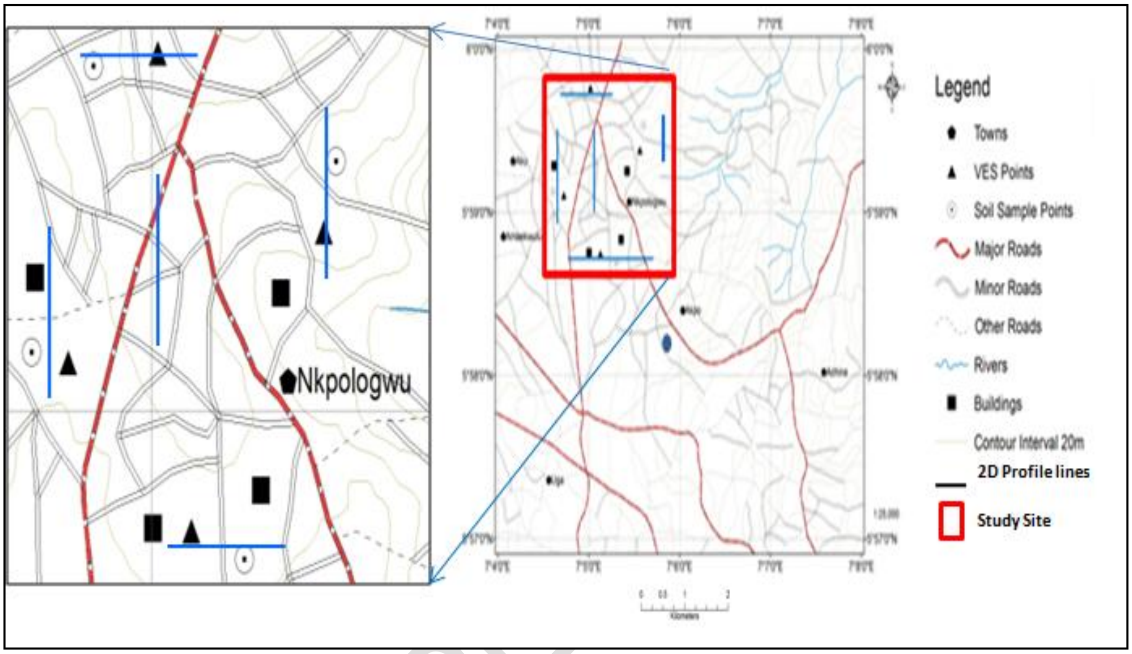

Figure 1: The Study Area; bounded in red coloured rectangular shape as a portion in Nkpologwu City, Anambra State, Nigeria.

3. METHODOLOGIES

3.1 Vertical Electrical Sounding (VES) Survey

Vertical Electrical Sounding (VES) was carried out using ABEM SAS 1000 Terrameter to define the lithological arrangement of the proposed site. Schlumberger electrode configuration was applied for the sounding. The distance between the current electrodes was designated L while the distance between potential electrodes was designated lResistance data obtained in the field was converted to resistivity using the formula. Hence, the

$$\rho = \pi\left[\frac{L^2}{2L} - \frac{l}{2}\right]\frac{\Delta U}{I} \quad (1)$$

The apparent resistivity values obtained were then plotted against half current separation to obtain curves. The data obtained from the curve were analyzed using the WINGLET software which generates the model curve of the data. By iteration, the software finds the line of best fit for the plotted points and the best resistivity curve.

3.2 Geotechnical Tests

Furthermore, samples were collected with the aid of an Auger at the site at depths of about 2.0 m. To ensure that pure soil samples were collected, plant residue was removed from the samples collected. The samples were then air dried at room temperature for 24 hours, after which they were divided into parts depending on the number of laboratory test intended. The geotechnical tests carried out includes; Soil Compaction test, California Bearing Ratio, Atterberg Limit and Particle Size distribution.

British Standard (BS) mould was used for the test of soil compaction [15]. With the aid of Proctor/Compaction Mould, the soil compaction was determined by calculation of the bulk and dry densities $in\ (mg/m^3)$of some sample moulds were measured based on equation 2.

$$\rho_b = \frac{M_2 - M_1}{X} \qquad (2)$$

Where ρ_b is the bulk density, $M_1$the weight of the mould, M_2 weight of the mould and soil and X is the volume 1000 cm^3 of the BS Mould used were measured. Based on the bulk density, the dry density ρ_d, of the soil was determined using equation 3.

$$\rho_d = \frac{\rho_b}{1+W} \qquad (3)$$

Standard mould, fittings and tools were used to determine the CBR. With a compression machine having corrected zero error, readings were taken at displacement of 0.25 mm interval and at 7.5 mm penetration. Hence, the moisture contents of the specimens were measured. The percentage ratio of the pressure for the soil samples P (N/mm^2) to the pressure of equal penetration on standard soil P_s (N/mm^2) for each sample were determined based on equation 4 respectively.

$$CBR = \frac{P}{P_s} \times 100 \qquad (4)$$

Atterberg Limit machine was used was used to determine the Plastic Index (PI) of the soil samples, Each soil sample was sufficiently mixed with of distilled water, stirred, kneaded and chopped with aid of spatula. Using a measured quantity of the mix (well stirred, kneaded and chopped), the liquid limit (LL), plastic limit (PL) of the sample were both taken. The samples were thoroughly mixed with distilled water, kneaded to form a plastic ball, then rolled on a glass plate using steady pressure which was maintained until the thread crumbled. This crumbling point is the Plastic Index (PI) of the samples defined by equation 5:

$$PI = LL - PL \qquad (5)$$

With the aid of mechanical sieve shaker, the particle sizes of the samples were determined. The percentage weight of the sample retained and that passing in the sieves were determined based on equations 6a and 6b given as;

$$\%\,weight\ retained = \frac{weight\ retained}{initial\ weight} \times 100 \qquad (6a)$$

$$\%passing = 100 - \%weight\ retained \qquad (6b)$$

4. RESULTS AND DISCUSSION

4.1 VES Results and Interpretations

Curves types identified in the study area is predominantly curve K type. Typical curve types in the area are as shown in Figures 2a – 2d ranging from 1524Ωm to 96561Ωm. The VES interpretation results were used to prepare 2-D geoelectric sections displayed.

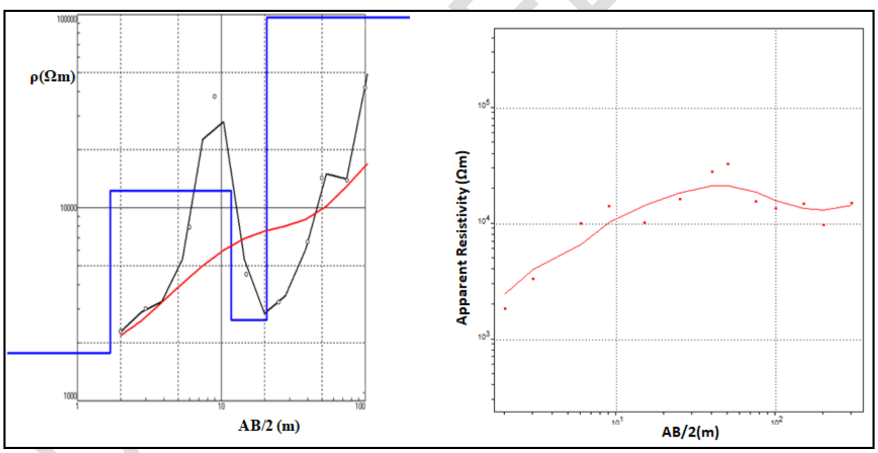

Figure 2a: Typical Sounding curves at VES point 1 of the study area.

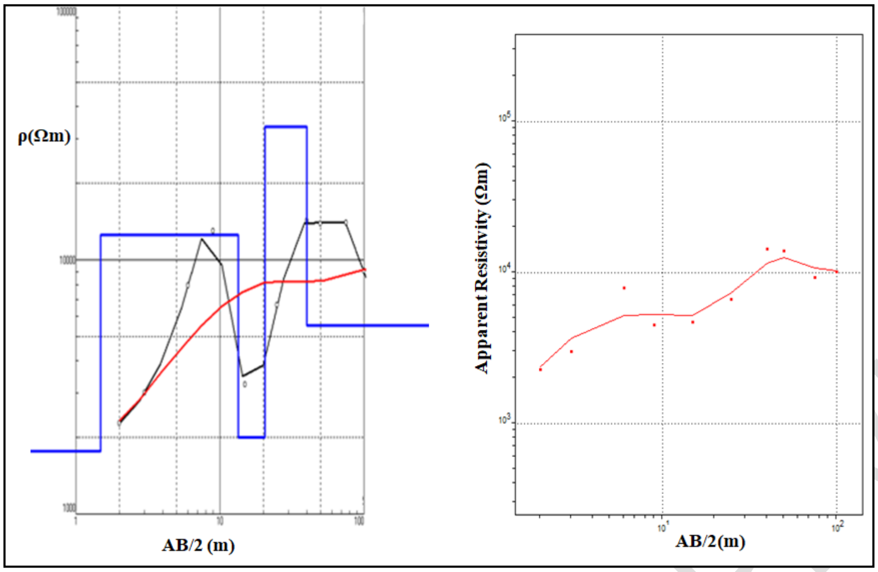

Figure 2b: Typical Sounding curves at VES point 2 of the study area.

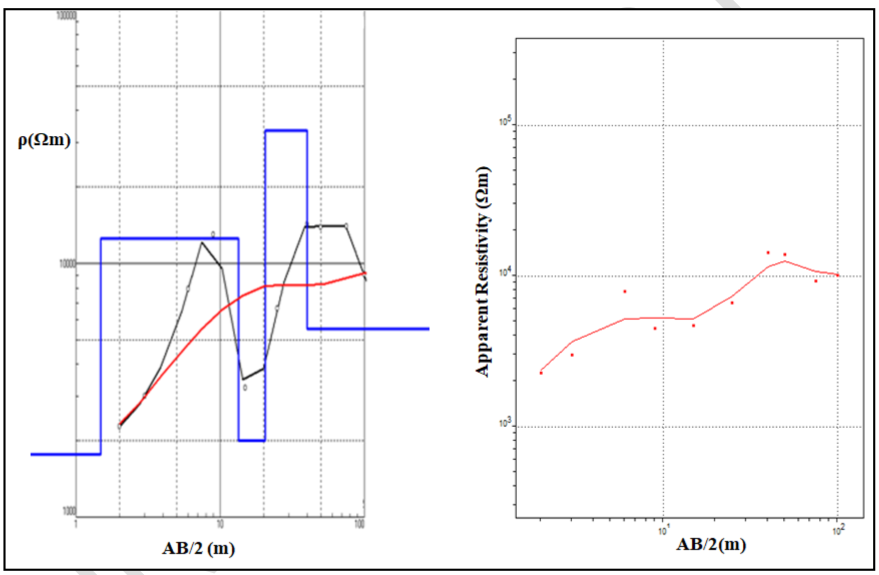

Figure 2c: Typical Sounding curves at VES point 3 of the study area.

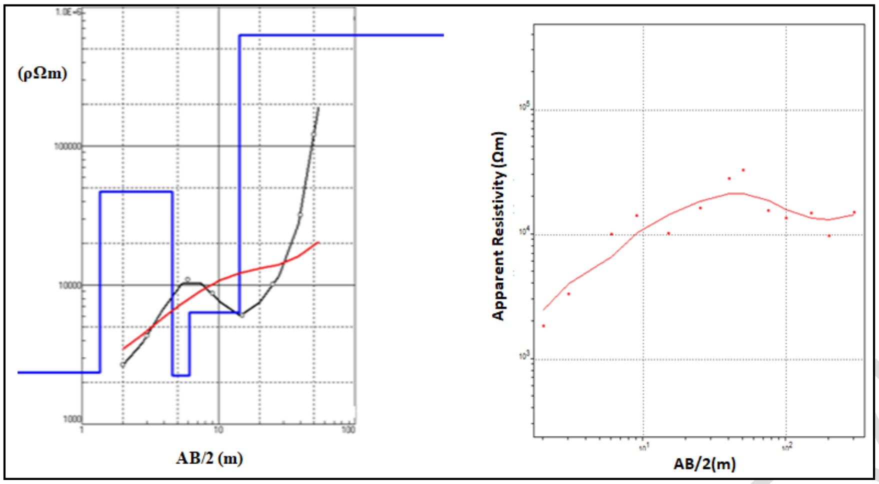

Figure 2d: Typical Sounding curves at VES point 4 of the study area.

The geoelectric model sections show four geoelectric and geologic subsurface layers comprising sandy clay topsoil (1524 to 1905 Ωm) having thickness range from 1.23 to 1.69 m; laterite (12,231 to 15,717 Ωm) having thickness range from 1.6 to 10.0 m; sandstone (1,600 – 96,600 Ωm having thickness ranges from 4 to 36 m and sand (2,000 – 5,860 Ωm) having thickness range from 4.22 to 8.98 m respectively

4.2 Geotechnical Results Analyses

The geotechnical analyses carried out in accordance to part 4 of British standard test procedure [15] depending on the type of test. The summary of the geotechnical tests results (Table 1) of the laboratory tests in the foregoing show that the soil at the site were suitable at the foundation depths were all found to be competent hence suitable for house constructions..

Table 1: Summary of the Results of the Geotechnical Tests carried out

Tests Conducted	P1	P2	P3	P4	Mean value	FMWH standard for Buildings construction (superstructures)	Level of competence
COMPACTION TEST							
OMC(%)	11.5	10.4	12.4	10.5	11.2	<18%	suitable
MDD (g/cm^3)	1.99	1.99	1.95	2.01	1.9	>0.04	suitable
CBR	36.0	33.0	30.0	39.0	34.5	≤80%	suitable
ATTERBERG LIMITS							
PI (%)	11.1	10.9	10.9	9.8	10.7	≤12%	Suitable
LL (%)	23.3	19.8	21.5	23.7	22.1	≤35%	Suitable
PARTICLE SIZE DISTRIBUTION							
% of fines	30.5	23.2	22.3	21.0	24.3		

non-plastic	Non-cohesive

Table 1 is evaluated using American Association for State and Highway Transportation (AASHTO) official classification system [16]. The AASHTO (Table 2) comprises seven groups of inorganic soils ranging from A-1 to A-7 based on particle size distribution, liquid limit, plasticity index respectively. The summary sheet of the geotechnical results (Table 1) shows that the soil sample can be classified as A-2-4 and A-2-6 of AASHTOSystem of Soil Classification [16] which consists of clayey-sand and sand. Also, Table 3 shows that the soil formation at the site belongs to non-plastic to low plastic, non-cohesive to low cohesive soil types in plasticity Index [17]. The soil was rated as excellent materials for construction of superstructures. The result of the compaction test shows that the grade is good for house construction. This is based on the fact that the sample falls within sandy-clay [5] when using standard proctor compaction test method. The plastic index (PI) of the samples indicates little or no presence of expansive clay whereas the liquid limit (LL) values obtained indicates that the soil at foundation depths is suitable for house construction. The CBR values show good strength percentage at a mean value of 35% for house construction.

Table 2: Revised AASHTO System of Soil Classification (Braja, 2010)

General Classification	**General Materials (35% or less passing 0,075 mm)**							**Silt-Clay materials (more than 35% passing 0.075 mm)**			
Group Classification	A-1			A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-a	A-1-3	A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis % passing											
2.00 mm (No.10)	50 max										
0.425 (No. 40)	30 max	50 max	51 min								
0.725 (No. 200)	15 max	25 max	10 max	35 mas	35 max	35 max	35 max	36 max	36 max	36 max	36 max
Characteristics of Fraction Passing	6 max										
Liquid Limit			N.P.	40 max	41 min	40 max	41 min	40 max	41 min	40 max	40 min
Plastic Index				10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual types of Significance	Stone Fragment		Fine	Silty or Gravel and sand				Silty Soils		Clayey Soils	
Constituent Material	Gravel and Sand		Sand								
General Rating	Excellent to Good							Fair to Poor			

Table 3: Type of soils based on plasticity Index (Prakash and Jain, 2002)

Plasticity index (%)	**Soil type**	**Degree of plasticity**	**Degree of cohesiveness**
0	Sand	Non-plastic	Non-cohesive
<7	Silt	Low plastic	Partly-cohesive
7-17	Silt clay	Medium-plastic	Cohesive
>17	Clay	High-plastic	Cohesive

4.3 Comparison of the Geophysical and Geotechnical Results

In consideration of the general geology of the study area, there are points of agreement. First, it can be observed that the PI tests results (9.8-11.1%) are within the classification of sandy materials in the AASHTO System of Soil Classification. This agrees with the geology of the area comprising Nanka sand which is primarily sand. The sand and sandy-clay were observed to have occurred in various formation aggregates at the depths of the sub-soil.In agreement with the geology of the study area, the delineated soil from both the geophysical and geotechnical surveys suggest that the occurrence of the medium to coarse grain sand that is loose and unconsolidated, with cross bedded white to yellow sand having intercalation of silty sand and clay with bands of fine grained sandstone and sandy clay on top [6]

5. CONCLUSIONS

The soil formation at the study area generally encompasses sand, laterite, sandstones and saturated sandstones. Predominantly, sand and sandy clay characterizes the top soil within the study area. The competency of the topsoil falls within the acceptable range of Federal Ministry of Works and Housing (FMWH) of Nigeria specifications; therefore, it is possible to have stability of high-rise superstructures at the site. Hence, the study site is relatively stable based on the kind of soil delineated therein.

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COMPETING INTERESTS DISCLAIMER:

AUTHORS HAVE DECLARED THAT NO COMPETING INTERESTS EXIST. THE PRODUCTS USED FOR THIS RESEARCH ARE COMMONLY AND PREDOMINANTLY USE PRODUCTS IN OUR AREA OF RESEARCH AND COUNTRY. THERE IS ABSOLUTELY NO CONFLICT OF INTEREST BETWEEN THE AUTHORS AND PRODUCERS OF THE PRODUCTS BECAUSE WE DO NOT INTEND TO USE THESE PRODUCTS AS AN AVENUE FOR ANY LITIGATION BUT FOR THE ADVANCEMENT OF KNOWLEDGE. ALSO, THE RESEARCH WAS NOT FUNDED BY THE PRODUCING COMPANY RATHER IT WAS FUNDED BY PERSONAL EFFORTS OF THE AUTHORS.

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