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Locating Buried Structural Features in Parts of Benin City by the Seismic Refraction Method

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Abstract: *Seismic refraction survey was carried out in three locations in Benin City, Nigeria, which are at Ekosodin (6°24.5´N, 5°37.7´E), Ekehuan (6°19.6´N, 5°35.8´E and Ikpoba Hill (6°21.5´N, 5°40.4´E), to determine the subsurface structural features and their suitability for engineering and geotechnical purposes. Results reveal two layers, with the overburden material of thicknesses, 2.91m; 4.30m and 3.77m at the respective locations of Ekosodin, Ekehuan and Ikpoba Hill. The respecive velocities for the two layers at Ekosodin are* V_1*=482ms*$^{-1}$*;* V_2*=817ms*$^{-1}$*, indicating Silt for the overburden and Gravel or Silt for the underlying layer. The respective velocities for the two layers at Ekehuan are* V_1*=339ms*$^{-1}$*;* V_2*=532ms*$^{-1}$*, indicating Loose Sand for the overburden and Silt or Gravel for the underlying material. The respective velocities for the two layers at Ikpoba Hill are* V_1*=418ms*$^{-1}$*;* V_2*= 664ms*$^{-1}$*, indicating Loose Sand for the overburden and Silt or Gravel for the underlying layer. For the location at Ekosodin the interface dips slightly from the horizontal at an angle of 0.55°. At Ekehuan the angle of dip is 4.4°, while at Ikpoba Hill it is 5.97°.*
Keywords: *Geophone, Refraction, Seismic waves, Seismograph, Subsurface.*

I. Introduction

Seismic refraction is quite a useful technique for investigating subsurface formations which has been applied to various geological and geotechnical problems. It has been successful in mapping contaminant transport, transport in fractured rock, expansive clay soils, stability of rock slopes, seepage in dams, landslides, regolith mapping and sinkholes [1][2][3][4][5]. Subsurface material properties are paramount in any investigation for engineering strength of a region for any construction work. In some cases where the topmost materials are not suitable for the construction, excavation and filling with appropriate material becomes an option, mostly in road constructions, or developing pillars from the bedrock upon which construction may be done as in the case of skyscrapers in Dubai and some regions with considerable sedimentary fill which do not support engineering construction. Otherwise other options to avoid rupturing or collapse as a result of overpressure on the underlying feeble material may be deployed to achieve a durable work. Classifying subsurface materials using geophysical methods is a promising method used, hence, works already done in the area would be an advantage to the research, interpretation and seismic refraction survey is usually a good option for such investigation [6].Three locations were investigated using seismic refraction survey within the study area (Benin City) from which velocities and average depths were computed/analysed to ascertain lithologic composition apart from structural features of the study area.

1.1 Seismic Refraction Survey

Seismic refraction method is a geophysical method that has been developed for shallow subsurface investigation. It provides 2 – dimensional profiles including depth and distance that simplifies the characterization of relatively large volumes of the subsurface [7].Seismic refraction is a powerful investigative tool for shallow survey; it was the first major geophysical method to be applied in the search for oil bearing structure and other buried features, though its application in oil exploration has reduced over the years due to a variety of modern reflection surveys.[8] Ahmed et al. used 2-D seismic refraction method to investigate a sewage treatment site located at Ahmadu Bello University Zaria, Nigeria. By using this method, they were be able to determine the overburden thickness and velocity of the subsurface layers in the area, and delineating any geological structures, such as fracture zone, that may pose a threat to the safe running of the Sewage lagoon system in the area.

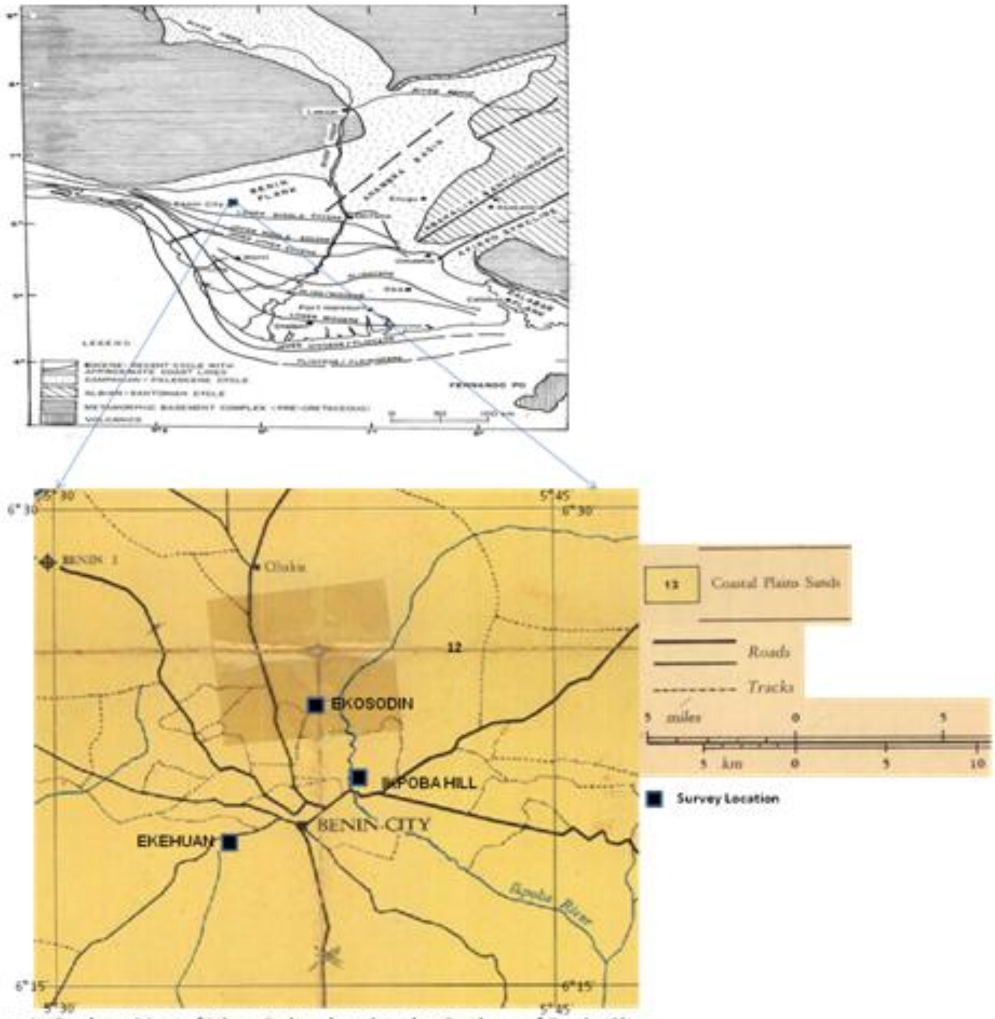

Figure 1: Geology Map of Niger Delta showing the Geology of Benin City

1.2 Location and Geology of Study Area

This research was carried out in three different locations in Benin City, namely: Ekosodin (near the ugbowo campus of the University of Benin), Ekehuan campus of the university and off Ikpoba Hill. For the Ekosodin location, the latitude is 6˚24.5ꞌ N and the longitude is 5˚37.7ꞌ E. For Ekehuan location, the latitude is 6˚24.5´N and the longitude is 5˚35.8ꞌ E. For the Ikpoba hill location the latitude is 6˚21.5ꞌ N and its longitude is 5˚40.4´ E. Figure 1 shows the geology map of Niger Delta and a projection of Benin City, the study area, indicating the survey locations.

Benin City is located in Niger Delta which is framed on the northwest by a subsurface continuation of the West African Shield, the Benin Flank. Well sections through the Niger Delta generally display three vertical lithostratigraphic subdivisions: an upper delta top facies; a middle delta front lithofacies; and a lower pro-delta lithofacies [9]. These lithostratigraphic units from the topmost are the Benin Formation, which were deposited between Oligocene and Recent, Agbada Formation of Eocene and Recent depositional era and Akata Formation deposited between Paleocene and Recent [10]. The Akata Formation is composed mainly of marine shales, with sandy and silty beds which are thought to have been laid down as turbidites and continental slope channel fills. It is estimated that the formation is up to 7,000 metres thick. The Agbada Formation consists mostly of shoreface and channel sands with minor shales in the upper part, and alternation of sands and shales in equal proportion in the lower part. The thickness of the formation is over 3,700 metres. The Benin Formation is about 280 metres thick, but may be up to 2,100 metres in the region of maximum subsidence [15](Whiteman, 1982), and consists of continental sands and gravels.

II. Methodology

Materials used for the survey include FS-3 portable Fascimile Seismograph, hammer, geophone, metal plate, extension cable and a tape. The geophone was fixed in the ground in a vertical position on the side of the transverse line and connected at right angles to the FS-3 console. The hammer was blow on the metal plate through which sound signal passed through the earth. Through the geophone, the arrival times were recorded by the FS-3 seismograph which was plotted and analyzed. From the graph, the depth and thickness of each subsurface layer were obtained by taking the average velocities of the forward and reverse curves (V_1 and V_2 respectively) and the intercept time (t_o). If these values are substituted into the equation below, the value of the thickness Z can be calculated

$$Z = \frac{t_o(V_1V_2)}{2(V_2^2 - V_1^2)^{1/2}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where t_o is intercept time in millisecond (ms), V_1 and V_2 are velocities of layer 1 and 2 respectively in metres per second (m/s).

Dipping angle, Θ for the layers were calculated thus

$$\theta = \frac{1}{2}\left(\sin^{-1}\frac{V}{V_d} - \sin^{-1}\frac{V}{V_u}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

V_d is the velocity of layer 2 for reverse shooting and V_u is the velocity of layer 2 for forward shooting. V is the average of the velocities for layer 1 in both forward and reverse shooting.

III. Results And Discussion

The seismic refraction survey results revealed two layers for the three locations, with the first layers all dipping slightly and have average thickness of about 2.9m, 4.3m and 3.8m respectively for Ekosodin, Ekehuan and Ikpoba sites. Calculated velocities for the first and second layer at Ekosodin are 482m/s and 817m/s respectively, at Ekehuan, the first layer recorded 339m/s and the second layer 532m/s and at Ikpoba Hill velocity of the first layer is about 418m/s while the second layer is about 664m/s. These varying velocities which are not very far from one another at respective layers for the three locations suggests a lithology of unconsolidated materials within an average thickness of about 3.6m in the entire area studied and more consolidated material evidently in the velocity difference starting from an average depth of 3.6m. Figure 2 shows the forward and reverse shooting at Ekosodin; Figure 3 shows the forward and reverse shooting at Ekehuan, while figure shows the forward and reverse shooting at Ikpoba Hill.

The subsurface geologic features as suggested by the calculated velocities suggest the first layers for the three locations to be loose sand while the second layers as clay or gravel.The refraction survey also revealed that at Ekosodin, the interface dips slightly from the horizontal at an angle of 0.55^o. At Ekehuan the dipping is 4.40^o, while at Ikpoba Hill the dipping is 5.97^o.

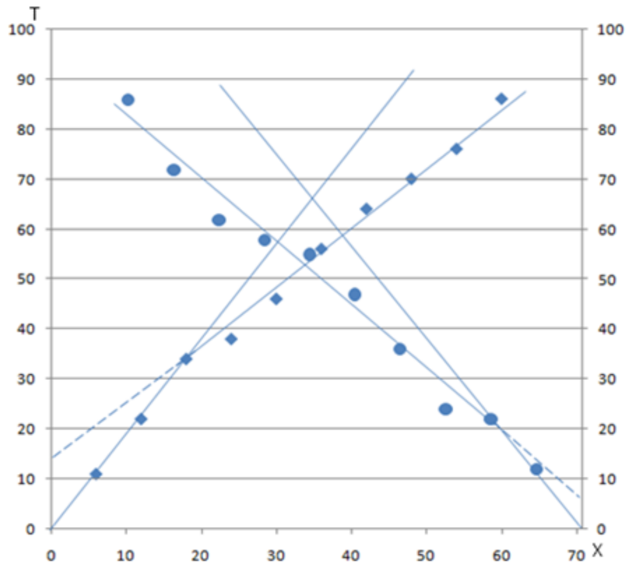

Figure 2: Forward and Reverse Shooting at Ekosodin

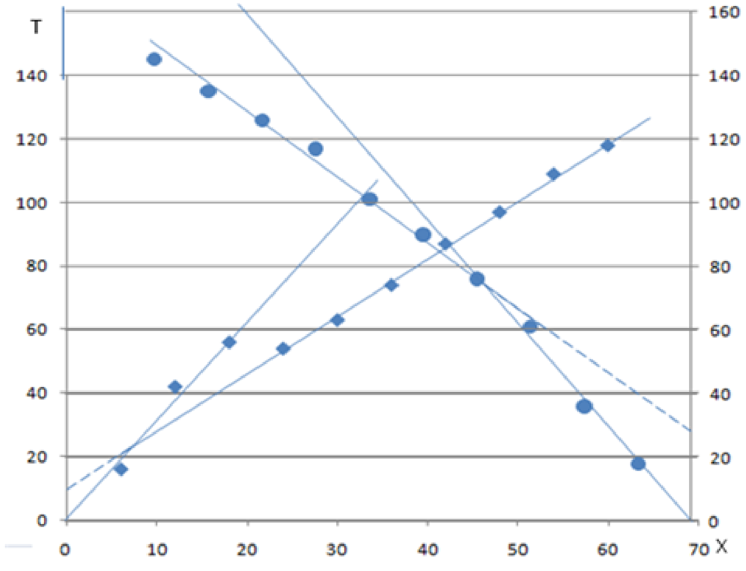

Figure 3 : Forward and Reverse Shooting at Ekehuan

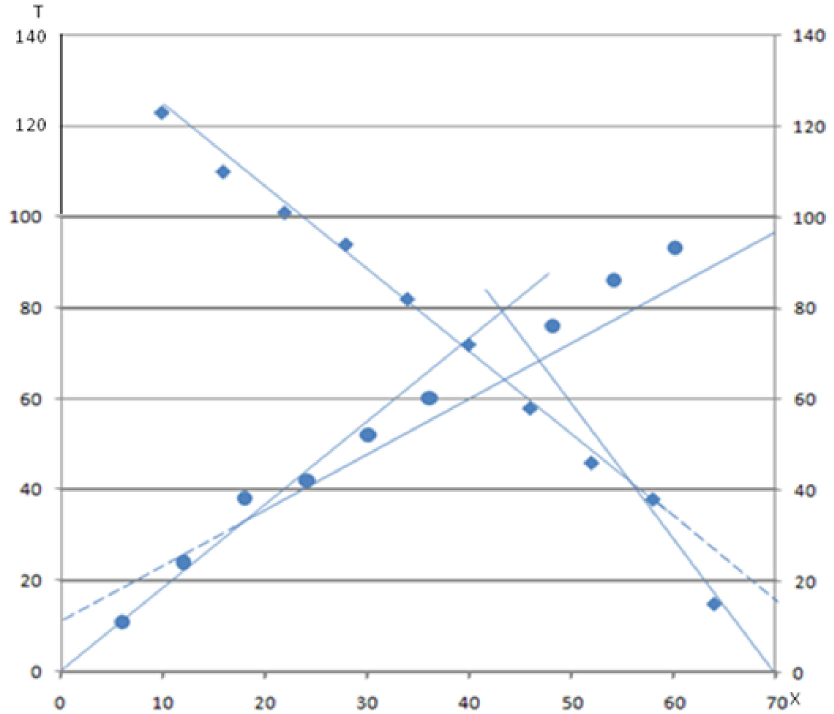

Figure 4: Forward and Reverse Shooting at Ikpoba Hill

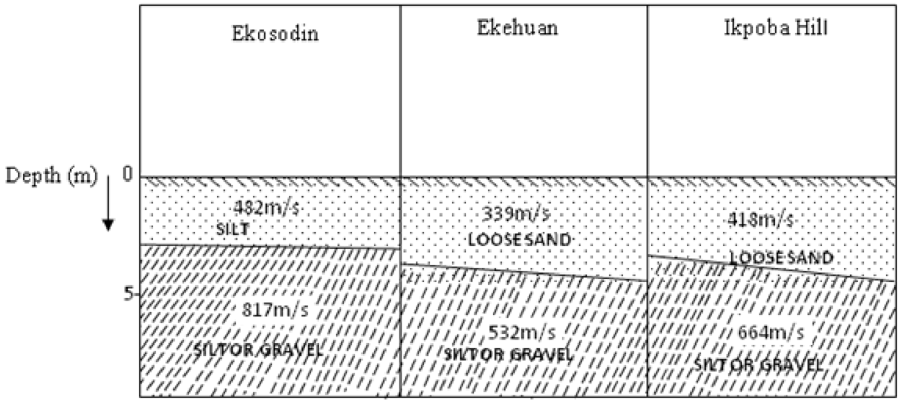

Figure 5: Summary of the seismic refraction survey results for the three locations

IV. Conclusion

Seismic refraction survey has been used to delineate subsurface structural features at three different locations in Benin City of Niger Delta. Result from the plots suggests an underlying silt or gravel overburdened by dipping unconsolidated sand of about 3.6m thickness. Velocity of the silt or gravel ranges between 532m/s and 817m/s; while the loose sand velocity is between 339m/s and 482m/s. The overburden material is also suggested to be dipping at an average angle of 3.5^o.

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