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Seismic Refraction Investigation of Thickness and Velocity of the Weathered Layer in Emuoha Town, Rivers State, Nigeria.

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Abstract: *Seismic refraction survey was carried out using 12 channel Terraloc Mark 6 seismograph to obtain data in Emohua, River state in the Eastern Niger Delta, Nigeria. This study aimed at determining the thicknesses and velocities of the low velocity layer in four different locations. The velocities and thicknesses were calculated from the critically refracted arrivals using the Time-intercept method of interpretation. The thickness of the low velocity layer in the study area varies from 1.60m to 1.89 with a regional average of 1.98m. Also, the velocity of the weathered layer ranges from 255.55 to 312.00 m/s with an average of 267.56m/s. The sub weathered layer velocity ranges from 346.94 to 368.00m/s with an average of 354.90m/s. The knowledge of the velocity and thickness of the low velocity layer is extremely important in civil engineering works as well as, in groundwater exploration. Civil engineers and construction experts can use the result among other fundamental soil parameters to determine the soil type and position of foundation for structures to be erected.*
Keywords: *Refraction, Weathering Layer, Velocity, Travel Time, Offset.*

I. Introduction

The application of geophysical methods for the determination of rock/soil condition for geotechnical and civil engineering construction has increased rapidly in developed and some developing countries in recent time. This is due to the important of the subsurface in the stability of the foundation of civil engineering structures such as high-rise buildings, dams, and highways (ASTM, 2000; Rucker, 2000; Obianwu, et.al., 2015; Agha et. al., 2006; Griffiths and Kings, 1981; Oyeyemi, and Akintunde, 2000). The rate at which building and roads collapse in Nigeria should be of concern to the government, corporate organizations, and individuals.
Seismic refraction method is very effective and efficient for subsurface investigation in geotechnical studies. Seismic refraction data provides information about the primary wave velocities and boundary depths of subsurface layers which are very important in the geotechnical characterisation of the subsurface. Many geoscientists and engineers have used the method in investigating the nature of the subsurface for geotechnical and civil engineering construction purposes (ASTM, 2000; Rucker, 2000; Rucker and Fergason, 2006). The velocity of the subsurface layer can be used to evaluate the strength, rippability and the fluid content of the rocks.A good knowledge of the thicknesses distribution and elastic properties of the superficial layers of the earth is of immense importance to civil engineering structures, petroleum and groundwater explorations (Osagie, 2009). The topmost layer of the earth is non homogenous and unconsolidated as a result of weathering and it is known as weathering or low velocity layer. The thickness and velocity of the layer are not constant but vary from place to place.

Seismic refraction survey works have been carried out in some parts of the Niger Delta. Seismic refraction survey works have been carried out in some parts of the Niger Delta. Adeoti et al. (2013) used uphole seismic refraction survey in parts of Niger Delta to determine the thickness and velocities of the weathered layer. The weathering thickness ranges from 2.9m to 8.9m with an average of 4.8 m and the velocity ranging from 362m/s to 689m/s with an average of 466 m/s. The consolidated layer average velocity is 1746m/s. They concluded that the second layer can support engineering structures. Ayolabi et al. (2009) carried out seismic refraction and resistivity studies of part of Igbogbo township, South-West, Nigeria. The study delineated three layers with the first layer having velocity 150m/s to 336m/s and a thickness ranging from 1.0m to 3.3m. The second layer composed of lateritic clay with thickness 4.5m to 10.5m has velocity 578 to 878m/s and the third layer which consists of sandy clay has velocity 1000m/s to 2500m/s.

Igboekwe and Ohaegbuchu (2011) used seismic refraction method to investigate the thickness and velocity of the weathering layer and concluded that the information obtained from the study is extremely important in the determination of time delays needed for static corrections during seismic reflection data processing. The average thickness of 18.15m and velocity ranging from 800m/s to 1385m/s were recorded. Similar work by Osagie (2009) in southwestern Niger Delta showed that the thickness of the low velocity weathered layer in the area varies from 3.6 m to 46.2 m with a regional average of about 24.0 m. The weathered layer and the refractor beneath it has an average primary wave velocity of 600.0 m/s and 1842.0 m/s respectively.

Nwankwo et al. (2013) carried out Seismic Refraction Investigation for groundwater potential in parts of Rivers State, Nigeria. The seismic data revealed a three-layer model in the subsurface, with the aquifer layer having an average velocity of 500m/s. The estimated depth to the aquifer in the area ranges from 12.52m to 26.56 m. The refraction results correlated closely with aquifer depth range of 14.48 m to 53.68 m obtained from resistivity data of the area.

Nwachukwu (2001) used uphole shooting technique to determine the weathering layer depth in some parts of Owerri, Southeastern Nigeria and discovered that the weathering and sub-weathered layers have a total average depth and velocity of 21.76m and 547.3m/s respectively. Ajani et al. (2013) used Seismic refraction method in Omerelu for geotechnical investigation. They observed that the depth of the weathered layer ranges from 12 to 13m while the velocity of the weathered and consolidated layers ranged from 500m/s to 550m/s and 1790m/s to 1895m/s respectively.

Emujakporue (2012) in a study of the causes of road failure observed along East-West highway Port Harcourt near the present study area highlighted that the integrity of highway pavement can be undermined by the presence of geological features and/or engineering characteristics of the underlying geologic sequences. It, therefore, follows that proper engineering site investigation using different geophysical techniques is required before embarking on construction work to avoid the huge expenditure in the rehabilitation of failed engineering structures. Emuoha is the headquarter of Emuoha local government area, Rivers State, Nigeria. It is very close to Port Harcourt, the capital of the state. Due to rapid development and influx of people into the state capital, it is almost becoming congested and as a result, there is the tendency of industries and people to start moving toward Emuoha. For this reason, it is necessary to have a knowledge of the nature of the subsurface to avoid collapsed of civil engineering structures that will be built in the area. In the present study, effort is made to use seismic refraction data in determining the quality and suitability of the topmost (weathering) layer of the earth in the studied area for the geotechnical and civil. The information obtained from this study will be useful for the foundation of civil engineering structures in the area and for correcting some of the near-surface geotechnical problems caused by unconsolidated layers.

II. Geological Setting of the Study Area

Emohua is situated in Latitude 4^0 $53'$ $2''$ North and Longitude 6^0 $51'$ $39''$ East (Fig.1). It is within the Niger Delta Sedimentary basin, Nigeria. The Niger delta sedimentary basin covers an area of about 200,000 square kilometers situated on the West African continental margin. It is divided into three stratigraphic units which include: Akata, Agbada and Benin Formation.The marine Akata Formation is a continuous shale unit, which in most places is under-compacted and may contain lenses of abnormally high pressured siltstone or fine-grained sandstone. It represents the pro-delta facies.

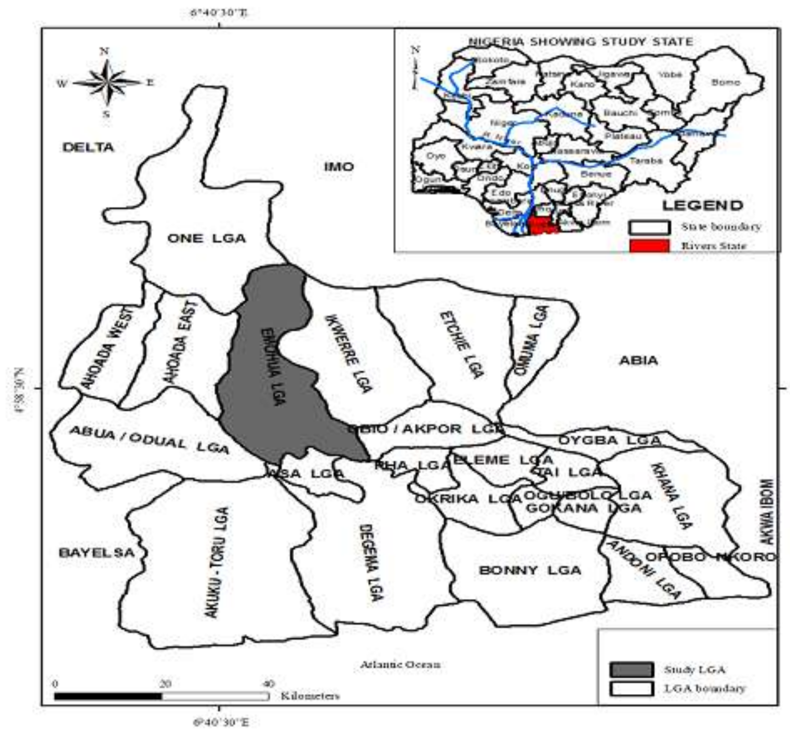

Fig 1: Map of Rivers State showing the study area Emohua (Osagie, 2009).

The marine Akata Formation is a continuous shale unit, which in most places is under-compacted and may contain lenses of abnormally high pressured siltstone or fine-grained sandstone. It represents the prodelta facies. The formation which directly overlies the Akata Formation has been described by Reyment (1965) to be a sequence of sand and sandstones bodies alternating with shale. This lithostratigraphy is known as Agbada Formation. The alternations of sands, sandstones and shale are due to local transgressions and regressions. It is up to 3000 meters thick and ranges in age from Eocene to Holocene (Okwueze, 2011). The topmost unit of the Niger delta is the Benin Formation. The formation is predominantly sandy containing over ninety percent sands and sandstones, with a few shale intercalations which become more abundant towards the base. The sands and sandstones are coarse grained and pebbly, locally fine-grained, poorly sorted, sub angular to well rounded and bears lignitic streaks and wood fragments. The formation was deposited in a continental upper deltaic environment. The formation generally exceeds 2000 metres in thickness and ranges in age from Miocene to Recent. The total thickness of sediments in the Niger delta may be as much as 12,000 metres.

III. Materials and Methods

The equipment used in this study include ABEM Terraloc Seismograph, tape, Global Positioning System (GPS), sledge hammer and striking steel plate. The sledge hammer was used for generating the seismic wave energy by striking it against the steel plate. The generated energy travelled into the subsurface at a critical angle and it is refracted at layer interface to the surface where it is being picked up by the geophones. The geophones also receive direct wave energy from the source. The geophones send the received signals through cables to the seismograph.The seismograph records data digitally and is compatible with digital computers. The seismograph picked both the primary wave and random noise. In order to reduce the noise and enhance the quality of the seismic signal, the steel plate was strike five times and the acquisition was done in an area free of unwanted seismic signal and traffic noise. The summation of these signals causes the amplitude of the refracted signal to be enhanced while the random noise cancelled out. By stacking signals from the 5 shots, the first arrival energy increases significantly. The tape was used to mark the offset distances between the energy source and geophones while the GPS was used to measure the coordinates of each location. A total of four seismic refraction profiles were carried out in the study area. Each profile has a total length of 120 meters with the geophones having inter-spacing of 10 meters.

IV. Data Processing and Interpretation

The first breaks arrival time of the seismic traces were picked with the aid of a computer software program (Reflex 2D Quick) and the arrival time versus geophone offset distance plotted in a graph for each profile. Linear lines were fitted to the plotted points in the graph to obtained the numbers of layers in the subsurface. The data were interpreted using the critical distance method. The inverse of the slope of each line in the graph was used to obtained the primary velocity of the layer. The intercept time method was used for determining the depth to each layer. The intercept time technique is given as;

$$D_W = \frac{1}{2} + t_i \frac{V_0 V_1}{\sqrt{V_1^2 - V_0^2}}. \qquad 1$$

where

Dw = depth of the weathered layer

t_i = intercept

V_0 = velocity of weathered layer

V_1 = velocity of sub-weathered layer

V. Results and Discussion

Two lines were fitted to the plotted points to obtain two-layer model within the maximum depth probed. This model represents the subsurface structure of the studied area. Two layers were obtained from the interpretation**.** The results obtained from the interpretation for the four location is shown in Table 1. The topmost layer with velocity ranging from 255.55m/s to 312.00m/s with an average velocity of 267.56m/s is characterized with loose and unconsolidated sediments and it corresponds to the first arrivals. The thickness of the first layer ranges from 1.60m to 2.30m with an average of 1.98m. The thickness of the first layer varies laterally within the surveyed area**.** The second layer velocity ranges from 346.94m/s to 368.00m/s with an average of 354.90m/s. The second layer is characterized by a slightly higher velocity**.** The survey shows variations in the thickness and velocity of the topmost layer as well as the velocity of the second layer. There is a linear increase in velocity with depth within the probed depth. Comparing the computed layer velocities with the established standard P-wave velocity in Table 2 shows that the sub-weathered velocity falls within the range of sandy clay, which is good to set up a foundation for engineering structures. The low velocity obtained from the interpretation could be attributed to the effect of the water because the work was carried out in the rainy season. The wet subsurface affected the velocity at which the wave travelled. Besides, the source used is a sledge hammer which cannot generate stronger seismic waves as compared to explosives. In spite of these limitations, the result of this study proved to be very reliable. The results agreed closely with that obtained by other researchers (Uko, et al.,1992; Agoha, 2015).

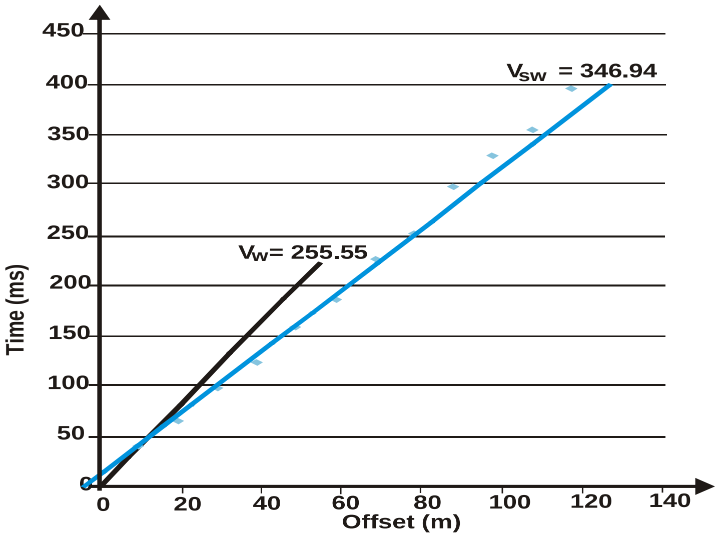

Fig. 2: Time vs Offset plot for location 1

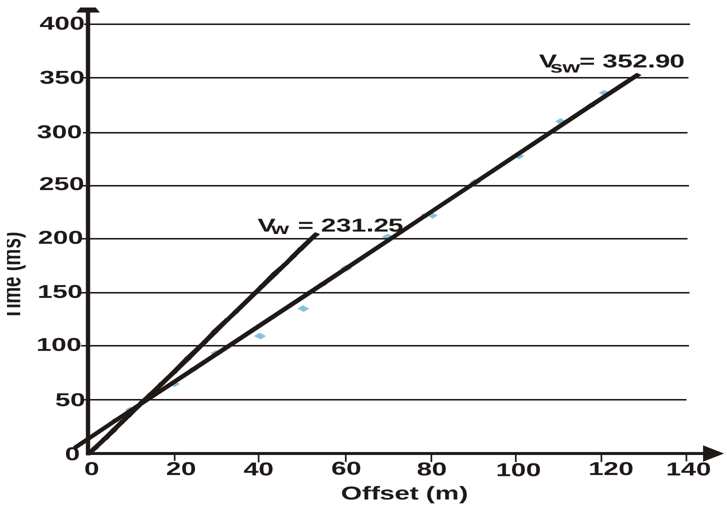

Fig. 3: Time vs Offset plot for location 2

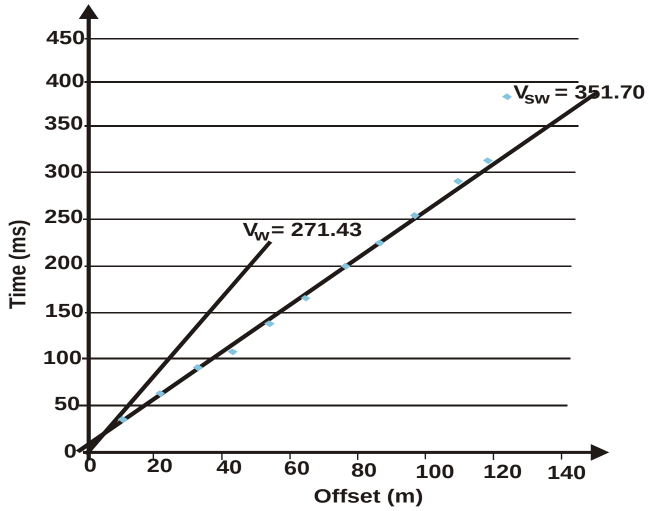

Fig. 4: Time vs Offset plot for location 3

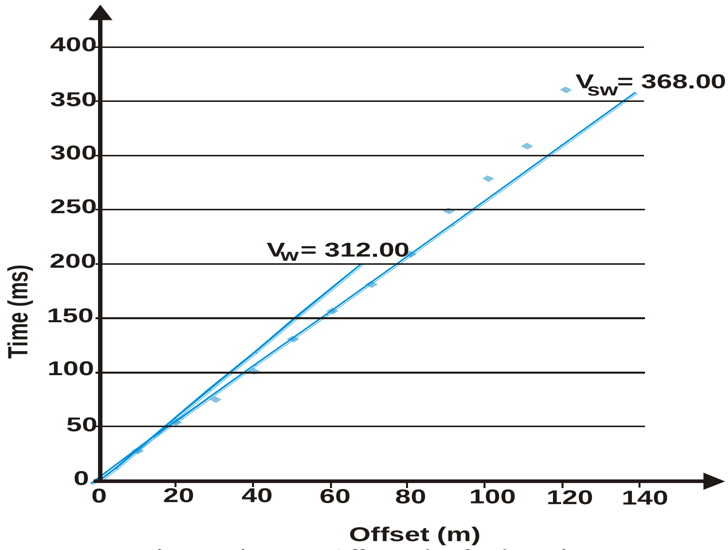

Fig. 5: Time vs Offset plot for location 4

Table 1: Showing the Analysis of the Result obtained for Emohua

S/N	*Vw* (m/s)	*Vsw* (m/s)	*Dw*(m)
Location 1	255.55	346.94	1.89
Location 2	271.43	351.70	2.13
Location 3	231.25	352.94	2.30
Location 4	312.00	368.00	1.60
Average	267.56	354.90	1.98

Table 2: Established Standard P- wave (Culled from Ugwu, 2010)

Rock type	Standard p-wave velocity (m/s)
Sandy clay	360-430
Sand with gravel (dry)	490-690
Sand with gravel (wet)	690-1150
Coarse sand (wet)	1150-1670
Clay	1100-4200
Sandstone	1400-4300
Loose sand	1800

It was inferred from the interpretation that from the earth surface to an average depth of 2.0m, the materials are loose, unconsolidated and composed of clayey sand. The layer has high porosity and a high degree of saturation which are an attribute of poor and low-quality sub soil. Therefore, it is advisable to excavate this topmost weak and unconsolidated layer in the area before laying the foundation of any massive structure.

VI. Conclusion

The results of this study show variations in the thickness of the weathering layer which varies from 1.60 m to 2.30m with an average value of 1.98 m. The topmost layer velocity ranges from 255.55m/s to 312.00 m/s with an average value of 267.56 m/s. The velocity of the sub-weathered layer ranges from 346.49m/s to 368.00m/s with an average value of 354.90m/s. The seismic refraction method used in this surveyed is simple, efficient and economical. The results of the study will be useful to Civil and Construction engineers in the area.

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