Case Study

ANALYSIS OF NEAR SURFACE SEISMIC REFRACTION FOR GEOTECHNICAL PARAMETERS IN OPOLO, YENAGOA OF BAYELSA STATE.

ABSTRACT

Three surface refraction seismic profiles were conducted in a site targeted for huge construction in an underdeveloped area in Opolo, Yenagoa city to portray some of the subsurface soil engineering characteristics for the purposes of construction. The Generalized Reciprocal Method (GRM) was used to interpret the acquired P and S-wave. Various shallow rock engineering parameters such as Oedometric modulus, Concentration Index, Material Index, Lame's constant, Density Gradient, Stress Ratio, Shear modulus, Bearing capacity, and N-value were calculated in other to assess the strength of the subsurface from a geophysical and engineering perspective. The values from the seismic velocity and strength parameters indicates that the bedrock layer (layer 3) of the area studied is characterized by more competent rock quality than layer 1 and 2. Hence, the Opolo site is suggested for construction activities with percussive measures.

INTRODUCTION

Understanding the subsurface rock quality and structure is a recent and strong development in geophysics (Mohamed H. Khalil1 and Sherif M. Hanafy, 2017.). Before now, obtaining geotechnical parameters of subsurface soil or rock requires direct measurements from a cone penetrometer (CPT), which measures soil resistance to penetration. The disadvantage of CPT method is that it undrained shear strength and could lead to soil failure because this experiment tend to spread very quickly and undesirably. Seismic refraction is one of the most important geophysical techniques for exploring underground layers and local anomalies. This technique is occasionally used in many applications, such as engineering studies, ecology, hydrology, hydrocarbons, and exploration by the mineral industry. The refraction seismic method is based on the measurement of the propagation time of seismic waves which is refracted at different speeds to the interface between the underground layers. It is mostly used to ascertain the depth and speed of the source and refractors on the underground surface.

Seismology is an ancient science with a long history. Its principles are mainly based on signal generation at a time known to be suitable for producing seismic waves that move through the subsurface and are refracted to the surface where the received signal is captured and recorded. The time variation between the source that is triggered and the arrival of seismic waves (which propagates either as a body wave or as a surface wave) is used to ascertain the nature of the underground layer. Systematic recording and subsequent data processing allows detailed analysis of seismic waves to be carried out. Information collected by developed seismograms is then used to develop images of underground structures, which in turn enable a good understanding of the physical properties of materials found in the investigated area.

The process of seismic refraction requires that the earth's material increases with increasing depth at the seismic time. Analysis of refraction data becomes more complex if the material contains a submerged or damaged layer. At the shallow, applications where low speed layers only occur a few meters above ground, acceleration requirements are a mandatory constraint. A difficult situation can occur when the low speed layer is at the base of the high speed layer. Sand on the base of a loamy material. Another complex situation occurs when seismic waves pass through a blind zone (that is, when the layer is too thin to appear as the first arrival of a seismogram). These two situations can cause wrong results.

Therefore, the present study is aimed at calculating geotechnical parameters using the refraction seismic method (both P- and S-waves) values at a sites targeted for massive construction in an underdeveloped area within the capital city of Bayelsa state. We hope that the results of this work will benefit civilian and geotechnical engineers as well as geo-hydrology in the rapidly developing city of Yenagoa.

Keyword: Geotech, Seismic refraction, construction site, Yenagoa.

GEOLOGY OF STUDY AREA

The area under investigation is Opolo which is located in Yenagoa, the capital city of Bayelsa state, Nigeria, which covers an area of 170km. This area lies within longitudes 006^{0} 25’30” and

006^0 21’0” East of the prime meridian and Latitudes 04^0 56’30” and 04^0 57’0” North of the equator within the coastal area of the recent Niger Delta. (Fig. 1.).

The study area lies within the fresh water swamps, backswamps, deltaic plain, alluvium and meander belt geomorphic unit of the Niger Delta (Akpokodje, 1986). The Niger Delta is basically an alluvial plain and consists of the modern and Holocene delta top deposits. Grain-size profiles of the Holocene alluvial deposits consist of sequences of fine sand capped by fine silts and clay indicating a fluvial environment of deposition (Amajor, 1991).

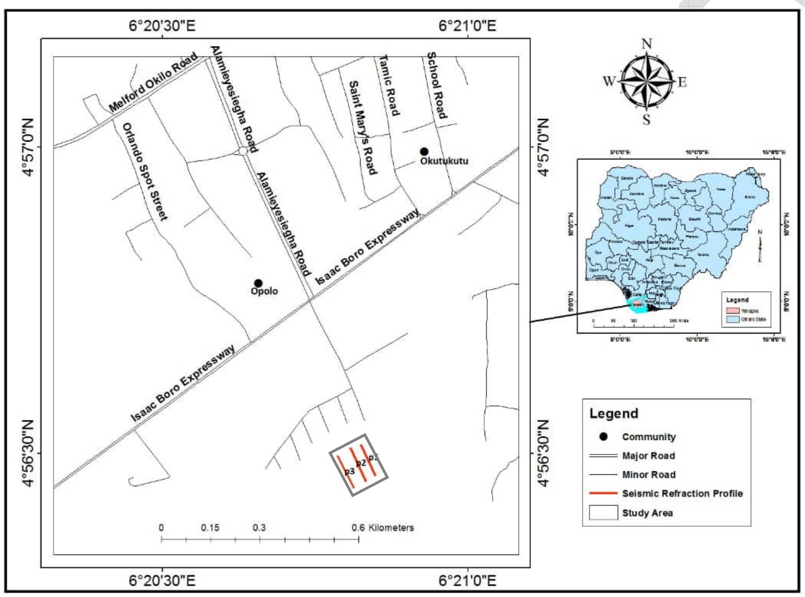

Fig.1: Map of the study Area.

The fine grained silts and clay overlying the basal sandy sequence is often referred to as the near surface aquitard. The thickness of the surface water layer ranges from 4m to about 12 m, and because of the different amounts of clay, mud and fine sand, water surface permeability is very heterogeneous (Amajor, 1991).

There are three main subsurface lithostratigraphic units of the Niger Delta (Short and Stauble, 1967). From top to bottom they are Benin, Agbada and Akata Formations. The Benin Formation which is fluvial in origin is the main aquifer in the study area. The geography of Niger delta is well-known and has been discussed by several authors.

BACKGROUND THEORY

Geophysical geophysics is a geophysical engineering application for geotechnical problems, For example, technical studies on highways, including: soil features (rock size, rock type, boundary layer, groundwater, disturbance location, vulnerability, excessive clay, etc.) and technical/ engineering characteristics of earth materials (stiffness, density, electrical resistance, porosity, etc.).

It is known that the ground has the most varying technical and physical parameters. These parameters vary from side to side and in different levels, and often variations are very strong (Bowles, 1982). For underground competency evaluation for the building industry, several technical parameters of the land must be calculated. In this work, some basic parameters are calculated, namely the concentration index (Ci), material index (V), density gradient (Di), Stress Ratio (Si), Bearing capacity (Br) and N-value (N). Integration of these parameters is used to find out whether the site is suitable for construction. The summary of Abd El-Rahman (1989), Brich (1966), Gassman (1973), Sheriff and Geldart (1986) and Tatham (1982) scope of land descriptions in accordance with the land competency is listed in Table 2 and 3.

The Concentration Index (C_i)

The concentration index is a technical parameter that shows the level of material concentration or competence for the foundation and other civil engineering needs. The concentration index depends mainly on material elasticity and depth distribution. Basically, "Ci" is a material dependent factor. The concentration index is formulated by Bowles (1982) as a Poisson ratio (**σ**) as

$$C_i = \frac{(1+\sigma)}{\sigma}$$

where σ is Poisson's ratio which is obtained using the formula as described in Table 1.

C_i was further defined in terms of velocities (P- and S-wave velocities V_P and V_S) by Abd El-Rahman (1991) as:

$$\boldsymbol{C_i} = \frac{\left[3 - 4\left(\frac{V_s^2}{V_p^2}\right)\right]}{\left[1 - 2\left(\frac{V_s^2}{V_p^2}\right)\right]} \qquad (1)$$

The Material Index (V)

From the engineering point of view, this parameter is use to determine the material quality for foundation purposes. According to Abd El-Rahman (1989), this term refers to the level of competence because of its elastic module. Thus, the material index greatly influences material composition, compaction rates, fragmentation, assemblies and also the presence or absence of fluids in porous spaces that affect the material environment and wave velocity. Abd El-Rahman (1989) obtained a material index from the relationship between the Lame constant (λ) and the stiffness modulus (μ) or the Poisson coefficient (σ) as follows:

$$V = \frac{\mu - \lambda}{\mu + \lambda} = (1 - 4\sigma) \quad (2)$$

where μ and λ represent the rigidity and Lame's constant, respectively. The values of μ and λ can be ascertain using the equations as described in Table 1.

The Density Gradient (D_i)

Adams (1951) defines Density Gradient as a function of density (ρ) and bulk modulus (κ) or in terms of the compressional wave velocity (V_p) and Poisson's ratio (σ).

$$D_i = \frac{\rho}{k}$$

Where (ρ) is the Density and (*K*) is the Bulk Modulus.

The density gradient was also expressed in terms of compressional and shear wave velocities bt Stumpel et al. (1984) as:

$$D_i = \left[V_p^2 - \frac{4}{3}V_s^2\right]^{-1}$$

While Abd El-Rahman (1991) also expressed this equation in terms of velocity-squared ratio as

$$D_i = \left[\left(\frac{3}{V_p^2}\right) - \left(\frac{4\mu}{E} - 1\right)\right] = \left[\left(\frac{3}{V_p^2}\right) - \left(\frac{1-\sigma}{1+\sigma}\right)\right] \quad (3)$$

Where (E) is the Young's Modulus. The value of *E* can be determined using the equations shown in Table 1.

The Stress Ratio (S_i)

As long as excessive pressure is caused by a stress change, a consolidation settlement is band to occurs when there is excessive pressure. At the end of a consolidation process, the excess pressure will almost be zero and the stress change will shift from the total to the effective condition. In this tense state, a soil condition is defined as a steady state with zero lateral and vertical pressure (Bowles, 1982). Bowles (1982) shows that there is a relationship between the Poisson ratio (σ) and the stress ratio (Si) for normally consolidated soils. This relationship is given by Bowles (1982) and Thomson (1982) as:

$$S_i = \frac{\sigma}{1-\sigma}$$

From several general observations about (S_i), Bowles (1982) highlighted that S_i becomes greater for loose soils, and also Si decreases with increasing load pressure and Si becomes larger when the soil is too consolidated. Abd El-Rahman (1991) highlighted the relationship between Poisson's Ratio, Si and wave velocities as follows:

$$S_i = 1 - 2\left(\frac{V_s^2}{V_p^2}\right) = (C_i - 2)^{-1} \quad (4)$$

The Bearing Capacity (B_r)

The maximum load volume needed to break ground shear failure is called bearing capacity. It can be estimated using the Parry formula (1977) by using the standard penetration test (SPT) or N-value as:

$$B_r = \log(30N) \quad (5)$$

The N-value (N)

The N-value which is also called the standard penetration test (SPT) is used to evaluate soil only and not rocks. It is defined according to Imai et al. (1976) and Stumpel et al. (1984) as the penetration resistance below the normal pointy rod under normal load. The relationship between the N-value and the shear wave velocity is as follows:

$$N = \left(\frac{V_s}{76.55}\right)^{2.24719} \quad (6)$$

where higher N-values indicate greater soil penetration resistance.

Table 1

List of equations used to calculate elastic moduli

Elastic Modulus	Used equation	Reference
Shear Modulus	$\mu = \frac{E}{2(1+\sigma)}$	King (1966), Toksoz et al. (1976)
Young's Modulus	$E = \rho\left[\frac{3V_p^2 - 4V_s^2}{(V_p/V_s)^2 - 1}\right]$	Adams (1951)
Poisson's Ratio	$\sigma = \frac{1}{2}\left[1 - \frac{1}{(V_p/V_s)^2 - 1}\right]$	Adams (1951), Salem (1990)
Lame's Constants	$\lambda = \frac{\sigma E}{(1+\sigma)(1-2\sigma)}$	King (1966), Toksoz et al. (1976)

V_P and V_S are the P- and S-wave velocities, respectively.

Table 2

Ranges of Concentration Index, Stress Ratio, Bearing capacity and N- Value correspondent to the soil competent degree, after Abd El-Rahman (1989).

	Weak (Incompetent)		Fair (Fairly competent)		Good (Competent)
	Very Soft	Soft	Fairly compacted	Moderate compacted	Compacted
Concentration index C_i	3.5 – 4.0	4.0 – 4.5	4.5 – 5.0	5.0 – 5.5	5.5 – 6.0
Stress Ratio S_i	0.7 – 0.61	0.61 – 0.52	0.52 – 0.43	0.43 – 0.34	0.34 – 0.25
Bearing Capacity (Br)	2 – 2.6	2.6 – 3.2	3.2 – 3.8	3.8 – 4.4	4.4 – 5.0
N – Value (N)	0 – 250	250 – 500	500 – 750	750 – 1000	1000 – 1200

MATERIALS AND METHODS

Three (3) seismic refraction profiles were conducted in order to cover the study area (Fig. 1). Each profile extends for a total length of 60m. The inter-geophone spacing was 5 m and the shot-to-1st geophone spacing was 1 m with a total of 12 geophones per profile.

The total record length for P-waves and S-wave was 1024ms with sample interval of 0.25ms and total number of samples per trace was 1500. The study area is an undeveloped area which is located far from any noise sources such as traffic, daily human activities, machinery, and other factors, which contributed to enhance the signal-to-noise ratio.

A sledgehammer (10 Kgm) was used to generate the seismic P-waves and S-waves. To generate the waves a metallic plate (20×20 cm^2) was used to receive the sledge hammer strikes. A total of 5 stacks were made per each shot location. Both P-waves and S-waves was recorded using 14 Hz geophones.

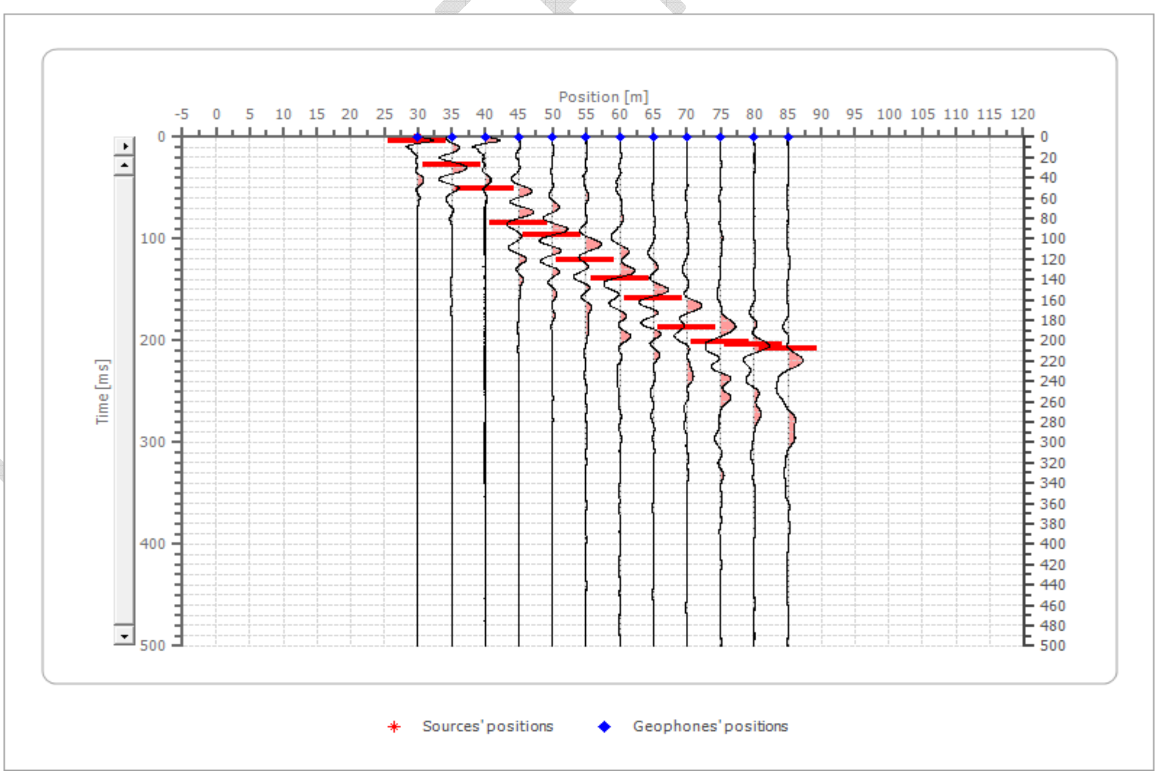

Fig. 2: A sample of a picked first wave arrival time from the collected wave records

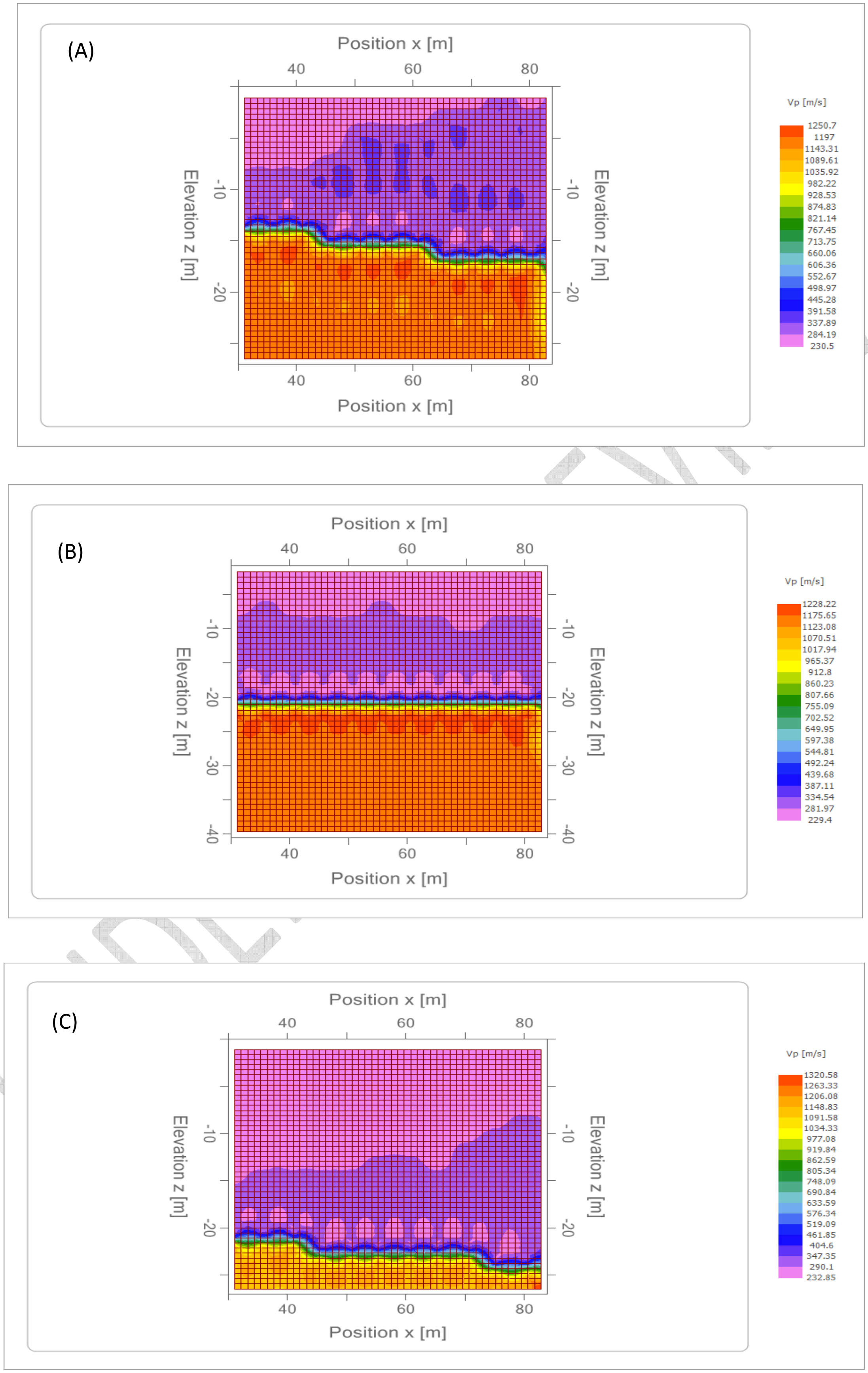

Fig. 3: GRM-depth velocity model for profile 1 to 3 respectively

The obtained data was analyzed and interpreted using Easyrefract software. The first arrivals of the waves were directly picked from the collected wave records (Fig. 2). For each profile, interpretation of the first arrival times was performed using the Generalized Reciprocal Method (GRM) as described by Palmer (1980, 1981). The first arrival travel-times of the obtained GRM-depth velocity model were calculated using a Finite Difference (FD) method (Fig: 3a - c) (Vidale, 1988, 1990; Qin et al., 1992). The FD-times and observed-times were compared.

V_P and V_S values at each profile location was produced following the steps stated in the above paragraph. In this study, the P- and S-wave velocities of all layers within the depth of investigation was considered and analyzed. The P-, S-wave velocities and density values are then used to calculate the elastic moduli and hence the geotechnical parameters listed in Equations (1) to (6).

Table 3

Soil description with respect to Poisson's Ratio and Material Index, after Birch (1966), Gassman (1973), Tatham (1982), Sheriff and Geldart (1986).

	Weak Incompetent to slightly competent	Fairly competent to moderately competent	Competent Material	Very high competent material
Poisson's ratio *σ*	0.41 – 0.49	0.35 – 0.27	0.25 – 0.16	0.12 – 0.03
Material index *V*	(-0.5) – (-1)	(-0.5) – (0.0)	0.0 – 0.5	>0.5

RESULTS DISCUSSION

Geotechnical parameters which include Bulk density, Poisson's Ratio, Young's modulus, shear modulus, oedometric modulus and Lame's constant were obtained from the result of the primary and secondary wave velocities for each layer using formulas from Table 1. Other parameters were also determined for further investigation. The study area consist of three (3) geologic layers within the depth of our investigation. Easyrefact software was used to process this data. The calculated geotechnical parameter results from all three profiles within the study area are summarized in Table 4 and analyzed as follows.

Layer 1 whose depth ranges from 4m to 13m have P-wave velocity ranging from 236m/s to 264m/s and S-wave velocity ranging from 114m/s to 127m/s. The summary of the elastic moduli results of layer one across all profiles are summarized as follows:

- ✓ ***Poisson's Ratio (σ):*** The poisons Ratio of layer 1 across the three profile is 0.35. It has a relatively high Poisson ratio value and this indicates that this layer is a fairly competent soil (Salem, 1990).
- ✓ ***Bulk Density (ρ):*** This layer across all profile have Bulk density value of 1800 kg/m^2. This indicates a relatively high rock densities.
- ✓ ***Young's Modulus (E):*** ranges from 66 to 97 MPa (Mega Pascal = (Newton/m^2)/106). The study area is characterized by relatively low values of Young's Modulus.
- ✓ ***Lame's Constants (λ):*** ranges from 14 to 21 MPa. The study area is characterized by relative low "λ" values.
- ✓ ***Oedometric modulus*:** ranges from 100MPa and 126MPa. This indicates a low oedometric modulus value.
- ✓ ***Shear Modulus (μ) or Rigidity:*** ranges from 23 to 29 MPa. The study area is characterized by relatively low rigidity or shear modulus "μ" values.
- ➢ In the study area, the calculated C_i for layer 1 reveals values of 4.0 across all profiles. This indicates that the area is characterized by relatively low C_i values which according to *Abd El-Rahman (1989)*, reflects weak incompetent soil (very soft to soft soil).
- ➢ The calculated material index (ν) for layer 1 reveals value of –0.4 across all profiles. The area is characterized by relatively low Material Index (ν) which reflects weak incompetent soil (soft).
- ➢ The calculated Density Gradient (D_i) for layer 1 across all profiles reveals value of –0.5. The study area is characterized by relatively low Density Gradient (Di).
- ➢ The calculated Stress Ratio (Si) for layer 1 reveals values of 0.5. This indicates that layer 1of the study area is characterized by lowest Stress Ratio (S_i) which, according to *Abd El-Rahman (1991)*, reflects weak (Soft) compacted soil.
- ➢ The bearing capacity (Br) for layer 1 reveals value of 2.0 across all the profiles. This indicates that layer 1 of the study area is characterized by low bearing capacity (Br) which, according to *Abd El-Rahman (1991)*, reflects very soft compacted soil.

- The N-value (*N*) for layer 1 reveals values ranging from 2.4 to 3.6 across all the profiles. This indicates that layer 1 of the study area is characterized by very low N-value (*N*) which, according to *Abd El-Rahman (1991)*, reflects very soft compacted soil.

Layer 2 whose depth ranges from 21m to 23m have P-wave velocity ranging from 302m/s to 333m/s and S-wave velocity ranging from 145m/s to 160m/s. The summary of the elastic moduli results from layer two across all profiles are summarized as follows:

- ✓ ***Poisson's Ratio (σ):*** The poisons Ratio of layer 2 across the three profiles is 0.35. It has a relatively high Poisson ratio value and this indicates that this layer is a fairly competent soil (Salem, 1990).
- ✓ ***Bulk Density (ρ):*** Layer 2 across all profiles consist of Bulk density whose value is 1800 kg/m^2. This indicates a relatively high rock densities.
- ✓ ***Young's Modulus (E):*** This layer have young's modulus values ranging from 124MPa to 146MPa (Mega Pascal = $(Newton/m^2)/106$). This range of value indicates that layer 2 of the study area is characterized by relatively low values of Young's Modulus.
- ✓ ***Lame's Constants (λ):*** ranges from 26MPa to 31MPa. The study area is characterized by relatively low "λ" values.
- ✓ **Oedometric modulus:** ranges from 165MPa and 199MPa. This indicates a relatively low oedometric modulus value.
- ✓ ***Shear Modulus (μ) or Rigidity:*** ranges from 23MPa to 29 MPa. Layer 2 of the study area is characterized by relatively low rigidity or shear modulus "μ" values.

- In the study area, the calculated C_i for layer 2 reveals values of 4.0 across all profiles. This indicates that layer 2 of the investigated site is characterized by relatively low C_i values which according to *Abd El-Rahman (1989)*, reflects weakly compacted soil (very soft soil).
- The calculated material index (ν) for layer 2 reveals value of –0.4 across all profiles. Layer 2 of the study area is characterized by relatively low Material Index (ν) which reflects weak incompetent soil (soft).
- The calculated Density Gradient (D_i) for layer 2 across all profiles reveals value of –0.5. This value indicates that layer 2 of the study area is characterized by relatively low Density Gradient (Di).

- ➢ The calculated Stress Ratio (Si) for layer 2 reveals values of 0.5. This indicates that layer 2 of the study area is characterized by very low Stress Ratio (S_i) which, according to *Abd El-Rahman (1991)*, reflects weak (Soft) compacted soil.
- ➢ The bearing capacity (Br) for layer 2 reveals value of 2.2 across all the profiles. This indicates that layer 2 of the study area is characterized by low bearing capacity (Br) which, according to *Abd El-Rahman (1991)*, reflects very soft compacted soil.
- ➢ The N-value (*N*) for layer 2 reveals values ranging from 4.2 to 5.2 across all the profiles. This indicates that layer 2 of the study area is characterized by very low N-value (*N*) which, according to *Abd El-Rahman (1991)*, reflects very soft compacted soil.

Layer 3 also known as the bedrock layer have its depth values as infinite. Its P-wave velocity ranges from 1117m/s to 1153m/s and S-wave velocity ranging from 537m/s to 554m/s. The summary of the elastic moduli results from layer three across all profiles are summarized as follows:

- ✓ ***Poisson's Ratio (σ):*** The poisons Ratio of layer 3 across the three profiles is 0.35. It has a relatively high Poisson ratio value and this indicates that this layer is a fairly competent soil (Salem, 1990).
- ✓ ***Bulk Density (ρ):*** Layer 3 across all profiles consist of Bulk density whose value is 1800 kg/m^2. This indicates a relatively high rock densities.
- ✓ ***Young's Modulus (E):*** This layer have young's modulus values ranging from 1490MPa to 1834MPa (Mega Pascal = (Newton/m^2)/106). This range of value indicates that layer 3 of the study area is characterized by relatively high values of Young's Modulus.
- ✓ ***Lame's Constants (λ):*** ranges from 316MPa to 389MPa. The study area is characterized by high "λ" values.
- ✓ **Oedometric modulus:** ranges from 2246MPa and 2391MPa. This indicates a relatively high oedometric modulus value.
- ✓ ***Shear Modulus (μ) or Rigidity:*** ranges from 518MPa to 552MPa. Layer 3 of the study area is characterized by relatively high rigidity or shear modulus "μ" values across a profiles.
- ➢ In the study area, the calculated **C**$_i$ for layer 3 reveals values of 4.0 across all profiles. This indicates that layer 3 of the investigated site is characterized by relatively low C_i values

which according to *Abd El-Rahman (1989)*, reflects weakly compacted soil (very soft soil).

- The calculated material index (ν) for layer 3 reveals value of −0.4 across all profiles. Layer 3 of the study area is characterized by relatively low Material Index (ν) which reflects weak incompetent soil (soft).
- The calculated Density Gradient (D_i) for layer 3 across all profiles reveals value of −0.5. This value indicates that layer 3 of the study area is characterized by relatively low Density Gradient (Di).
- The calculated Stress Ratio (Si) for layer 3 reveals values of 0.5. This indicates that layer 3 of the study area is characterized by very low Stress Ratio (S_i) which, according to *Abd El-Rahman (1991)*, reflects weak (Soft) compacted soil.
- The bearing capacity (Br) for layer 3 reveals value of 3.4 across all the profiles. This indicates that layer 3 of the study area is characterized by moderate bearing capacity (Br) which, according to *Abd El-Rahman (1991)*, reflects fairly compacted soil.
- The N-value (*N*) for layer 3 reveals values ranging from 80 to 85 across all the profiles. This indicates that layer 3 of the study area is characterized by very low N-value (*N*) which, according to *Abd El-Rahman (1991)*, reflects very soft compacted soil.

From the above results, the first and the second geologic layers have a lower seismic wave velocity while the third layer have a higher seismic wave velocity (Fig.4a - c). The results from the Bulk density result shows that all layers are adequately compressed. This may be as a result of the geologic formation, level of saturation and level of cementation of the geo-material. The young modulus results from the three layers shows that layer three has more strength than the first and second layer.

The results from the oedometric modulus, which measures the ease of deformation of subsurface geo-material indicates that layer one and two would deform more easily under shear stress than the third layer. The shear modulus results from all three layers shows that the third geologic layer is more competent than the first and second layers. Although the Concentration index, Bearing capacity, N-Value, Material index, Stress ratio and Density gradient in all three layers all have values that fall within the weak soil competency range according to Birch (1966), Gassman (1973), Tatham (1982), Sheriff and Geldart (1986), and Abd El- Rahman (1989, 1991) as summarized in table 2 and 3, layer three still shows to have more competency than layer one and two. Furthermore, it shows that the depth to the most competent layer starts within the range of 20m and 23m.

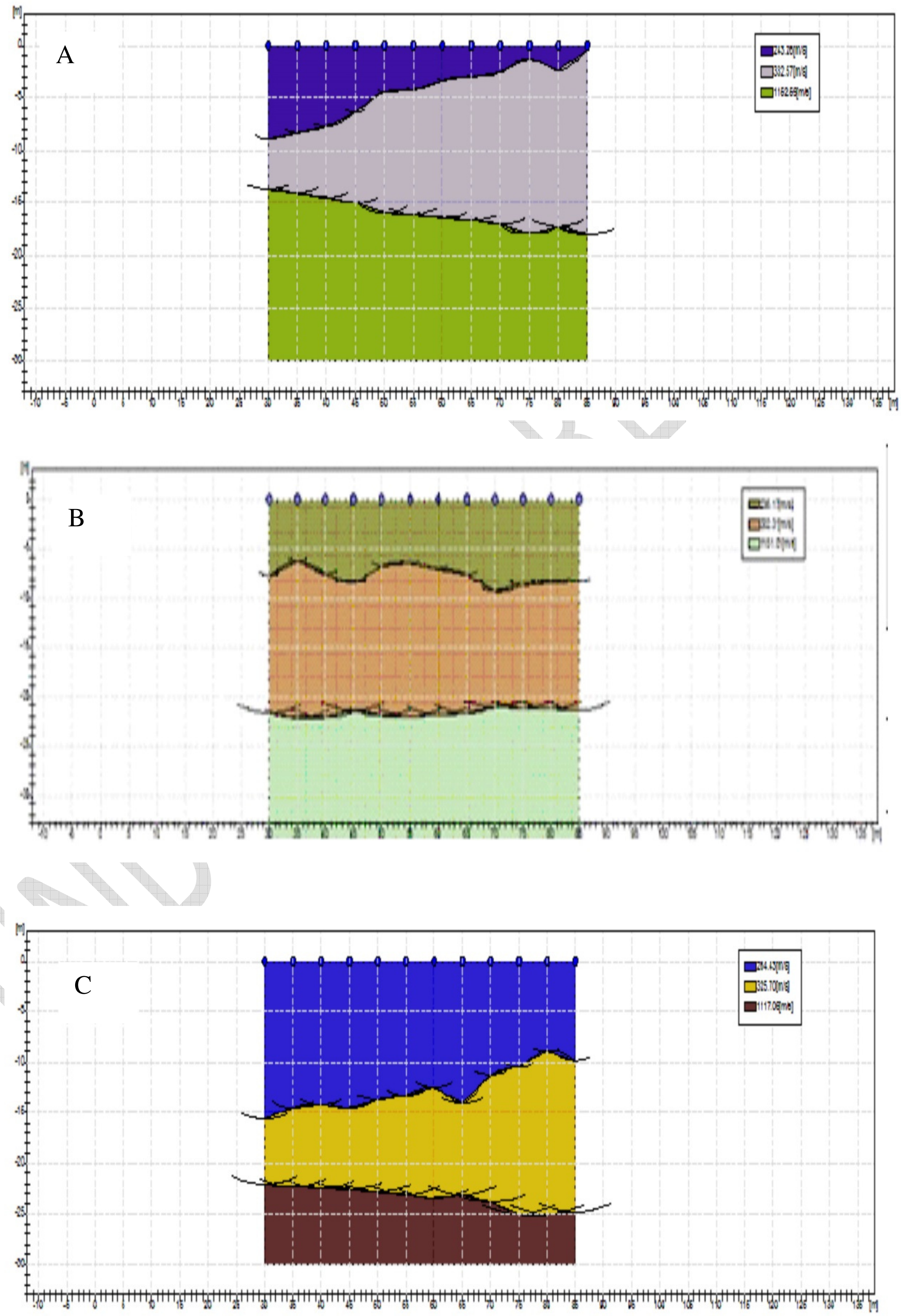

Fig. 4: Morphology of refractor showing seismic velocity of each layer across the three profiles respectively.

Table 4

Seismic velocities of the investigated site as obtained from the refraction profiles and the corresponding calculated elastic moduli

GEOTECHNICAL PARAMETERS	PROFILE 1			PROFILE 2			PROFILE 3		
	Layer 1	***Layer 2***	***Layer 3***	***Layer 1***	***Layer 2***	***Layer 3***	***Layer 1***	***Layer 2***	***Layer 3***
Depth (m)	4.39	20.9	∞	7.76	21.71	∞	12.73	23.38	∞
Poisson's ratio	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Density *(kg/m³)*	1800.00	1800.00	1800.00	1800.00	1800.00	1800.00	1800.00	1800.00	1800.00
Vp *(m/s)*	243.26	332.57	1152.59	236.17	302.31	1151.01	264.43	325.70	1117.06
Vs *(m/s)*	116.86	159.76	553.68	113.45	145.23	552.93	127.03	156.46	536.62
Shear modulus *(MPa)*	24.58	45.94	551.82	23.17	37.96	550.32	29.05	44.06	518.33
Bulk modulus *(MPa)*	81.94	153.15	1839.40	100.40	164.51	2384.70	125.87	190.95	2246.10
Young's modulus (E) *(MPa)*	66.37	124.05	1489.91	77.23	126.54	1834.38	96.82	146.88	1727.77
Lame's Constants	14.08	26.31	316.04	16.38	26.84	389.11	20.54	31.16	366.50
Oedometric modulus *(MPa)*	106.52	199.09	2391.21	100.40	164.51	2384.70	125.87	190.95	2246.10
Concentration index (C_i)	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.87
Density Gradient (D_i)	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48
Stress Ratio (S_i)	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Bearing Capacity (Br)	2.0	2.2	3.4	2.0	2.1	3.4	2.0	2.2	3.4
N – Value (N)	2.59	5.22	85.32	2.42	4.21	85.05	3.59	4.99	79.52
Material index (*V*)	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4

CONCLUSION

The aim and purpose of this work is to describe a vase site in Opolo of Yenagoa city of its characteristics for engineering constructions. A total of 3 surface refraction seismic profiles were acquired at the site for that purpose. Both P and S waves were acquired from the field and interpreted. GRM method was used to make a preliminary depth-velocity model. Shallow rock engineering parameters such as Concentration Index, Material Index, Density Gradient, Stress Ratio, Shear modulus, Lame's constant, Bearing capacity, Oedometric modulus and N-value were calculated to assess all layers from a geophysical and engineering prospective. Integration of various parameters for elasticity and strength of the soil shows adequate competency of the site's rock foundation. Therefore, the area has the potential to be recommended for technical purposes and basic objectives (Figure 5). The conclusion drawn from this work is that, we have shown ways to integrate geophysical research with technical parameters to characterize sites.

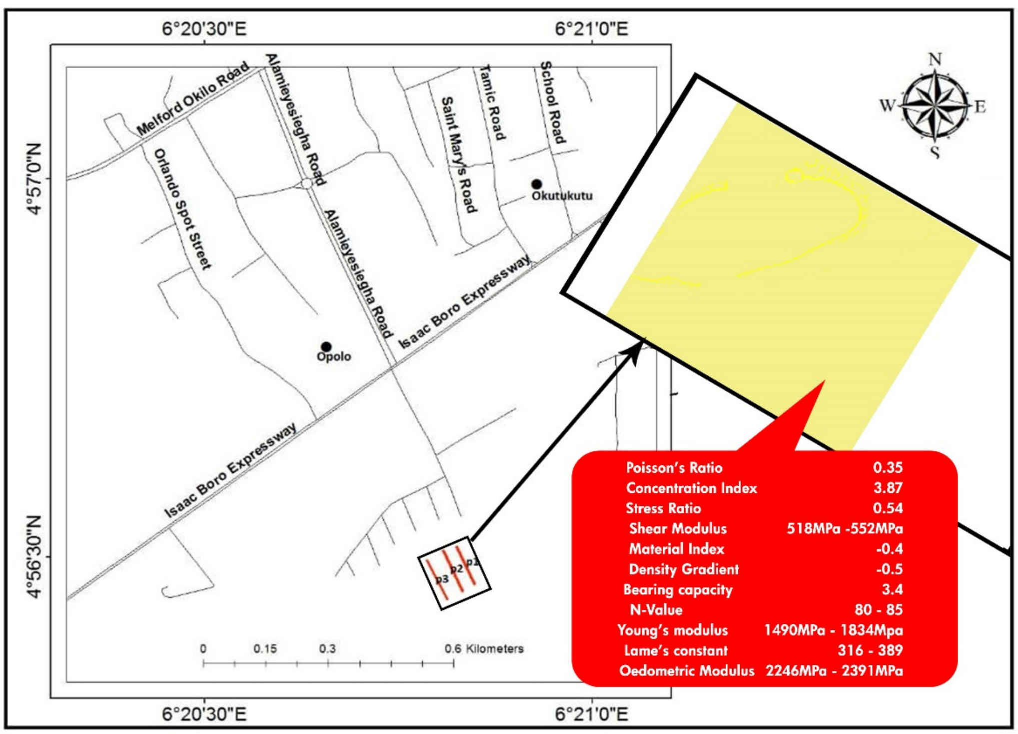

Fig. 5: The most eligible layer for engineering and foundation purposes in the study area.

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