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TOPIC: Geophysical and Geotechnical Investigation of a Proposed Building Site along Laniba Ajibode, Ibadan, Southwestern, Nigeria

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ABSTRACT

The need for preconstruction investigation is imperative in line with preventing loss of lives and property. This relates to some earth materials which cannot support some solid and rigid structures.

Geophysical and geotechnical studies were conducted in Laniba, Ajibode behind IITA in Ibadan, to determine the general condition of the of the foundation soils. The geophysical survey includes 25 Vertical Electrical Soundings (VES), 10 Cone penetrometer tests and digging of 5 test pits. Sieve analysis (mechanical and hydrometer), Atterberg limits, oedometer consolidation, and triaxial tests were conducted.

The Unified Soil Classification System (USCS) classified the soil as Sandy Silty Clay. Liquid Limit (LL) of the soil between 35% and 48% and Plasticity Index (PI) range from 16 to 19%. The VES data for the proposed building site showed six geoelectric layers; the topsoil, lateritic clay (some of which are compacted), sandy clay, clayey soil, fractured basement and fresh basement. The cone penetrometer result revealed a significant increase of cone resistance with depth indicating an increasing bearing capacity.

There were correlations between VES data and geotechnical parameters as well as between index and basic geotechnical parameters, at foundation depth of 1.5m based on compressibility values, with no likelihood of either excessive total or differential settlement was found to be suitable for the proposed structure.

INTRODUCTION

Some clays and clay bearing earth materials are not usually competent to support solid and rigid structure in engineering practices. This most times, would require a form of treatment or stabilization. However, Preconstruction studies would provide information that will aid the civil engineer in designing the foundation of engineering structures. Over the years, geophysics has been applied in building construction to provide useful information regarding the early detection of hypothetically dangerous subsurface conditions.

Incorporating geophysical information and geotechnical investigation has become a promising approach (Adepelumi and Olorunfemi, (2000), Adepelumi et.al. (2009). Site characterization usually provides subsurface information that is useful in designing engineering structures. Akintorinwa and Adesoji, (2009), Oyedele et.al. (2011), Oyedele et.al., (2013) and Akinlabi and Adeyemi, (2014) have employed geophysical and geotechnical method for site characterization. The core purpose of all site investigation is to acquire data required for analysis and design. However, the most challenging part of this investigation is to obtain this data with the least amount of money. This can be achieved with geophysical investigation. Again, the use of geotechnical investigations for foundation studies can be very expensive, cumbersome involving digging and drilling of boreholes which can also alter the natural state of the soil. Geophysical methods are being integrated to foundation studies and the method is cheap, faster and yet uncompromising to the quality of the study. Hence, this research was carried out to determine the subsoil strata and thickness of the various strata within the proposed site, to determine the subsoi1 parameters for assessment of the strength or competence of the subsoil on which the building will be founded. It was also meant to establish mathematical relationship between the electrical resistivity data and geotechnical parameters.

STUDY AREA DESCRIPTION

The area of study is Laniba, Ajibode behind IITA in Ibadan. It lies within the geographical location of Latitude 7^{O}29'07" and Longitude 3^{O}55'02" with an average elevation of 273m.

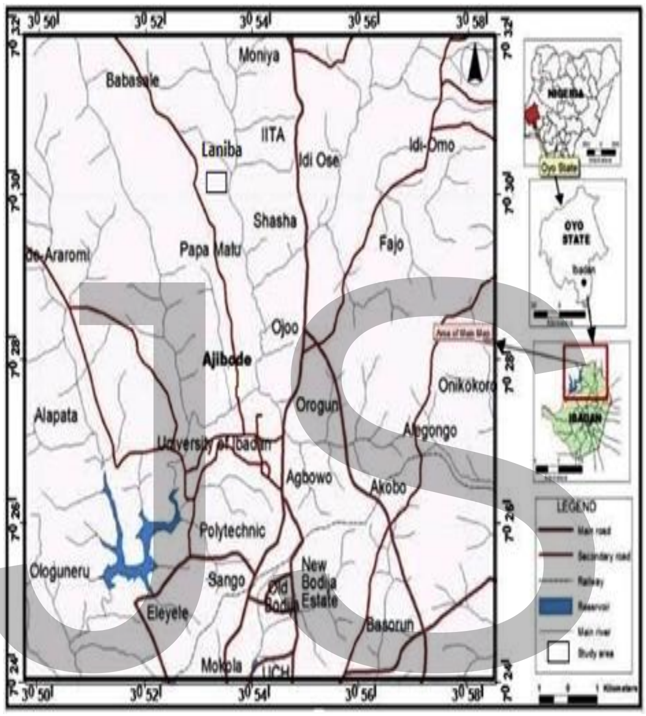

Fig 1: Topographic map of the study area after Adelekan et al, 2016

The main lithologies includes migmatite gneiss, granites and pegmatites. Other important rock types are schists made up of biotite schist, quartzite schist, talc-tremolite schist and the muscovite schists.

MATERIALS AND METHODS

Three phases of investigation were carried out in this research.

Field work: Comprehensive fieldwork was carried out included:

Geophysical Survey

A total of twenty-five VES were carried out as the plot was divided into 25 points. The Schlumberger electrode configuration was used to account for lateral variation due to inhomogeneity.

Test Pitting

A total of five test pits were excavated in order to determine the suitability of the soil for building purposes, each about 3m deep.

Laboratory analyses

Bulk samples collected from the trial pits were subjected to particle size analysis and Atterberg limits tests. Undisturbed samples were subjected to geotechnical tests which included oedometer consolidation and quick undrained triaxial tests to determine the settlement and shear strength parameters.

The VES data were interpreted first by preliminary partial curve matching using 2-layer master curves which were followed by computer iteration while the field data were adjusted to obtain good fit with calculated apparent resistivity profiles.
Ultimate Bearing capacity were obtained from the cone penetration test. Other parameters were also obtained from the triaxial compression test (cohesion, angle of internal friction and unit weight of the soil).

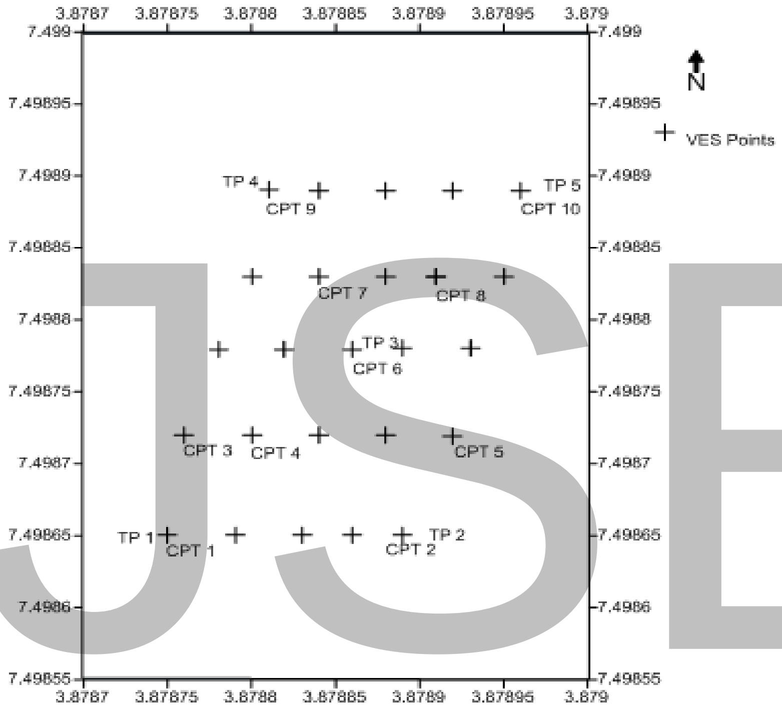

Fig 2: Distribution of VES Points, CPT Points and Test pits in the Study Area

RESULTS AND DISCUSSIONS
GEOPHYSICAL RESULTS
The VES data for the proposed building site show six geoelectric layers; the top soil, lateritic clay sandy silty clay, clayey soil, fractured basement and fresh basement.

Profile 1
The resistivity of the topsoil varied from 231Ωm to 623Ωm while its thickness varied from 0.5m to 3.1m. The second layer has resistivity values ranging from 315Ωm to 1128Ωm with thickness ranging from 1.7m to 9.6m and the inferred lithology was lateritic clay. High resistivity values were obtained in the VES of layer 3, 4 and 5 which suggests that the lateritic clay was compacted at these points. The last layer was fractured basement which has resistivity range of between 240Ωm to 565Ωm.

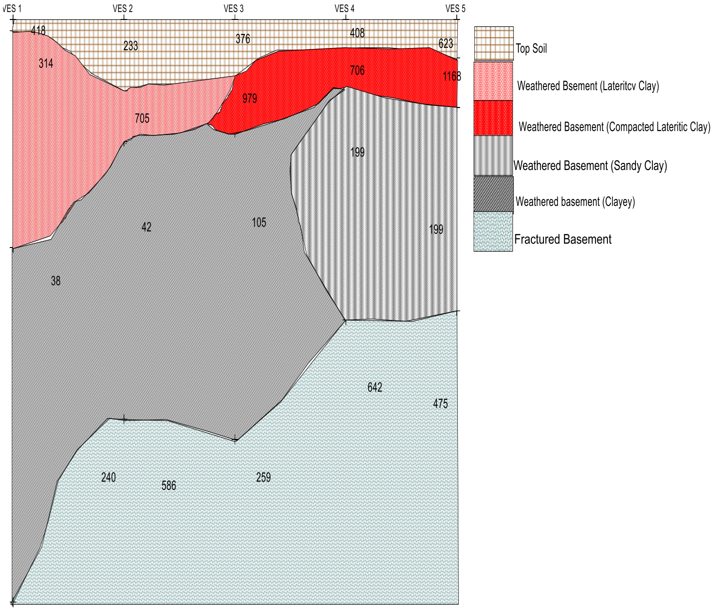

Fig 3: Geoelectric and Lithologic Section beneath Profile 1

Profile 2
The resistivity of the topsoil varied from 546Ωm to 1152Ωm while the thickness varied from 0.4m to 1.7m.

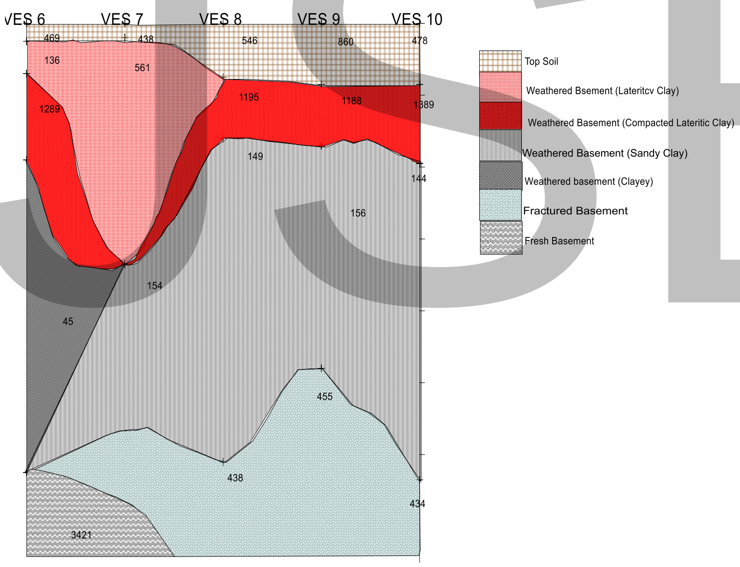

Fig 4: Geoelectric and Lithologic Section beneath Profile 2

The high resistivity at VES 6 and VES 7 can be attributed to laterisation. The first layer was clayey and made up of sandy clay. The resistivity of this layer ranged from 46Ωm o 154Ωm with layer thickness from 6.2m to 9.0m. The last layer is made up of fractured basement with fresh basement present at VES 6. The resistivity of this layer varied from 259Ωm to 2923Ωm.

Profile 3
The resistivity of the topsoil varied from 252Ωm to 983Ωm while the thickness varied from 0.5m to 5.4m.

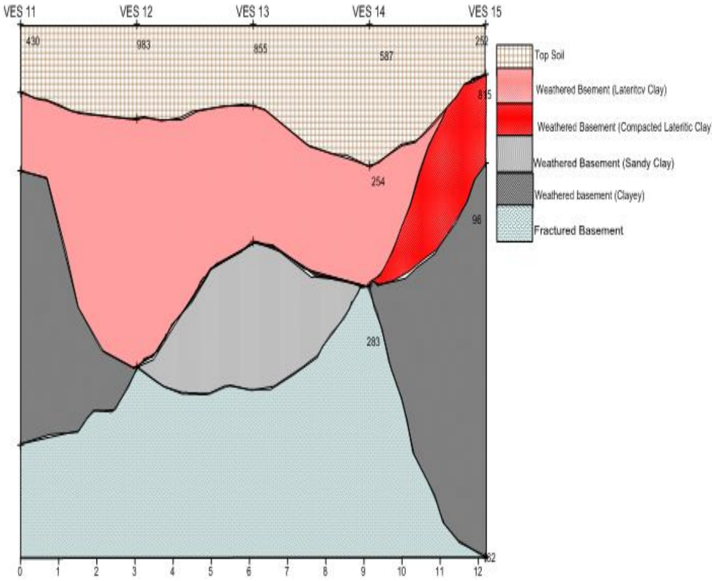

Fig 5: Geoelectric and Lithologic Section beneath Profile 3

Higher resistivity shown at VES 11 and VES 15 can be attributed to competence of the layer. This is followed by a mixed layer composed of fractured basement and sandy clay. The resistivity of this layer varied from 96Ωm to 435Ωm and layer thickness from 9.5m to 15.1m. The last layer is made up of fractured basement with resistivity varying from 162Ωm to 594Ωm.

Profile 4

The resistivity of the topsoil varied from 474Ωm to 714Ωm while the thickness varied from 0.6m to 3.9m.

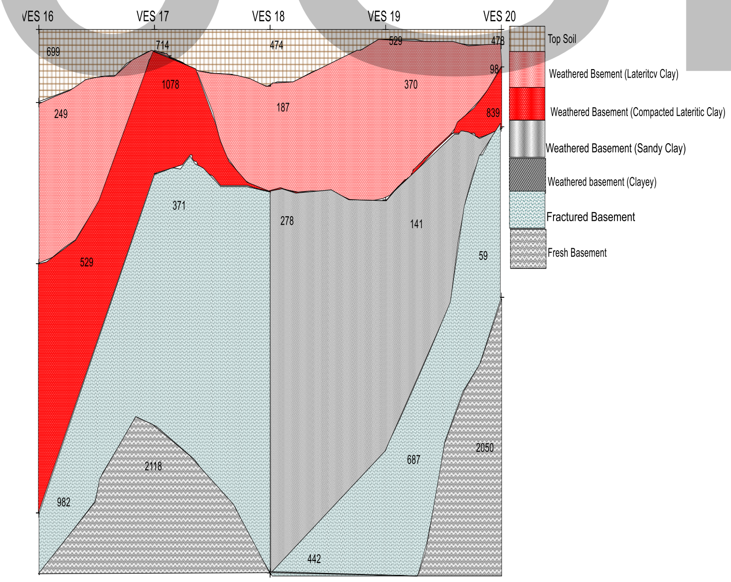

Fig 6: Geoelectric and Lithologic Section beneath Profile 4

The high resistivity at VES 16 and VES 17 can be attributed to laterisation. This is followed by a mixed layer composed of fractured basement and sandy clay. The resistivity of this layer

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varied from 59Ωm to 982Ωm and layer thickness from 13.4m to 20.4m. The last layer is made up of fractured basement and fresh basement with resistivity varying from 162Ωm to 594Ωm.

Profile 5

The resistivity of the topsoil varied from 198Ωm to 463Ωm while the thickness varied from 1.8m to 4.4m. This layer is underlain by lateritic clay with resistivity ranging from 407Ωm to 1340Ωm and thickness ranging from 2.6m to 7.9m.

The resistivity of the next layer ranges from 50Ωm o 125Ωm and layer thickness from 9.2m to 16.4m. The last layer is made up of fractured basement with fresh basement present at VES 22, 24 and 25. The resistivity of this layer varied from 259Ωm to 2923Ωm.

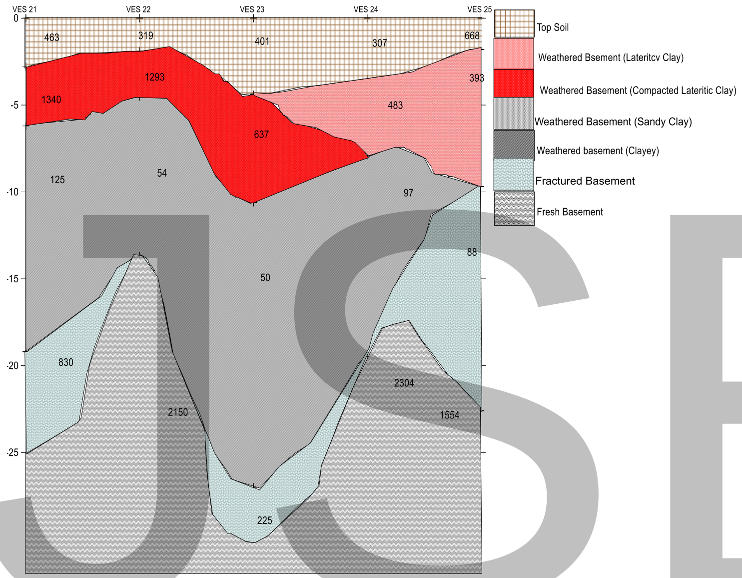

Fig 7: Geoelectric and Lithologic Section beneath Profile 5

GEOTECHNICAL PROPERTIES

The was a significant increase of the Allowable Bearing Pressure (ABP) with depth. The bearing capacity ranges from 27KN/m^2 to 351KN/m^2. This falls within the range of soft clay to compact sand (BS 8004, 1986 – Code of Practice for Foundations). Coefficient of variation had values at 0.25m, 0.50m, 0.75m, 1.00m, 1.25m and 1.5m are 0.21%, 0.48%, 0.33%, 0.34%, 0.20% and 0.13% respectively. This shows that there is lowest possibility of differential settlement at the depth of 1.5m

SOIL CLASSIFICATION

Grain Size Distribution

Based on the Unified Soil Classification System, the sieve and hydrometer analysis conducted on representative soil samples shows that the soil is silty clayey sand. It has poor drainage condition and may act as a fair material for foundation.

Atterberg Limits

Results of the Atterberg limits test conducted on the soils shows that the soils have Liquid Limits (LL) between 35% to 48% and Plasticity Index (PI) between 16 to 19%.

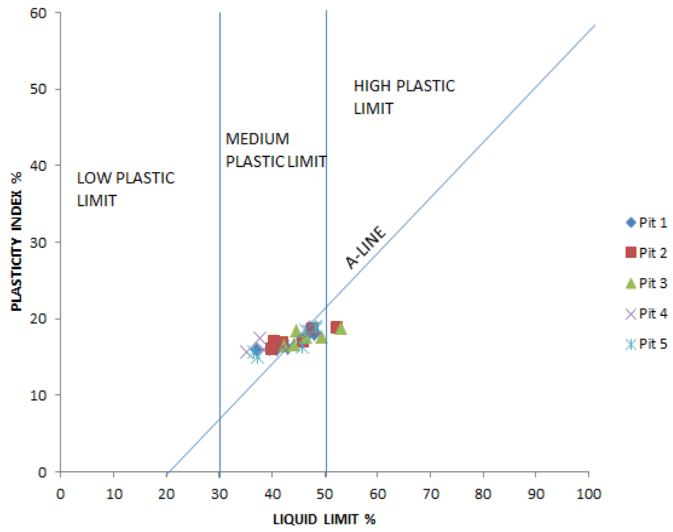

Fig 8: Casangrande chart Classification of the Soil Samples.

Most of the samples fall above the A-line Casangrande PI-LL chart, also suggesting the fines is clay with medium plasticity and medium compressibility and the soil will present good foundation material for engineering structures (Casangrande, 1948). The activities of the clays are between 0.25 to 0.72 which implies that they are normal clays and they have low swelling potential (Sivakugan, 2000).

STRENGTH AND CONSOLIDATION TEST

Triaxial Compression Test

At 1m depth, the cohesion (C) varied from 24KN/m^2 to 37KN/m^2 while the angle of internal friction (Φ) varied from 5^0 to 15^0, at 2m depth, C varied from 24KN/m^2 to 39KN/m^2 and Φ from 6^0 to 12^0 while 3m at depth, C varied from 16KN/m^2 to 40KN/m^2 with Φ varying from 5^0 to 11^0. Estimating Safe Bearing Capacity using 1 unit meter width, showed that there is a general increase from 1m depth to 2m depth which conforms to the result obtained from the cone penetration test (as the cone penetration depth barely exceeded 2m).

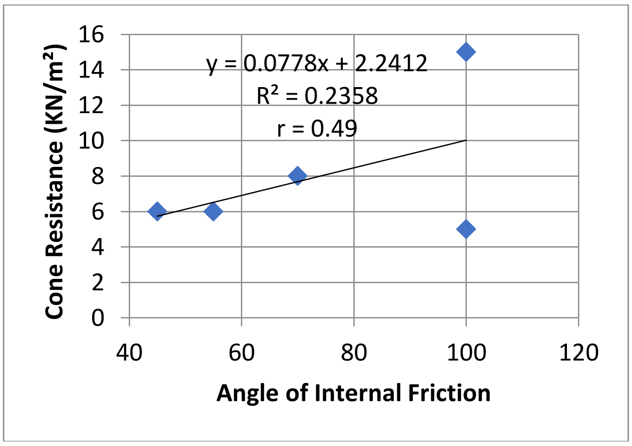

Fig. 9: Empirical Relationship between Cone Resistance and Angle of Internal Friction.

The result shows a positive relationship of 0.49 between angle of internal friction and the cone resistance from the CPT.

CONSOLIDATION PARAMETERS

The results of the Oedometer test on the undisturbed soil suggests considerably low values of the coefficient of volume compressibility (Mv) and a moderately high coefficient of consolidation (Cv). The Mv values ranges from 1.13 × 10^{-7} to 1.74 × 10^{-6} m^2/KN and the Cv values ranges from 39 to 138 m^2/year. The amounts of settlement of the proposed structure will low with no likelihood of differential settlement

RELATIONSHIPS BETWEEN GEOLECTRICAL DATA AND GEOTECHNICL PARAMETERS

A strong positive correlation of 0.72 was established between resistivity values and those Allowable Bearing Pressure (Fig. 10)

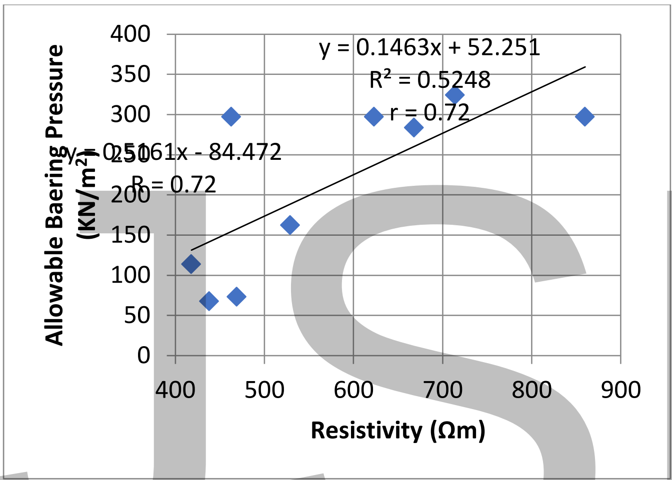

Fig. 10: Relationship between Electrical Resistivity and ABP.

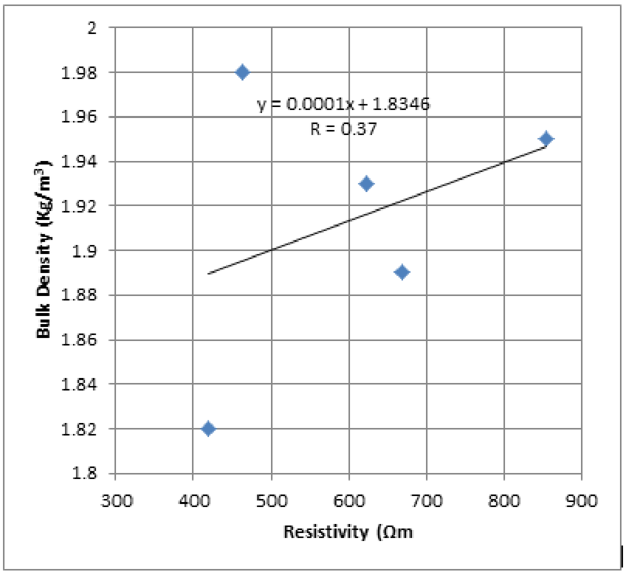

Fig. 11: Relationship between Resistivity and Bulk density

Table 1 Showing the Apparent Resistivity, Allowable Bearing Pressure and Bulk Density

Sounding Station	Depth (m)	Apparent Resistivity (Ωm)	Allowable Bearing Presuure (KN/m²)	Bulk Density (Kg/m3)
VES 1	0.5	418	113.4	1.82
VES 5	1.7	623	297	1.93
VES 6	0.5	469	72.9	
VES 7	0.4	438	67.5	
VES 9	1.5	860	297	1.95
VES 13	1.3	714	324	
VES 19	2.8	529	162	
VES 21	297	463	297	1.98
VES 25	1.8	668	283.5	1.89

Table 2 Showing Cone Resistance and Angle of Internal Friction

Cone Resistance (KN/m²)	Angle of Internal Friction
15	100
8	70
5	100
6	55
6	45

CONCLUSIONS

This work reveals that there are significant correlations between apparent resistivity and geotechnical parameters.

Results of the Cone Penetration Test (CPT) shows that the Ultimate Bearing Capacity increases with depth from 27KN/m^2 to 378KN/m^2 with a coefficient of variation ranging from 13% to 48%. It also revealed that the best depth to place the foundation with insignificant differential settlement is about 1.5m depth.

Estimating Safe Bearing Capacity using 1 unit meter width, depicts that there is a general increase from 1m depth to 2m depth which conforms to the result obtained from the cone penetration test (as the cone penetration depth barely exceeded 2m). The results of the

Oedometer test of the soil samples indicate considerably low values of the coefficient of volume compressibility (Mv) hence, low amount of settlement.

In conclusion, a foundation depth of 1.5m based on ABP and Mv values, with no likelihood of either excessive total or differential settlement was found to be suitable for the proposed structure.

RECOMMENDATIONS

This study has shown the importance of electrical resistivity survey in preconstruction investigation for structures.

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