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Engineering Site Investigations using Surface Seismic Refraction Technique

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Abstract. In this study, surface seismic refraction method together with cone penetration test were used to provide 2-dimensional (2D) information of the subsurface geological features. This approach simplified the characterization of the subsurface condition of a relatively large area of land especially when it is required for engineering construction purposes. The results of the seismic refraction method disclosed two geologic layers with seismic velocity ranging between 258 and 3544 m/s. Similarly, the cone penetration test revealed the topsoil to a depth of 6 m as soft and highly compressible formation, which is suspected to be Alluvium. Moreover, at depth between 7 and 10 m into the subsurface, a geomaterial with good geotechnical formation and low compressibility potential was encountered. This geologic formation is suspected to be sandy clay. The results of the two methods were correlated, it was revealed that the depth to the most competent layer in the study area is between 7 and 10 m depth.

Keywords: Seismic Refraction, Cone Penetration Test, Geotechnical, Geomaterial

1. Introduction

Adequate understanding of the near surface geology in relation to engineering projects is of major importance in deciding the best land use in many areas. When the subsurface condition of the sol is not competent, it subjects the building on it to collapse or failure. This can result in loses of valuables and waste of lives. Studies have revealed that most of the major cities and highly populated areas like Lagos, Nigeria are located on soft sediments such as the estuaries, recent deposits and areas of similar characteristics [1-2]. Most commonly used method of soil characterizations are based on drillings, excavations and laboratory analyses. The results obtained from these approaches are often limited to the tested point and may be difficult to deploy in the development of a very wide urban setting [3-7]. Due to the heterogeneous nature of the subsurface, the results obtained for a point test cannot be assumed for other parts of the same site.

Therefore, it is highly recommended that the subsurface condition must be thoroughly evaluated for their engineering competence by other methods especially by geophysical methods. Some of the popular geophysical methods employed for engineering site characterization includes electrical resistivity methods, multi-channel analysis of surface waves (MASW), seismic refraction method, and so on [8]. The seismic refraction method is one of the first major geophysical methods that does not affect the geological formation of the soil during investigation [9-10]. It is on this basis, that the seismic refraction method was used in this study to determine the engineering competence of the study area for construction purposes.

2. Geology of the Study Area

The study area is located at Eti-Osa local government in the southeastern part of Lagos State. It lies between latitudes 60 301 3711 and 60 301 1811 N and longitude 30 361 311 and 30 351 3411 E in South West Nigeria (Figures 1 and 2). This area is in the zone of coastal creeks and lagoons developed by barrier beaches associated with sand deposition. It is situated in the Nigerian sector of the Benin-basin and near the eastern margin of the basin. The geological formation of the study area is composed

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of sediments that are typical of the marine environments, which is intercalation of sand and clay. These sediments also grade into one another and vary widely in both lateral extent and thickness [11].

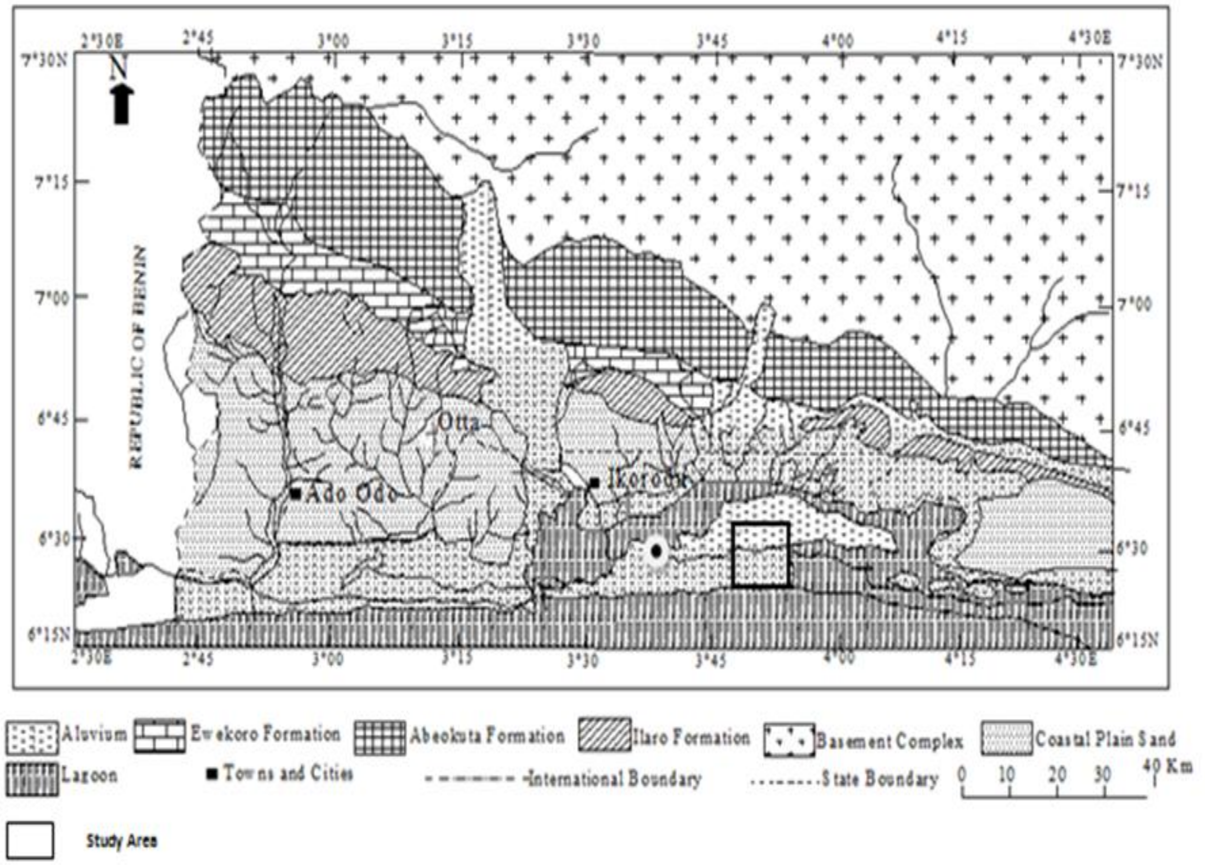

Figure 1: Geological map of the study area [2]

3. Materials and Methods

Seven (7) seismic refraction profiles were surveyed with each ranging between 48 and 200 m in length (Figure 3). A 15 kg weight Sledge-hammer was used as the source of energy and a 24 channel MK-6 Terraloc seismogram was used for the data acquisition. The geophones spacing of 2 m was used, so as to have adequate coverage of the refractive zone. Multiple shots were taken at different points along the profiles. The obtained data was analyzed with the use of seisImager 2DTM software package. The inversion tomograms for the seismic survey were displayed after the data were processed [12-13].

4. Results and Discussion

2D seismic refraction tomography showed the lateral and vertical distribution of the geologic layers. The results showed three distinct layers as presented in Figure 2. The three layers varied in thickness from the topsoil to a depth of about 10 m in the subsurface. The various colour configurations of the 2D seismic refraction profiles, revealed the variation in the thickness of each layer, which may be as a result of the age of deposition, the geologic composition and other geological processes [13-15].

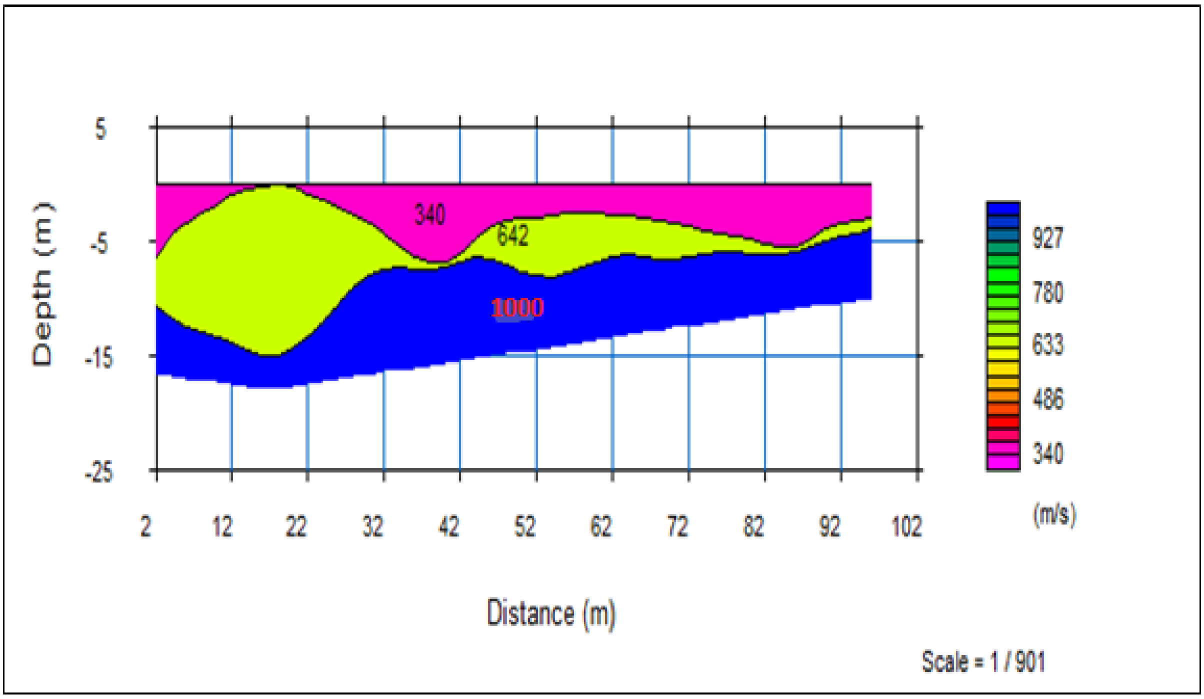

Fig 3: 2D seismic refraction profile conducted in the study area showing the length and the depth of investigation in meters (m)

The thickness of the first layer varied was found to vary between the topsoil and a depth of about 5 m. This layer is considered to be the unconsolidated layer [16], which is characterized by loose dry sand as delineated by the borehole log and also a low-velocity zone as revealed by the propagation of seismic wave velocity[12][15].
There is an intrusion of the geomaterials that composed the first layer in the second layer. This variation is pronounced the 2 and 28 m points along the length of the seismic profile. This layer is semi-consolidated as shown by the geotechnical parameters [17-19]. This layer was observed to gradually reduce in thickness towards the other end of the profile. The third layer was observed to have the highest seismic velocity which is a characteristic of a consolidated layer [20-21]. The thickness of this layer is greater than the first two layers earlier discussed; it was also noted that the second layer intruded greatly into the third layer between the 2 to 26 m along the length of the profile. This layer was noted to be more competent than the two previously outlined layers. The noted competence could be as a result of the composition or age of deposition of the sediments that formed this layer. The result obtained in this study agreed with the regional geology of the study area as well as the local geology obtained from a hand dug well in the study area.

5. Conclusion

In this study, a combination of 2D seismic refraction method and information on the local geology of the area of study were used to characterize a site in order to determine the depth to the most competent layer. In terms of geology the study area is interpreted as having three prominent subsurface layers from the topsoil to a depth of about 18 m, in which the first geologic layer, which is the topsoil is composed of unconsolidated geologic formation. The second layer is interpreted as a weathered or semi-consolidated formation while the third layer is found to be a consolidated geologic formation as revealed by the seismic refraction method. The local geology revealed the first layer to be loose sand, the second layer was noted to be soft sandy clay while the third layer, which was encountered from 7 m depth into the subsurface was observed to be composed of a more consolidated formation of medium to hard sandy clay. Therefore, it can be concluded that the lower part of the second down to the third layer is the most mechanically stable for siting any engineering construction in the study area.

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