Comparative Analysis of Foundation Materials Bearing Capacity Using MASW Techniques in Opolo and Amassoma, Bayelsa State, Nigeria

Abstract

The study of comparative analysis of the foundation material bearing capacity of soils in Opolo and Amassoma, Bayelsa State, Nigeria, utilized Multichannel Analysis of Surface Waves (MASW) techniques and Standard Penetration Tests (SPT). A 12-channel ABEM Terraloc Mark 6 geophone system surveyed undeveloped areas at two points in each location, spaced 70 meters apart, with 5-meter offset geophones. Borehole data from SPT revealed subsurface layers and N-values. Data processed with Easy MASW software indicated shear wave velocity profiles, showing increased soil stiffness with depth typical of Niger Delta Basin sediments. Shear wave velocities ranged from 213.71 m/s to 574.82 m/s in Opolo and 206.03 m/s to 589.68 m/s in Amassoma. Ultimate bearing capacities (Qult) from shear wave velocities ranged from 180.67 kPa to 517.09 kPa in Amassoma and 186.16 kPa to 504.06 kPa in Opolo, while allowable bearing capacities (Qa) varied from 60.22 kPa to 172.36 kPa and 62.05 kPa to 168.02 kPa, respectively. Comparative analysis indicates both locations have similar soil capabilities, suitable for medium to heavy structures. Correlation analysis between shear wave velocity and SPT-N values showed strong linear relationships (R^2= 0.9047 to 0.9329), validating MASW results against traditional geotechnical methods. These findings demonstrate the effectiveness of MASW in assessing soil properties and designing foundations in the diverse geological settings of study area.

Keywords: Bearing capacity; Shear wave velocity, MASW, SPT, Comparative analysis

INTRODUCTION

The bearing capacity of soil is a critical factor in the design and construction of foundations for civil engineering projects. Understanding the mechanical properties of soil is essential to ensure the safety and stability of structures. In recent years, geotechnical investigations have increasingly employed advanced geophysical methods to assess soil properties. One such technique is the Multichannel Analysis of Surface Waves (MASW), which has proven effective in evaluating the shear wave velocity (Vs) of subsurface materials, providing valuable data for estimating the bearing capacity of soils [1][2]. The Niger Delta region, characterized by its complex geological formations and challenging soil conditions, poses significant challenges to the construction industry [3]. Precisely understanding the subsurface soil properties is crucial for the successful design and construction of foundations. This study focuses on a comparative analysis of foundation material bearing capacity in Opolo and Amassoma, two key locations in Bayelsa State, Nigeria. Bayelsa State, situated in the Niger Delta, is predominantly underlain by soft, unconsolidated sediments susceptible to various geotechnical problems [4]. These challenges, coupled with the increasing demand for infrastructure development, necessitate reliable and efficient geotechnical investigation methods. MASW techniques offer a non-invasive, cost-effective, and efficient method for assessing the subsurface properties of soil. By measuring the shear wave velocity, MASW provides critical data on soil stiffness and elasticity, which are directly related to its bearing capacity [5]. Previous studies have demonstrated the effectiveness of MASW in diverse geological settings, making it a suitable method for this study [6][2]. Geotechnical investigations in the Niger Delta have underscored the importance of accurate soil characterization for sustainable infrastructure development [3][7][8][9]. The assessment of soil bearing capacity is crucial for foundation design as it determines the maximum load that the soil can support without undergoing shear failure. Traditional methods such as the Standard Penetration Test (SPT) and Cone Penetration Test (CPT) have been widely used to evaluate soil bearing capacity. However, these methods often involve invasive procedures and can be time-consuming and expensive. In contrast, MASW techniques offer a more efficient and non-destructive approach, providing reliable data on soil stiffness and stratification with minimal environmental impact [5]. The application of MASW to compare foundation material bearing capacity in Opolo and Amassoma is relatively unexplored.

This research aims to perform a comparative analysis of the bearing capacity of soils in Opolo and Amassoma using MASW techniques. The specific objectives include: determining the shear wave velocity profiles for the two locations, estimating the bearing capacity of the soils based on the obtained Vs values, conducting a comparative analysis of the results to identify any significant differences between the two sites, and (4) exploring the correlation between seismic refraction Shear wave velocity and Standard Penetration Test (SPT) N-value in these areas. By achieving these objectives, the study will provide valuable results into the geotechnical properties of soils in Opolo and Amassoma, contributing to safer and more effective construction practices in Bayelsa State.

METHODOLOGY

Study Area

The study area is situated in Opolo and Amassoma, within the Yenagoa and Southern Ijaw Local Government Area of Bayelsa State, Nigeria (Figure 1). Opolo is located between coordinates 006° 25’30” E to 006° 21’0” E longitude and 04° 56’30” N to 04° 57’0” N latitude, while Amassoma spans from 4°58'0" N to 4°56'25" N latitude and 6°5'45" E to 6°7'30" E longitude. The region is traversed by the River Nun, originating from the Niger River in southern Nigeria, which bifurcates into the Nun and Forcados channels after Aboh [10]. Additionally, the Epie Creek flows into the Ekole River, which connects to the River Nun. The study area, characterized by elevations ranging from 8 meters to 20 meters, lies entirely within the Niger Delta Basin, a geologically young region marked by thick sedimentary deposits. These sediments, dating from the Eocene to the present, include the Paleocene Akata Formation composed mainly of shales and clays [11]. Overlying this formation is the Eocene Agbada Formation, known for its alternating layers of sand and shale and significant hydrocarbon potential. The youngest formation, the Benin Formation (Miocene to Recent), comprises sands and gravels forming coastal plains and containing freshwater [12].

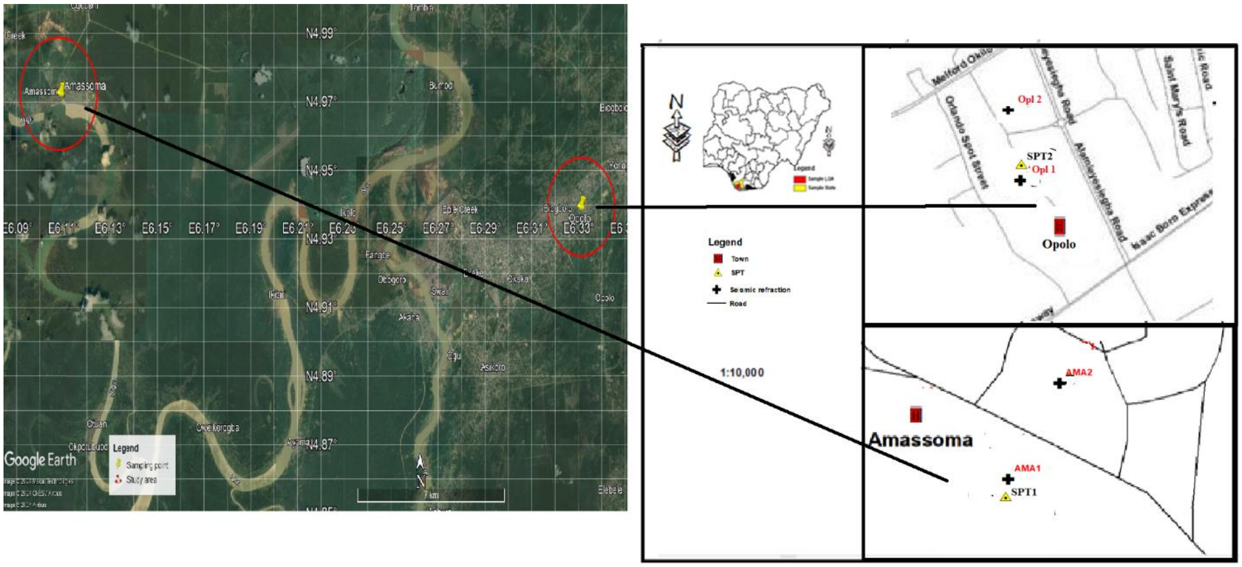

Figure 1: Map of study area

Seismic refraction theory

Seismic refraction theory forms the basis of a widely utilized geophysical method for investigating subsurface structures. This technique leverages seismic waves, which are elastic waves generated by a controlled source such as a sledgehammer, explosives, or specialized seismic equipment. As these waves travel through the Earth, they encounter geological boundaries that cause them to refract or reflect, depending on the contrast in seismic velocities between different subsurface layers [13]. The fundamental principle of seismic refraction is based on Snell's Law, which describes how waves change direction when they pass through interfaces between materials with different seismic velocities. When a seismic wave encounters a boundary at an angle, part of the wave's energy is refracted into the lower layer, while part is reflected back towards the surface. The refracted wave travels along the boundary layer and can be detected at the surface once it emerges from the subsurface [14][15][16]. In a typical seismic refraction survey, a line of geophones (seismic detectors) is laid out on the ground surface, and a seismic source generates waves at one or more locations along this line. The geophones record the arrival times of seismic waves at various distances from the source. These travel times are used to construct a travel-time curve, which reveals information about the subsurface layers' velocities and depths. By analyzing the time taken for the waves to travel from the source to each geophone, geophysicists can infer the velocity structure of the subsurface and map the depth to various geological interfaces [13][14]. One primary application of seismic refraction is determining the depth to bedrock, which is crucial for construction projects, mineral exploration, and environmental studies. Bedrock typically has a higher seismic velocity than overlying unconsolidated materials, making it easily identifiable in seismic refraction data. The technique is also employed to assess the rippability of materials, which is a measure of how easily the ground can be excavated. Materials with lower seismic velocities are generally easier to rip or excavate, while those with higher velocities indicate harder, more resistant materials [15]. Additionally, seismic refraction can provide valuable insights into the degree of weathering at the top of the bedrock. Weathered rock typically has a lower seismic velocity compared to unweathered rock, allowing for the identification of weathered zones, which can impact the stability of structures built on or within these materials. Seismic refraction is also used to estimate rock strength and determine the thickness of saturated aquifers, as water saturation significantly affects seismic wave velocities. Furthermore, the method can locate weathered fault zones, which are critical for understanding seismic hazards and planning safe construction projects [17]. The interpretation of seismic refraction data involves constructing velocity models that represent the subsurface layers. Advanced techniques, such as tomographic inversion, can provide more detailed and accurate images of the subsurface by iteratively refining the velocity models to minimize discrepancies between observed and calculated travel times. These models help geophysicists understand the subsurface geological characteristics and make informed decisions in various applications [16] [17].

Multichannel Analysis of Surface Waves (MASW)

Multichannel Analysis of Surface Waves (MASW) is a geophysical method used extensively in characterizing subsurface properties by analyzing the behavior of seismic waves as they propagate through different materials. This method has proven highly effective due to its ability to provide detailed insights into soil stiffness, layer thicknesses, and other important geotechnical parameters. Seismic waves generated for MASW can originate from various sources, including hammers, explosions, or vibrators. These waves interact differently with subsurface materials, allowing researchers to discern detailed information about the underlying geological structures. The key phases of seismic waves utilized in MASW include:

1. **Longitudinal-P (Primary) Waves**: These waves are compression waves that travel fastest through the Earth, capable of traversing both solid and liquid layers. Similar to sound waves, P-waves compress and expand the material in the direction of wave propagation.
2. **Transversal-S (Secondary) Waves**: Unlike P-waves, S-waves are shear waves that move perpendicular to the direction of wave propagation and can only travel through solids. They cause particles to move sideways and are slower than P-waves.
3. **Love-L Waves**: Love waves are a type of surface wave characterized by horizontal shear motion. These waves exist when a semi-infinite medium is overlain by an upper layer of finite thickness. Love waves travel slightly faster than Rayleigh waves and are known for their ability to identify layers with different stiffness and thicknesses in the subsurface [17].
4. **Rayleigh-R Waves (ʎ)**: Rayleigh waves propagate along the surface with an elliptical and retrograde motion of particles. They are responsible for much of the shaking felt during earthquakes and are particularly significant in MASW due to their sensitivity to near-surface material properties [16].

MASW involves recording these waves using multiple sensors (geophones) arranged in a linear array or grid pattern. By analyzing the dispersion characteristics of these waves — how their velocities vary with frequency — MASW can determine the shear wave velocity profile of the subsurface. This profile, in turn, provides information about soil stiffness variations and the depth to different geological layers. Recent advancements in MASW techniques include sophisticated mathematical models that enhance the interpretation of surface wave data in environments with varying stiffness properties [2]. These models improve the accuracy of subsurface imaging and increase MASW's applicability across different geological settings.

Modeling

From a synthetic geotechnical model characterized by parameters such as layer thickness, density, Poisson's ratio, and S and P wave velocities, it is possible to simulate the theoretical dispersion curve. This curve links velocity and wavelength according to established correlations and helps in interpreting the experimental data [5]. By comparing the experimental dispersion curve with the theoretical model, geophysicists can infer the material properties of the subsurface layers. Modeling involves iterative processes where the initial model is adjusted to minimize the differences between the experimental and theoretical dispersion curves. This approach ensures that the final model accurately represents the subsurface conditions. The use of advanced mathematical techniques and inversion algorithms allows for precise determination of subsurface parameters, such as shear wave velocity profiles, which are critical for geotechnical and environmental applications [1].

$$v = \text{ʎ} \times V \qquad (1)$$

Vibration Modes

In both theoretical models and experimental data, various configurations of ground vibrations can be identified. Specifically, for Rayleigh waves, these configurations include surface deformation, minimal deformation at depths of approximately half the wavelength, and negligible deformation at greater depths [1].

Depth of Investigation

Rayleigh waves diminish in amplitude at a depth roughly equivalent to their wavelength. As a result, high-frequency waves with shorter wavelengths are ideal for examining near-surface structures, while low-frequency waves with longer wavelengths are used to probe deeper into the ground [18].

Seismic Wave Velocities

Seismic waves are carriers of elastic strain energy that spread from a seismic source, such as an earthquake or an explosion. In seismic surveys, sources typically produce brief wave trains, known as pulses, that encompass a broad spectrum of frequencies. The speed at which these seismic pulses travel is influenced by the elastic properties and densities of the materials they traverse [14].

Seismic body waves can be subdivided into two classes:

Primary Waves Velocity

Primary waves, or P-waves, travel faster than other seismic wave types. In P-waves, the displacement of particles in the medium occurs in the direction of wave propagation, resulting in alternating compression and expansion of the material. This behavior is similar to that of sound waves traveling through air, which is why P-waves are also called compressional or longitudinal waves [16].

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

According to Kearey et al. [15] and Reynolds [14], the bulk modulus (K), shear modulus (μ), and density (ρ) are essential parameters that influence wave propagation through materials.

Secondary waves, or S-waves, travel slower than P-waves and cause particles to move perpendicular to the direction of wave propagation. This perpendicular motion creates shear stress in the material. Unlike P-waves, S-waves cannot travel through fluids because fluids cannot support shear stress [15][14].

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

where (μ) Shear modulus, and (ρ) density. [15][14].

Table 1: N-value classes (modified after Bowles [19])

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 (SPT) is a commonly used method to assess soil properties. It involves driving a standard cylindrical rod into the ground and measuring the resistance encountered. The number of blows required to penetrate a specific depth is termed the N-value. According to Stumpel et al. (20), higher N-values correspond to denser soils with greater resistance to penetration. Additionally, there is a correlation between N-values and shear wave velocity, as expressed by the equation provided by Stumpel et al. (20).

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

Ultimate bearing capacity

The ultimate bearing capacity of a soil, or the maximum load it can support before failure, is closely linked to the N-value. Parry (21) suggests using the N-value in conjunction with other soil properties to calculate ultimate bearing capacity through equations such as Parry's formula and the general bearing capacity equation.

$$Qult = \log(30N) \tag{4}$$

$$Qult={}_{c}N_{c}+{}_{\sigma}z_{c}{}'N_{q}+0.5B\gamma'BN\gamma \tag{5}$$

where:

- ${}_{C}$ is the cohesion of the soil,
- N_c,N_q,N_γ are factors related to the SPT N-values,
- σ'_{zc} is the effective overburden pressure at the depth of the footing,
- γ' is the effective unit weight of soil above the foundation,
- B is the width of the foundation.

This formula allows engineers to determine the safe load-bearing capacity of the soil for design purposes.

Allowable bearing capacity (Qa)

To determine the safe load-bearing capacity for structural design, the allowable bearing capacity (Qa) is calculated by dividing the ultimate bearing capacity by a safety factor (Parry, 21). This factor varies based on soil type. Additionally, Qa can be estimated using shear wave velocity for soft soil and hard rock conditions (22).

as: $Qa = \frac{\text{Qult}}{F}$ (6)

For cohesionless soils, F typically equals 2, while for cohesive soils, F is set to 3.

Alternatively, Qa can be estimated using shear wave velocity (Vs) [22].

$\log Qa = 2.932 \log Vs - 4.553$for soft soil (7)

$\log Qa = 2.932 \log Vs - 4.729$ for hard rock (8)

These equations provide a method to estimate Qa based on Vs values measured in the field.

Data Acquisition

Seismic refraction

Seismic refraction surveys were conducted at two locations: two profiles in Opolo and two in Amassoma, employing the 12-channel ABEM Terraloc Mark 6 system. The equipment setup included a 12-volt DC battery, trigger cable, seismic cable reels, a 15 kg sledgehammer, metal base plate, 12 geophones (14Hz), a logbook, and measuring tapes. Each profile spanned 70 meters with a 5-meter offset between geophones to ensure adequate data coverage and depth resolution (Figure 2). The study area, located away from noise sources like traffic and human activities, facilitated a high signal-to-noise ratio in data collection. During surveys, the sledgehammer generated seismic events recorded by the seismograph via the trigger cable connected to the equipment. Shear wave velocity data collected were processed and analyzed using Easy MASW software by GeoStru, enabling detailed investigation and interpretation of subsurface conditions.

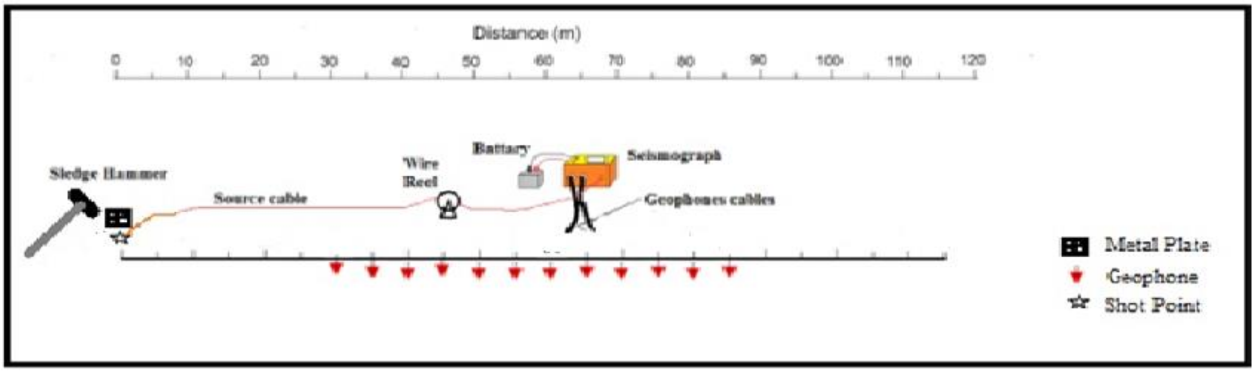

Figure 2: Equipment setup

Standard Penetration Test (SPT)

Standard Penetration Tests (SPT) were conducted at two different locations, Opolo and Amassoma in Figure 1, using a percussion boring technique. The boreholes were drilled with a diameter of 100 mm. At both sites, significant groundwater was encountered, with the water table located approximately 0.30 meters below the ground surface. This method involved driving a split-spoon sampler into the soil using a hammer with a standardized weight dropped from a set height. The number of blows required for the sampler to penetrate the soil by 300 mm (denoted as N-value) was recorded at regular intervals of depth. These N-values provide crucial data for assessing the soil's engineering properties, including its density and relative strength characteristics. The presence of groundwater at such shallow depths may influence the soil's behavior and strength parameters, affecting the interpretation of the SPT results. Therefore, careful consideration of the groundwater conditions is essential for accurate geotechnical analysis and foundation design in both Opolo and Amassoma.

Data processing

In Easy MASW, after importing seismic data, perform initial processing to remove noise and correct for instrument response (Figure 3a). Next, apply frequency-wavenumber (f-k) filtering to isolate dispersive curves. Use dispersion curve analysis to extract shear wave velocities and depth profiles (Figure 3a). Validate results through inversion modeling, adjusting layer parameters like velocity and thickness. Compare with borehole data for calibration, ensuring consistency and accuracy. Finally, generate reports and visualizations detailing shear wave velocity profiles and foundation material characteristics, crucial for assessing bearing capacity and geotechnical suitability in Opolo and Amassoma, Bayelsa State.

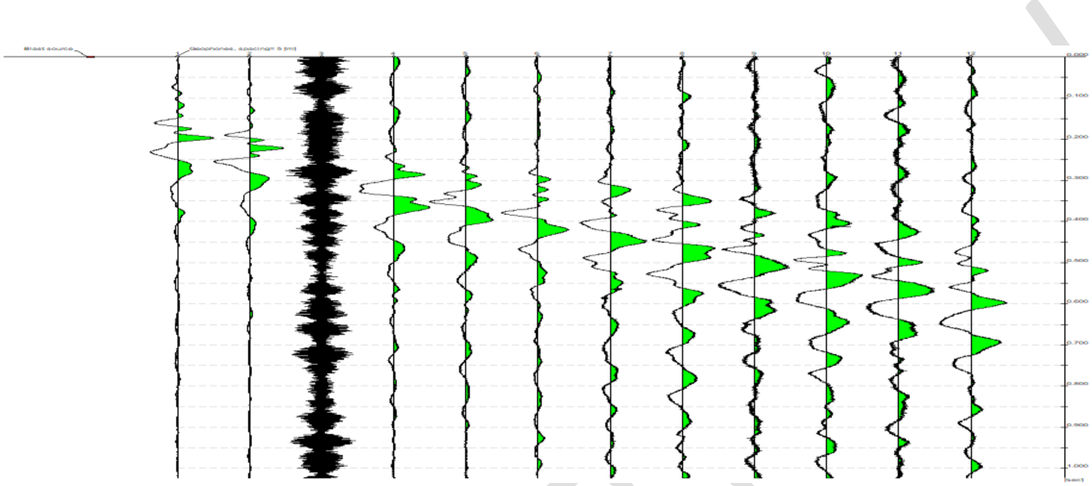

Figure 3a: A sample of a picked first wave arrival time from the collected wave records

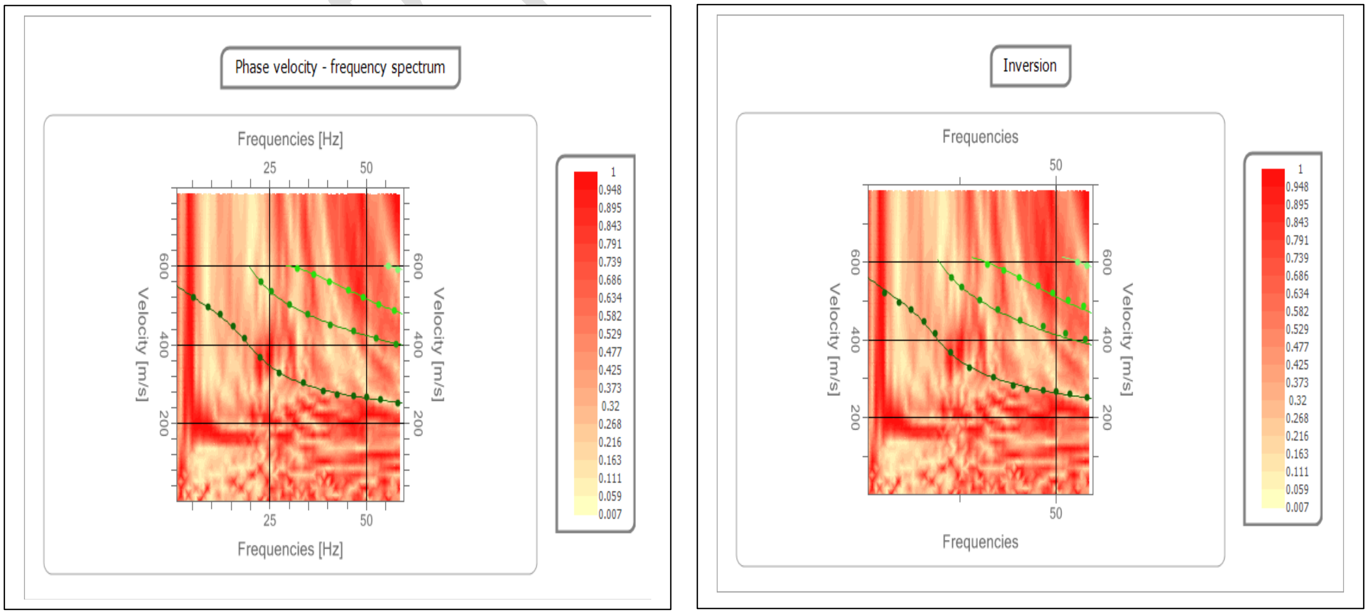

Figure 3b: Dispersion curve

RESULTS AND DISCUSSION

Shear Wave Velocity Profiles

Shear wave velocity (Vs) is a fundamental parameter in geotechnical engineering, reflecting the stiffness of soil. Higher Vs values indicate stiffer soils, which generally have higher bearing capacities.

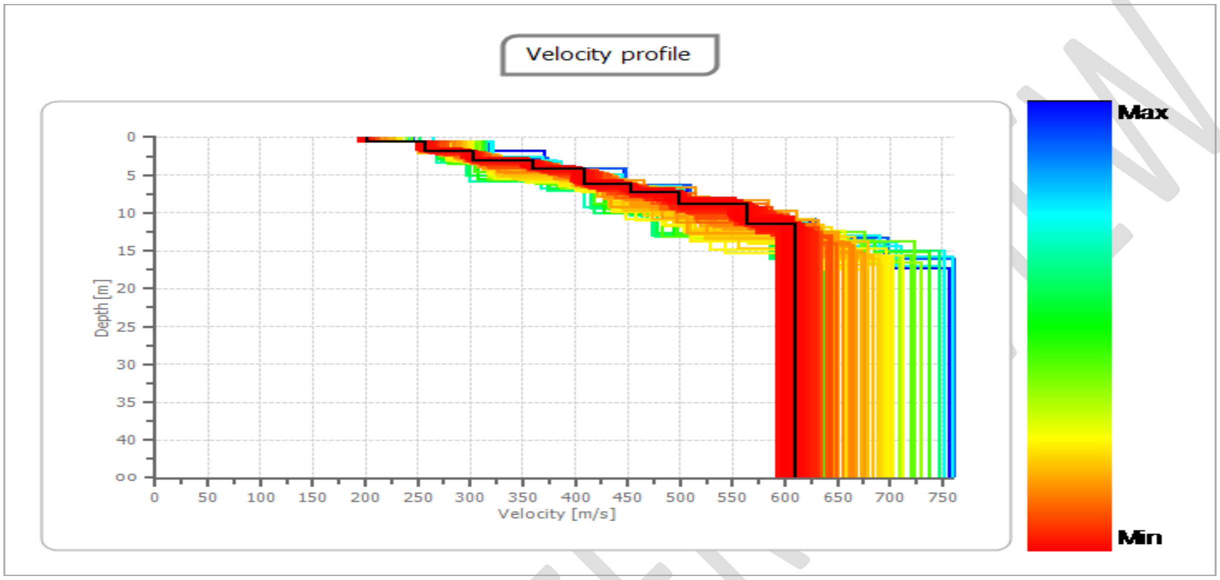

Figure 4a: Velocity model from seismic refraction in Opolo

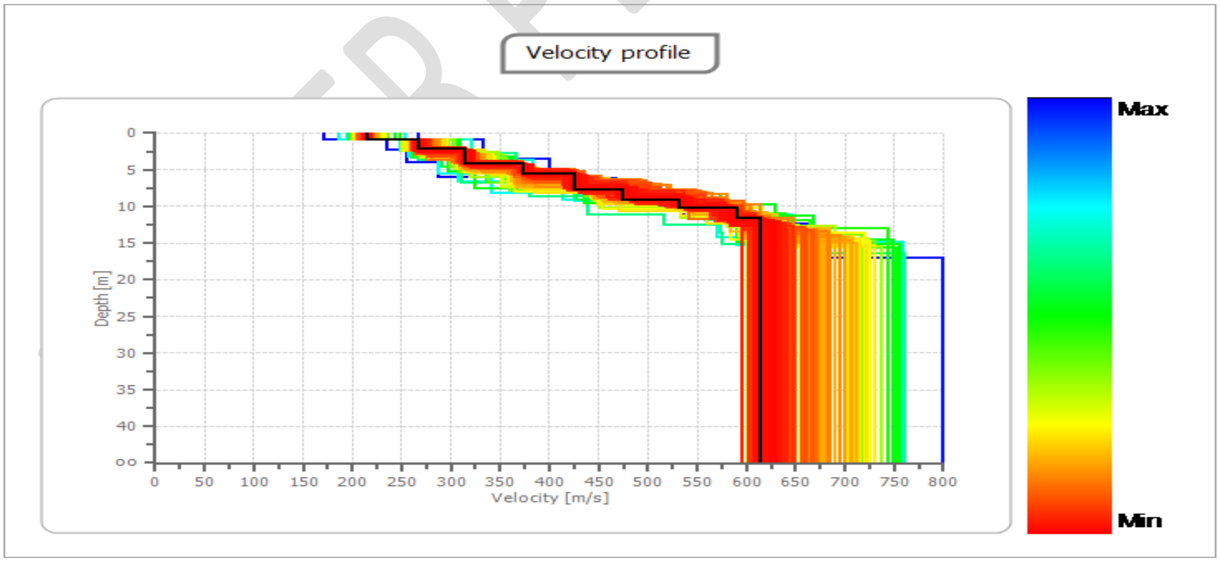

Figure 4b: Velocity model from seismic refraction in Amassoma

The shear wave velocity profiles for Opolo and Amassoma were obtained through MASW surveys, revealing distinct characteristics in each location. In Opolo, the shear wave velocity increases with depth, ranging from approximately 213.71 m/s at 0.8 meters depth to 574.82 m/s at 10.85 meters depth (Table 2a and Figure 4a). This trend is consistent across different profiles, as seen in Table 2b, where Vs ranges from 212.29 m/s at 0.8 meters depth to 565.84 m/s at 12.17 meters depth. These profiles indicate a gradual increase in soil stiffness with depth, revealing a well-graded soil profile suitable for supporting various types of structures. In contrast, Amassoma exhibits a slightly different pattern. The shear wave velocity in Amassoma also increases with depth but starts from a lower value compared to Opolo. For instance, Vs ranges from 214.88 m/s at 1 meter depth to 589.68 m/s at 11.66 meters depth in profile 1 (Table 3a) and from 206.03 m/s at 1 meter depth to 573.83 m/s at 11.59 meters depth in profile 2 (Table 3b and Figure 4b). Despite the lower initial values, the overall increase in Vs with depth indicate that the soil in Amassoma also becomes stiffer and more capable of bearing loads as depth increases.

Table 2a: Foundation bearing capacity and shear wave velocity in Opolo profile 1

Parameter	**Minimum Value**	**Maximum Value**
Depth (m)	0.8	10.85
Thickness (m)	0.8	2.15
Vs [m/s]	213.71	574.82
N-value	6.25	16.8
Qult [kPa]	187.4	504.06
Qa [kPa]	62.47	168.02

Table 2b: Foundation bearing capacity and shear wave velocity in Opolo profile 2

Parameter	**Minimum Value**	**Maximum Value**
Depth (m)	0.8	12.17
Thickness (m)	0.8	2.3
Vs [m/s]	212.29	565.84
N-value	6.21	16.54
Qult [kPa]	186.16	496.18
Qa [kPa]	62.05	165.39

Table 3a: Foundation bearing capacity and shear wave velocity in Amassoma profile 1

Parameter	**Minimum Value**	**Maximum Value**
Depth (m)	1	11.66
Thickness (m)	1	2.27
Vs [m/s]	206.03	589.68
N-value	6.02	17.24
Qult [kPa]	180.67	517.09
Qa [kPa]	60.22	172.36

Table 3b: Foundation bearing capacity and shear wave velocity in Amassoma profile 2

Parameter	**Minimum Value**	**Maximum Value**
Depth (m)	1	11.59
Thickness (m)	1	2.02
Vs [m/s]	206.03	573.83
N-value	6.02	16.77
Qult [kPa]	180.67	503.19
Qa [kPa]	60.22	167.73

Foundation Bearing Capacity

The ultimate bearing capacity (Qult) and allowable bearing capacity (Qa) are critical parameters for foundation design. These values were calculated based on the shear wave velocity profiles and standard geotechnical correlations. In Opolo, the ultimate bearing capacity ranges from 187.4 kPa at the shallowest layer to 504.06 kPa at greater depths (Table 2a). The corresponding allowable bearing capacities range from 62.47 kPa to 168.02 kPa. Similarly, in profile 2 (Table 2b), Qult ranges from 186.16 kPa to 496.18 kPa, and Qa ranges from 62.05 kPa to 165.39 kPa. These values indicate that the soil in Opolo has a robust bearing capacity, suitable for supporting medium to heavy structures. In Amassoma, the ultimate bearing capacity ranges from 188.43 kPa at the shallowest layer to 517.09 kPa at greater depths (Table 3a). The corresponding allowable bearing capacities range from 62.81 kPa to 172.36 kPa. In profile 2 (Table 3b), Qult ranges from 180.67 kPa to 503.19 kPa, and Qa ranges from 60.22 kPa to 167.73 kPa. These values are comparable to those in Opolo, showing that Amassoma's soil also possesses a strong bearing capacity, capable of supporting similar structural loads.

Comparative Analysis

The comparison between Opolo and Amassoma reveals several key information. Both locations exhibit increasing shear wave velocities with depth, indicating that soil stiffness and bearing capacity improve with depth in both areas. However, Opolo generally starts with slightly higher Vs values at shallower depths compared to Amassoma, indicating that the soil in Opolo may be slightly stiffer and more supportive near the surface. The ultimate and allowable bearing capacities in both locations are within similar ranges, indicating that both Opolo and Amassoma have soils capable of supporting medium to heavy structures. This finding is significant for construction planning and design in these areas, as it provides a basis for anticipating soil behavior under structural loads.

Correlation Between Seismic Refraction (Shear wave velocity) and SPT-N Value

In geotechnical engineering, the correlation between seismic refraction shear wave velocity and the Standard Penetration Test (SPT) N-value plays a pivotal role in assessing soil properties crucial for foundation design and construction. The SPT N-value is widely employed to estimate parameters such as shear strength and bearing capacity of soils. In Opolo, where the correlation coefficient ($R^2 = 0.9329$) between shear wave velocity and SPT-N values is notably high, this relationship indicates that changes in shear wave velocity reliably reflect variations in SPT-N values (Figure 4a). This finding underscores the utility of seismic refraction data as a dependable indicator of soil characteristics typically inferred from SPT-N values, thereby supporting robust geotechnical assessments. Similarly, in Amassoma ($R^2 = 0.9047$), the strong correlation between these parameters (Figure 4b) reinforces the predictive capability of shear wave velocity derived from seismic refraction, albeit slightly lower than in Opolo. Empirical studies by Daag et al. [23] & Nogueira et al. [24] further validate these correlations across different regions, highlighting the applicability and reliability of seismic refraction in enhancing geotechnical assessments and validating MASW results against conventional methods like SPT. This empirical evidence underscores the critical role of seismic refraction in ensuring consistency and reliability in geotechnical evaluations.

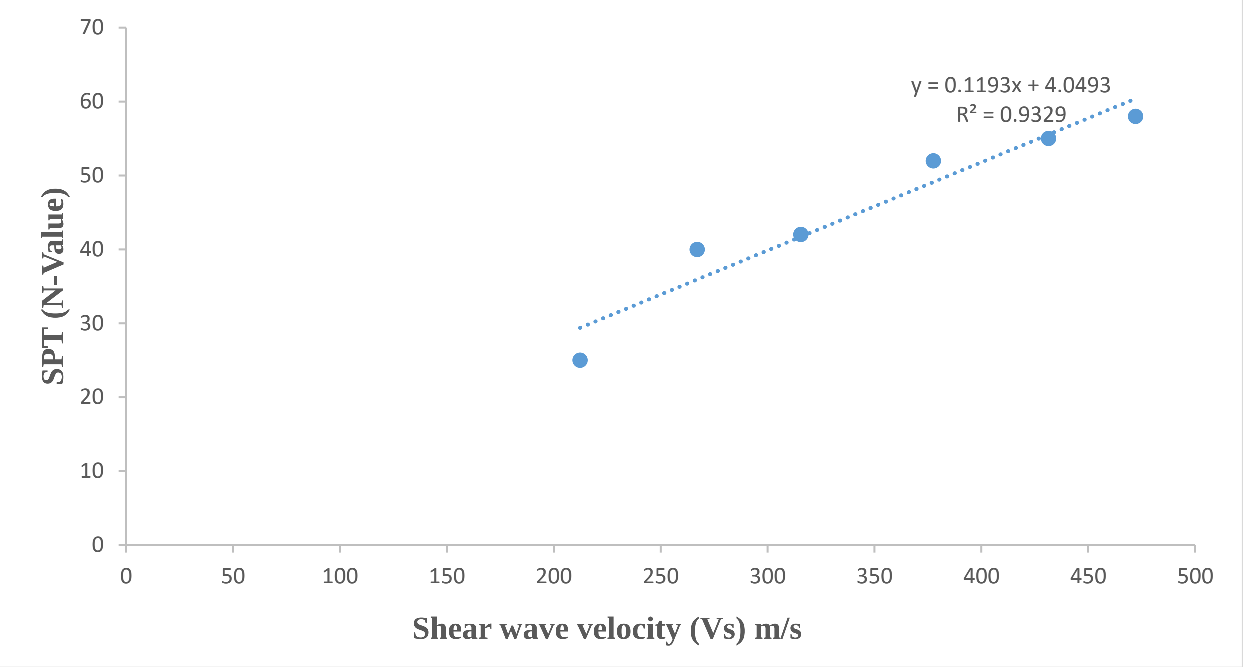

Figure 4a: Correction between Seismic refraction (Shear wave velocity) and SPT (N-value) in Opolo

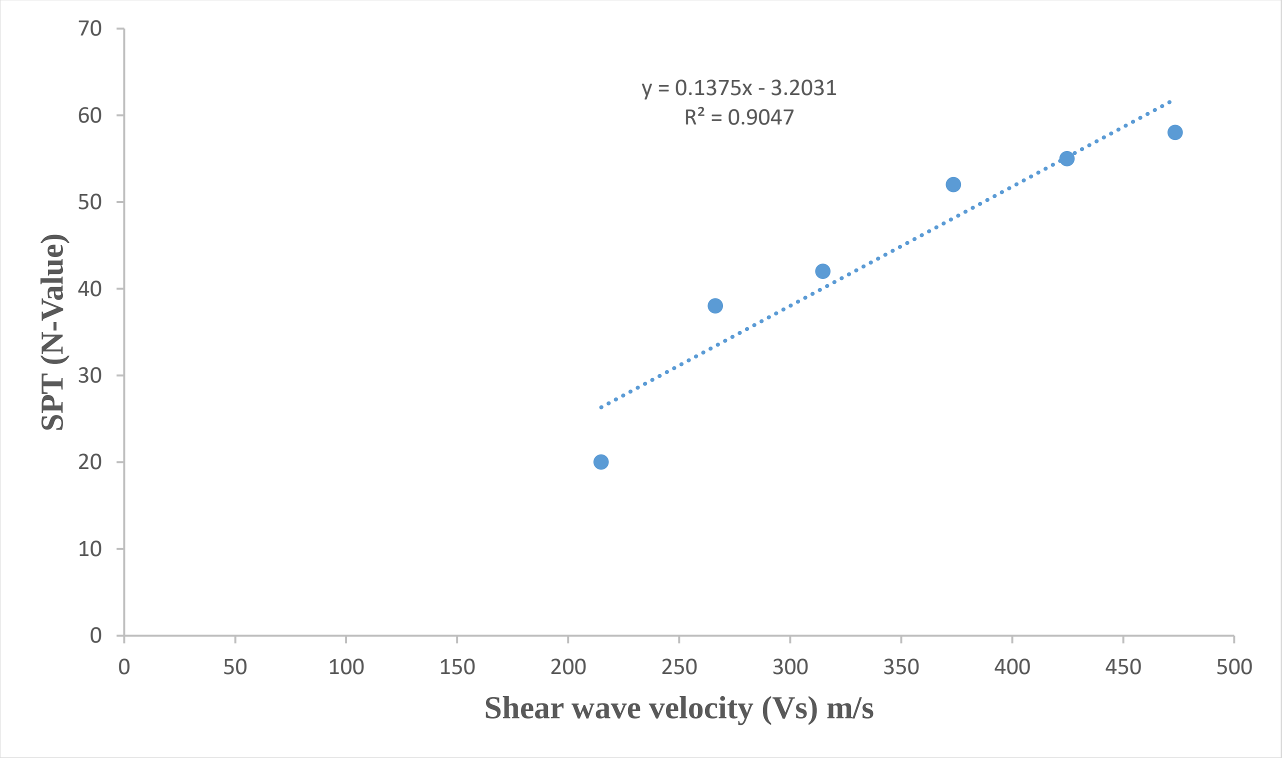

Figure 4b: Correction between Seismic refraction (Shear wave velocity) and SPT (N-value) in Amassoma

CONCLUSION

The comparative analysis of foundation materials bearing capacity using MASW techniques in Opolo and Amassoma, Bayelsa State, Nigeria, has provided valuable information into the geotechnical characteristics of these locations. The shear wave velocity (Vs) profiles obtained through MASW surveys reveal significant differences in soil stiffness and bearing capacity between Opolo and Amassoma. In Opolo, the shear wave velocity increases gradually with depth, indicating a well-graded soil profile with increasing stiffness. This characteristic indicates that Opolo soil is suitable for supporting various types of structures, with ultimate bearing capacities (Qult) ranging from 187.4 kPa to 504.06 kPa across different profiles. Similarly, Amassoma exhibits increasing shear wave velocities with depth, albeit starting from slightly lower values compared to Opolo. The ultimate bearing capacities in Amassoma range from 180.67 kPa to 517.09 kPa, indicating robust soil conditions capable of supporting medium to heavy structures. The comparative analysis highlights that while both locations demonstrate adequate bearing capacities, Opolo generally exhibits marginally higher initial shear wave velocities near the surface, showing potentially stiffer soil conditions in this area compared to Amassoma. However, both sites offer favorable conditions for construction activities, with comparable ultimate and allowable bearing capacities. Moreover, the strong correlation coefficients (R^2) between seismic refraction (shear wave velocity) and SPT-N values in both locations validate the reliability of MASW techniques in assessing soil properties. This consistency enhances confidence in using MASW alongside traditional geotechnical methods for accurate soil characterization and foundation design.

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