Foundation Materials Bearing Capacity of Tombia Yenagoa, Bayelsa State Nigeria Using Multichannel Analysis Surface Waves Method

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Abstract

This study used Multichannel Analysis of Surface waves Method from data obtained in seismic refraction survey conducted along three profiles targeted in Tombia Town of Yenagoa Metropolis was processed with aid of Easy MASW software then analysed, evaluated and interpreted for sustainable design of infrastructure, shear wave velocities deduced were used to estimate various subsurface soil parameters of geotechnical significance such as N-value, ultimate bearing capacity, and allowable bearing capacity. From the results, shear wave velocity of the first layer depth 0.95 m -1.5 m across the study area was characteristically low and ranged between 100.50 m/s - 121.70 m/s in shear wave velocity with corresponding low values N-value ranged 1.84 – 2.83, ultimate and allowable bearing capacity 20.77 Kpa -36.40 and 1.74 Kpa – 1.93 Kpa. These values indicative of soft unconsolidated alluvial deposits generally considered incompetent to support a substantial structural load. The evaluated geotechnical parameters of the second layer depth 5.01 m – 5.64 m show a marked increase in all the parameters analysed with an appreciable ultimate and allowable bearing capacity value range of 297.92 Kpa – 447.51 Kpa and 2.63 Kpa - 2.76 Kpa respectively. The third subsurface layer was delineated at a depth range of 12.99 m- 15.33 m with a variable thickness range of 8.03 m – 9.67 m. Thus, the first layer is not recommended for shallow footing and foundation designs for storey buildings while the second and third layers indicate they are fairly compacted and competent for support of multi-storey building constructions using either raft or pile foundation types.

Keywords: *MASW, Ultimate Bearing Capacity, Allowable Bearing Capacity, N-value, shear wave*

Introduction

Structural failures are often attributed to problems of substandard materials used for building, old age of buildings, and poor foundation design which is due to high cost of carrying out geotechnical investigation. Also, near surface structures such as cavities, sinkholes, faults etc. that seriously affect foundation design are trivialized by foundation designers and structural engineers prior to infrastructure development and construction (Adeyemo, et al., 2014). The layout of foundations is characteristic of civil engineering construction, involving an accurate assessment of the thickness of the underground material, its geotechnical quality, and its physical properties. When buildings carry very heavy loads and the area of influence is very deep, it would be desirable to invest some amount on sub-surface exploration than to overdesign the building and make it expensive. Like complex projects involving heavy structures, such as storey buildings, bridges, dams etc, it is very important to have detailed information of the area. The suitability of soil for a particular use should be determined based on its Geotechnical properties and not on visual inspection or apparent similarity to other soils. As such, the need arises for proper subsurface soil evaluation with a view of providing the earth subsurface information necessary for the proper design of formidable civil engineering structures. In accordance with Bowles (1984) and Adeyemo and Omosuyi (2012), foundation design, being a typical civil engineering infrastructure, requires the proper determination of depth to subsurface bedrock, its geotechnical integrity as well as an evaluation of its physical properties. Conventional methods such as boring, pits and trenches (Akintorinwa and Oluwole, 2018) for the determination of these technical properties: density, porosity, permeability, moisture content, consistency, compressibility, shear strength are invasive, expensive and time-consuming (Nwankwoala and Warmate 2014). They involve a long period of field acquisition by various methods and a long period of rigorous laboratory work. Besides, the properties of the soil are subject to strong spatial and temporal variations. For an accurate assessment of soil properties, high-density sampling will be required. However, drill sampling can be very expensive and time consuming under such conditions. To these end, geophysical methods are routinely used to complement geotechnical investigations. The geophysical methods that suit such investigations are seismic refraction, electrical resistivity, and gravity methods (Francis et al.,2019). Among these methods, the seismic refraction method is commonly used because it combines speed, accuracy with cost-effectiveness. In many cases, geophysical methods improve reliability and speed, as well as the volume and cost of geotechnical investigations. Seismic refraction is one of the most essential geophysical techniques for exploring underground layers and local anomalies (Francis et al.,2019). This technique is routinely used in many applications, such as engineering studies, ecology, hydrology, exploration for hydrocarbons, and solid minerals. The seismic refraction method is based on calculating the propagation time of seismic waves that are refracted at the interface between the underground layers at different speeds. It is mostly used to determine the depth and velocity of the subsurface. Since the velocity of the seismic waves is a function of the sub-surface materials ' intrinsic and secondary properties, seismic wave velocities may serve as indices for defining subsoil competence and their geotechnical properties (Momoh et al., 2019). Though geophysics is not a substitute for geotechnical boring or testing, it is often a very cost-effective and efficient means of constructing continuous 2D and 3D images of the subsurface and determining insitu bulk properties (Anderson et al. 2008). In the past decade a couple of building collapse consequent on foundation failures have been recorded in Bayelsa state and Yenagoa metropolis in particular (Oborie, et al.,2018). The Yenagoa area can be described as a peneplain, intersected by numerous creeks, rivers and lakes which include the Epie Creek, Ikoli River and Oxbow Lake. Results from boreholes show that the near surface deposits in the area are predominantly soft silty-clays with significant lateral and depth variations across the various interconnected suburban communities. The clays are subjected to mild desiccation during the dry season which results in some false enhancement of strength in the dry season (Oborie et al, 2018). Average annual rainfall is about 3000 mm such that the water table is exactly at the surface in some sections of Yenagoa during the peak of the wet season. A combination of the above conditions is generally undesirable for civil constructions. It is therefore pertinent to routinely carry out recommended and cost-effective scientific investigations so as to evaluate the shear strength and bearing capacity of the subsoil. The results of such studies will in turn serve as guides for foundation and footing designs that are adequate and well suited to accommodate the peculiar subsoil nature of study area.To estimate soil bearing capacity for building constructions and development using a cost-effective, rapid and method thereby determining the shear wave velocity of the shallow subsurface layers in the study area in other to estimate the N-Value and evaluate the strength of different subsurface soil layers in response to the depth of competent subsurface unit in the underground profile of the area study.

Materials and methods

Physiographic setting and Geology of the study area

The area under investigation is Tomia in Yenagoa, the capital city and It is one of the rapidly growing urban in the South-South geopolitical region of Nigeria. Its major communities surrounding it are Akaibiri Gbaratoru, Agudama Epetiama Bayelsa state, Nigeria. have a good road network connecting different parts of the city of Yenagoa and its surroundings. This zone is located in longitudes 006^0 14’30” and 006^0 17’0” east of the first meridian and latitudes 04^0 59’0” and 05^0 0’30” north of the equator in the coastal zone of Niger Delta. (Figure 1) with topography is generally low-lying with elevations ranging from below sea level in the southwestern flank of the region to about 39 m further inland (Eteh et al.2019). The Niger Delta lies in the humid tropic region within the equatorial type climate belt. It is characterized by high rainfall during the rainy season and a short duration of dry season which is about four (4) months. The average annual rainfall is about 4000 mm) and temperature of the area are 2,899mm and 26.7ºC respectively. (Okiongbo and Douglas, 2013 There are two (2) major seasons which defined this region. They are the dry and wet seasons. The dry season lasts from November to early March and the rainy season begins from late March to October. A short break in the rainy season is observed around mid-August. This region supports luxuriant fast-growing swamp forest which include palm tree, mangrove trees and grasses. The organic debris which originates in these swamps, an important thing is that they assist in the sedimentation of this region climate vegetation root, types of trees, shrubs, etc occupation of the people etc . The area is drained by tributaries link to the River Nun. Tomia community is home to close to hydrocarbon flow stations owned by the SPDC and Agip Oil Company and NLNG. The Niger Delta Basin was formed by a failed rift (Aulacogen) junction at the pulling apart of the South American plate from the African plate. The rifting in the basin was initiated during the late period of the Jurassic and terminated in the period of the mid-Cretaceous. Several faults occur which are more of thrust faults. The delta covers a land area in excess of 105,000 km2 (Reijers, 2011). These structures are facies of the pro-delta Akata Formation, facies of the Agbada Formation which constitute a paralic delta front. The Benin Formation constitute a continental delta top facies. The Akata Formation is the basal lithostratigraphic unit found in the Niger Delta Region, ranging from Paleocene to Holocene age (Reyment, 2018). Its marine pro-delta mega facies are composed of thick shales, turbidite sands, and small amounts of silt and clay. The Akata formation is made up of high pressure, low density, and deep marine deposits consisting of plant relics near the contact with overlying Agbada formation. The planktonic foraminifer may account for over 50 percent of the rich microfauna and benthonic assemblage (Chukwu, 1991). This assemblage indicates a shallow marine shelf depositional environment. The streak of sand and silt have been deposited at the high energy delta advanced into the sea. The approximate range of thickness is from 0-6000 meters. The formation crops out subsea at the outer delta area and is not visible at the shore (Etu-Efeotor, 1997).

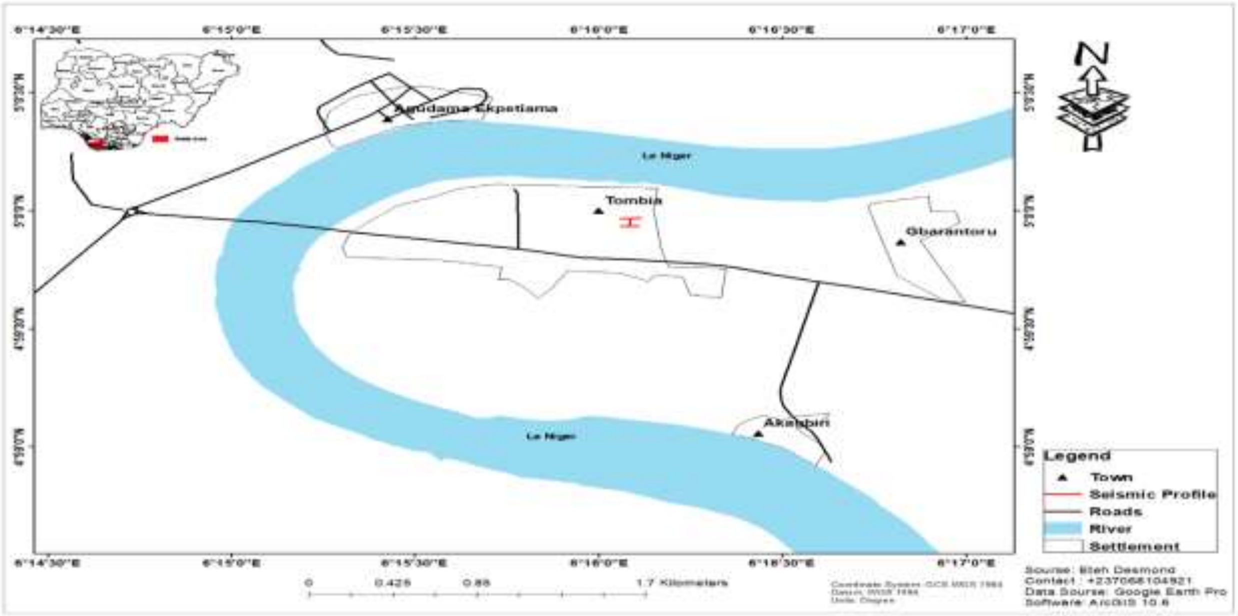

Figure 1: Map of the study area (Source: Eteh Desmond Rowland)

Literature review

Seismic refraction method is widely used in exploration geophysics and subsurface investigations (Hobson et al 1970 and Palmer 1986). In seismic refraction survey, the necessary condition for critical refraction is that the seismic velocities of different layers should be higher than those of the overlying layers. The first arrival travel times are detected on a seismogram, and if there are no hidden layers (such as low-velocity zones or thin beds), the interpretation is straightforward. The primary applications of seismic refraction are for determining the depth to bedrock and bedrock structure. Due to the dependence of seismic velocity on the elasticity and density of the material through which the energy is passing, seismic refraction surveys provide a measure of material strengths and can consequently be used as an aid in assessing rippability and rock quality. From the engineering point of view, soils are defined as the material overlying the bedrock produced by rock weathering. It is unconsolidated material of the earth's crust used to build upon or used as a construction material. The seismic method has emerged as a powerful tool in computing the elastic moduli from which their elastic deformation can be estimated (Stumpel et al.1984; Davis and Taylor1979). The technique has been successfully applied for mapping depth to the base of backfilled quarries, depth of landfills, thickness of overburden, and the topography of groundwater aquifers.

Hashim et al., (2011) used seismic refraction data to determine near surface geotechnical parameters of a proposed site in Riyadh, Saudi Arabia. The obtained seismic refraction data were interpreted with a term technique from which the geotechnical parameters such as stress ratio and poisson ratio were determined and subsequently used to characterise the shallow subsurface layers in terms of competent and incompetent zones.

According to Moharmd and Sherif, (2016) the chances of success of a survey are generally much greater with the surface wave method than other seismic methods, particularly for detecting anomalies near the sand surface of the low velocity layer. The strong nature of surface wave energy can be generated using a single impact source, followed by simple field logistics and processing. More importantly, surface waves respond effectively to various types of near-surface anomalies that are common targets of geotechnical studies.

Adewoyin et al., (2017) applied the seismic refraction method in combination with other site investigation methods in the characterization of rehabilitated land sites targeted for building construction. The results of the investigation show strong agreement between the seismic method and the traditional SPT and CPT methods.
Abdel et al., (2017) studied the application of superficial seismic refraction to detect engineering problems in the city of Madinaty, Egypt. Shallow seismic refraction studies were conducted at two proposed sites in the study area to determine their characteristics prior to construction.

Moharmd et al., (2016) Study the use of geotechnical parameter from seismic measurement in the field of Egypt and Saudi Arabia. Found that, the chance of successful survey is usually much higher with the surface wave method than with other seismic methods, particularly in detecting the near-surface anomalies sand the low velocity layer. The strong nature of surface wave energy can be generated by using a simple impact source, followed by simple field logistics and processing. Most importantly, surface waves respond effectively to the various types of near-surface anomalies that are common targets of geotechnical investigations; such as the low velocity layers, caves and the near-surface structures. Continuous recording of the multi-channel surface waves shows great promise in mapping the bedrock surface, delineating fracture system.... etc. Although, the surface waves are insensitive to cultural noises, they are sensitive to lateral changes in velocity.

Theory of Seismic Refraction

In seismic surveying, seismic waves are created by a controlled source and propagate through the subsurface. Some waves will return to the surface after refraction or reflection at geological boundaries within the subsurface. Instruments distributed along the surface detect the ground motion caused by these returning waves and hence measure the arrival times of the waves at different ranges from the source. These travel times may be converted into depth values and, hence, the distribution of subsurface geological interfaces may be systematically mapped.
The most common application of the seismic refraction technique is to resolve variability in the depth to the top of a refractor (e.g. bedrock) and the seismic velocity within it. However, the method can also be used to determine rippability of materials for excavation, the degree of weathering within the top of bedrock, rock strength, thickness of saturated aquifers, location of weathered fault zones, etc.

Multichannel analysis of surface waves (MASW)

Geophysics observes the behavior of waves propagating within a material. A seismic signal changes according to the characteristics of the crossed environment. The waves can be generated artificially through the use of hammers, explosions, etc.

The motion of the seismic signal

The seismic signal can be decomposed into several stages, each of which identifies the movement of particles invested by the seismic waves. The phases are:

- Longitudinal-**P**: the deep wave of compression;
- Transversal-**S**: the deep wave of shear;
- Love-**L**: surface wave, composed of P and S waves;

- Rayleigh-**R**: surface wave consists of an elliptical and retrograde movement.

When seismic energy is released suddenly at a point (P) near the surface of a homogeneous medium, part of the energy propagates through the body of the medium as seismic body waves. The remaining g part of the seismic energy spreads out over the surface as a seismic surface wave, analogous to the ripples on the surface of a pool of water into which a stone has been thrown. (Lowrie, 2007; Reynolds, 2011)

When a body wave reaches a distance r from its source in a homogeneous medium, the wave front (defined as the surface in which all particles vibrate with the same phase) has a spherical shape, and the wave is called a spherical wave. The direction perpendicular to the wave front is called the seismic ray path.

Rayleigh – "R" waves

In the past, studies on the spread of seismic waves have focused on the propagation of deep waves (P, S) considering surface waves as a disturbance of the seismic signal to analyze. Recent studies have allowed creating advanced mathematical models for the analysis of surface waves in environments with different stiffness.

Love waves: are horizontally polarized shear waves, existing only in the presence of a semi-infinite medium overlain by an upper layer of finite thickness. They usually travel slightly faster than Rayleigh waves, about 90% of the S wave velocity, and have the largest amplitude.

Signal analysis with MASW technique

The analysis of Rayleigh waves, using MASW technique is done with the spectral treatment of the signal in the transformed domain, where you can, quite easily, identify the signal for the Rayleigh waves from other types of signals, observing also, the Rayleigh waves propagate with a velocity that is in the function of the frequency. The velocity frequency link is called the dispersion spectrum. The dispersion curve identified in the f-k domain is called the experimental dispersion curve, and in that domain represents the maximum amplitudes of the spectrum.

Modeling

From a synthetic geotechnical model characterized by thickness, density, Poisson's ratio, S and P wave velocity it is possible to simulate the theoretical dispersion curve, which links velocity and wavelength according to the correlation:

$$v = \text{ʎ} \text{ x } V \qquad 1$$

By changing the parameters of the synthetic geotechnical model, it can be obtained an overlay of the theoretical dispersion curve with the experimental one: this is called inversion and is used to determine the profile of velocities in environments with different stiffness.

Vibration modes

Both in the theoretical and experimental inversion curve it is possible to identify the different configurations of vibration of the ground. The modes for the Rayleigh waves can be deformation in contact with the air, almost no deformation of the half-wavelength, and zero deformation at high depths.

Depth of investigation

The Rayleigh waves decay at a depth approximately equal to the wavelength. Small wavelengths (high frequencies) are used to investigate superficial areas and large wavelengths (low frequencies) allow investigations to a greater depth.

Seismic waves velocities:

Seismic waves are parcels of elastic strain energy that propagate outwards from a seismic source such as an earthquake or an explosion. Sources suitable for seismic surveying usually generate short-lived wave trains, known

as pulses, which typically contain a wide range of frequencies. The propagation velocities of seismic pulses are determined by the elastic moduli and densities of the materials through which they pass. (Reynolds, 2011)
Seismic body waves can be subdivided into two classes of waves:

Primary waves velocity: are also called primary waves, because they propagate through the medium faster than the other wave types. In P-waves, particles constituting the medium are displaced in the same direction that the wave propagates, in this case, the radial direction. Thus, material is being extended and compressed as P-waves propagate through the medium. P-waves are analogous to sound waves propagating through the air. P-waves also known as compressional and longitudinal waves (See Figure 2.2 a).

$$\text{The velocity of P-waves } V_p = \sqrt{\frac{k + {}^{4}/_{3}\,\mu}{\rho}} \qquad 2a$$

where (K) Bulk modulus, (μ) Shear modulus, and (ρ) density. (Kearey et al., 2002 and Reynolds, 2011) .

Secondary wave velocity (S-wave): are sometimes called secondary waves, because they propagate through the medium slower than P-waves. In S-waves, particles constituting the medium are displaced in a direction that is perpendicular to the direction that the wave is propagating. In this example, as the wave propagates radially, the medium is being deformed along spherical surfaces. S-waves also called transverse and shear waves

$$\text{The velocity of S-waves } V_s = \sqrt{\frac{\mu}{\rho}} \qquad 2b$$

where (μ) Shear modulus, and (ρ) density. (Kearey et al., 2002 and Reynolds, 2011).

Table1: Soil description to the parameter Abd ElRahman (1991)

	Weak		Fair		Good
Soil/Rock Description	Incompetent		Fairly Competent		Competent
Parameters	Very Soft	Soft	Fairly Compacted	Moderately Compacted	Compacted
Bearing Capacity(Qa) (Kpa)	0 -50	50– 100	100 – 550	550-5000	5000-8000

Table 2: N-value classes (modified after Bowles (1984))

Cohesive soil		Cohesionless soil	
N-value	Description	N-value	Description
<4	Very soft	0-4	Very Loose
4-6	Soft	5-10	Loose
7-15	Medium	11-30	Medium
16-25	stiff	31-50	Dense
<25	Hard	<50	Very dense

N-value (N)

The standard penetration test or the N-value is applicable only for soils; This is not valid for rocks. It is defined according to Stumpel et al., (1984) as resistance to soil penetration by standard cylindrical rods subjected to a standard load. According to the American Society for Testing and Materials Standards ASTM-D-1586-84, the values are classified as follows: 0-4 (very loose sediment), 5-10 (free material), 11-30 (medium density), 31-50 (dense) and more than 50 (very dense or rocky). The SPT is evaluated geophysically using the following formulas (Stumpel et al, 1984). The value N is related to the speed of the shear wave velocity as follows:

$$N=\left(\frac{Vs}{76.55}\right)\ 2.24719 \qquad 3$$

where higher N-values indicate greater soil resistance to penetration i.e. higher cohesion soil.

Ultimate bearing capacity (Qult)

The bearing capacity is the maximum load required to produce soil shear failure. It can be evaluated according to Parry's formula (1977) by using the standard penetration test or N-value as:

$$Qult = \log(30N) \qquad 4$$

Allowable bearing capacity (Qa)

The allowable should be taken into consideration before designing the structures. It can be obtained from the ultimate bearing capacity value by dividing on a suitable factor of safety (F), Parry's formula (1977)

as: $Qa = Qult/F$ 5

The factor of safety equals 2 and 3 for the cohesionless and cohesive soils, respectively.
Also, (Qa) can be estimated by using shear wave velocity (Abd El-Rahman, 1991) as
$\text{Log } Qa = 2.932 \text{ Log}Vs-4.553$ for soft soil 6
$\text{Log } Qa = 2.932 \text{ Log}Vs-4.729$ for hard rock 7

Relationship of seismic refraction to geotechnical parameters

Seismic waves or elastic stress waves travelling through soils interact with soil particles and interstitial fluids. This seismic wave responses are affected by the soil texture and structure, and they are sensitive to the variations in soil properties. Propagation of seismic waves through soils is a small-strain phenomenon that introduces a small perturbation without altering the fabric of the soil. The resistance of the body to deformation under applied force is termed stiffness (Clayton, 2011). The three stiffness parameters are known as Young's modulus, E, bulk modulus, B, and shear modulus, G. According to Atkinson (2007) the relationship between strain and stiffness of soils is generally non-linear and only at very small strains does the correlation between strain and stiffness behave in a linear fashion. It is at these smaller strains that the shear stiffness reaches its maximum value, usually referred to as G0 or Gmax

Seismic Data Acquisition

Seismic Refraction was carried out in the study area; three profiles were surveyed using the 12-channel ABEM Terraloc Mark 6. This method used ABEM Terraloc Mark 6, a 12- volt DC battery, a roll of trigger cable, 2 seismic cable reels, a 15kg sledgehammer, a metal base plate, 12 geophones (14Hz), a logbook and measuring tapes. Each profile extends for a total length of 60 m. The geophones are connected to the seismograph and placed in an interval of 5m from each other on the traverse to obtain good data and resemble depth of investigation. The study area is an undeveloped area that is located far from any noise sources such as traffic, daily human activities, machinery, and other factors, which contributed to enhancing the signal-to-noise ratio. The trigger cable reel is connecting to the sledgehammer and equipment, each time is triggered, by hitting the hammer on a base plate, the seismogram records a seismic event. A sledgehammer (10 Kg m) was used to generate the seismic Shear wave velocity and extract, import the data into Easy MASW software own by GeoStru, Software. (2016) thereby processing and analyze the data.

Results and Discussion

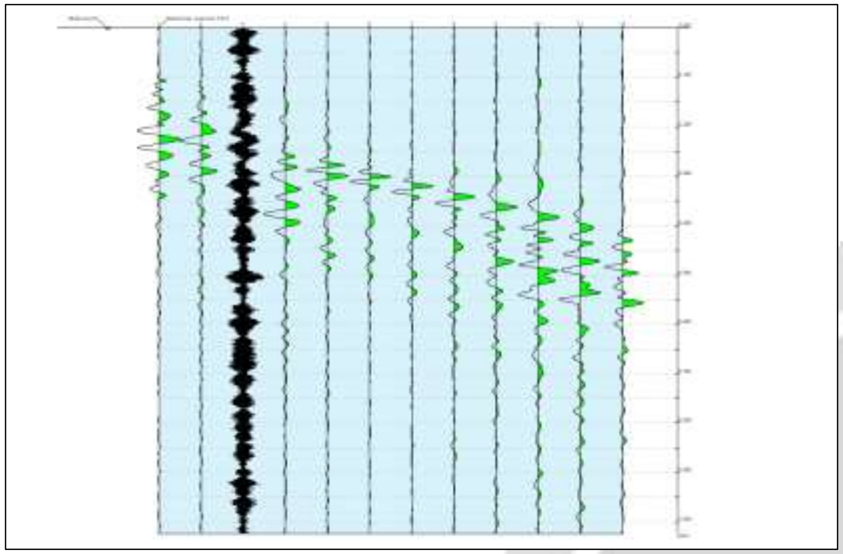

Figure 2: sample of a picked first wave

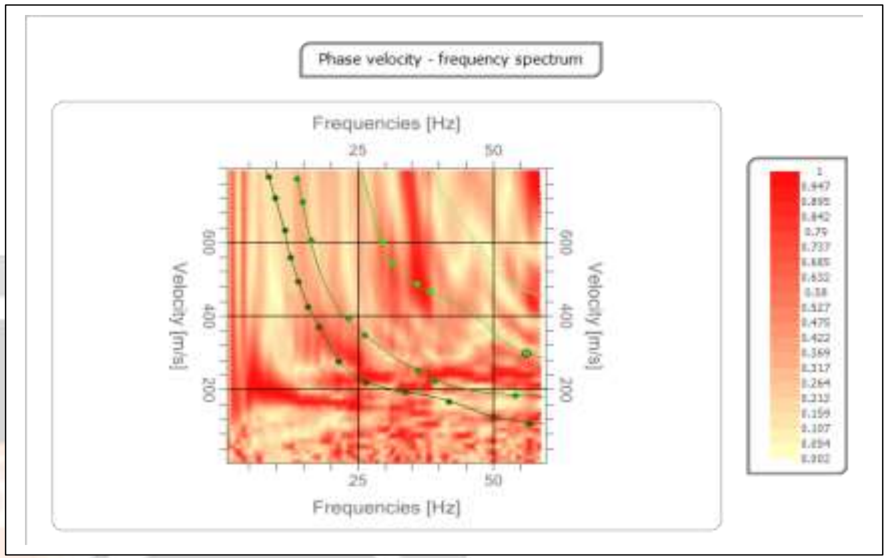

Figure: 2a Phase Velocity vs Frequency Spectrum profile 1

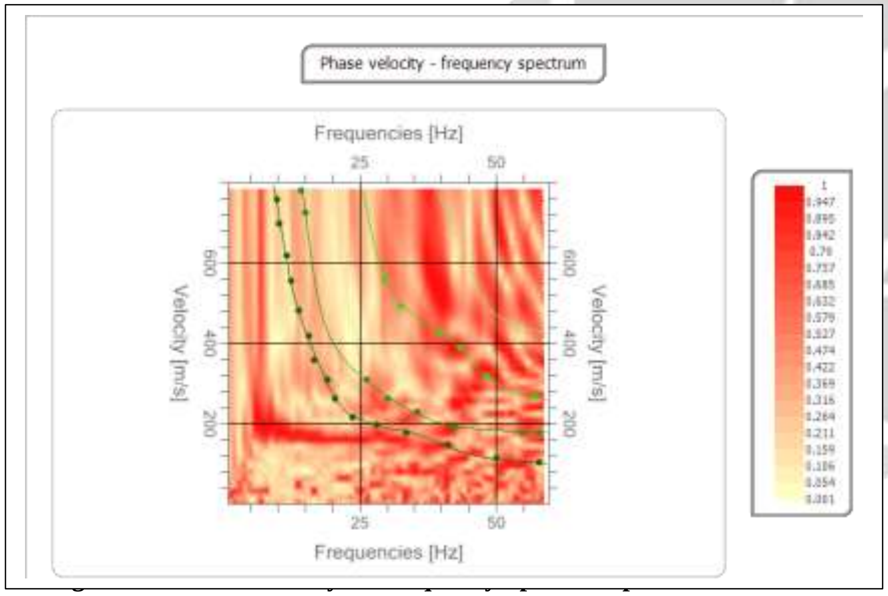

Figure 2b: Phase Velocity vs Frequency Spectrum profile 2

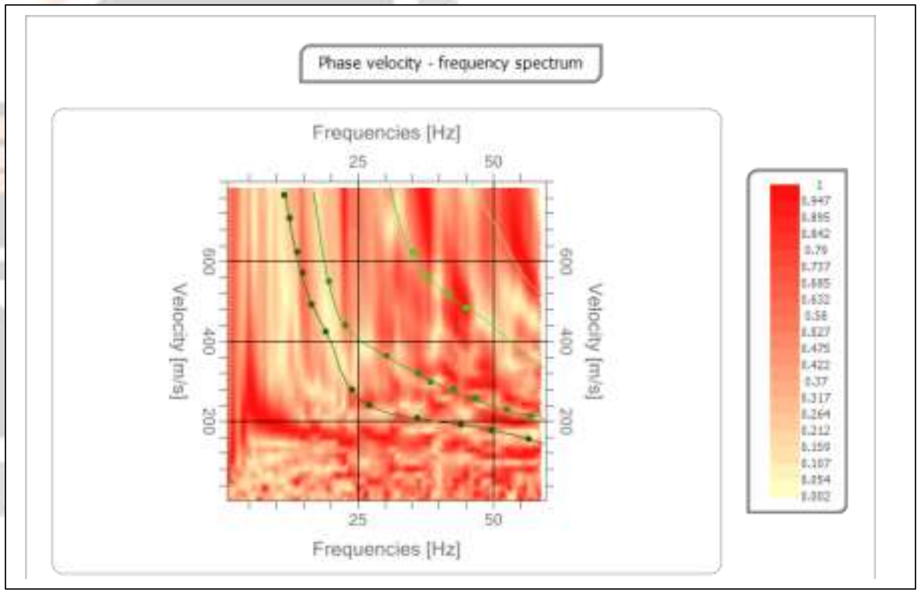

Figure 2c: Phase Velocity vs Frequency Spectrum profile 3

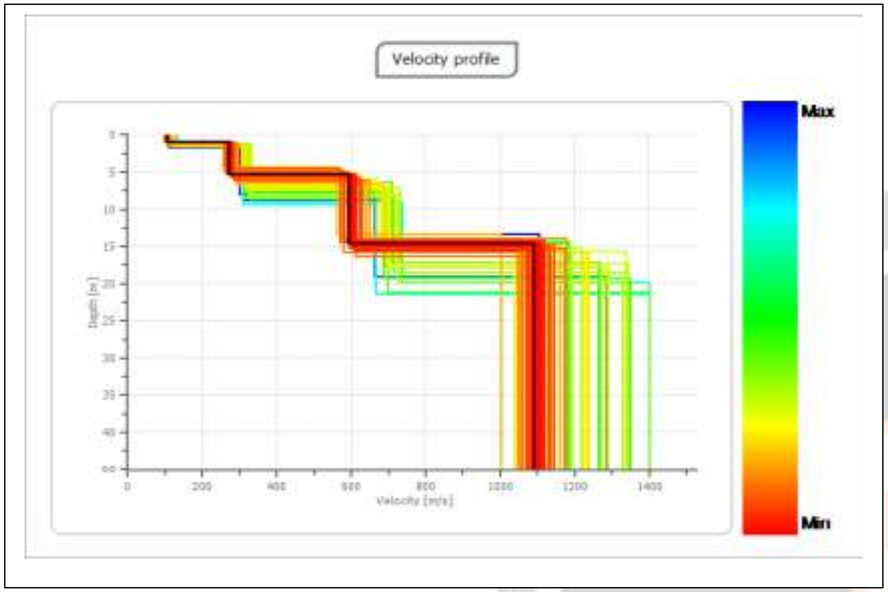

Figure 3a: Shear wave Velocity of profile 1

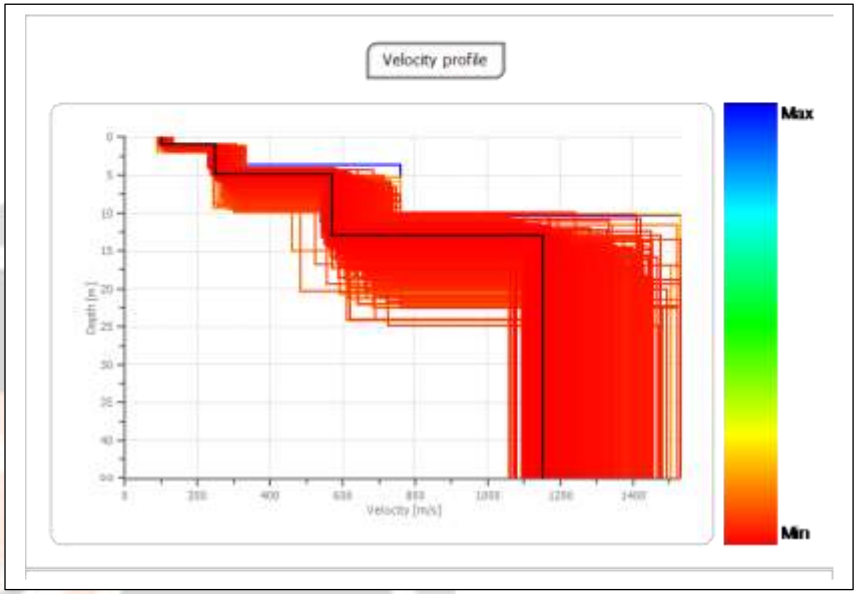

Figure 3b: Shear wave Velocity of profile 2

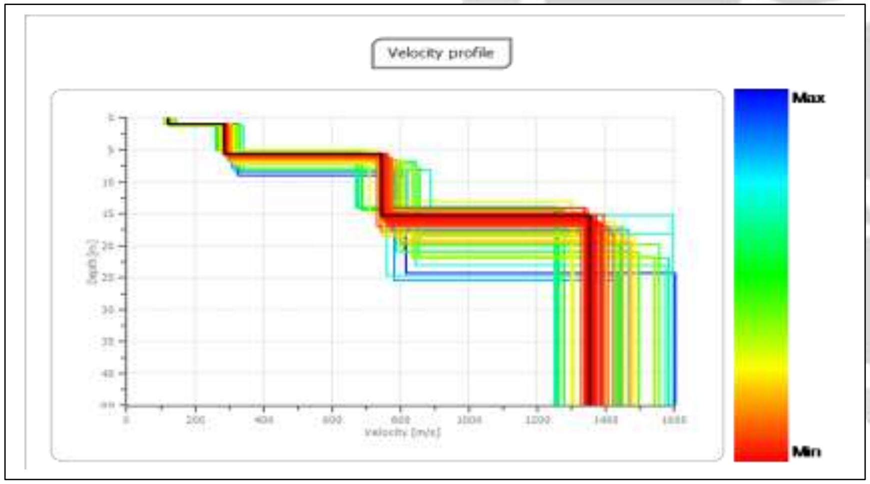

Figure 3c: Shear wave Velocity of profile 3

Table: 3: Result from Inversion for Foundation bearing capacity and shear wave velocity

	Profile 1			Profile 2			Profile 3		
	Percentage of error 0.03			Percentage of error 0.016			Percentage of error 0.021		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
Depth (m)	1	5.31	14.66	0.95	5.01	12.99	0.98	5.64	15.33
Thickness (m)	1	4.31	9.35	0.95	3.96	8.03	0.93	4.64	9.67
Vs (m/s)	104.6	271.5	595.1	100.5	249.3	571.5	121.7	286.4	744.9
N-Value	1.37	3.55	7.77	1.31	3.26	7.47	1.59	3.74	9.73
Qult (KPa)	1.78	2.71	3.48	1.74	2.63	3.43	1.93	2.76	3.70
Qa(KPa)	23.34	382.74	3820.32	20.77	293.92	3392.34	36.40	447.51	7379.04

Discussion

Shear wave velocities

The result of the Shear wave velocities in Table 3. range from 100.50 m/s to 121.70 m/s for layer 1 with a corresponding depth ranging from 0.95 m to 1.00 m in Figure 3a, 271.5 m/s to 286.4 m/s in layer 2 with the depth ranging from 5.01 m to 5.64 m in Figure 3b and layer 3 ranging from 571.50 m/s to 744.90 m/s for shear wave velocity and a corresponding depth ranging from 12.99 m to 15.33m in Figure 3c

Foundation bearing capacity

N-Value (N):

The calculated parameter in equation 3. In the study area, N-Value shown in Table 3 values ranges from 1.84 to 2.83 for the topmost layer which indicates very loose sediments when compared with Table 2. (Bowles 1984). Second layer values range from 14.20 to 19.40 which indicates medium material and also the third layer values vary from 91.61 to 166.17 indicate very dense when compared with Table 2.2 (Bowles 1984).

Ultimate Bearing capacity (Qa):

From Table 3. The calculated ultimate bearing capacity was calculated using equation 6. the area shows values ranged from 20.77 kPa to 36.40 kPa for the topmost layer indicate firm clays and silt which is incompetent when compared with Table 1. Second layer values ranged from 297.92 kPa to 447.51 kPa indicate dense sand which is fairly competent and the values for layer three ranged from 3392.34 kPa to 7379.04 kPa indicate Dense sand which is competent when compared with Table 2.

Allowable Bearing Capacity (Qult):

From Table 3., the calculated allowable bearing capacity were calculated in equation 5 at the reveal, the topmost layer values vary from 1.74 kPa to 1.93 kPa which indicate weak soil, 2.63 kPa to 2.76 kPa for the second layer indicate fairly compacted soil and the third layer value range from 3.44 kPa to 3.70 kPa which indicate compacted.

Conclusions

shear wave velocity of the first layer depth range from 0.95 m to 1.00 m across the study area was found to be characteristically low and N-value ranged from 1.84 – 2.83, ultimate, allowable and bearing capacity ranging from 20.77 kPa -36.0 kPa ,1.7 kPa -1.93 kPa. These values are indicative of soft unconsolidated alluvial deposits generally considered incompetent to support the substantial structural load when compared with standard Tables 1 and 2.

Geotechnical parameters of the second layer depth 5.01 m – 5.64 m show a marked increase in all the parameters analysed with an appreciable N-value ranged from 14.20 – 19.4 indicate dense sand, allowable and ultimate bearing capacity value range of 297.92 kPa to 447.51 kPa and 2.63 kPa to 2.76 kPa respectively and fall within the moderately competent to competent and could support substantial structural load including layer 3 the delineating at a depth range of 12.99 m- 15.33 m, with Calculated values of the geotechnical parameters is well compacted.

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