GEOPHYSICAL AND GEOTECHNICAL CHARACTERIZATION OF A RECLAIMED LAND FOR CONSTRUCTION PURPOSES IN LAGOS NIGERIA (A CASE STUDY)

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ABSTRACT: *Near-surface seismic refraction and electrical resistivity methods were used to characterise the subsurface condition of a site reclaimed from water bodies in order to determine its competence for construction purposes. Nine seismic refraction profiles were acquired and the results were interpreted using SeisImager software. Also, twelve vertical electrical soundings were conducted and the acquired data were interpreted using WinResist computer package. Four-five geoelectric layers were delineated and the resistivity values obtained ranges between 23.3 and 1705.1* Ωm*. The result of the resistivity method showed that the third layer is the most competent layer in the study area. The depth of this layer is between 7.5 m and 51 m in the subsurface. In a related development, three layers were delineated by the seismic refraction method and the third layer which is between 7 m and 18 m, may be the most competent because it had the highest engineering parameters. The Young modulus of the competent layer at this site ranges between 1.558 and 25.106* GPa *and bulk modulus ranges from 0.999 to 16.093* GPa*, it was also noted that the shear modulus ranges between 0.638 and 10.123* GPa*. There is an agreement in the results of the two methods of investigation. Therefore, it was recommended that some form of arrangement must be made to transfer the load from the civil engineering construction to the most competent layer underneath so as to avoid building failure.*

Key words: seisImager, near-surface seismic refraction method, electrical resistivity method, reclaimed land.

INTRODUCTION

The rampant cases of building collapse have risen to a level of concern to both the government and private sectors as a result of the number of lives and the amount of resources that are lost in the process. Houses are important to man and they rank high among the life basic amenities, but it becomes a thing of concern when what was designed to protect man and his belongings turned out to as a trap for him [10]. When buildings collapse, some factors must have contributed to it, some of which may be sub-standard building materials, age of the building, lack of experience of the contractors, etc. The factor least considered as the cause of building failure is the condition of the ground on which the building is placed [19,21].

The high demand for accommodation in recent times has caused buildings to spring up in less likely places, with little or no consideration of the mechanical stability and bearing capacity of the land on which these buildings are. On many occasions, there have been cases of building failure on soil layers that appear mechanically stable, based on this it is not sufficient to just build a house anywhere, adequate tests must be carried out to ascertain the condition of the soil layer before buildings are erected. Lands reclaimed from water bodies such as lagoon, sea, swamp, river, flood zones that were formerly left alone because of their inability to accommodate engineering structures are known to contain certain mechanically unstable geological formations which may be harmful to the foundation of engineering structures on it [6][11]. This is because, these areas are composed of impermeable soil layers such as clay or peat and as a result, they are naturally flooded. Therefore, in order to ensure a proper foundation system for buildings within such area, adequate information about the subsurface soil layer and geological formation is necessary. At this point, a comprehensive subsurface investigation can be planned and this will require adequate geophysical and geotechnical methods [9][19].

Geophysical techniques study the contrast in the physical properties of the different units in the subsurface such as velocity, electrical resistivity, (conductivity), acoustic properties, subsurface geology and the environmental conditions [8][7][15][18][4] and they can provide some of the information required to delineate those materials in the subsurface space such as the overburden thickness, horizontal and vertical lithologic extents, depth to water table, fault zones [22]. Geotechnical investigations on the other hand are carried out as a ground truthing investigation to assist in accurate interpretation of geophysical data. It is often by using intrusive methods which normally extend to a total depth of less than several hundred feet or more where necessary. The most widely used geotechnical investigation methods are the light cable percussion boring test, static and dynamic penetration tests are the cone penetration test (CPT) and the standard penetration test (SPT) [14,16,8,17,24,26]. The present research effort is aimed at determining the geotechnical characteristics of the subsurface structures using both electrical resistivity and seismic refraction methods so as to determine its competence in siting engineering structures.

GEOLOGY AND LOCATION OF THE STUDY AREA

The site investigated is within the Eti-Osa local government area of Lagos State, southwestern Nigeria (Fig. 1). The area is a gentle sloping, low-lying elevation with respect to the sea level. The site is wholly on land and flooded as at the time of investigation. The Site is waterlogged due to water-in-flow from the lagoon. The site is bounded by the Lagoon at the rear. The entire neighbourhood is mostly undergoing rapid development. The Nigeria coastal zone lies within the tropical climate area which has two seasons: the rainy season and the dry season. The rainy season is usually between April and November, while the dry season is between December and March [8]. Although, occasional rainfall is often

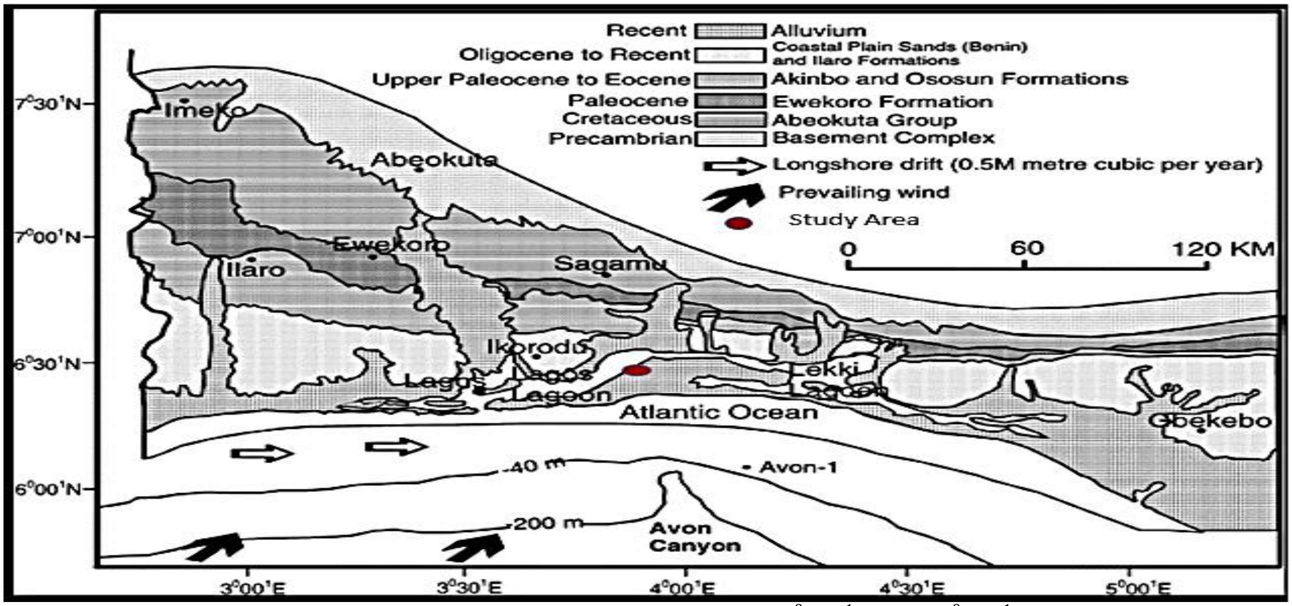

Fig.1. A sketch of the geological map of Nigeria (Modified after [1]).

witnessed within the dry season, this is because of the proximity of the area to the Atlantic Ocean [1]. The amount of rainfall varies between 2030mm and 2540mm annually. The area is located between latitude 6^0 26^1N and 6^0 32^1N and Longitude 3^0 35^1E and 3^0 45^1E.The area lies within the alluvial deposits of southwestern Nigeria basin, which is an integral part of the Dahomeyan Embayment (Fig. 2)

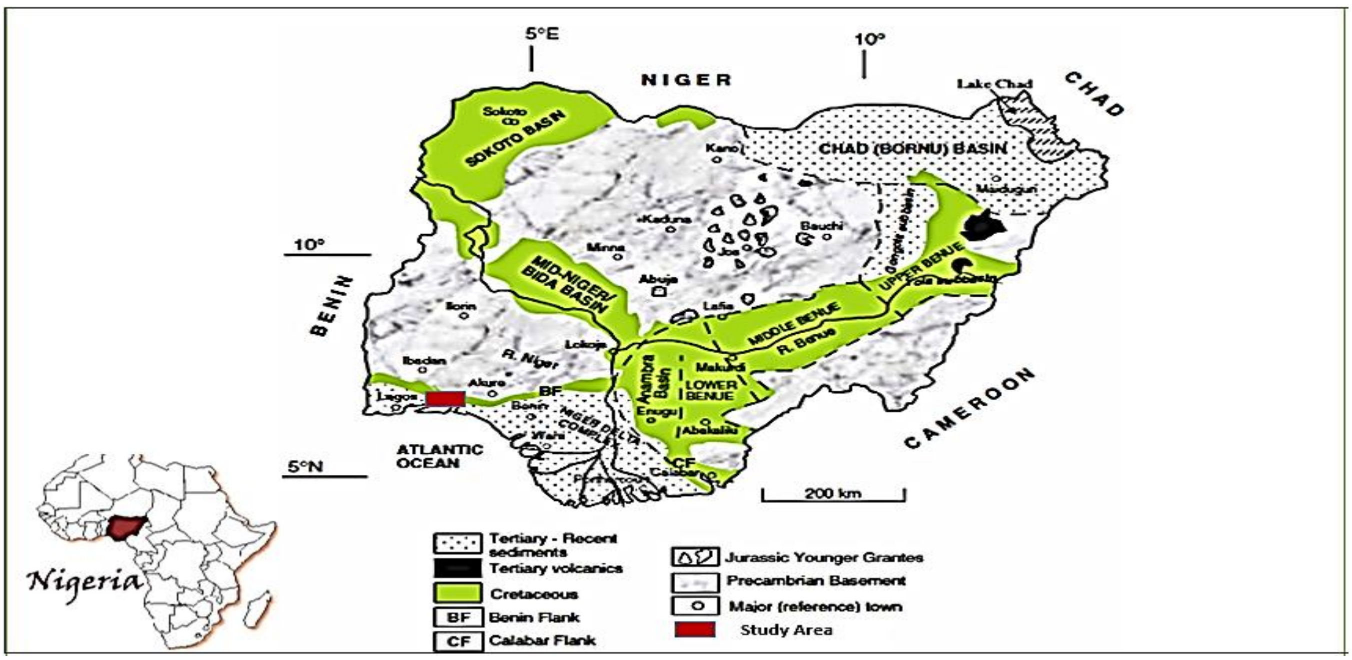

Fig. 2. Geological map of the Nigerian part of the Dahomey basin. (Modified after [13]).

MATERIALS AND METHODS

Electrical resistivity Method

In this study, an ABEM Terrameter (SAS 1000/4000 model) [3] was used for the electrical resistivity study with electrode spread varying between 1-260 m where there were no constraints. Twelve (12) vertical electrical soundings were carried out using Schlumberger array configuration. The VES data obtained were analysed by plotting the apparent resistivity values against the half current electrode spacing (AB/2) on a log-log graph. The plots were then compared to standard curves or models to determine the number of layers, the layer thicknesses, depths and their true resistvities. A computer iterative software WinResist [27] was used for their interpretation. This method was used to obtain information on the lithology of the area of study and their geoelectric parameters such as the thickness of each layer and layer resistivity.

Seismic Refraction Method

Seismic refraction was carried out in the study area, using a 24-Channel ABEM Terraloc Mark 6 seismogram [2]. The seismic refraction was carried out along the traverses marked out for the resistivity method to allow for easy comparison of the results obtained by the two methods. The energy source used was a 15 kg hammer and geophone spacing of 2 m was used. Shots were carried out at the following points: at the offset distance which is 2m to the first geophone, between the 6th and 7th geophones, between the 12th and 13th geophones, between the 18th and 19th geophones and 2m after the 24th geophones which are termed the offset, quarter spread, mid-spread, three quarter spread and off-end shots respectively. The purpose of these multiple shots along a traverse is to obtain adequate coverage of the refractor surface and to provide adequate lateral resolution [23]. Also, it is worthy of the resistivity of the original material in this area except in

The high resistivity values observed in the first geoelectric layer of VES 1, 2, 4, 5-7 may be because this region of the study area was recently filled with foreign material (sand or laterite) which had not really settled with the host materials. These foreign materials are sand materials transported to the study site in order to reduce the level of water logging the area. Also, the variable resistivity could be attributed to upward migration of suppressed fluid during the filling that may have resulted in the decomposition of imported soils and rocks of different composition buried within the near surface. The top soil in this part of the study area is mainly dry sand which is characterized by high resistivity values which may be as a result of the poor water retention of the material in the surface. The resistivity values observed in VES 8-12 characterised the original material that composed near-surface of the area of study. The moderately high resistivity measured in the second layer of VES 1-4, 6 and 7 may also be the influence of the foreign material deposited in this area. The effect of the high surface water level that characterise this area is readily influencing the geologic formation in this layer. The resistivity values observed for the third layer is relatively low except in VES 2 and 5. These values may be

this method is to obtain information on the depth to the most competent layer in the subsurface and to determine the strength and competence of each subsurface layer for construction purposes.

RESULTS AND DISCUSSION

The results showed that the subsurface is heterogeneous all through the study area. The electrical resistivity methods revealed four to five geoelectric layers in the study area and their lithologies are loose dry sand, wet sand, sandy clay,

sand and clay/peat. The resistivity and the thicknesses of the delineated geoelectric layers are presented in Table 1.

note that the longer the length of a profile the deeper the depth of investigation [12][20]. The seismic waves generated by this shot travelled down and along different refractor boundaries, only the refracted energies are detected by the geophones [9]. The seismic data acquired were interpreted using SeisImager software [25]. The essence of employing

Table 1: Geoelectric layered parameters from interpretation of VES

Layers	Resisitivity (Ωm)	Thickness (m)
1	81.4-1556.2	0.2-1.4
2	29.6-1705.1	0.1-7.4
3	23.3-1107.2	0.9-51.0
4	14.2-2183.0	7.8-9.4
5	17.4-107.9	----

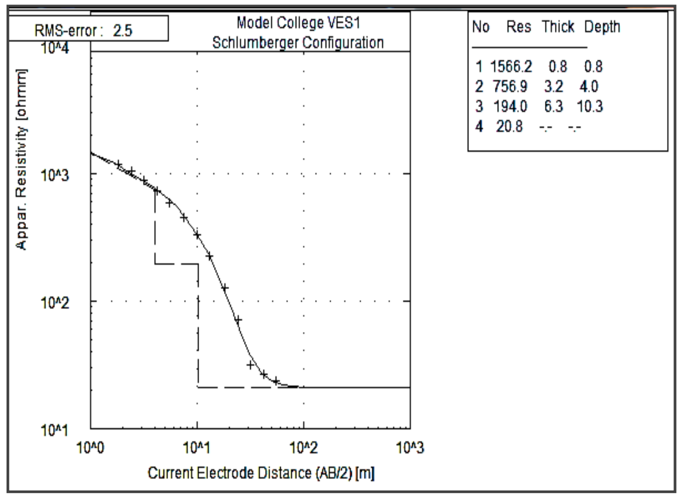

Fig. 3: Sounding curve and geoelectric parameters for VES 1

VES 5 which may be a deposit of an impermeable material within the subsurface according to the information gathered from the local geology and hand dug well in the area. Also VES 2 may be the continuation of the layer of foreign material that was encountered in layer 2.

The fourth layer also showed relatively low resistivity values which may be the influence of the salt water that characterise the region of study [5]. VES 5 and 6 showed very high value of resistivity which may be the continuation of the material earlier encountered in the third geoelectric layer. The variation in the thicknesses of the various layers may be as a result of the influence of the upward migration of saline water on the geomaterial. The geomaterials with good geotechnical properties are found at different depths across the study area. These geomaterials are sand and sandy clay because of their high shear strength and low compressibility potential. Different curve types were obtained across the study area, ranging from HK, KQ, QH, KH, AK, K, HA, KQH and KHK. These curves (Figures 3 and 4) are typical of what are obtainable in the coastal environment [5]. This explains why the study area is always

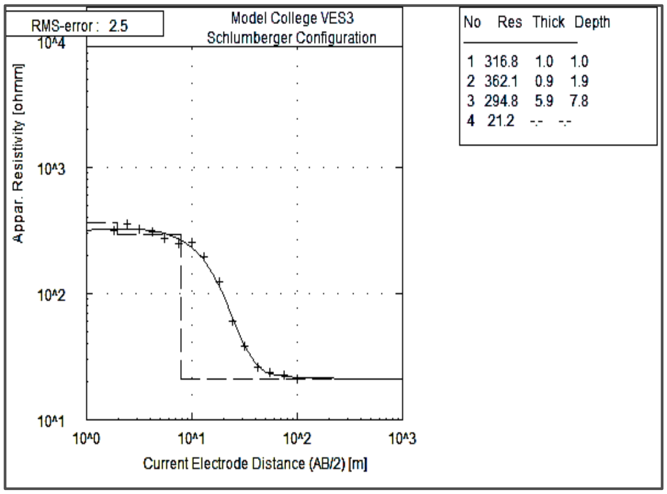

Fig. 4: Sounding curve and geoelectric parameters for VES

waterlogged and why some of the buildings are already sinking. On the other hand, the seismic refraction method delineated three layers at the study site (Figures 5 and 6). The values of the p-wave velocity for each layer was used to determine all other elastic parameters. The first layer is dry soil, while the second layer is saturated and the third layer contained some impermeable materials which are suspected to be stiff clay. This may be the reason the study area is always logged with water and it takes a long time for it to drain. The third layer all across the study area may be the most competent because it has the highest engineering parameters when compared with others. The density of the third layer ranges between 1836.7 kg/m^3 and 2355.9 kg/m^3, the Young's modulus ranges between 1.42 GPa and 25.30 GPa which are far greater in values than the two layer on it. Furthermore, the bulk modulus of the third layer ranges between 0.99 GPa and 15.94 GPa. The average bulk modulus for this layer is 4.86 GPa. The shear modulus also ranges between 0.57 GPa and 10.24 GPa with an average shear modulus of 3.12 GPa. The Poisson's ratio for the third layer is 0.23 with an error margin of $\pm 0.12 \times 10^{-4}$. This showed that the geomaterials possess the least tendency of compressiblity. This high variation in elastic parameters observed in the third layer may be largely as a result of the compaction of the geologic formation in the area. The presence of water in the subsurface as shown by the electrical resistivity method would also aid in the decomposition of the soil structure and cementation of the subsurface formation. Therefore, the difference between the minimum and maximum values measured for the various engineering parameters confirmed the heterogeneity of the subsurface. The competence observed in the third layer may be as a result of the level of compaction and also the age of deposition. Thus, the depth to the most competent layer is between 7 m and 18 m in the subsurface

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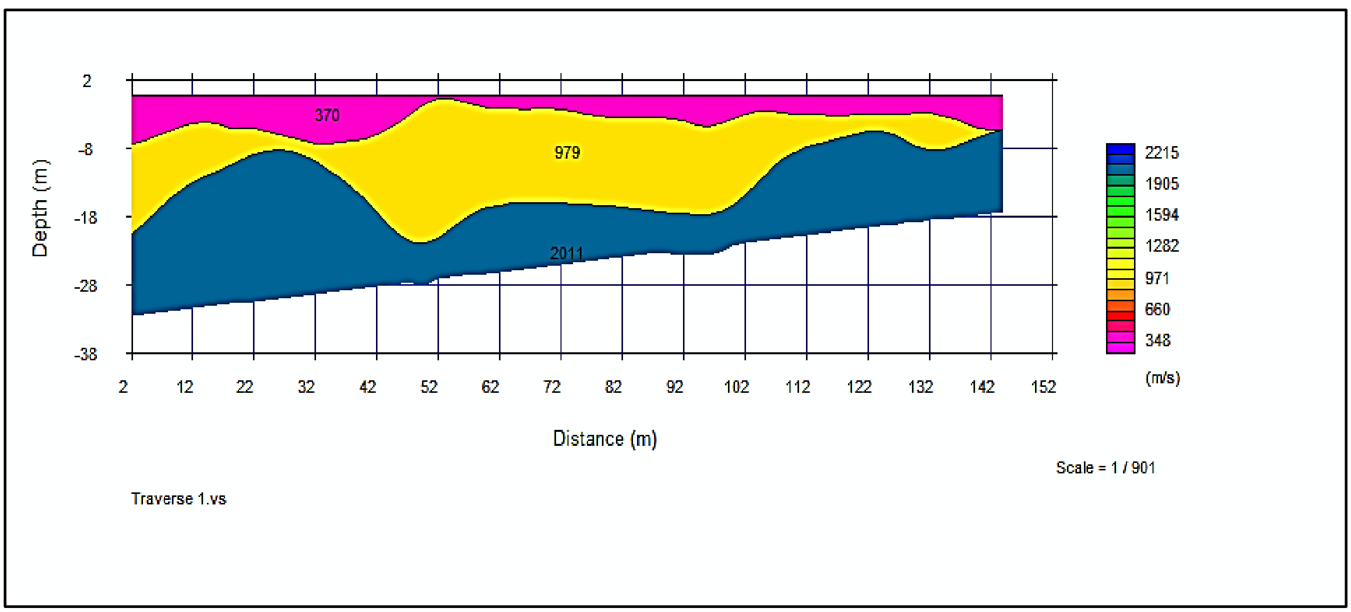

Figure 5: 2D seismic refraction sections indicating the number of layers, their velocities and the depth of investigation for Traverse 1.

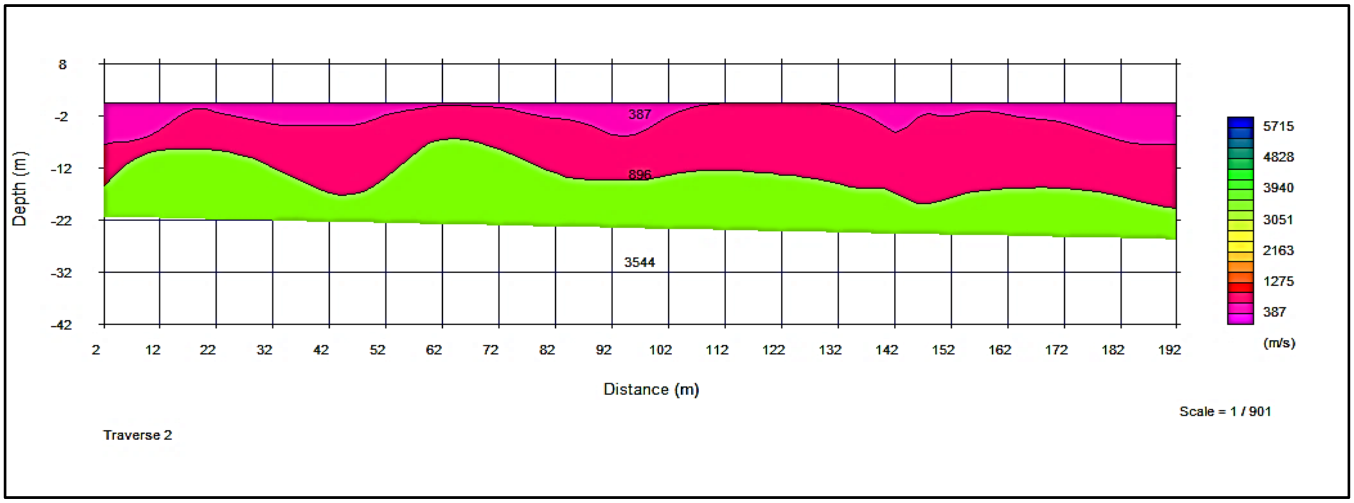

Figure 6: 2D seismic refraction sections indicating the number of layers, their velocities and the depth of investigation for Traverse 2.

CONCLUSION

Geophysical investigations were carried out at the study site in order to determine the geotechnical characteristics of the subsurface for construction purposes. The electrical resistivity method revealed that the formation within the third geo-electric layer (Table 1) which is between 7.5 m and 51 m depth in the subsurface, has good geotechnical properties for engineering construction. Similarly, the result of the seismic refraction method obtained showed that the third layer which has the highest engineering parameters is the most competent layer and this layer is in the depth range of 7 m and 18 m in the subsurface. There is an agreement between the results of the electrical resistivity and seismic refraction survey. Therefore, it is recommended that some form of arrangement must be made to transfer the weight of the building on the surface to the most competent layer at the subsurface. Otherwise, any civil engineering construction at the surface will sink and eventually collapse if proper pile foundation is not done.

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