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Shallow Site Investigation using Seismic Refraction Method: Case Study of FUPRE Stadium and Its Environs

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ABSTRACT

The shallow site investigation was done in the second campus of Federal University of Petroleum Resources Effurun (FUPRE) stadium and its environs with the aim to determine the shallow site level and also to estimate some geotechnical parameters for potential construction sites within the study area with the application of seismic refraction method. The research was done using seismograph (PASI GEA 24 model) using 24 geophones with 4 m spacing and the traverse distance for the area of investigation is 100m. The data acquired was interpreted after the unwanted signal has been removed in order to identify and estimate the thickness layer and velocities of different subsurface interfaces. From the three traverses employed around the investigated area, the results showed that the subsurface of the study area is made up of three layers. The first layer is a top soil with an average thickness of 7m and the P-wave velocity is 284.5 m/s. The second layer, which is a weathered Phyllite composition, has an average thickness and P-wave velocity of 24.5 m and 419.2 m/s respectively and this indicates that the saturated zone in this layer is vertically extensive. The third layer has the p-wave velocity of 765.6 m/s, however, all the three layers has the same Poisson's ratio value of 0.35 and density value of 1800 kg/m^3. From the values of other geotechnical parameters; which are young modulus, bulk modulus, shear modulus and s-wave velocity. It is concluded that the first two layers are poor bearing capacity that have low shear strength and high compressibility due to the low values of the parameters compared to the third layer; however an additional geophysical method is recommended for more revelation of geophysical characteristics or features.

1. INTRODUCTION

The term shallow site typically refers to a site where the subsurface exploration is limited to the shallow subsurface, which is up to a few tens of meters. And this definition is in contrast to deep site investigations, which has its own investigation to depths of several hundred meters or more (Griffiths and Barker, 1993). In order to obtain subsurface information using shallow site investigations, the following geophysical methods such as ground-penetrating radar (GPR), electrical resistivity imaging (ERI), and seismic refraction can be used. The main target of these investigations is to provide a high-resolution image of the shallow subsurface

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and to identify any subsurface features, such as boulders, lenses of clay, or changes in soil type, that may affect the stability or performance of the proposed construction. Shallow site investigations are non-invasive type of investigation, which means that they do not require excavation of boreholes or other intrusive methods, making them a valuable tool for shallow site investigations, so seimic refraction are commonly applied in geotechnical studies and have successfully delineate areas with fairly complex geology (Amidu and Olayinka, 2006; Aizebeokhai et al., 2010).

This type of investigation is usually performed prior to construction of a building or other structure, and it is used to identify soil types and properties, to assess the presence of contaminants, and to determine the soil's bearing capacity and stability. In order to have a well-informed decision about the type of foundation required for any construction of a proposed structure, it is compulsory to carry out shallow site geophysical investigation and the results are often used in conjunction with the results of other geotechnical and geologic data which include soil improvement measures. (Brown and Mussett, 1976).

Seismic refraction method due to its versatility is one of the most commonly used geophysical method for site investigation, However, for a new academic environment, like FUPRE that is currently engaging in construction of different pattern of structures, and there is need to conduct a proper geophysical investigation which now informed the shallow depth investigation of subsurface in FUPRE stadium and its environs using seismic refraction method. In order to delineate the features in the study area, there is need to process the data acquired from the study area for good interpretation of the subsurface layers.

However, seismic refraction method has been successful utilized and well proved in different parts of this country and beyond. Seidu et al.,2000 did investigation at the University of Mines and Technology, Ghana and the data obtained during the geotechnical investigations are used to estimate material parameters such as strength, bearing capacity, unit weight of foundation soils, depth to bedrock and soil stratigraphy. The study revealed all the geotechnical engineering parameters of the subsurface material at UMaT Campus, from the P-wave velocity values and the results of the study area showed that there are four layers ; top soil with an average thickness and P-wave velocity of 4 m and 324 m/s respectively, second layer is a weathered Phyllite and has an average thickness and P-wave velocity of 10m and 909 m/s respectively, third layer is a saturated zone with an average P-wave velocity of 1759 m/s while the fourth layer is a Rock (Phyllite)and has an average P-wave velocity of 3000 m/s and a Poisson’s ratio of 0.46.

2. FIELD DESCRIPTION AND GEOLOGY OF STUDY AREA

The study area is located at the other side of the main campus that is opposite the gate of the Federal university of Petroleum Resources Effurun (FUPRE), Nigeria as shown in Figure 1

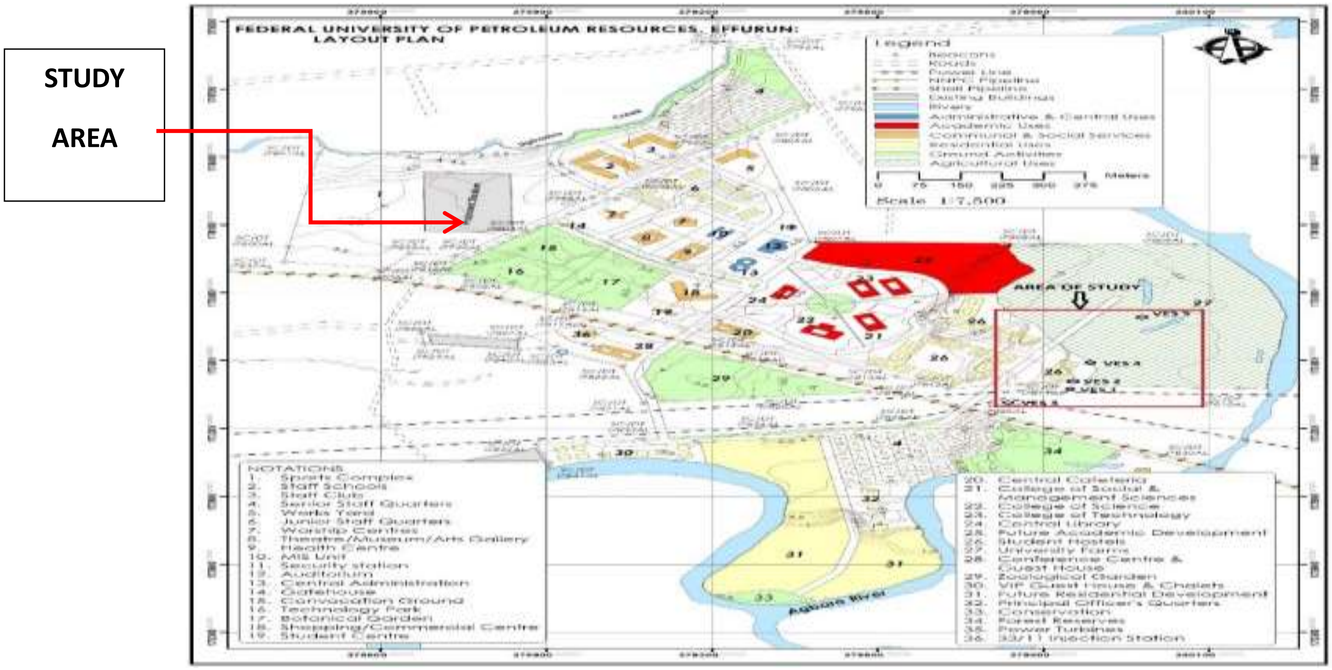

Fig 1.0: Map of FUPRE campus showing the study area

The study area is lowland with elevation not greater than 30m above sea level and it is a relatively flat terrain. The area is a hot/wet equatorial climate region made of two main seasons: the wet and dry seasons with mean annual rainfall greater than 300m and mean temperature of about 28°C (Iloeje, 1981).

2.1 Field Data Acquisition

PASI GEA 24 seismograph and other geophysical instruments were used to acquire data on field, the ranging pole was used to measured 108 meters difference at two different points, the first geophone was inserted at the first 8 meters difference and 4 meters respectively till 100 meters point was reached. 24 geophones were used and connected to the seismograph through the streamer cables. The impact of sledge hammer on the metal plate coupled to the ground created seismic vibrations displayed on the seismograph through the help of trigger geophone extension attached to all geophone points along the traverse.

2.2 Data Processing and Interpretation

The unwanted signal was eliminated or reduced to minimal using SeisSpace software so as to create images of the subsurface features and to enable geological interpretation.

According to Sandmeier, 2008, he made use of proprietary software called Reflex W, Version 5 to process his seismic refraction data he acquired in which it involved some routine steps. These steps were also employed to process the data acquired using SeisSpace geophysical software.

3. RESULTS AND DISCUSSION

3. 1. Display of Images and Results

Figure 2 below is the field travel curve times gotten from the 24 geophones during the acquisition of data while the figure 3 is the processed travel times curves.

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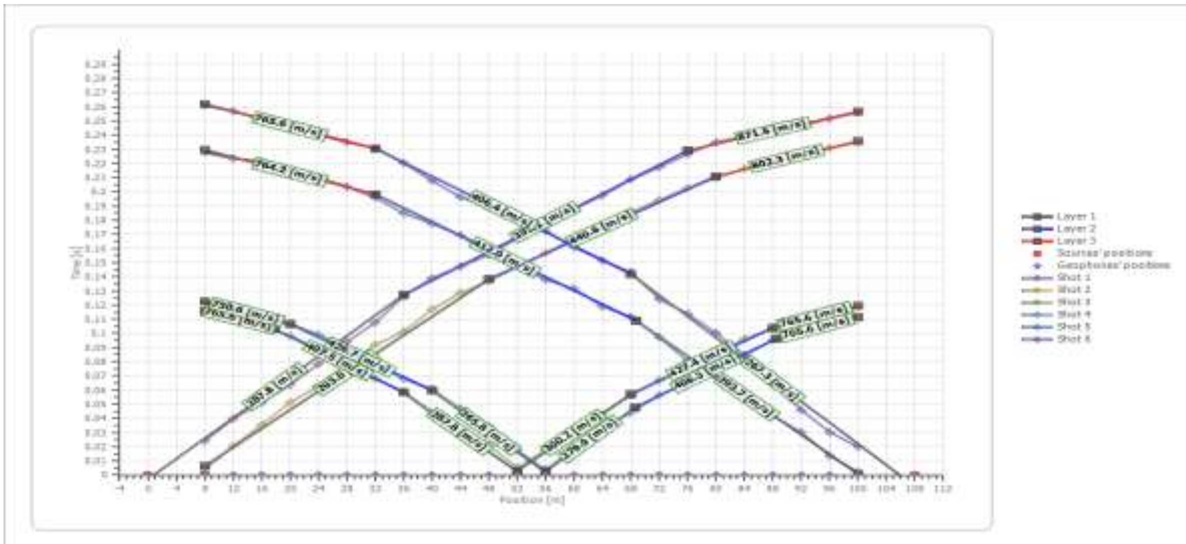

Fig 2: Travel time curve

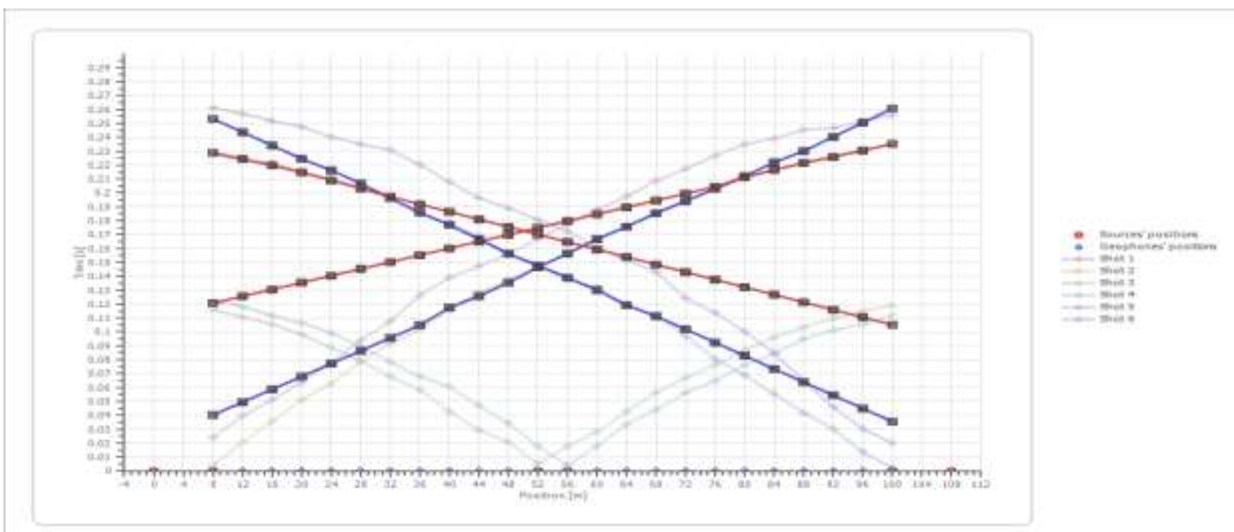

Fig 3: Processed travel time curves

Figures 4 to 8 are the results gotten from each point of the geophones, which are the images of the seismic waves and these images are derived by plotting geophone position against the time taken of arrival and they were used to make conclusions for the subsurface geo-investigation.

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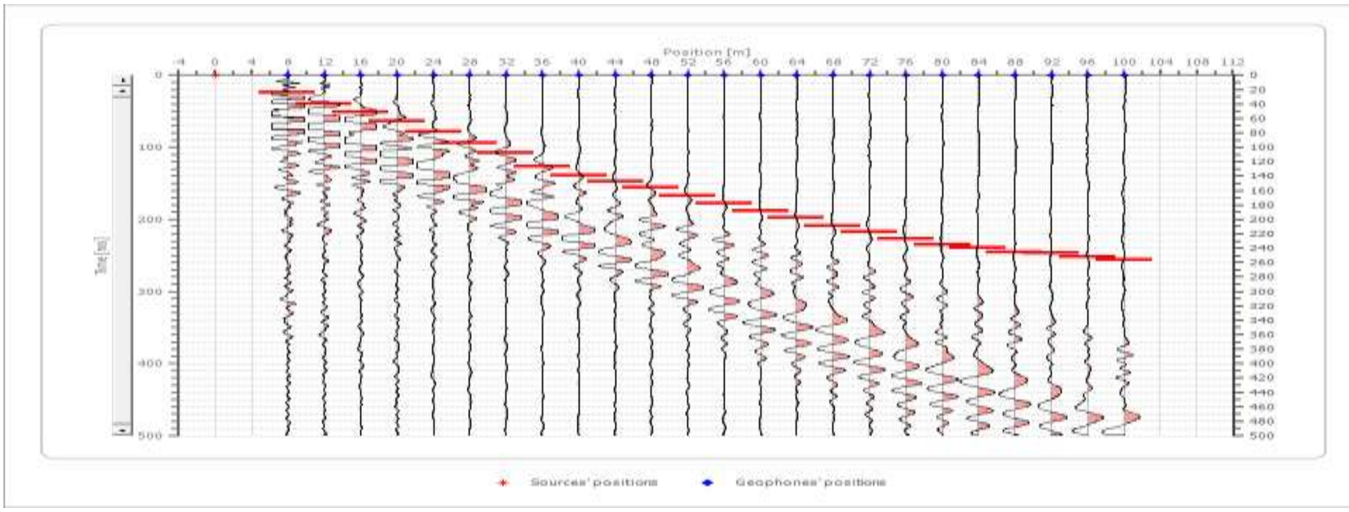

Fig 4: Seismic waves gotten at the first point at 0m

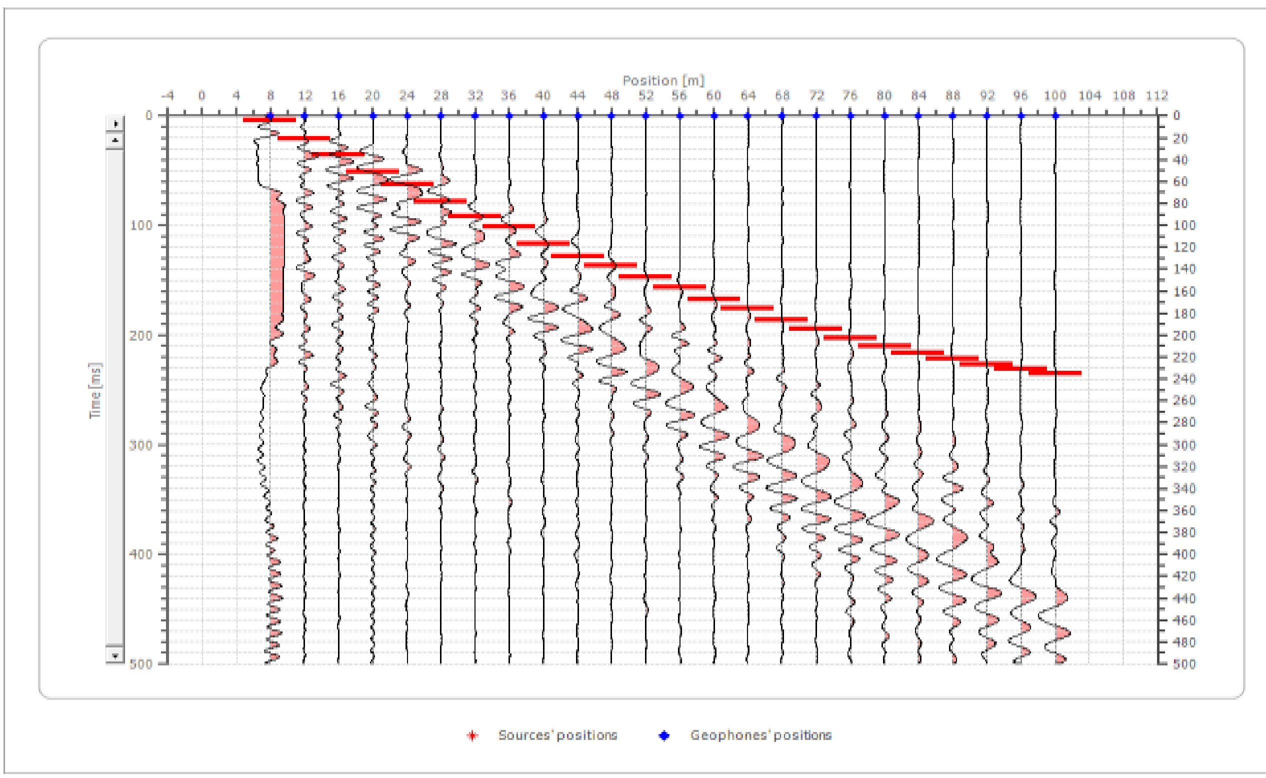

Fig 5: Seismic waves gotten at the Second point at 8m

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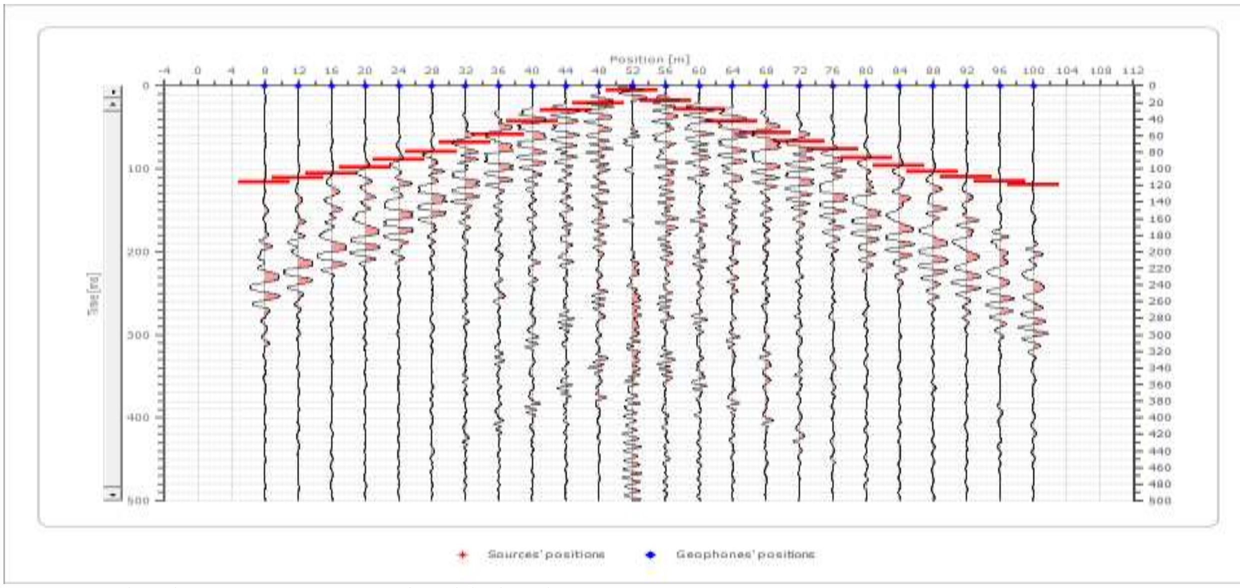

Fig 6: Seismic wave gotten at the third point at 52m

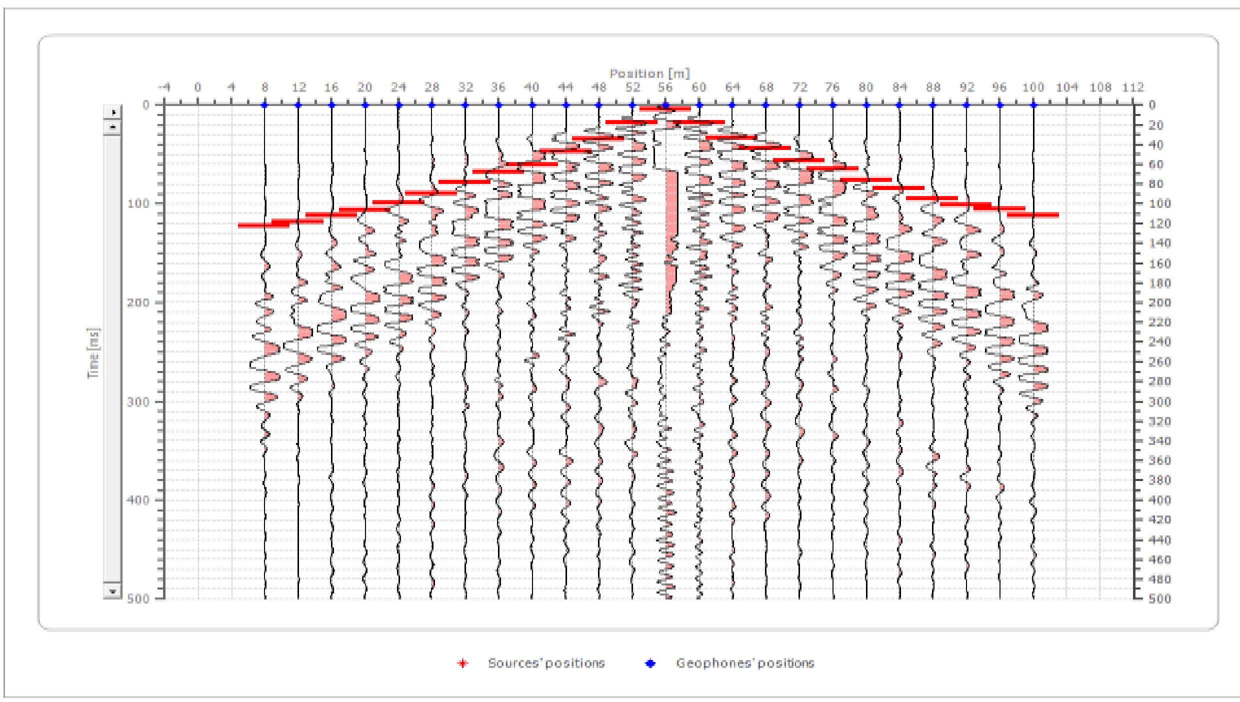

Fig 7: Seismic wave gotten at the fourth point at 56m

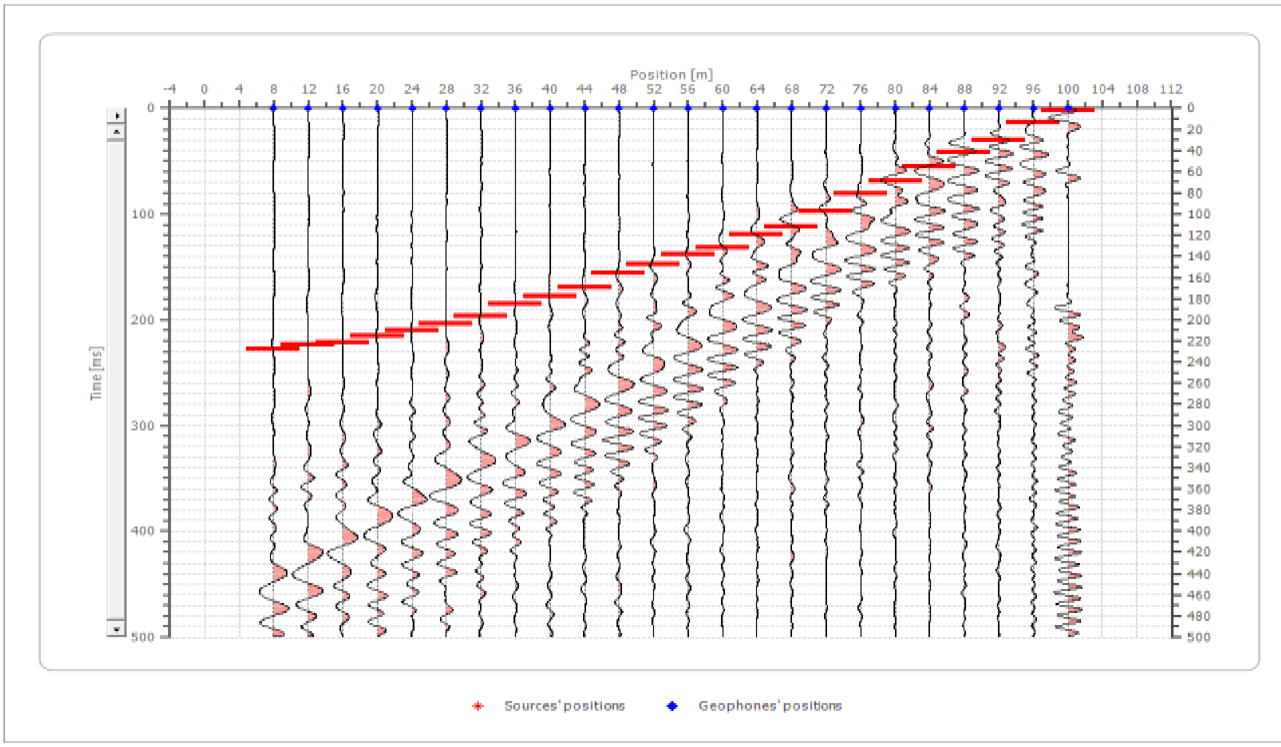

Fig 8: Seismic wave gotten at the fifth point at 100m

3.2. Discussion of Images/results

The results of the images displayed in the study area in figures 4 to 8 for shallow seismic refraction analysis showed that the subsurface of the study area is made up of three layers. The first layer is a top soil with an average thickness of 7m and the P-wave velocity is 284.5 m/s. The second layer found in the investigated area is the weathered Phyllite composition and has an average thickness of 24.5 m and the P-wave velocity of this layer is 419.2 m/s. The value of the Poisson's ratio for second layer is gotten as 0.35 and this indicates that the saturated zone for this layer is vertically extensive and the third layer has the p-wave velocity of 765.55 m/s.

Apart from the values of the p-wave velocity and poison's ratio parameter for the three layers, the other geotechnical parameters obtained are: bulk modulus, young modulus, shear modulus, oedometric modulus, density and s-wave velocity. The table 1.0 is the geotechnical parameters values obtained for the three layers in the study area.

Table 1.0: Geotechnical Parameters obtained

S/N	Geotechnical Parameters	Layer n=1	Layer n=2	Layer n=3
1	Poisson's ratio	0.35	0.35	0.35
2	Density [kg/m³]	1800.00	1800.00	1800.00
3	Vp [m/s]	284.45	419.19	765.55
4	Vs [m/s]	136.65	201.37	367.76
5	Gd [MPa]	33.61	72.99	243.44
6	Od [Mpa]	145.64	316.29	1054.92
7	Bd [MPa]	112.03	243.30	811.48
8	Yd [Mpa]	90.75	197.07	657.30

where:

Vp : P-wave Velocity   Vs : S-wave Velocity   Gd : Shear modulus
Od : Oedometric modulus   Bd : Bulk modulus   Yd : Young modulus

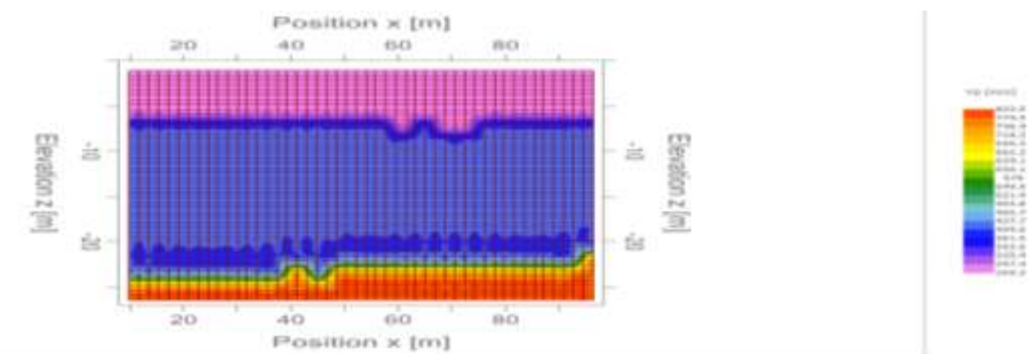

Fig 9: Velocity distribution model in the study area

However, from the values of the above parameters in table 1.0, it can be concluded that the three layers have the following characteristics; which are poor bearing capacity that have low shearing strength, high compressibility which may have high erosion potential. These statements mean that the soils are susceptible to liquefaction in which it may result to a minor crack to any structure built on this investigated area. However, this does not necessarily mean that it is not suitable for construction, but any additional care and design considerations may be necessary to ensure the stability and safety of structures built on the study area.

Figure 9 showed the velocity distribution model in the study area in which it showed how p- wave velocity is distributed and spread when signal was introduced into the subsurface via impact of sledged hammer on the metal coupled on the ground, the reflection of these waves was sensed by all geophones inserted at the surface.

It is recommended that additional geophysical methods like electrical resistivity method should be employed in the study area for more revelation of geophysical characteristics or features. According to Dahlin and Loke, 1998, this electrical resistivity method can characterize the subsurface by locating voids, fissures, faults and also determining the extent of compaction of the weathered zone in any geotechnical investigation.

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