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Geophysical and Geotechnical Investigations of the Subsurface for Construction Purposes at Federal College of Education Osiele, Abeokuta, Southwestern Nigeria

Aderemi A. Alabi [1], Ridoh Lawal[1], Kafayat Hamzat[1], A. M. Olaoye[2], A. S. Ogungbe[2] and *Joseph O. Coker[3]

[1]Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria
[2]Department of Physics, Lagos State University, Ojo Lagos, Nigeria
[3]Department of Physics, Olabisi Onabanjo University, Ago Iwoye, Ogun State, Nigeria

*Corresponding author's email: coker.joseph@oouagoiwoye.edu.ng

ABSTRACT
Knowledge of the surface and subsurface structures are vital for construction procedures. Integrated geophysical and geotechnical methods were applied to image the subsurface for evaluation of the stratigraphy and the competency of each geoelectric layer for construction purposes at the Federal College of Education Osiele, Abeokuta South-western Nigeria. Nine Vertical Electrical Sounding (VES) using Schlumberger electrode configurations were conducted over a current electrode spacing of 200 m. Multi-channel Analysis Surface Wave (MASW) was the seismic technique used for the geotechnical analysis of the study area and laboratory analysis was performed to investigate, Atterberg limit, particle size distribution, compaction test, specific gravity, and California bearing ratio. Results from the geophysical investigation revealed four to five geoelectric layers: topsoil, clayey sand, sandy clay, laterite, and fresh basement. The MASW results have s-wave velocities range of 40–500 m/s and analysis showed four layers. The laboratory analysis revealed that all the ten traverses have specific gravity, which is out of limit except sample 8 which is 2.80, plastic index and Atterberg limits of liquid were within permissible values of 12% and 35% respectively except samples 9 and 10, and California Bearing Ratio within specified limits. Geophysical and geotechnical investigation of the subsurface carried out in the study area for construction purposes revealed that the foundation of a heavy structure should be targeted at around 20 m into the subsurface.

Keywords:
Electrical resistivity,
Geotechnical,
Seismic,
Subsurface.

INTRODUCTION

The increasing rate of structural failures in Nigeria which could be traced to human errors or lack of adequate investigation before construction is embark upon could halted if the necessary fundamental procedures are strictly followed (Chendo and Obi, 2015). Natural phenomena such as floods, earthquakes, heavy wind, and the state of the subsurface on which an engineering structure is to be sited are also required to be considered to mitigate against these failures. Site characterization for construction purposes has subsequently become fundamental to prevent structural failure which in turn leads to loss of lives and properties. Some broad explanations why engineering structures might be helpless to collapse include low quality of building materials, saltiness, mature age of building structures, and all other things considered as the state of the subsurface on which the engineering structures are sited (Oyedele *et al.*,2011). Site characterization involves data collection, field and laboratory investigations, analysis of data and presenting the result in the form of a map. The basic soil index and the engineering properties which are determined though in-depth exploration and could be used to detect and calculate hazard potential can be provided. Site characterization provides appropriate and dependable statistics on the site condition which helps in decision making during construction stages of projects.

Knowledge of the surface and subsurface structures are vital to the design of engineering structures and development of construction techniques. For a case where a gigantic engineering structure is to be constructed in an area, the topography and the nature of the subsurface needs to be considered. Overburden clearing, poor soil excavation, and appropriate land filling may be necessary so that the structure can be sustained by the soil. The purpose of these exploration details is to understand the engineering properties of the soils at different layers (Arora, 2008). Soil is the unconsolidated layers that cover the earth's surface and its classification for engineering purposes is very crucial. In civil engineering, the soil is seen as a material that a structure can be built on. It can serve as foundations to buildings and bridges. Tunnels, culverts, and basements can also be built in the soil while roads, runways, and dams can be built with soil (Balasubramanian, 2017). The soil has dynamic characteristics that are constantly changing (Ashraf *et al.*, 2014).

Foundation is one of the essentials parts of a structure that bears the load over a large area of soil and that the ultimate bearing capacity of the soil must not be exceeded. Soil inevitably undergoes one form of deformation or the other under the influence of the foundation load and structures. The upright settlement experience at the foundation is usually initiated by the drop in the volume of the air void ratio in the soil (Abeele, 1985; Amit, 2020). The amount of foundation settlement experience is affected by the nature of soil. Foundations that are sited on bedrock experience a minor quantity of settlement while foundations on other types of soil such as clay may experience greater amount of settlement (Poulos, 2016).

Aladejana *et al.* (2015) conducted a Geophysical and Geotechnical surveys on a proposed site in Afijio Local Government Stadium Ilora, South-western Nigeria. The degree of weathering of the soil and structural deficiency was determined using electrical resistivity survey. Based on the deprived engineering parameters of the soil and geophysical survey result, the site was declared unsuitable for the location of the stadium. It was however, suggested that Cone Penetration Testing should be done for further investigation to corroborate or otherwise of the submission.

Mundher (2016) assessed the subsoil of a proposed engineering site in the city of Bagdad by using geoelectrical and geotechnical survey. Vertical Electrical Sounding using Schlumberger array was implemented. Distributed and undistributed soil samples were collected at depth below 1m from different points and analysed in the laboratory. The integrated technique applied at the proposed site for has shown the existence of four geo-electrical sequences, which consists the mixture of clay and sand, the top soil, sandy gravel and gravely sand.

Adejumo *et al.* (2015) conducted an evaluation on subsoil of pre-foundation of a proposed site at the polytechnic of Ibadan employing geophysical and geotechnical methods. The investigation is to know the capability of the subsurface materials to host the structure. The survey included vertical electrical sounding and geotechnical laboratory analysis. The geotechnical result revealed that the soils are of low clay constituent. Thus, the subsoil in the area of study are capable of hosting foundation for the proposed structure.

Egwuonwu (2012) studied structural failure of building in three different areas in Zaria, Northern Nigeria using geophysical imaging. Seismic refraction tomography methods were adopted. Multidimentional modeling employed in the survey depicts that geophysical method can be brought nearer to their theoretical resolving power. Having shown a strong positive correlation of tomography micro-model , electrically resistivity imaging and seismic refraction have naturally mapped the near surface targets.

Adewoyin *et al.* (2017) evaluated geotechnical parameters using geophysical data. Generated Seismic wave velocities from near surface refraction were combined to acquire a comprehensive geotechnical survey. Young modulus, Bulk modulus, Bulk density, Shear modulus and allowable bearing capacity of capable layer to support structural buildings were determined. The seismic refraction showed two geological layers with the second layer being more capable, and this result was also confirmed by the geotechnical method, therefore establishing a correlation between the depths mapped by the two methods. P–waves velocities can be employed to detect the geotechnical parameters of a site that can be easily used to characterize its subsurface conditions.

Alabi *et al.* (2017) employed Geophysical and Geotechnical methods, adopting Vertical Electrical Sounding to performed site characterization for the purpose of building construction at Federal University of Agriculture Abeokuta, Ogun state, Nigeria. Laboratory analysis were performed to study particle size, Compaction limit, Atterberg limit, specific gravity and California bearing ratio. The investigations was effective in characterizing the subsurface material that lie beneath the surface and the depth to the bedrock. The results revealed that the area is capable of hosting both shallow and deep foundations, except at two VES points, where reinforcement is needed to hold shallow and deep foundations.

Knowledge of the subsurface lithology is significant to pre-determine types of engineering structures each sections of the land can withstand and excavation or reinforcement that may be required to support civil engineering structures therefore prolonging the lifespan of the engineering structures without endangering lives and properties. The aim of this study is to employ the geophysical and geotechnical techniques to examine the subsurface structure of a proposed site at Federal College of Education Osiele, Abeokuta, Ogun State, to ascertain the suitability of hosting engineering structure or determining the appropriate reinforcement or depth of foundation needed for hosting civil engineering structure in heterogeneity subsurface, without posing danger.

MATERIALS AND METHODS

Geomorphology and Location of the study area

The site investigated is within the Federal College of Education Osiele, Abeokuta Ogun State, Nigeria and is located between latitude 70 8′ 16.9″ to 70 8′ 24″ and longitudes 30 17′ 9.2″ to 30 17′ 13.4″ (figure 1). The study area falls under the Basement Complex area of Ogun State, Southwestern Nigeria. The basement rocks in the area are a composition of folded gneiss, schist, quartzite, older granite, and amphibolites/mica schist (Badmus and Olatinsu, 2010). The presence of basement rocks makes the area suitable for engineering construction. The study area is characterized by wet and dry seasons. The wet and dry season occurs from March to October and November to March respectively.

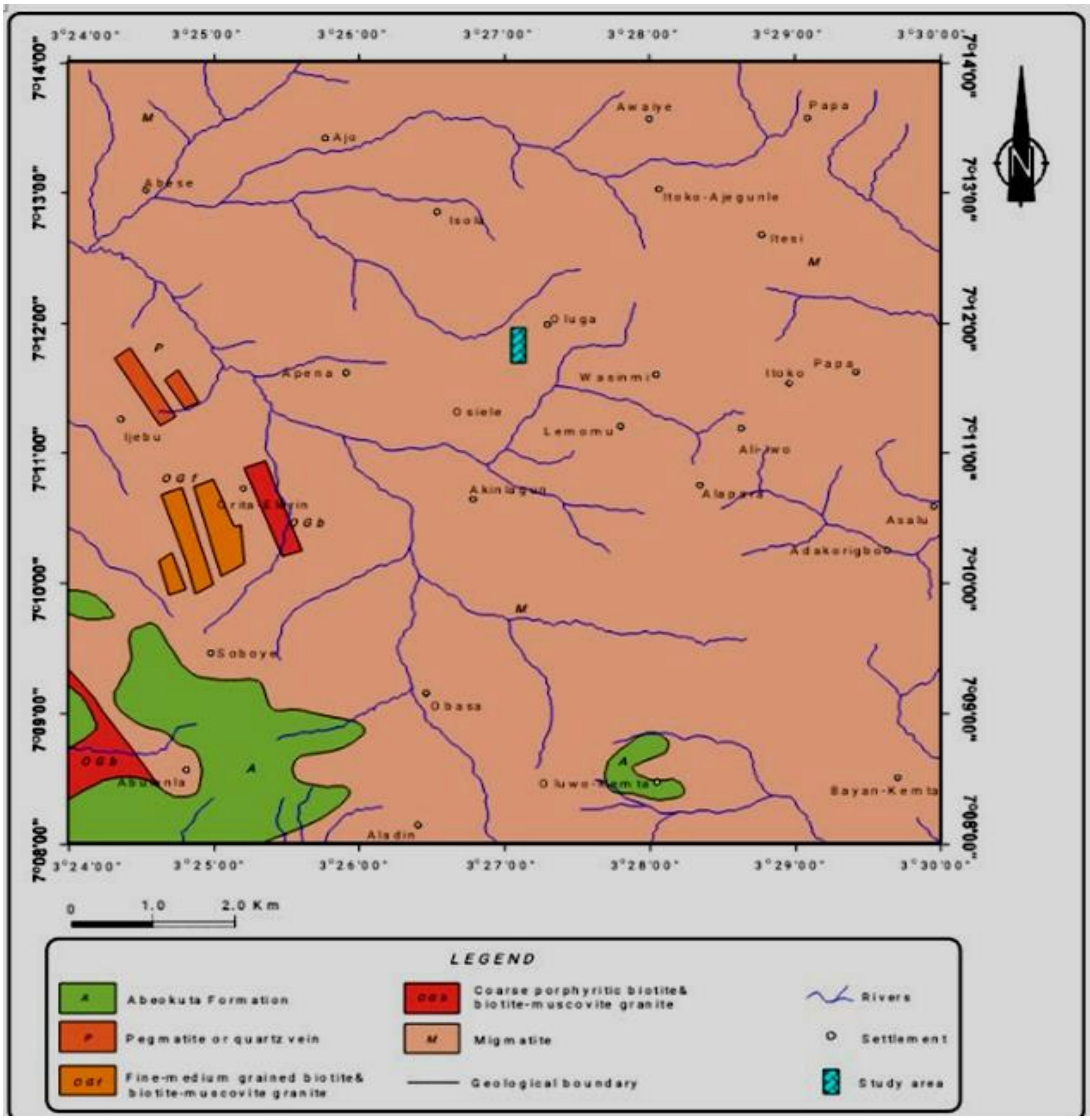

Figure 1: Geological map of the study area

Electrical Resistivity Method

Electrical resistivity investigation of the subsurface can be carried out using an electrical apparatus with a couple of current and potential electrodes each. Electrical current is injected into the current electrodes whose potential difference is measured on the potential electrodes kept in line on the surface. The electrodes spacing is progressively expanded to obtain the corresponding resistivity values which can be used to estimate the electrical profile of the subsurface under investigation. The field is distributed near the surface at a very close electrodes spacing while the electrical flux streams deeper into the subsurface at larger electrodes spacing. The electric flux crowd into a more conductive layer and will become less dense in the more resistive layers. The potential at the surface mirrors the path differences and data set for determine an electrical profile model of the subsurface was obtained. Electrical resistivity can be applied in: lithology investigation, landfill evaluation, fault problem finding, contamination plumes identification, tunnel or cavern mapping, groundwater exploration, and so on.

The essence of Vertical Electrical Sounding is to expand electrodes spacing from a fixed center and as the spacing is increasingly large, deeper penetration of electricity is achieved into the sub-surface (Reynolds, 1997; Mosuro *et al.*, 2011). In Schlumberger type of array (Figure 2), the potential electrodes at M and N remain fixed (Figure 2), while the current electrodes at points A and B are adjusted to vary the separation (S). The potential electrode spacing likewise needs to be adjusted when S increases to a point where the potential difference becomes very low due to a decreasing sensitivity in measurement (Keller and Frischknecht, 1966).

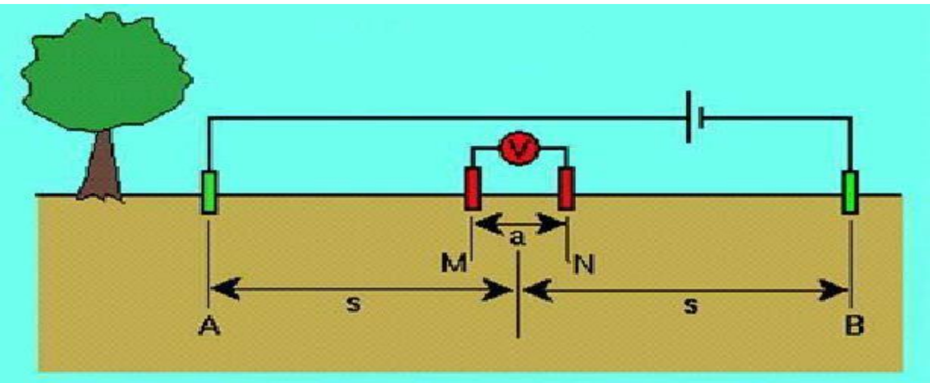

Figure 2: Electrode Configuration of Schlumberger array (Abdullahi, 2017)

The principle used in the resistivity method of geophysical survey is centred on Ohm's law (V=IR). The potential difference (V) is measured in volts for a linear element. The electrical current (I) is measured in amperes and resistance (R) in ohms. Considering a current (I), passing through a unit cube of the earth with side length L at opposite sides. The three-dimensional resistivity which has the dimensions of ohms multiply by length is given by Equation 1 and the unit is written as ohm-meter (Gary, 2004).

$$R = \frac{V}{I}(L * L)/L \quad (1)$$

Resistivity surveys do not usually seek to determine the resistivity of some uniform rocks rather it is used to determine the apparent resistivity (ρa) which is the resistivity of an electrically homogeneous and isotropic half-space that would produce the measured relationship between the applied current and the potential difference for a particular electrodes spacing and arrangement (Telford *et al.,* 1990). Mathematically, apparent resistivity is the product of the measured resistance, R and geometric factor (Equation 2) and having the units of Ohmmetre (Ωm). The geometric factor (G) is a function of the electrode spacing and configuration given by Equation 3.

$$\rho_a = GR \quad (2)$$

$$\rho_a = 2\pi G \frac{V}{I} \quad (3)$$

$$G = \pi \left(\frac{s^2 - \left[\frac{a}{2}\right]^2}{a} \right) \quad (4)$$

where: ρ_a is apparent resistivity for Schlumberger array; G is the geometric factor; S is half current electrode spacing in metres and $\frac{a}{2}$ is half potential electrode spacing in metres.

Seismic refraction method

The seismic refraction method was applied in the study with a multi-channel analysis surface wave (MASW) technique that uses a Split-Spread arrangement. The technique provides detailed information about the geomechanical properties and the layering structure of the subsurface. An active technique was employed in the study to obtain a shear wave velocity data with 24 geophones. The geophones were placed vertically on the ground at 2 m spacing and a 15 kg sledgehammer was used to generate surface waves which are measured by a seismograph. Five shots were carried out at an offset distance of 1, 7, 14, 19, and 23 m from the first geophone. Five time-stacking was adopted to improve the signal-to-noise ratio (SNR) and are termed the offset, quarter spread, mid-spread, three-quarter spread, and off-end shots. The multiple shots along the traverse were done to achieve suitable coverage of the refractor surface and provide sufficient lateral resolution (Awelia *et al.*, 2018). The seismic waves produced by this shot went down along diverse refractor boundaries to produce refracted energies which are detectable by the geophones (Ibrahim, 2014). The Acquired MASW data were processed and interpreted using Seismic imager and Pickwin software to obtain the shear-wave velocity. This method is applied to determine the competence of each subsurface layer, its depth and its strength for construction purposes. The seismic refraction and the electrical resistivity were conducted on the same traverses to give room for comparison of the results.

Geotechnical techniques

Geotechnical techniques were employed to obtain facts on the physical properties of soil earthworks and the underlying rock. It is used to determine the physical, chemical and mechanical properties of the soil, which are relevant to the quality or otherwise of the foundation of construction work to be carried out (Oyeyemi, *et al.*, 2017). The geotechnical technique entails the review of the material properties and site investigation of soil, rock, bedrock properties and fault distribution. The site investigation takes into consideration both the surface and the subsurface properties of the site where construction is to take place. It includes the evaluation of the threat of the construction to property, environment and human beings. The risk can either be human-induced or natural hazards such as earthquakes, flooding, landslides, ground stability and rockfalls (Soupios, *et al.*, 2007). The geotechnical properties of soil that is of interest to this study include Atterberg limits, Shear strength, Particle size analysis, Compaction Test, Specify gravity, and Permeability. The geotechnical procedure include collection of 30 kg soil samples at a depth of 1 m below the surface from ten different sampling points. The samples were subjected to laboratory tests analysis to study the physical properties of the soils like; California bearing ratio (CBR), particle size distribution, Atterberg Limit, compaction, and specific gravity.

RESULTS AND DISCUSSION

Results of Electrical Investigation Method

The Vertical Electrical Sounding results showed that the subsurface is of diverse materials. Four to five geoelectric layers were revealed which are topsoil, clayey sand, sandy clay, laterite, and fresh basement. The geo-materials that are known to be appropriate for construction are sand and sandy clay due to their low compressibility ability and high shear strength potential (Adewoyin *et al.,* 2017). These geologic formations were found at a depth range of about 10 m – 32.6 m across the study area. The curve type reflecting the lithological variations with depth ranges from H, HA, KH, KQH, AKH, and KQH of which HA is the most prominent. The quantitative and qualitative interpretation of the curves were shown on Table 1.

The geoelectric sections of VES 1,2,3,4 and 9 showed three to four geoelectric layers (Figure3). The topsoil has resistivity value ranging from 60.6 - 375.5 Ωm with thickness varying from 0.7 - 5.5 m. The second layer displays sandy clay with layer thickness between 17.9 - 36.5 m and resistivity values between 72.2 and 142.6 Ωm. The third bedrock layer in VES 4 is characteristic of fractured/fresh basement with layer thickness that could not be established because the current ended within this stratum with resistivity value of 172.0 Ωm. The same third layer on VES 1, 2, 3, and 9 depicts partly weathered/fractured basement with a layer thickness range of 28.8 - 48.79 m and resistivity value within the range of 26.8 - 86.0 Ωm. The fourth layer in VES 1, 2, 3, and 9 show the existence of fractured/fresh basement having resistivity value of 3583 – 12875 Ωm. The thickness was undetermined because the current terminated within this stratum.

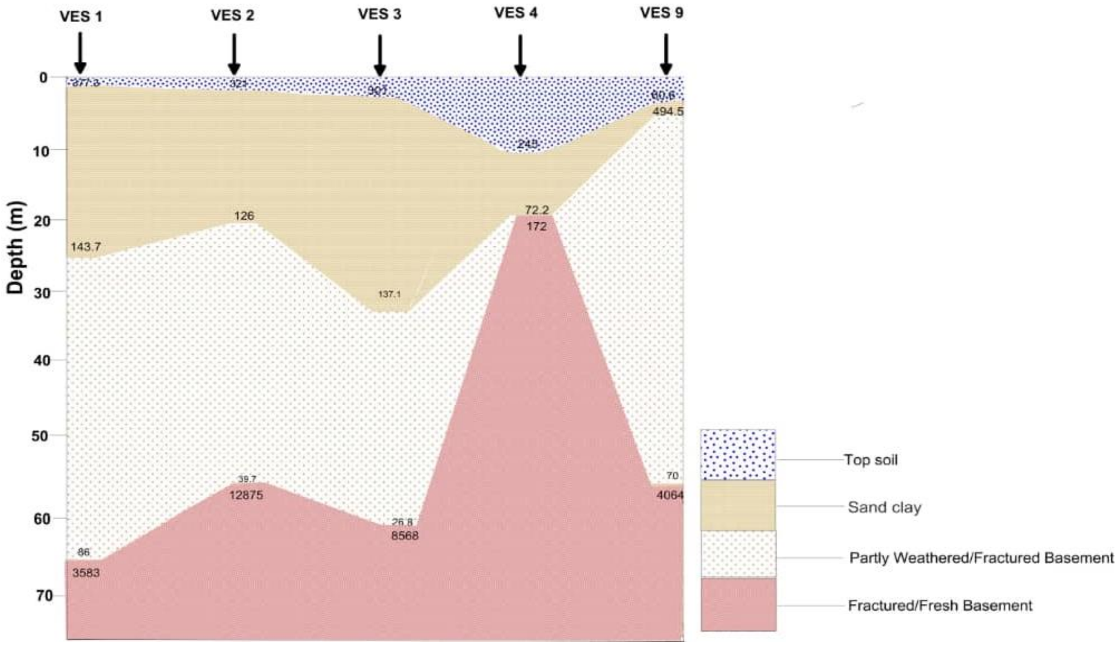

Figure 3: Geoelectric sections along VES 1,2,3,4 and 9.

Table 1: Summary of the results of the VES

VES	Location	Layers	Resistivity (ρ)	Thickness (m)	Depth (m)	Inferred Lithology	Curve Type
	Lat	1	375.5	0.54	0.54	Topsoil	
	07^{0}11’43.9”	2	142.6	20.04	20.58	Sand clay	
1		3	86.0	48.79	69.37	Clayey sand	HA
	Long					(Weathered)	
	003^{0}27’04.1”	4	3407.3	-	-	Fractured basement	
	Lat	1	321.0	0.7	0.7	Topsoil	
	07^{0}11’43.9”	2	126.0	20.2	20.9	Sand clay layer	
2	Long	3	39.7	36.5	57.4	Clayey sand	HA
	003^{0}27’02.5”	4	15065.0	-	-	Fresh basement	
	Lat	1	301.3	1.1	1.1	Topsoil	
	07^{0}11’43.8”	2	137.1	31.5	32.6	Sand clay layer	
3		3	26.8	28.8	61.4	Clay (Weathered)	HA
	Long	4	8568.8	-	-	Fractured basement	
	003^{0}27’02.9”						
	Lat	1	254.0	5.5	5.5	Topsoil	
	07^{0}11’44.0”	2	72.2	17.9	23.4	Clayey sand	
4		3	172.0	-	-	Fractured basement	H
	Long						
	003^{0}27’05.4”						
	Lat	1	257.5	0.9	0.9	Topsoil	
	07^{0}11’44.1”	2	815.6	1.4	2.3	Laterite	
5		3	82.8	8.3	10.6	Clayey sand	KQH
	Long	4	22.4	11.9	22.5	Clay (Weathered)	
	003^{0}27’06.4”	5	6920.2	-	-	Fresh basement	
6	Lat	1	99.2	0.4	0.4	Topsoil	AKH

	07^{0}11’41.36”	2	34.0	1.1	1.5	Clayey sand layer	
		3	214.8	2.1	3.6	Sand clay layer	
	Long 003^{0}27’08.85”	4	48.4	6.4	10.0	Clayey sand (Weathered)	
		5	666.0	-	-	Fractured basement	
	Lat	1	61.5	0.5	0.5	Topsoil	
	07^{0}11’41.37”	2	527.0	0.5	1.1	Lateritic soil	
7	Long	3	184.0	13.8	14.9	Sand clay	KQH
	003^{0}27’07.55”	4	41.5	14.9	29.7	Clayey sand	
		5	39939.0	-	-	Fresh basement	
	Lat	1	110.0	1.4	1.4	Topsoil	
8	07^{0}11’43.9”	2	267.0	8.3	9.7	Lateritic soil	
		3	91.4	15.9	25.6	Sand clay (Weathered)	KH
	Long 003^{0}27’02.5”	4	4146.0	-	-	Fractured basement	
	Lat	1	60.0	1.4	1.4	Topsoil	
	07^{0}11’43.95”	2	494.5	2.3	3.6	Lateritic soil	
9		3	70.0	53.3	57.0	Clayeysand (Weathered)	KH
	Long 003^{0}27’02.55”	4	4064.0	-	-	Fractured basement	

The second geoelectric section of close sounding points is four to five geo-electric layers, which comprises: VES 5, 6, 7, and 8 (Figure 4). The topsoil is depicted by resistivity values between 61.5 and 257.5 Ωm with thickness varying from 0.4 - 1.4 m. The second identified layer depicts lateritic clay having layer thickness between 0.5 - 8.3 m with resistivity values ranging from 34.0 - 815.6 Ωm. The third substratum layer suggests a weathered layer having a layer thickness of 2.1 - 15.9 m with resistivity value ranging between 82.8 -214.8 Ωm. The fourth layer in VES 5, 6, and 7 show the presence of partly weathered/fractured basement having a resistivity value of 22.4 - 48.4 Ωm with a layer thickness of 6.4 -14.9 m. The same layer in VES 8 depicts a fresh basement with a resistivity value of 4146 Ωm. The thickness was undetermined since the current terminated within this stratum. VES 5, 6, and 7 revealed the fifth layer to be a fresh basement with resistivity values varying between 666 – 39939 Ωm and the thickness extends to infinity.

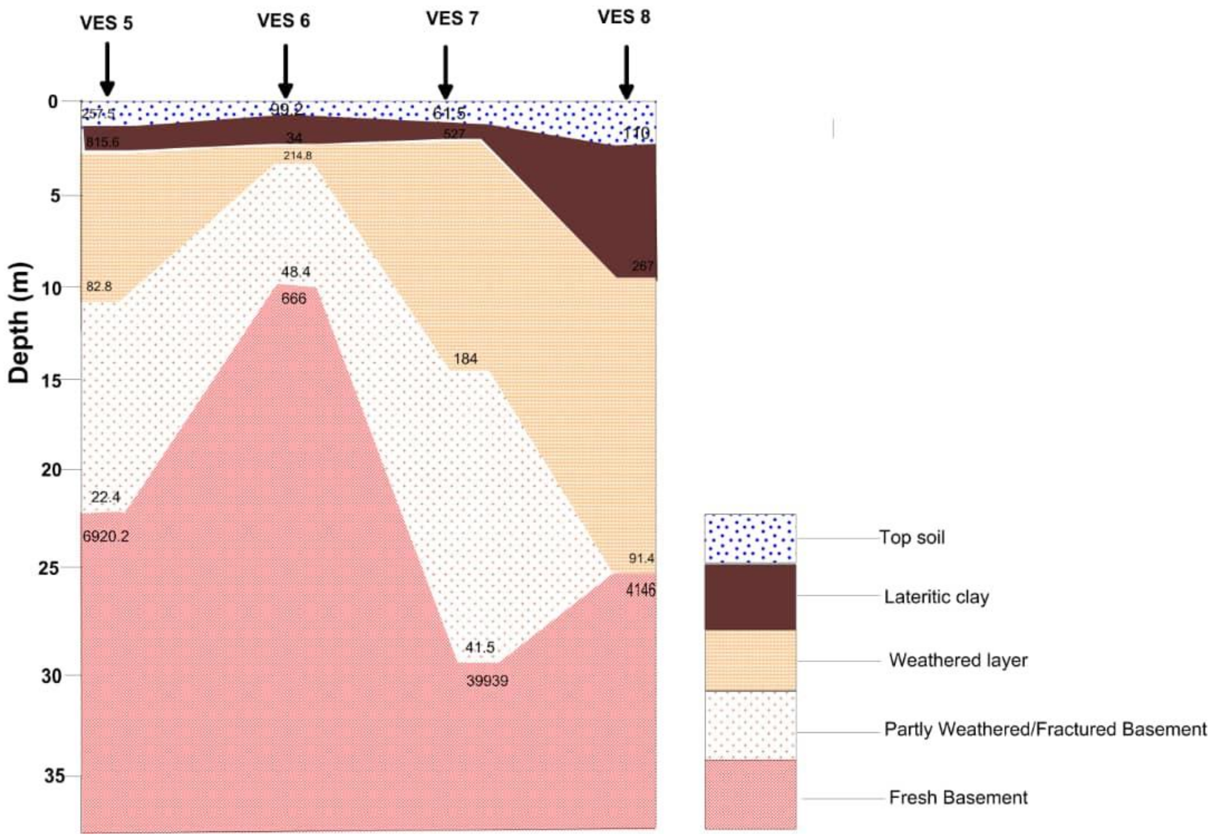

Figure 4: Geoelectric sections along VES 5, 6, 7 and 8

Results and Interpretation of Seismic Investigation

The seismic refraction technique outlined four layers at the study site (Figure5) and the values of both primary and secondary wave velocities for each profile were used to evaluate the engineering and physical properties of the subsurface. The first layer is dominated by unsaturated sand while the underlying layers, which are assumed to be sandy/ lateritic clay as inferred from the geology of area. The results of the MASW data analysis over a spread of 100 m showed that the value of the s-wave velocities was ranging between 40 – 500 m/s.

The s-wave velocity on profile 1 (Figure 5) ranges from 180 – 320 m/s with a maximum thickness of 7 m for the topsoil and another layer ranging from 150 – 200 m/s within the depth of 7 – 14 m. The third layer was between the depth of 14 – 19 m with an s-wave velocity ranging from 180 to 280 m/s and the fourth layer occupies the space between 19 and 25 m with an s-wave velocity ranging from 180 to 320 m/s.

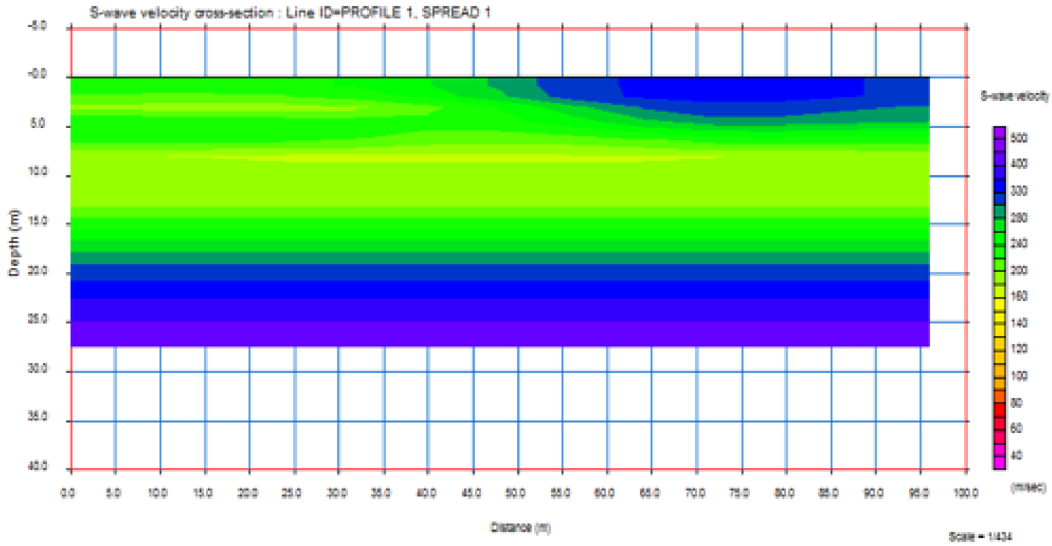

Figure 5: 2 D imaging for MASW profile 1.

The topsoil on profile 2 has S-wave velocity ranging from 160 – 200 m/s at depth 0 – 2 m (Figure 6). The second layer S-wave velocity ranges from 100 – 150 m/s at depth 2 – 8 m while the third layer was at depth 8 – 15 m with the S-wave velocity ranges from 50 – 90 m/s. The fourth layer has S-wave velocity ranging from 120 – 140 m/s at the depth of 15 – 19 m. The profile 2 data analysis revealed five layers. The S-wave velocity of the fifth layer ranges from 160 – 250 m/s between the depths of 19 – 25 m.

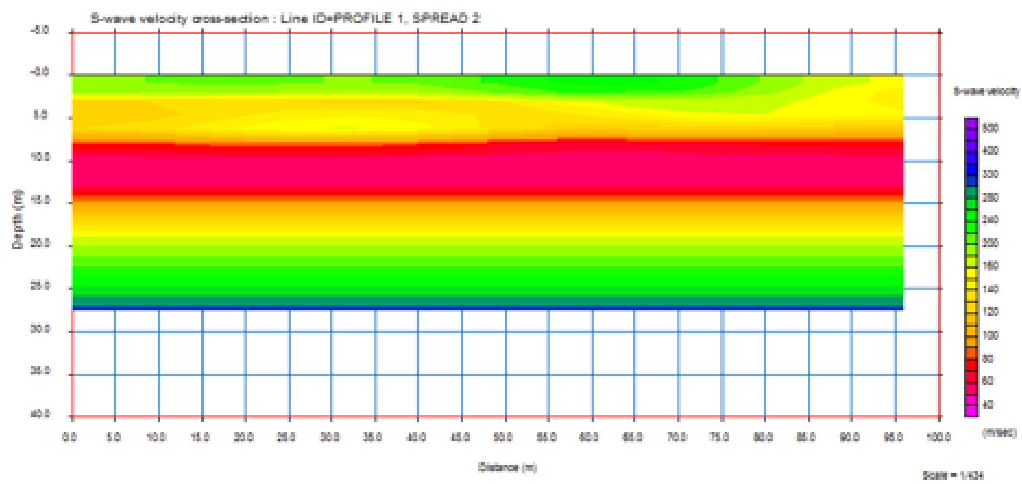

Figure 6: 2 D imaging for MASW for profile 2

On profile 3, the topsoil has S-wave velocity ranging from 180 – 220 m/s at depth 0 – 3 m. The second layer occurs at depth 3 – 7 m with the S-wave velocity ranging from 120 – 140 m/s. The S-wave velocity of the third layer ranges from 100 – 130 m/s at depth 7 – 16 m (Figure 7). The fourth layer was at depth 16 – 25 m with the S-wave velocity ranging from 190 – 290 m/s.

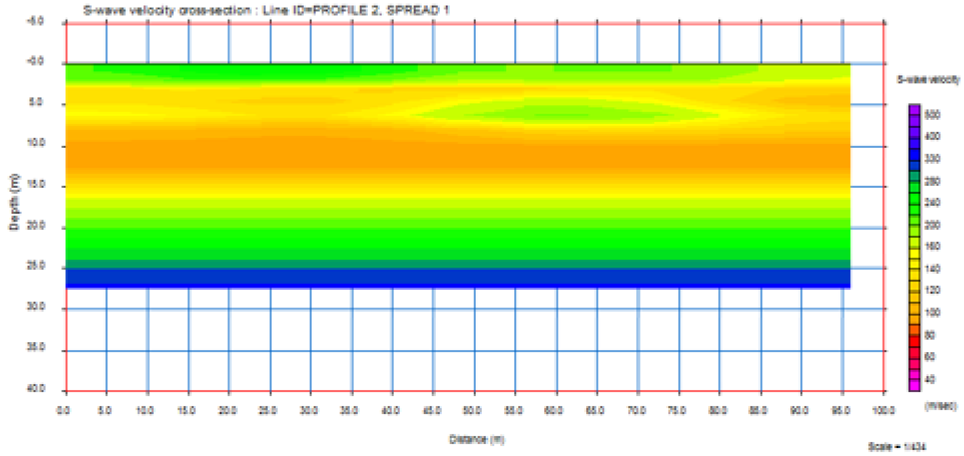

Figure 7: 2 D imaging for MASW profile 3

The topsoil on profile 4 has S-wave velocity ranging from 140 – 300 m/s at depth 0 – 8 m and the second layer has S-wave velocity ranging from 100 – 140 m/s at depth 8 – 14 m (Figure 8). The third layer occupies at space within 14 – 20 m with the S-wave velocity ranging from 180 – 250 m/s. The fourth layer was at a depth of 20 – 25 m with the S-wave velocity ranging from 290 – 400 m/s.

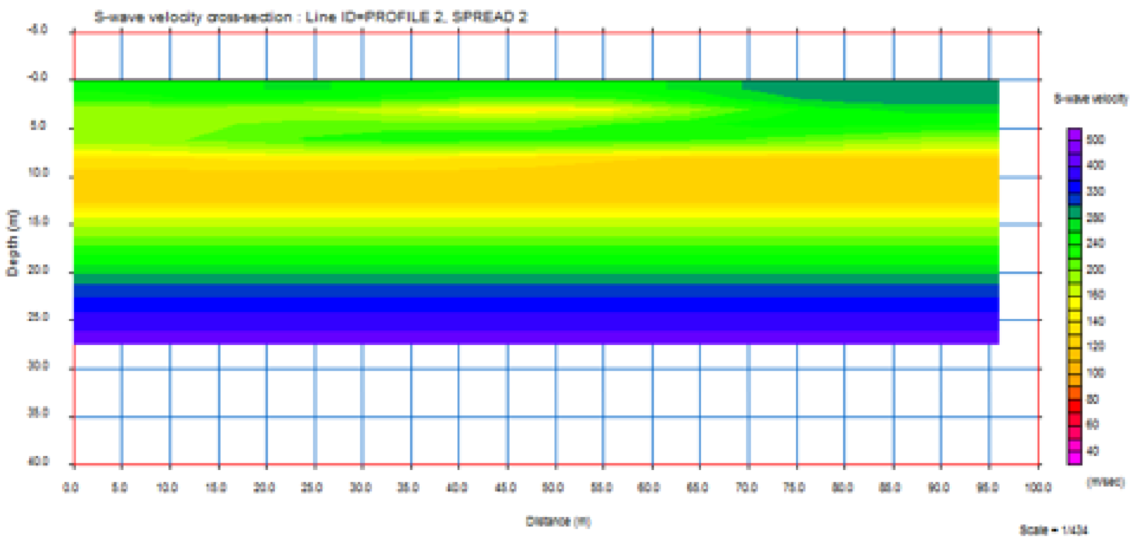

Figure 8: 2 D imaging for MASW Profile 4

On profile 5, the S-wave velocity of the topsoil ranges from 200 – 280 m/s to a depth of 3 m into the subsurface. The second layer was at depth 3 – 9 m with the S-wave velocity ranging from 130 – 240 m/s. The S-wave velocity of the third layer ranges from 180 – 250 m/s at depth 9 – 18 m and the S-wave velocity of the fourth layer ranges from 190 – 400 m/s at depth of 19 – 25 m (Figure 9).

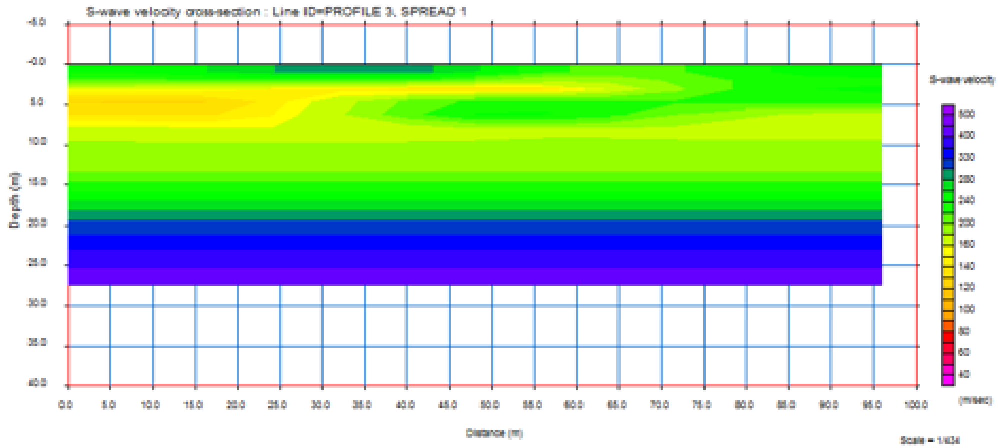

Figure 9: 2 D imaging for MASW Profile 5

Geotechnical Analysis

The parameters employed in evaluating the competence of the subsurface soil measured both lateral and vertical competence of the subsurface. The density of the subsurface soil revealed higher value at both the top and bottom of the investigated profiles. The density of the topsoil to about 1 m below the surface ranges from 1.798 to 1.811 g/cc while the highest density of a range 1.831 to 1.877 g/cc was obtained at the depth of 20 m across the area. The density of the geo-material in between the topsoil and the fourth layers is lower which makes the fourth layer most competent for construction purposes. The average Young's modulus peaks at the fourth layer of profile 1 (0.636 MPa), profile 2 (0.552 MPa), profile 3 (0.480 MPa),and at the topsoil of profile 4 (0.552 MPa), profile 5 (0.364MPa). The fourth layer of profiles 1 to 5 has the highest average bulk modulus: 4.988, 4.534, 4.257, 4.708, and 4.936 respectively. The average shear modulus has the highest values at the fourth layer of profile 1 (0.216 MPa), profile 2 (0.187 MPa), profile 3 (0.163 MPa), and profile 4 (0.263 MPa). The topsoil at profile 5, however, has the highest average shear modulus of 0.123MPa. The fourth layer of profiles 1 to 5 has the lowest mean plastic index of 0.4965, 0.5103, 0.5154, 0.5031, and 0.4980 respectively.

Compaction Limit Test

The results of the compaction limit test showed that the Maximum Dry Density (MDD) for the soil samples ranges from 1680 to 2025$kgm^{-3}$and the Optimum Moisture Content (OMC) ranges from 9.5 to 16.16%. The MDD results of all the tested samples were within the requirement of not less than 1680 kgm^{-3} and OMC is expected to less than 18% for effective competence (FMWH, 2000). It has been established that the density and the strength of the soil affects one another (Wu, 2013). The strength of soil typically increases with increasing in dry density. Dry density refers to the mass of solid particles in a given volume of soil without considering the presence of water. When the dry density of soil increases, it means there is a higher concentration of solid particles, resulting in greater interlocking and cohesion between the particles. This leads to an increase in soil strength.

On the other hand, higher soil densities also mean reduced air voids or air spaces within the soil mass. This reduced presence of air space can limit the soil's ability to absorb or retain water. When soil has limited air voids, it becomes less permeable to water, decreasing its potential to take in more water at later times.

The in-place moisture content of soil, which refers to the amount of water present in relation to the soil's total mass, is useful in determining the suitability of soil for various applications. Increase in moisture content of soil will generally decrease its strength. This is because excess water fills the void spaces between soil particles, reducing interparticle friction and cohesion, which are essential for soil strength.

Moreover, higher moisture content can lead to increased potential for deformation and instability. Excess water causes the soil particles to become lubricated, reducing their ability to resist shear forces. This can result in soil settling, increased compression, and even slope failures or landslides in some cases.

It's important to note that the relationship between soil strength, moisture content, and density is a complex interplay that is governed by various elements like; soil type, particle size distribution, and mineralogy. It is essential to consider these factors when assessing the suitability of soil for different engineering and construction purposes.

Specific Gravity Test

The specific gravity of the soil is affected by the amount of sand in a collected sample which also governed by manner of formation and mineral constituents of the soil. According to clause 6201 of the Federal Ministry of Works and Housing (FMWH, 2000) Specification, the specific gravity of a good lateritic material should range between 2.5 and 2.75. The specific gravity of the ten Soil samples collected are; 2.50, 2.05, 2.53, 2.43, 2.50, 2.50, 2.40, 2.80, 2.50, and 2.50 respectively. Only sample 8 showed distinctive good lateritic materials as it exhibits specific gravities of 2.80. The higher specific gravity value especially towards the upper limit of the standard of the soil supports construction and engineering works (Gidigasu, 1976).

Atterberge Limits for Soil Samples

According to Federal Ministry of Works and Housing (2000) Specification Requirement in clauses 6201 and 6252, material passing the 425µm sieve shall have a liquid limit of not more than 35% and a Plastic Index (P.I) of not more than 12% as determined by American Society for Testing Materials Method (Quadri*et al.*, 2012). The collected soil samples 1 to 8 have the liquid limit and the plastic index below 35% and 12 % respectively. However, the values of samples 9 and 10 exceeded the specification requirement.

California Bearing Ratio Test

According to clause 6201 of Federal Ministry of Works and Housing (1997) Specification Requirement, the minimum strength of base course material is expected to be more than or equal to 80% C.B.R for unsoaked material while minimum strength of material shall be more than or equal to 10% after at least 48 hours soaking. The results of the C.B.R. test revealed that the collected samples have CBR values for soaked materials ranging from 1.77 – 8.51% and the CBR values for unsoaked materials range from 1.95 – 9.35%.

CONCLUSION

Comprehensive geophysical and geotechnical investigations of the subsurface for construction purposes at the Federal College of Education Osiele, Abeokuta Ogun State have been carried out and the results delineate a maximum of five geo-electric layers which include topsoil, clayey sand, sandy clay, laterite, and fresh basement rock. The geoelectric section revealed that the second layer of VES 1,2,3,4 and 9 are occupied with sandy clay and are not proper for heavy construction but can only be withstand buildings that require shallow foundations without reinforcement. The Atterberg limits obtained from collected soil samples 5, 6, 7 and 8 confirmed that the second layer of VES 5,6,7 and 8 are filled with lateritic clay with low plastic index and moderate liquid limit which may be desirable for a foundation with minimal reinforcement. Geophysical and geotechnical investigation of the subsurface carried out in the study area for construction purposes revealed that the foundation of a heavy structure should be targeted at around 20 m into the subsurface.

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