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NEAR SURFACE GEO-ELECTRIC STUDY OF OSHOSUN VILLAGE AND ITS ENVIRONS FOR ENGINEERING PURPOSES

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ABSTRACT

The near surface investigation of Oshosun community and its environ was carried out in order to delineate the geotechnical properties of the subsurface layers in anticipation of engineering construction purposes. Integrated methods of geophysical and geotechnical techniques were deployed to characterize the nature and competence of the subsurface strata prior to construction of foundation for engineering structures. The geophysical technique employed involved 2-D Electrical Resistivity Imaging (ERI) while Standard Penetration Tests (SPT) were used as geotechnical methods. The 2-D ERI were acquired in outlined three different sites within the study area. Five traverses of 2-D ERI were established and an SPT borehole data was obtained from each site. The 2-D ERI data were processed with DiprofWin software to obtain the 2-D resistivity structure. The 2-D resistivity structure results revealed the presence of peat/clay with resistivity of 15 – 37 Ωm, clayey sand with resistivity of 37 – 57 Ωm, sandy clay with resistivity of 88 – 136 Ωm and sand with resistivity of 136 – 500 Ωm. The fourth geo-electric layer was outlined as the competent layer due to its resistive and suspected consolidated nature. The SPT borehole data showed the presence of three lithologic layers, namely; topsoil with blow count of 18 – 20, clayey sand/clayey silty sand with blow count of 2 – 5/11, sand with blow count of 10 – 15. The contrast of the 2-D ERI with SPT data revealed the same lithology within the same depth value. However, foundation studies are highly recommended in this area prior to the commencement of any engineering structures to avert loss of properties and other resources.

Keywords:

INTRODUCTION

Recently, engineering structures (such as roads, pavement and building) have been reported to collapse frequently. This menace has been ascribed to numerous factors but not exclusive to presence of low strength materials, bad design, poor supervision and use of inferior materials (Mogami and Kubo, 1953; Watermeyer and Tromp 1992; Oyedele *et al.,* 2011; Salami *et al.,* 2012; Ayolabi *et al.,* 2013). The immense hazards recorded from failed engineering structures, usually involve loss of lives and properties thereby making the cost of repairing, rehabilitating and reconstructing of failed structures to be enormous and time wasting when compared to the initial cost of construction (Ayolabi *et al.,* 2010; Amer *et al.,* 2014; Ademila, 2016). Generally, these failures are initiated through the presence of low strength materials in the foundation footings. Reports have shown that soil materials with low shear strength tends to tilt, settles, liquefy among others when there is an increased load (Adlinge and Gupta, 2010; Ademila, 2016).

The foundations of engineering structures are usually implanted within the Earth surface (Ozegin *et al.,* 2011) serving as a pillar that provide a support for the structure. The reliability of the structure (superstructure) depends on the structural integrity, the soil stiffness and high durability of the foundation. The integrity of the founding layer of the superstructure is keenly influenced by the integrity and the competence of the constituents of the sediments making the founding layer. Materials with low shear strength in the founding layer usually give rise to deformation of the superstructure in form of settlement (excessive or differential), structural failure and cracks or fracture on the completed structure (Idornigie *et al.,* 2006; Akintorinwa and Adeusi, 2009). Based on this, the foundation layer must be of the type that has uniform load transmitting ability to resist any form of settlement. Founding layer on hard bedrock/ hard soil has the ability to control any shrinkage that might arise due to fluctuation of the water level in the subsoil when compared to that on clay formation which expand and contract with water intake and ejection (Siddique and Safiullah, 1995; Whitlow, 1995; Ramamurthy and Sitharam, 2005).

Oshosun town, being the suburb of the Ifo part of Ogun State is described with sedimentary features. The study area is characterized with different forms of structural and engineering failures being attributed to the presence of soil with low shear strength. Detailed soil subsurface information during foundation studies have been mapped with use of different geophysical (Loke, 2001; Akintorinwa and Adeusi, 2009; Ayolabi, et al., 2009; Oyedele and Olorode, 2010) methods. Different researchers (Raj, 2012; Roy and Dass, 2014; Roy, 2016) has demonstrated the competence and efficacy of the geotechnical method in investigating the shear strength of soil for foundation design, earth and rock fill dam design, highway and airfield design and lateral earth pressure problems. Studies have shown that delineation of competent layer in sedimentary terrain is highly complex because of various factors involved in it. These factors are the heterogeneity of the soil, the challenge associated with the location of the water table, the drainage facility, the stress history, among others (Laskar and Pal, 2012; Akayuli *et al.,* 2013; Nwankwoala and Warmate, 2014; Ogbenero *et al.,* 2014).

The study area is sparsely populated with about two thousand people living in the area with structures such as schools, churches, health center and several petty trading shops. Oshosun village is located in Ifo Local Government of Ogun state, Southwestern Nigeria. The study area falls within geographical longitude of 07 27' 06.5'' - 07 27' 15.1'' and latitude 3 53 27.6 – 353 40.4 (Figure 1). The area is about 10km south of Abeokuta, the capital city of Ogun State. It is accessible through an untarred road that pronged from Lagos – Abeokuta Express Road. The Lagos -Abeokuta - Ibadan railway gauge pass through the study area thereby opening the it to other infrastructural activities.

The study area has the same climate and vegetation with that of Ifo which is characterized by a wet of the equatorial type. It is identified by fresh water mangrove swamps forest with a marked dry season between (November – March) and described with a daily maximum temperature of about 35^0C having the hottest months being February and March. Cool and cold nights are common, most offered during the rainy season (April - October) as well as during harmattan season (December – February). The average rainfall is about 1000 to 1500mm of rainfall (Akanni, 1992).

The study area falls within the Eastern Dahomey basin of Nigeria (Agagu, 1985, Ikhane *et al.,* 2011). The basin extends from the eastern part of Ghana to the Okitipupa/Benin Hinge. Generally, the stratigraphy of eastern margin of cretaceous to tertiary sedimentary sequence of the Dahomey Basin can therefore be divided into the following lithostratigraphic unit. The Abeokuta group, Imo group, Ilaro formation and the Coastal Plain Sands. The Abeokuta group consist of Ise, Afowo and Araromi Formations (Omatsola and Adegoke 1981). The Ise Formation is the oldest sedimentary unit in Dahomey basin and lies unconformably on the block faulted Precambrian basement complex of southwestern Nigeria (Nton *et al.,* 2006; Nton *et al.,* 2009). The Afowo formation overlies the Ise formation and the sediments are composed of interbedded sands, shales and clays, which ranges from medium to fine grained in size (Omatsola and Adegoke 1981; Ikhane 2011). It consists of sandy facies that are tar bearing around Okitipupa while the Shales are organic rich (Obaje, 2009). The next formation which is the youngest sequence in the group is the Araromi formation. The formation is composed of shales, fine-grained sand, thin interbeds of limestone clay and lignite bands (Omatsola and Adegoke, 1981; Agagu, 1985; Obaje, 2009). The Imo group comprises of shales limestones and marls and conformably overlies the Abeokuta group. Just like the Abeokuta group it also consists of Ewekoro and Akimbo formations Omatsola and Adegoke 1981. The Ewekoro Formation directly overlies the Araromi formation in the eastern Dahomey basin (Jones and Hockey, 1964). Ilaro Formation is also known as Oshosun formation. It is conformably overlying the Imo group in this basin, it's a lateral equivalent of Ameki formation in Eastern Nigeria, (Adegoke, 1969, Bowersox, 2004) and the formation was named by Jones and Hockey, 1964).

The study area which lies within the Oshosun formation is characterized with phosphate deposits, occurred as discrete bands of shales and phosphate noodles. The sediments of the gypsum appear as mud-supported gyspiferous shale with poorly consolidated sandstones up to 6 m depth calling for attention for engineering structures.

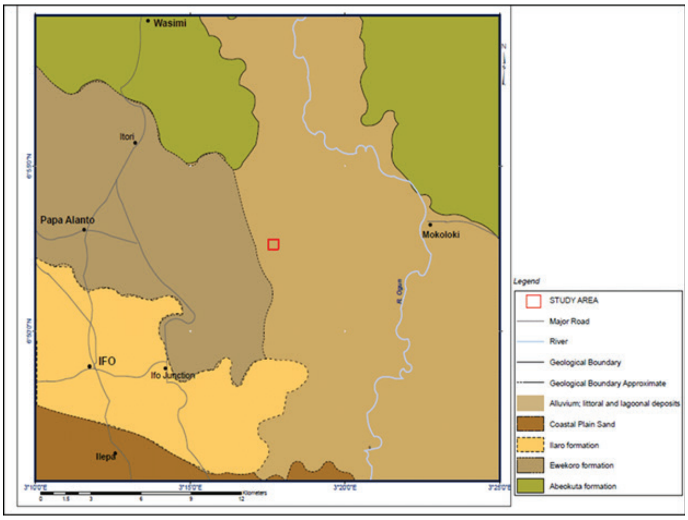

Figure 1: Location of the study area showing the geological formations (After Sanuade and Oladunjoye, 2012)

MATERIALS AND METHODS

Integrated geophysical and geotechnical methods were employed for the purpose of this study. Electrical Resistivity Imaging (ERI) using Wenner technique was used to delineated the two-dimensional imaging of subsurface information. Eighteen (18) profile lines were established within the three locations of the study area. Each profile line has horizontal distance of 50 – 60 m with the electrode spacing of 2 m (a = 2m) in order to avert the possibility of masking out any subsurface information. The Wenner array was employed with traverse length of 100 m and electrode spacing of 2 m while the Schlumberger array was used for the VES with a maximum spread of 100 m.

Borehole data was acquired through the Standard Penetration Technique (SPT) to corroborate the information obtained from the 2-D resistivity imaging. Three (3) borehole logs were drilled at strategic positions within the study areas to map out lithology with low shear strength which is inimical to engineering structures. The equipment used for the acquisition comprises of the Split Spoon Sampler, Drop Hammer, Guiding Rod, Drilling Rig and Driving Head (anvil). The test was conducted in a borehole by means of a standard split spoon sampler. Drop hammer of about 63.5kg mass was made to fall through a height of 750 mm in order to drive the sampler into the soil. The number of blows of hammer required to drive a depth of 150mm was counted. Furthermore, it was driven by 150 mm and the blows were counted. Similarly, the sampler was once again further driven by 150 mm and the number of blows recorded. The number of blows recorded for last two 150 mm intervals were added to give the standard penetration number (N).

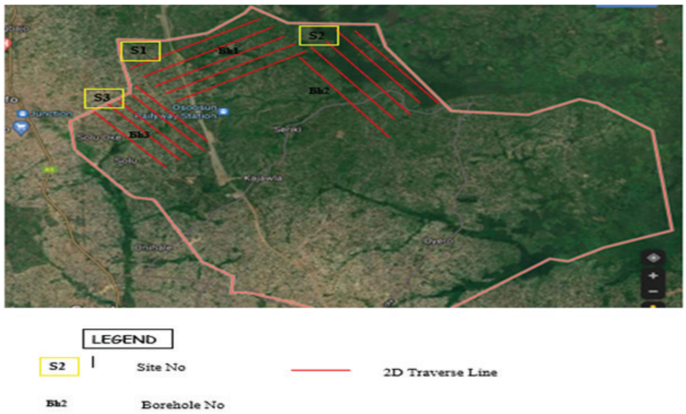

Figure 2: Basemap of the study area showing the 2D traverse lines and Borehole points.

The 2-D ERI data were analyzed and processed using the DIPRO computer software to obtain the inverted section that represents the 2-D resistivity structure of the study area. The geoelectrical layers obtained from the 2-D ERI were characterized with the lithology described by the borehole log data. The N - values measured on the field were corrected with aid of equation 3.18 for overburden pressure (CN), Hammer Energy (CE), borehole diameter (CB) sample liner, (CS) and Rod Length (CR) corrections.

$$(N_1)_{60} = N \times C_N \times C_E \times C_B \times C_S \times C_R \quad ....(3.18)$$

The corrected $(N_1)_{60}$ was further corrected for fines content based on the revised boundary curves derived by Idriss and Boulanger (2004) for cohesionless soils using equation 3.21 and 3.22

$$(N_1)_{60cs} = (N_1)_{60} + \Delta(N_1)_{60} \quad ....(3.21)$$

$$\Delta(N_1)_{60} = \exp\left[1.63 + \frac{9.7}{FC + 0.001} - \left(\frac{15.7}{FC + 0.001}\right)(N_1)_{60} \quad ....(3.22)$$

The resultant N- values obtained from the processing procedure as obtainable in eq 3.2-3.3 are used to classify the lithology with the aid of table 1.

Table 3.2: Classification of soil based on SPT 'N' value (After, Terzaghi and Peck, 1948)

SPT 'N' Value	Classification
0 - 4	Very Loose
4 - 10	Loose
10 - 30	Medium Dense
30 - 50	Dense
> 50	Very Dense

2 - D Resistivity Structure of the Study Area

Figure 3a-e presents the 2-D resistivity structure in Site 1 of the study area. The lithology delineated along this site showed the intercalation of sand, clay, clayey sand and sandy clay materials. The six profiles along this site depicts the presence of 3 geoelectric layers comprising of peat, sandy clay, clayey sand and sandy layer. The resistivity values characterized for this lithology are peat or clay (15 – 37 Ωm), clayey sand (37 -57 Ωm), sandy clay (88 – 136 Ωm) and sand (136 – 500 Ωm).

The lithological arrangement along profile 1 in this site comprises of topsoil, clayey sand and sandy layer. The second geoelectric layer is characterized as clay with resistivity value that range between 37 – 57 Ωm within a depth of 1.5 – 5.0 m. The third geoelectric layer comprises of sandy layer with resistivity values that range between 136 – 250 Ωm within the depth of 5.0 to 10.0 m. Likewise, the first geoelectric layer along the profile 2 is described with the resistivity values that range between 37 – 57 Ωm representing clayey sand. This layer is conspicuously apparent between the depth values of 0.7 – 1.7m. The 2-Dimensional resistivity imaging showed the increase in resistivity values from 88 – 136 Ωm and 136 – 324 Ωm representing the sandy clay and the sandy layer respectively.

The profiles 3 and 4 of the site 1 depict similar lithological arrangement. The topsoil of profile 4 comprises of inorganic clay materials inform of peat with resistivity value ranging from 15 – 30 Ωm with thickness of 0.5 m. The second geoelectric layer is illustrated with resistivity value ranging from 37 – 57 Ωm representing clayey sand with depth value that range between 1.5 – 2.8 m. the third geoelectric has a resistivity value ranging from 88 – 136 with depth values varying from 2.8 – 5.0 m. Some portions of profile 5 are described with 3 geoelectric layers. The profile is majorly dominated by sandy clay with bulk of clay materials. The clay materials in this profile spanned from distance 35 m from the starting point of the to the end of the profile.

The lithological arrangement along profile 6 showed the presence of topsoil materials with resistivity values that varies between 37 – 57 Ωm. Low strength materials with resistivity value that vary between 27 – 37 Ωm described as clay were delineated along the SW of the profile with horizontal progression of about 28 m (from point 4 – 32 m). While, towards the NE of the profile semi-stable materials with resistivity value that range between 57 – 88 Ωm illustrated as sandy layer was mapped. The third geoelectric layer composed of sand materials with resistivity value that range between 136 – 500 Ωm between the depth value of 3. 0 -5.0 m.

The lithological arrangement obtained in S1 of the study area unravel the distribution of the clay and sand materials in the profiled areas. The figures 3a-e showed the degree of competence of the subsurface material in each profile. The second geologic materials delineated in the site are illustrated with resistivity values that range between 54 – 136 Ωm representing clayey materials inform of peat, clay or clayey sand. This is an indicative of the presence of materials with low shear strength which are not suitable for shallow foundation of engineering structure. The third geologic layer mainly comprises of sand mixtures with resistivity value that loiters between 136 -500 Ωm. The resistivity structure showed that the competent sand materials were not evenly distributed in some profile. As a result of this, careful precautions have to be followed when selecting the choice of shallow foundation. From 3e, the profile is less suitable for any subsurface foundation exercise. The stiffness of the engineering materials decreases downward in this profile making shallow foundation footings to be impossible.

The site 2 of the study area comprises of six (6) profile lines with horizontal distance of about 50 m. The resistivity values delineated range from 10 - 500 Ωm representing the clayey and sandy materials. The resistivity values of the topsoil (mainly sandy layer) delineated in the site loiters between 88 – 500 Ωm with thickness values that range between 1.0 – 3.0 m. the materials underlying the topsoil are generally low shear strength materials. The second and third geologic materials are characterized with resistivity values that range between 24 – 57 Ωm and 10 -53 Ωm representing clayey sand and clay (peat) materials respectively. Obviously, shallow foundation for engineering structure won't be possible in this site as it contains materials with low strength.

Likewise, the site 3 of the study area which has six (6) traverses is characterized with resistivity values that range between 10 – 136 Ωm representing the peat, clay, clayey sand and sandy clay materials (Figure 4). The site was generally dominated with poor engineering materials that devoid the possibility of having shallow foundation without excavation or pilling systems. The topsoil in the site is illustrated with resistivity values that range between 17 – 57 Ωm representing clayey and clayey sand materials. The second geologic layer is characterized with resistivity values of 10 – 37 Ωm representing clay and peat materials. Similarly, the third geoelectric layer is described with resistivity values that vary 10 – 136 Ωm representing the clay peat and sandy clay materials.

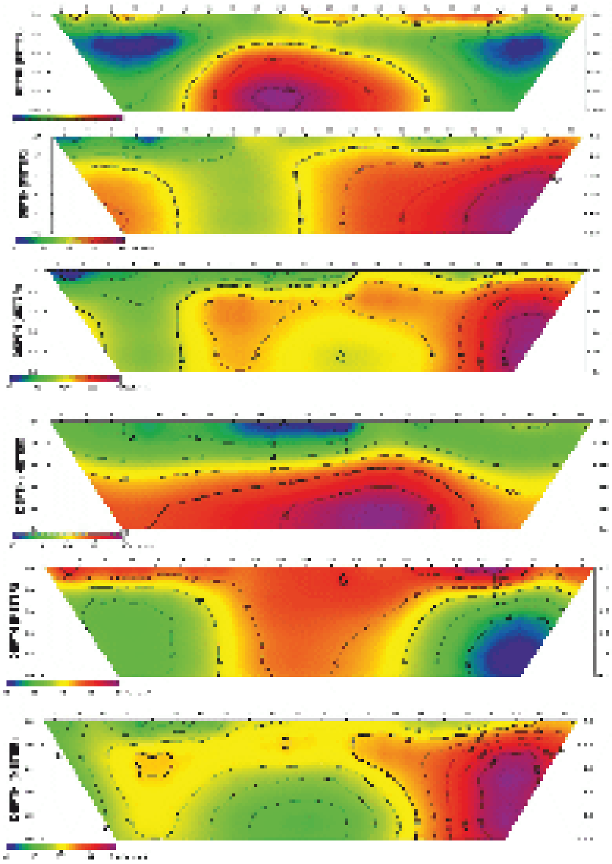

Figure 3: 2D Resistivity Structure at the Location 1 of the Study Area

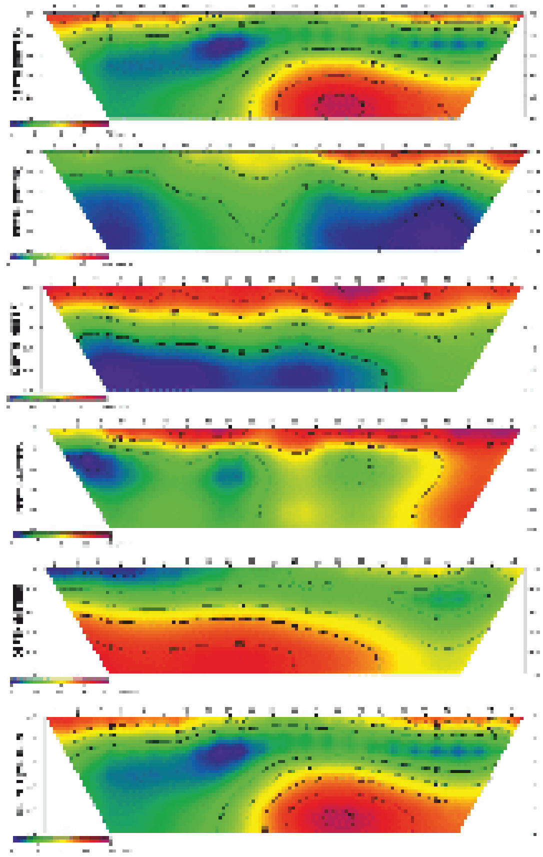

Figure 5: 2D Resistivity Structure at the Location 3 of the Study Area

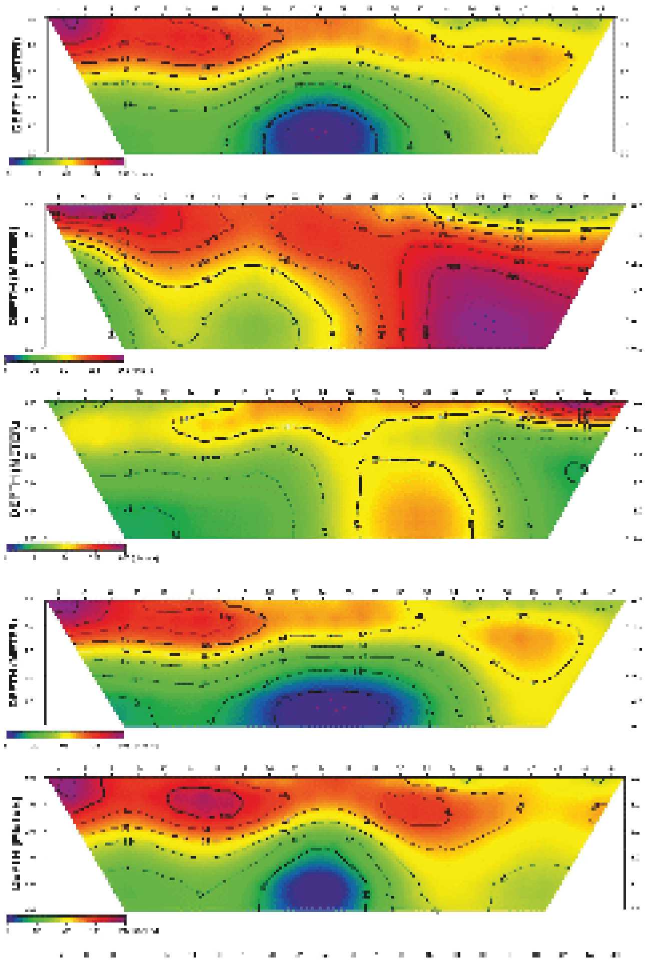

Figure 4: 2D Resisitivity Structure at the Location 2 of the Study Area

BOREHOLE LOG RESULTS

The N -values obtained from the acquired SPT data were used to plot the SPT log of the study area to depict their lithologies (Figure 6 - 8). The Figures showed the sequential arrangements of the sediments of the sounding points within the study area. The general subsoil stratigraphy that characterized the entire investigated site is found to be predominated by silts, sands and a band of fibrous peat at the upper parts. The SPT results from the Site1 (Figure 6) showed the presence of topsoil, clayey sand and sandy layer. The borehole log showed that the topsoil comprises of sediments with SPT N values of 18 – 20. The clayey sand underlain the topsoil was described with SPT "N" values that ranged between 10 and 15 within the depth of 2.00 – 5.00 m. The third geologic units in the log have SPT "N" value that range between 12 – 15 is characterized as sandy layer with the depth values of 5.00 – 15.00 m.

Subsequently, the borehole log obtained in the site 2 of the study area illustrated four (4) lithologic units comprising of topsoil, peat, clayey sand and medium dense sand. The topsoil is characterized with SPT "N" value of 18 - 20 with thickness of 1.50 m. The topsoil was underlain by fibrous organic peat with depth values that range between 1.50 – 4.00 m. This layer was underlain by clayey sand with SPT "N" values that range 2 – 4. The layer spanned between the depth values of 4.00 – 7.00 m (Figure 7) The sandy layer underlying the clayey sand are illustrated within the depth values 7.00 – 13.00 m characterized with

SPT "N" values varying from 8 – 15. The fibrous peat that represents the second lithologic units in this log symptomize incompetent layer that cannot withstand engineering structure. Likewise, the sediments characterized in the site 3 (Figure 8) comprises of three (3) lithologic units. The lithology includes the dense topsoil, clayey - silty sand and sandy layer. The dense topsoil is delineated with SPT "N" value that range between 15 - 18. The topsoil layer has the thickness value of 2.00 m. The sediments that underlie the topsoil are described with SPT "N" value that ranges between 2 – 11 representing clayey sand to silty sand spanning between depth of 2.00 – 7.00 m. the sandy layer with SPT "N" value that range between 12 – 15 were mapped between the depth of 7.00 – 14.00 m.

The presence of peat and clayey layer in the study area depicts the vulnerability of the area to engineering failure. These sediments (peat and clayey layer) are incompetent for concealment of the substructure of engineering structures. The intercalation of the clayey sand and sandy clayey described the area to be belonging to Holocene geologic age. The embolism of the peat, clayey sand and sandy clay require more attention as regards the foundation studies of the study area.

Comparisons of Lithology Obtained from 2D resistivity structure with that delineated from Standard Penetration Tests (SPT) Log

The inferred lithology obtained from SPT log and that of 2D resistivity structure were compared to obtain the true stratigraphy of the subsurface materials in the study area. This was done to draw a convincing conclusion as regards the stratigraphical arrangement of the lithology in the area. The comparisons of SPT log and 2-D resistivity values obtained from the study locations were presented in Figure 9.

The comparisons showed a good agreement between the SPT log and the 2-D resistivity structure imaging as obtained in Figures 3a-e. In Figure 9 (representing Site 1), the 2-D resistivity imaging presented the topsoil of resistivity value that range between 24 – 37 Ωm evinced with the SPT "N" values of 15 – 18 described within the same depth values. Similarly, the second geologic layer was identified as fibrous peat with resistivity values of about ~10 Ωm with no SPT "N" value, as the no blow count was recorded in the layer because of no shear strength. The third layer (clayey sand) was described with resistivity values that vary between 37 - 57 Ωm has the SPT "N" values of 7 – 11 with thickness of 4 m.

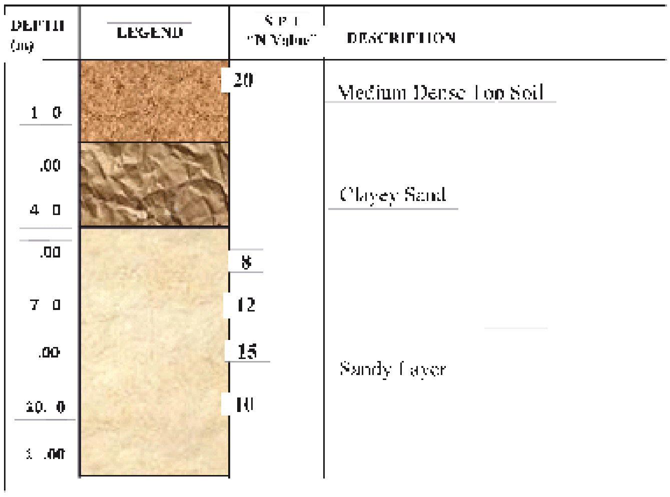

Figure 6: Lithology obtained based on SPT "N-Value" within the Site 1 of the Study Area

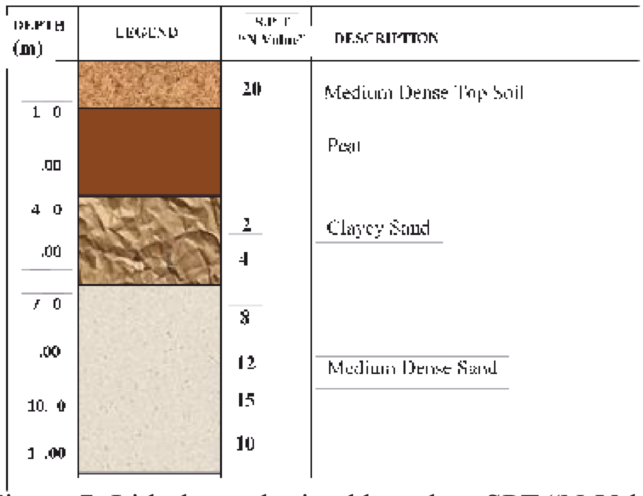

Figure 7: Lithology obtained based on SPT "N-Value within Site2 of the study Area

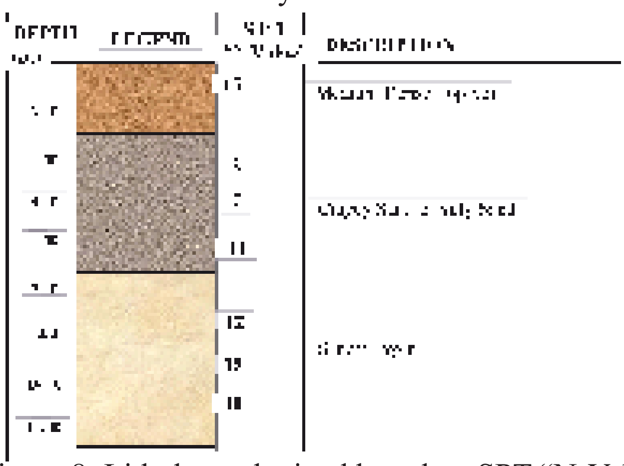

Figure 8: Lithology obtained based on SPT "N-Value within Site3 of the study Area

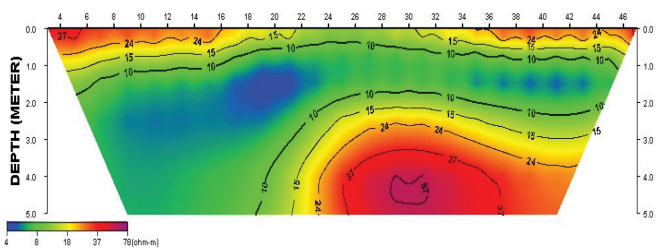

Figure 9: SPT Borehole log embedded in the 2-D resistivity structure of Site

CONCLUSION

The geophysical and geotechnical studies carried out in Oshosun to study the engineering properties unraveled the nature of the subsoils in the study area. This includes topsoil, peat, clayey sand, sandy clay, clayey layer and sandy layer with resistivity contrast of (10 – 500 Ωm). The integrated methods delineated sandy layer at the third and fourth layer at depth range of 2 – 7 m which is symptomatic to be competent layer that will give sound support to the foundation of any proposed engineering structures. It is noteworthy to state that the comparison of the results for the 2-D resistivity imaging correlates significantly with the borehole log information (SPT) obtained within the study area. However, geotechnical investigation is highly recommended prior to any construction of structures in the study area. This is due to the fact the study area consists of soil of low shear strength that require adequate study before embanking of the foundation laying.

REFERENCES

Adagunodo, T. A. (2018). Groundwater exploration in Aaba residential area of Akure, Nigeria. *Frontiers in Earth Science, 6, 66-78.*

Adegoke, O. S. (1969). Stratigraphy and paleontology of the marine Neogene formations of the Coalinga region, California. University of California Press.

Ademila, O. (2016). Application of geophysical survey for subsurface investigation of an erected multistory building in southwestern Nigeria. *international basic and Applied Research Journal, 2(12), 1-12.*

Adlinge, S., & Gupta, A. (2010). Pavement deterioration and its causes. *Journal of Mechanical and Civil Engineering, 9-15.*

Agagu, O. K., Fayose, E. A., & Paters, S. W. (1985). Stratigraphy and sedimentation in the senonian Anambra basin of Eastern Nigeria. *J Min Geol,, 2, 25-35.*

Akanni, C. (1992). Aspects of climate In: Ogun State in Maps, Onakomaya, S.O Oyesiku and J. Jegede . Rex Charles Publication, Ibadan, Nigeria. .

Akayuli, C. F., Gidigasu, S. S., & Gawu, S. K. (2013). Geotechnical evaluation of a Ghanaian black cotton soil for use as clay liner in tailings dam construction. *Ghana Mining Journal, 14, 21-26, 14, 21-26.*

Akintorinwa, O. J., & Adeusi, F. A. (2009). Akintorinwa, O. Integration of geophysical and geotechnical investigations for a proposed lecture room complex at the Federal University of Technology, Akure, SW, Nigeria. Akintorinwa, O. J., & Adeusi, F. A. (2009). Integration of geophysical and geotechnical investigati *Journal of Applied Sciences, 2(3), 241-254.*

Amer, R., Saad, A., Elhafeez, T., Kady, H., & Madi, M. (2014). Geophysical and geotechnical investigation of pavement structures and bridge foundations. *Austin Journal of Earth Sciences,, 1(1), 6.*

Ayolabi, E. A., Adeoti, L., Oshinlaja, N., Adeosun, I., & Idowu, O. (2009). "Seismic refraction and resistivity studies of part of Igbogbo township, south-west Nigeria.

Ayolabi, E., Enoh, I., & Folorunso, A. (2013). Engineering site characterization using 2-D and 3-D electrical resistivity tomography. *Earth Science Research, 2(1), 133-142.*

Ayolabi, E., Folorunso, A., & Oloruntola, M. (2010). Constraining Causes of structural failure using Electrical Resistivty Tomography (ERT): A case study of Lagos, Southwestern, Nigeria. . Mineral Wealth, Greece, 7-18.

Bowersox, J. R. (2004). Late Neogene paleobathymetry, relative sea level, and basin-margin subsidence, northwest San Joaquin basin, California. American Association of Petroleum Geologists, Annual Convention Abstracts, 13.

Idornigie, A. I., Olorunfemi, M. O., & Omitogun, A. A. (2006). Idornigie, A. I., Olorunfem Electrical resistivity determination of subsurface layers, subsoil competence and soil corrosivity at and engineering site location in Akungba-Akoko, southwestern Nigeria. Idornigie, A. I., Olorunfemi, M. O., & Omitogun, A. A. (2006). Electrical resistivity determination of subsurface layers, *subsoil competence and soil corrosivit Ife Journal of Science, 8(2), 159-177.*

Ikhane, P. R., Omosanya, K. O., & Afolabi, A. O. (2011). Stratigraphy of Imobi Southwestern Nigeria. *Research Journal Earth Planetary Study, 33-45.*

Jéquier, E., & Constant, F. (2010). Water as an essential nutrient: the physiological basis of hydration. *European journal of clinical nutrition, 64(2), 115-123.*

Jones, H., & Hockey, R. (1964). Geological survey of Nigeria. Jones HA, Hockey RD (1964) The geology of part of southwestern Nigeria. Geological survey of Nigeria.

Laskar, A., & Pal, S. (2012). Geotechnical characteristics of two different soils and their mixture and relationships between parameters. EJGE, 17, 2821-2832., 17, 2821-2832.

Loke, M. (2001). Constrained time-lapse resistivity imaging inversion. Symposium on the Application of Geophysics to Engineering and Environmental Problems 2001, EEM7-EEM7.

Mogami, T., & Kubo, K. (1953). The behaviour of soil during vibration,. 3rd International Conference on soil Mchaics and Foundation, (pp. 152-155).

Nton, M. E., Ezeh, F. P., & Elueze, A. A. (2006). Aspects of source rock evaluation and diagenetic history of the akinbo'shale eastern dahomey basin, southwestern Nigeria.

Nton, M. E., Ikhane, P. R., & Tijani, M. N. (2009). Aspect of rock-eval studies of the Maastrichtian-Eocene sediments from subsurface, in the Eastern Dahomey Basin Southwestern Nigeria. *European Journal of Scientific Research, 25(3), 417-427.*

Nwankwoala, H., & Warmate, T. (2014). Geotechnical assessment of foundation conditions of a site in Ubima, Ikwerre Local Government Area, Rivers State, Nigeria. IJERD,, 9(8), 50-63.

Obaje, N. G. (2009). The Dahomey Basin. In Geology and Mineral Resources of Nigeria , 103-108.

Oghenero, A., Akpokodje, E., & Tse, A. (2014). Geotechnical properties of subsurface soils in Warri, Western Niger Delta, Nigeria. *Journal of Earth Sciences and Geotechnical Engineering., 4(1), 89-102.*

Oladunjoye, M. A., & Sanuade, O. A. (2012502-521). Thermal diffusivity, thermal effusivity and specific heat of soils in Olorunsogo Powerplant, southwestern Nigeria. *International Journal of Research and Reviews in Applied Sciences., 13(2).*

Omatsola, M., & Adegoke, O. (1981). Tectonic evolution and Cretaceous stratigraphy of the Dahomey Basin. Niger J Min Geol. *Niger J Min Geol, 18(1), 130-137.*

Oyedele, K., Oladele, S., & Adedoyin, O. (2011). Application of geophysical and geotchnical methods to site characterization for construction purposes at Ikoyi, lagos Nigeria. *Journal of Earth Sciences and Geotechnical Engineering, 1(1), 87-100.*

Ozegin, K. O., Oseghale, A., Okolie, E. C., & Ujuanbi, O. (2011). Ozegin, K. O., Oseghale, A., Okolie, E. C Integration of very low-frequency electromagnetic (VLF-EM) and electrical resistivity methods in mapping subsurface geologic structures favourable to road failures. Ozegin, K. O., Oseghale, A., Okolie, E. C., & Ujuanbi, O. (2011). Integration of very low-frequency electromagnetic (VLF-EM) and electrical resistivity *International Journal of Environmental Engineering, 3(6), 126-131.*

Ramamurthy, T. N., & Sitharam, T. G. (2005). Geotechnical engineering. S. Chand, New Delhi.

Roy, S. (2016). Assessment of soaked California Bearing Ratio value using geotechnical properties of soils. Resources and Environment., 6(4), 80-87., 6(4), 80-87.

Roy, S., & Dass, G. (2014). Statistical models for the prediction of shear strength parameters at Sirsa, India.,. *Journal of Civil and Structural Engineering., 4(4), 483-498., 4(4), 483-498*.

Salami, B., Falebita, D., Fatoba, J., & Ajala, M. (2012). Integrated Geophysical and geotechnicaal investigation of a bridge site-A case study of a wsamp/creek environment in south-east Lagos, Nigeria. *ife Journal of Science, 14(1), 87-100.*

Siddique, A., & Safiullah, A. M. (1995). Permeability characteristics of reconstituted Dhaka clay. Siddique, A., & Safiullah, A. M. M. (1995). *Permeabili Journal of the Civil Engineering Division, the Institution of Engineers, Bangladesh., CE(23), 103-108.*

Watermeyer, R., & tromp, B. (1992). A systematic approach to the design and construction of single storey residential masonry structures on problem soils. Civil Engineer in South Africa, 34(3), 83-96.

Whitlow, R. (1995). Basic soil mechanics,. Wesley Longman Limited.