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BENEATH THE SURFACE: DETECTING SOIL INSTABILITY AND SUBSIDENCE RISKS WITH ERT AND SEISMIC REFRACTION

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EXTENDED ABSTRACT

La problematica geotecnica dei terreni saturi d'acqua in ambienti deltizi può determinare numerosi cedimenti strutturali. La regione del Delta del Niger è gravata da numerosi problemi di instabilità del terreno che mette a repentaglio la durabilità di edifici e infrastrutture.

A tal proposito, sono state eseguite indagini geofisiche con tecniche ERT e di rifrazione sismica per esaminare le condizioni del sottosuolo a seguito del leggero cedimento e crollo di una struttura nel sito di Amassoma della Niger Delta University.

I risultati dell'indagine ERT hanno mostrato che il sottosuolo era caratterizzato da tre diversi strati con valori di resistività compresi tra 0.453 Ωm e 145 Ωm determinati dalla composizione del terreno e dai relativi livelli di umidità presenti. I risultati delle indagini di resistività elettrica mostrano che gli strati argillosi saturi d'acqua hanno bassi valori di resistività, mentre gli strati di terreni sabbiosi mostrano misure di resistività più elevate. Le aree del sottosuolo con terreni scadenti e compressibili mostrano un elevato potenziale ai cedimenti, causando così, potenzialmente, il crollo strutturale osservato.

L'analisi della velocità delle onde di taglio (V_s) tramite rifrazione sismica ha aiutato a studiare la stabilità del sottosuolo da 0 a 13.6 metri sotto il livello del suolo. I valori di V_s misurati variano da 128.23 m/s a 230.59 m/s, il che implica strati di terreno scadenti ad elevata compressibilità. Le basse velocità delle onde di taglio misurate nei sedimenti non consolidati rivelano caratteristiche sfavorevoli perché creano condizioni che portano a cedimenti differenziali e causano possibili instabilità delle fondazioni. Pertanto, gli edifici richiedono la progettazione di fondamenta che tengano conto delle condizioni avverse dei terreni al fine di determinare una corretta capacità portante.

I valori del numero di colpi N ricavati dalle prove penetrometriche standard (SPT) hanno fornito dati aggiuntivi per valutare la resistenza dei terreni studiati. I risultati dimostrano che i valori di N aumentano progressivamente negli strati superiori più superficiali da 2.09 a 3.71, il che indica che la presenza di terreni che vanno da molto sciolti a sciolti. I valori di N negli strati più profondi mostrano stabilità con un intervallo tra 9.97 e 11.43. Gli strati superiori deboli del terreno dimostrano la necessità di sistemi di fondamenta profonde e tecniche di miglioramento del terreno poichè tali misure aiutano a ridurre i potenziali rischi di cedimenti.

I risultati di questa indagine dimostrano che la progettazione di fondamenta inadeguate su terreni deboli e comprimibili ha portato al crollo dell'edificio presso la Niger Delta University. ERT e rifrazione sismica si sono dimostrati efficaci insieme per rilevare le caratteristiche del sottosuolo, portando a una valutazione completa dei terreni.

Attraverso un approccio combinato, le indagini geotecniche raggiungono una maggiore affidabilità che a sua volta consente di costruire pratiche di sviluppo più sicure all'interno di ambienti deltizi. È necessario, quindi, eseguire indagini appropriate sul sito prima della costruzione per proteggere quei progetti che interessano regioni vulnerabili ai cedimenti. Gli ingegneri dovrebbero implementare fondamenta profonde insieme alla stabilizzazione dei terreni e miglioramento del drenaggio per massimizzare la stabilità strutturale. L'adozione delle strategie menzionate riduce i rischi nei terreni deltizi scadenti, consentendo così uno sviluppo sicuro e sostenibile in contesti geotecnici comparabili.

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ABSTRACT

The dominant geotechnical challenge in deltaic zones stems from subsidence because water-saturated soft soils lead to structural failures in buildings. ERT and Seismic Refraction methods were utilized to identify sub-surface conditions at Niger Delta University Amassoma after one of its buildings collapsed into the ground. The sub-surface contains three different layers of soil with resistivity measurements between 0.453 Ωm and 145 Ωm that represent different levels of moisture content and earth composition. Seismic refraction analysis shows shear wave velocities (V_s) between 128.23 m/s and 230.59 m/s in the upper 13.6 m, correlating with weak, highly compressible soils. N-value analysis demonstrates weak soil strength because N-values show an increase from 2.09 to 3.71 in the upper layers before reaching 9.97-11.43 at deeper levels which signifies improved stability. The results suggest that the collapsed/inking building's foundation was most likely built on unstable, low-strength soils prone to settlement and failure. This study emphasizes the importance of deep foundation designs and soil improvement strategies for reducing subsidence hazards in similar conditions. The integration of ERT and seismic refraction provides a comprehensive assessment of subsurface instability, offering valuable insights for geotechnical engineering and safer construction in deltaic regions.

Keywords*: ERT, MASW, building subsidence, resistivity, N-value*

INTRODUCTION

Land and building subsidence represent a significant geotechnical hazard in the deltaic regions of the Niger Delta particularly in Nigeria (George & Ogobiri, 2021). Constructs in these sites encounter settlement and failure hazards because they are built upon waterlogged soil that compresses very easily (George & Biere, 2021; George & Oki, 2018). The collapsing and sinking building at Niger Delta University (NDU) in Amassoma, Bayelsa State illustrates the vital need for decisive assessment of soil stability and appropriate foundation measures. Normal foundational approaches demonstrate limited success when applied to deltaic soils because they do not guarantee permanent structural stability (Bedrosian *et alii*, 2012). The necessity for detailed geophysical investigations consists of evaluating subsurface conditions to determine improved construction techniques (Apkoku & George, 2023; Adagnodo *et alii*, 2018). Soil strength measurement through Standard Penetration Tests (SPT) and N-values has been complemented by Electrical Resistivity Tomography (ERT) and Seismic Refraction (SR) technologies which deliver improved soil behavior assessment methods (Camarero *et alii*, 2019; Adagnodo *et alii*, 2018; Airen & Oboshenure, 2021; Cardarelli *et alii*, 2024; Guérin *et alii*, 2004; Omonefe *et alii*, 2019).

ERT provides detailed findings about soil moisture content distributions and type distributions while identifying potential weak zones through its resistivity profiling technology whereas seismic refraction generates P-wave velocity results that indicate soil stiffness details and compaction levels (Blake *et alii*, 2024; Camarero *et alii*, 2019; Raji & Adedoyin, 2020; Kneisel, 2004; Guo *et alii*, 2022) The current research combines ERT and seismic data through depth analysis rather than profile analysis thus revealing superior information about underlying stratigraphy and foundation support characteristics (Sazal *et alii*, 2022; Rahimi *et alii*, 2019; Ouhichi *et alii*, 2022; Mazzini *et alii*, 2022; Magnekou *et alii*, 2022; Ikard *et alii*, 2015; Ismail *et alii*, 2012; Dahlin *et alii*, 1990; Cassiani *et alii*, 2009; Chang *et alii*, 2022)

The main objective of this research involves determining the exact cause between weak soil conditions and faulty construction materials in the building collapse. The assessment investigates N-values with resistivity measurements together with seismic velocity data to determine potential causes of soil instability and subsurface vulnerabilities leading to the building collapse. Subsurface instability stands as the main cause when a foundation depth resides within poor soil layers. When foundations reach soil layers with sufficient bearing capacity beyond 15 m depth yet fail to meet safety specifications it may indicate issues related to construction quality and design structural flaws.

The research findings from this particular study extend their significance to structures built in coastal and deltaic environments whose subsidence risks intensify because of rising sea levels and climate change impacts. This interdisciplinary research combining geophysical and geotechnical approaches gives fundamental knowledge required for sustainable development of infrastructure and urban planning together with civil engineering in areas affected by subsidence (Ayolabi *et alii*, 2013)

The current research shows how ERT combined with seismic refraction methods provides a solution to evaluate soil instability and foundation suitability in complicated geotechnical sites. The research results will enable improved techniques for foundation design together with standardization of construction procedures and hazard reduction methods applicable to Niger Delta University facilities and similar geologically risky locations.

Geology of the study area

The study location Niger Delta University is in Amassoma, a town in the Southern Ijaw Local Government area in Bayelsa State, Nigeria, and is part of the Niger Delta region, a huge sedimentary basin recognized for its complex geology and geomorphological features (Okagbue, 1989). This region is part of the wider Niger Delta Province, which includes one of the world's largest deltas, produced by millions of years of sediment deposition. The Niger Delta is underlain by a thick succession of Tertiary to Quaternary sedimentary rocks, primarily clastic deposits deposited in a

fluvio-deltaic setting (Ojoh, 1990). The stratigraphy of the Niger Delta is often classified into three formations: Akata, Agbada, and Benin. The Akata Formation, the deepest of the three, is mostly made up of marine shales and is notable for its overpressured shale bodies. Above the Akata Formation is the Agbada Formation, which is made up of a diverse mix of sands and shales deposited in both marine and river environments (Nwajide, 2013; Doust & Omatsola, 1990), this formation is critical to comprehending the petroleum system in addition to the geotechnical features that are vital to construction. The topmost formation, the Benin Formation, is composed primarily of continental sands with some shale intercalations and was formed in a river to deltaic environment. The Benin Formation is where much of the Niger Delta's urban and infrastructure development is concentrated (Short & Stauble, 1967). The depositional history and lithology of the Benin Formation influence the geotechnical properties of Amassoma's soils. The region is distinguished by soft, compressible soils with high moisture content, such as silts, clays, and sandy clays, which present substantial obstacles to construction and urban development. The high groundwater table and frequent flooding exacerbate geotechnical conditions, compromising soil stability and building foundation integrity (Avbovbo, 1978; Ejedawe, 1981; Reijers, 1996).

This study's inquiry into Amassoma's underlying conditions is especially important given the region's complicated geological framework. Understanding the relationship between lithological composition, soil qualities, and groundwater dynamics is critical for assessing geotechnical risks associated with construction and developing mitigation solutions for probable building collapses.

MATERIALS AND METHOD

Geophysical Investigation (Electrical Resistivity Imaging)

The use of integrated geophysical techniques such as 2-D Electrical Resistivity Imaging (ERI), Vertical Electrical Sounding (VES) and Seismic refraction could provide useful information about the geotechnical properties of subsoil layers underlying a proposed engineering site (George & Biere, 2021).

This research was carried out around the Newsite Campus of the Niger Delta University situated in a sinking building using the electrical resistivity imaging (ERI) method and Seismic refraction technique. The survey divided into 100 m by 60 m square grid pattern and Pasi Earth Resistivity metre (Terrameter Model 16-GL) was used measuring the resistivity variation of the subsurface. Resistivity measurements were carried out along ten (10) established equally spaced resistivity profiles which were 10 m apart. Twenty-one (21) geo-referenced electrode stations were occupied on each profile line at 5 m station interval using Wenner-Schlumberger electrode configuration with an electrode separation distance which ranges from a=5 m to a=30 m. Wenner array was employed for Electrical Resistivity Imaging (ERI) with spacing between adjacent electrodes represented by 'a', all the possible measurement made with Wenner array is of electrode spacing of "na" where n=1, 2….5 and 'a'=5 m. The traverse line varies due to the availability of space within the study area. The apparent resistivity values for each traverse were collated in a format that is acceptable by the RES2DINV inversion computer code used in the inversion of the 2D data. The data obtained were processed and inverted using the

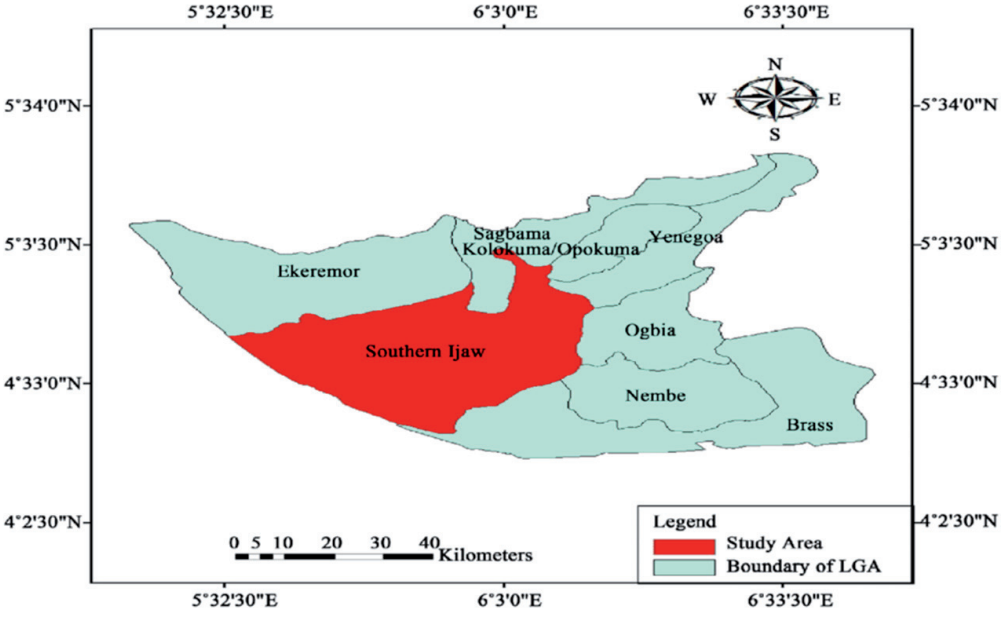

Fig. 1 - Map of Bayelsa state showing southern ijaw LGA

RES2DINV software with a least inversion algorithm using a regularization technique (Loke, 1997; 2019)

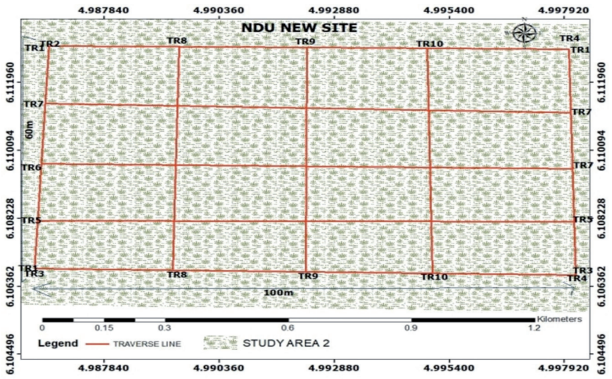

Fig. 2 - ERI 2D square grid layout

Geotechnical Investigation (Seismic Refraction)

In seismic surveying, seismic waves are generated by a controlled source, propagate through the subsurface and return to the surface after refraction and reflection at geological boundaries or travelling along free interface within the subsurface. Geophones arranged linearly along the surface are used to record the arrival times of the waves at different ranges from the source (Yilmaz, 2001). These travel times are converted into depth and, hence, the distribution subsurface geological interfaces may be mapped.

The field measurement of seismic refraction profiles was acquired using the ABEM Terraloc MK6 (seismograph) with 12 channels, 4.5 Hz vertical geophones with the profile length ranging from 0 m - 95 m. The trigger geophone is located at the origin 0 m which is used to transmit analog electrical impulses from geophones to seismograph, the separation distance for each geophone (receiver geophones) ranges from 20 m - 75 m (20 m, 25 m, 30 m, 35 m, 40 m, 45 m, 50 m, 55 m, 60 m, 65 m, 70 m and 75 m) using reverse and forward offset of 20 m apart. The receiver geophones are electrochemical transducers that convert ground motion into an electrical analog signal, these geophones are also used to detect arrival times (compression or P-waves) emanating from the subsurface features. Energy Source (hammer and metallic plate) was armed at the origin (0 m) which is the first shot point, the value obtained from the first shot point is displayed on the seismograph, which is the unit of recording the information detected from the subsurface by the receiver geophone. A total of two (2) shot points were acquired and was recorded on the seismograph for the first profile, second and third profiles respectively (Kearey *et alii,* 2002). The ReflexW 3.5.7 software was used to process the seismic refraction data. The first arrivals, which were direct as well as refracted arrivals, were selected first by the software (Figs. 2 and 3). In most refraction surveys, direct and critically refracted waves generally arrive first and are detected by the seismometer before other waves. The direct waves and the refracted waves arrive at different times depending on the paths traveled and layer velocities. Then t-x curves (arrival times versus geophone positions) were plotted after choosing the first breaks for each seismic event (Nwankwo & Aigbedion, 2022; Oyeyemi *et alii*, 2021). The velocities (V_p) of the homogeneous and isotropic layers were calculated as the inverse of the slope of curve segments, while the layer depths/ thicknesses were determined from the seismic plot intercepts. The linear regression equation to model-calculate the V_s based on the V_p acquired from the seismic refraction investigation (Nwankwo & Aigbedion, 2022).

$$V_p = 1.7 \times V_s \quad (1)$$

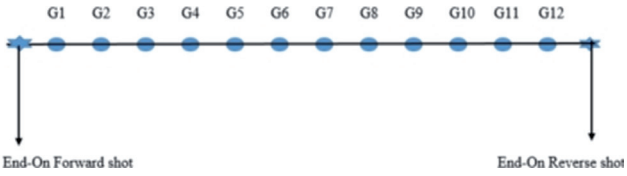

Fig. 3 - Seismic refraction field survey geophone layout

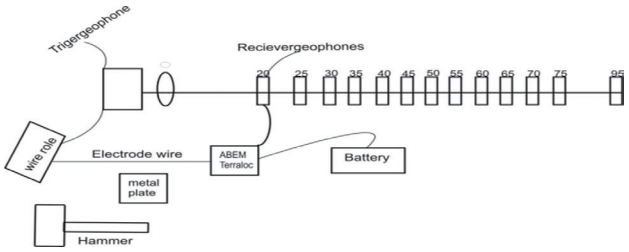

Fig. 4 - Schematic diagram of field procedure during data acquisition

Computation of N-value

The N-value, which is a primary factor used in expressing how soft or hard a formation is and can support foundation bearing capacity; was computed using the (Kirar *et alii*, 2016) relations.

$$V_s = 99.5N^{0.345} \quad (2)$$

Where Vs is the shearwave velocity and N is the computed N-value.

RESULTS

Presentation of ERT results

The First Profile covered a 100-meter spread and probed a depth of 19.8 metres, with resistivity values that ranged from 1.93 to 38.6 Ωm. The resistivity structure consists of three layers: 1.93 to 4.54 Ωm, 6.97 to 16.4 Ωm, and 25.2 to 38.6 Ωm. Figure 5 depicts the 2D resistivity section along Traverse 1.

The second profile covered 100 metres and reached a depth of

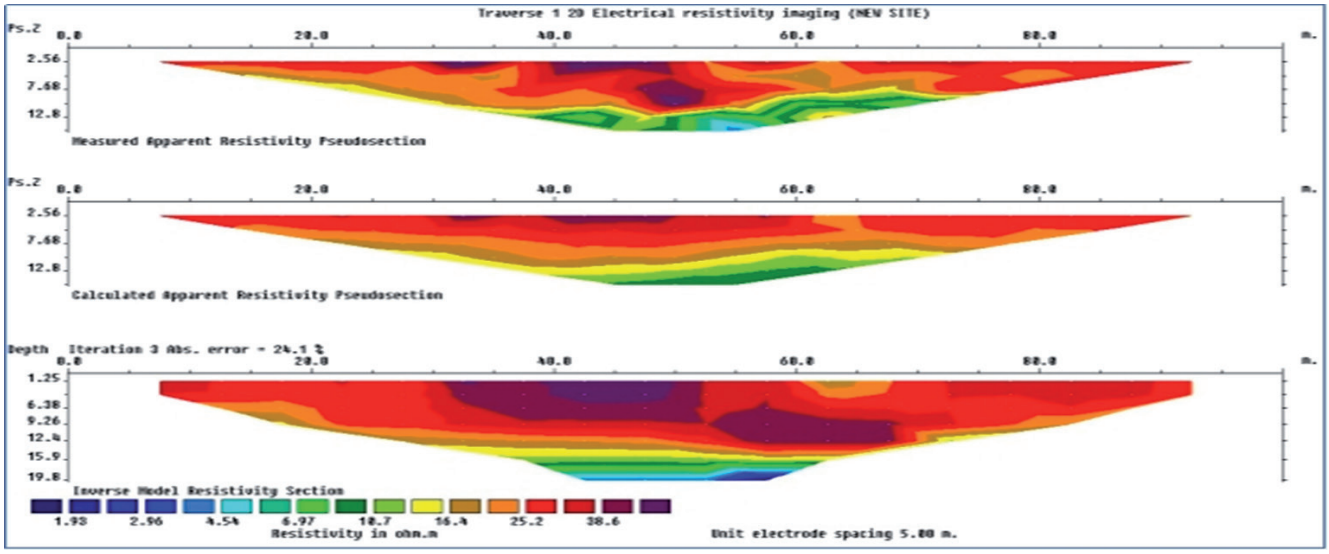

Fig. 5 - Traverse 1: 2D-Electrical resistivity imaging at NDU Newsite 0 m

19.8 metres. Resistivity values ranged from 5.58 to 71.7 Ωm. The resistivity structure is separated into three layers: the first layer (5.58-11.6 Ωm), the second layer (16.7-34.6 Ωm), and the third layer (49.8-71.7 Ωm). Figure 6 shows the 2D resistivity section along traverse 2.

The third profile covered 100 metres and reached a depth of 19.8 metres. Resistivity values ranged from 7.84 to 68.1 Ωm. The resistivity structure is separated into three layers: 7.84-14.5 Ωm, 19.8-36.7 Ωm, and 50.0-68.1 Ωm. Figure 7 depicts the 2D resistivity section along traverse 3.

In the fourth profile, a total spread of 100 m was measured and a depth of 19.8 m was investigated with resistivity values ranging from 0.453-145 Ωm. Three separate resistivity structures are delineated, with the first layer having resistivity values ranging from 0.453-2.35 Ωm, the second layer having resistivity values ranging from 5.36-27.8 Ωm, and the third layer having resistivity values ranging from 63.4-145 Ωm. Figure 8 shows the 2D resistivity section.

The Fifth Profile examined a total spread of 100 m and probed a depth of 19.8 m, with resistivity values ranging from 6.61 to 46.9 Ωm. The resistivity structure is divided into three layers: 6.61-11.6 Ωm for the first layer, 15.3-26.7 Ωm for the second layer, and 35.5-46.9 Ωm for the third layer. Figure 9 shows the 2D resistivity section along traverse 5.

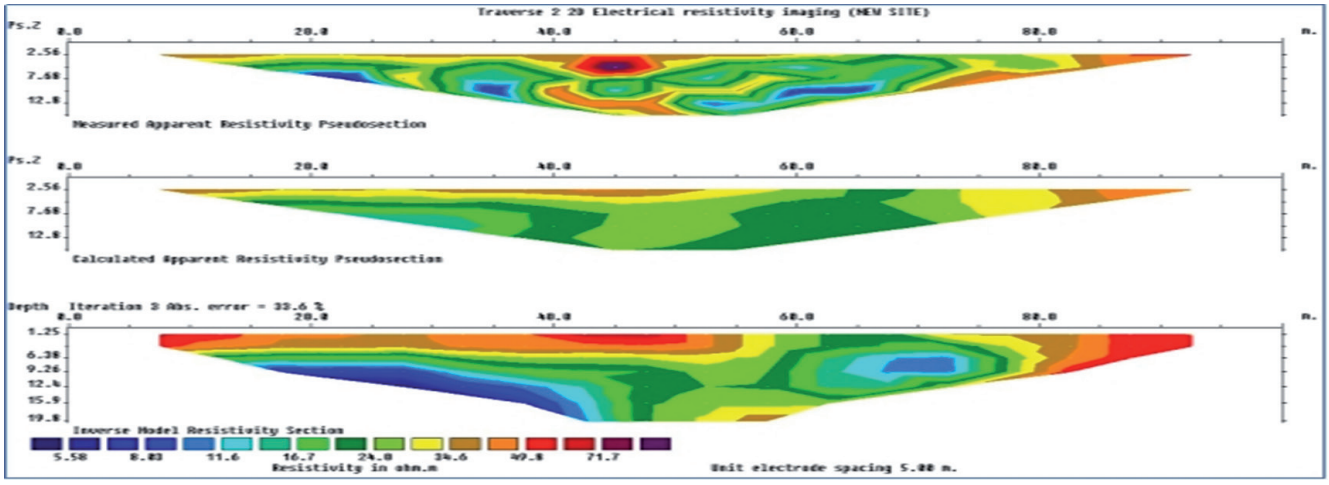

Fig. 6 - Traverse 2: 2D-Electrical resistivity imaging at NDU Newsite 25 m

Seismic refraction result

Three profiles were carried out using seismic refraction method.

The result of the shear wave velocities of the first layer of the three profiles ranges from 128 m/s to 156 m/s (with an average

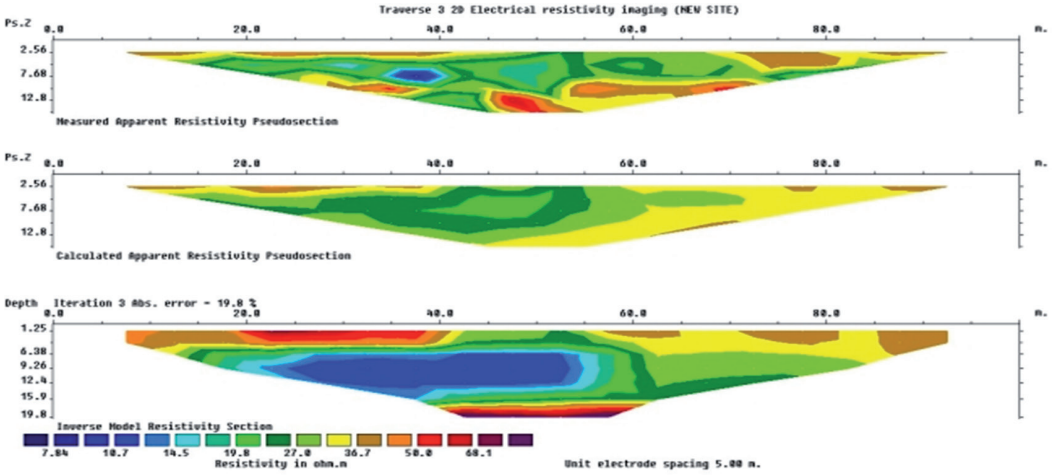

Fig. 7 - Traverse 3: 2D-electrical resistivity imaging at NDU Newsite 50 m

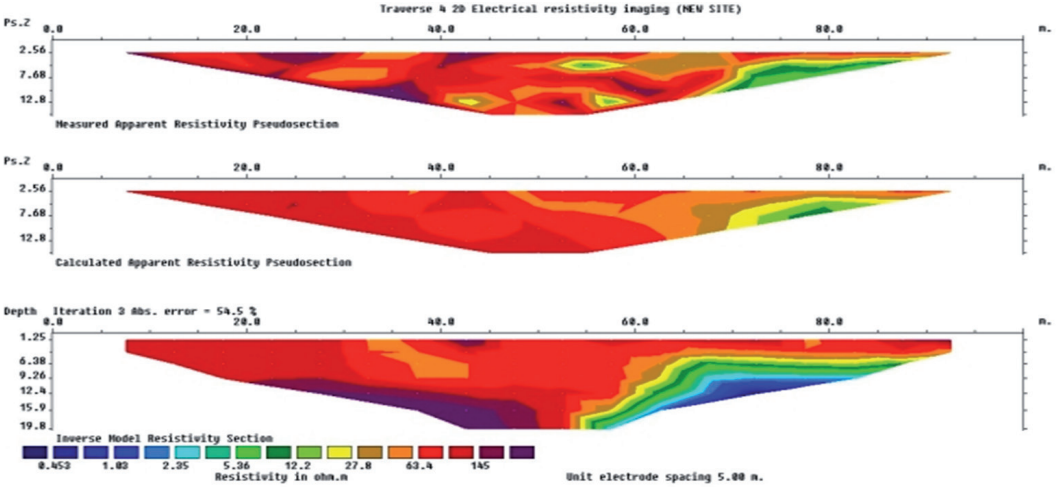

Fig. 8 - Traverse 4: 2D-electrical resistivity imaging at NDU Newsite 75 m

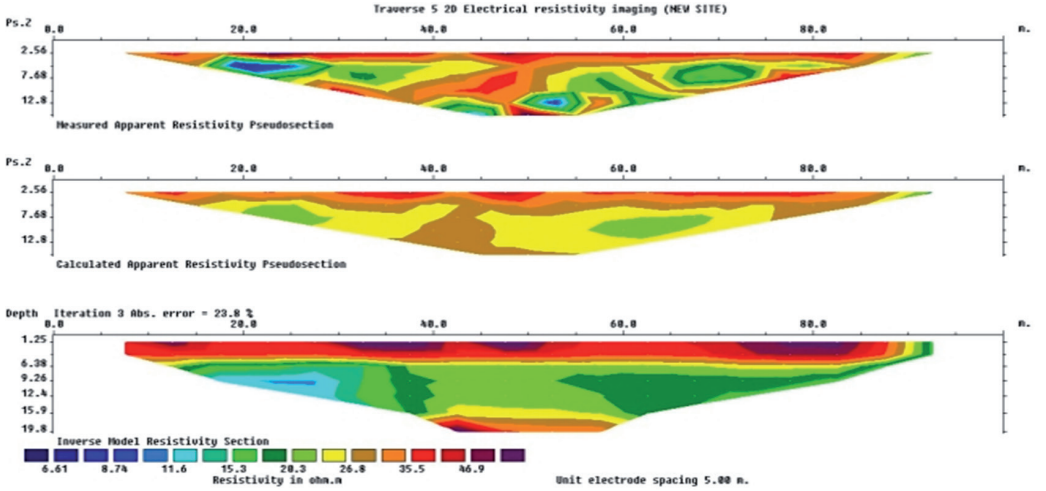

Fig. 9 - Traverse 5: 2D-electrical resistivity imaging at NDU Newsite 100 m

thickness of 9.65 m), that of the second layer ranges from 133 to 231 m/s (with a thickness of averagely 13.2 m). This quantitative interpreted result is displayed in Table 1. Figures 10-13 displays the extracted seismogram and the processed seismogram from the acquisition procedure.

N-Value (N)

N-Value ranges from 2.09-3.71 for the topmost layer which indicates very loose sediments, Second layer values range from 2.32-9.97. This quantitative interpreted result is also displayed in Table 1.

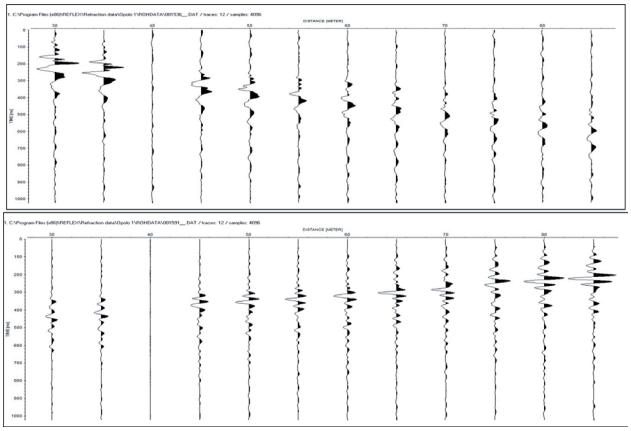

Fig. 10 - The seismogram obtained for the forward and reverse shots representing Profile-1 in the first location of the study area (Nwankwo & Aigbedion, 2022)

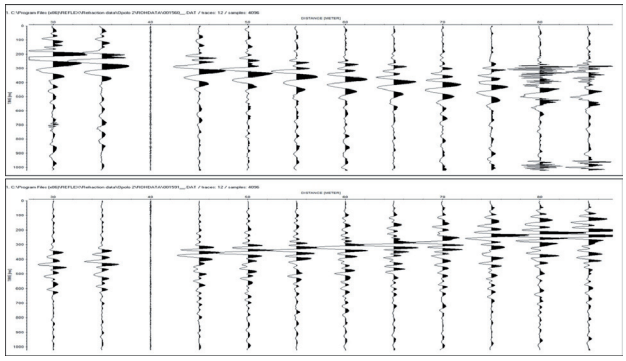

Fig. 11 - The seismogram obtained for the forward and reverse shots for Profile-2 in the second location within the study area (Nwankwo & Aigbedion, 2022)

DISCUSSIONS

The geophysical and geotechnical investigations done at Niger Delta University, comprising Electrical Resistivity Tomography (ERT) and seismic refraction techniques, revealed detailed insights concerning subsurface conditions. These findings are very essential to recognizing the geotechnical issues responsible for sinking structures on the university campus.

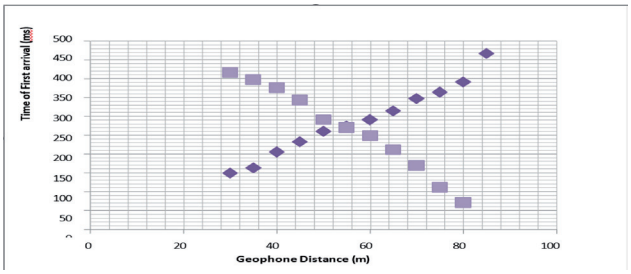

Fig. 12 - Travel time- geophone distance (t-x) plot for the first profile in the first location of the study area (Nwankwo & Aigbedion, 2022)

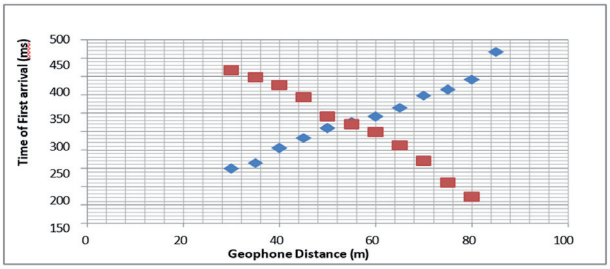

Fig. 13 - Travel time-geophone distance (t-x) plot for the second profile in the first location of the study area (Nwankwo & Aigbedion, 2022)

	Profile - 1		Profile - 2		Profile - 3	
	Layer-1	Layer-2	Layer-1	Layer-2	Layer-1	Layer-2
Thickness (m)	10.30	11.80	3.00	10.60	6.00	17.10
Depth (m)	10.30	22.10	3.00	13.60	6.00	23.10
Vp (m/s)	218	226	229	392	266	374
Vs (m/s)	128.23	132.94	134.71	230.59	156.47	220
N-Value	2.09	2.32	2.41	11.43	3.71	9.97

Tab. 1 - Result from inversion for foundation bearing capacity and shear wave velocity

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

Tab. 2 - N-value classes (modified after Bowles (1984)

Electrical Resistivity Tomography (ERT) Analysis

The ERT data identified three distinct resistivity layers across five profiles, indicating significant lateral and vertical changes in soil composition. The uppermost layer has the lowest resistivity values, indicating high moisture content and possibly organic materials or clays, which are reputed for their poor load-

bearing characteristics. For example, the first profile showed resistivity as low as 1.93 Ωm. Such materials under foundation can give rise to differential settlement and subsidence when compress under load. The middle layers across the profiles generally have resistivity values (ranging from 6.97 to 34.6 Ωm), suggesting a transition to more compact soils, such as silty or sandy clays. These layers typically offer better support than the uppermost layers, but pose risks of consolidation under persistent loading. The third and deepest strata have the highest resistivity values (up to 145 Ωm), indicating denser, more cemented substrates such as gravel or rock. These layers provide the most solid foundation conditions, yet they are frequently inaccessible by normal building foundations without specialized deep foundation techniques.

Seismic refraction Analysis

The Seismic Refraction (SR) results confirmed the stratigraphic profiles proposed by ERT, with shear wave velocities rising with depth. The highest layer (128 m/s to 156 m/s) corresponds to extremely soft ground, which is compatible with the high moisture content indicated by low resistivity values. Such soft soils are prone to seismic liquefaction during earthquakes and can compress significantly under static loads, both of which are crucial for building stability. The next layer with shear wave velocities between 133 to 231 m/s, indicate moderately stiff soil characteristics that can support construction loads better but may still undergo significant settlement over time, particularly under wet conditions or if inadequately compacted. Below this layer is believed to have very stiff to hard earth conditions, which are appropriate for foundational support and correspond to the dense materials suggested by the maximum resistivity.

Foundation bearing capacity (N-Value analysis)

The collapse and subsidence of some buildings in Niger Delta University are of concern to soils instability, subsurface conditions and foundation design. ERT and SR integration can provide significant knowledge in the subsurface properties that have most likely led to failure. However, both approaches vary considerably with the depth in subsurface properties, distinguishing weaker, water saturated zones from more competent load bearing materials. The N-values provide a more accurate estimate of soil compaction and strength when computed using (Kirar *et alii*, 2016) relations. The upper layer's N-values (2.09-3.71) indicate relatively loose circumstances when compared to usual building norms. These numbers demonstrate that, while the surface layer may support certain types of building, it is nevertheless subject to compression and settling under severe loads. The second layer has N-values (2.32-9.97). The increase in N-values with depth corresponds to the denser material layers reported in ERT and Seismic refraction analysis, implying a medium compacted condition capable of supporting considerable buildings without undue settling.

Correlation between ERT and seismic refraction by depth

A depth-based comparison of resistivity and seismic velocity results shows a consistent trend:

- Shallow depths (0-5 m):
  1. low resistivity values (0.45-11.6 Ωm) in the ERT results indicate that these sediments are water saturated or contain large amounts of clay;
  2. seismic refraction data confirm low P-wave velocities, this is a characteristic of loose, unconsolidated soils;
  3. implication: it implies if the collapsed structure had a shallow foundation (less than 5 m deep), the failure was most probably a result of insufficient soil strength and high abundance of settlement hazards rather than from construction materials defects.
- Intermediate depths (5-15 m):
  1. a gradual increase in resistivity (5.36-34.6 Ωm) suggests improved drainage conditions, reduced moisture content, or a transition to sandy or silty soils;
  2. there was an increase in seismic velocities this depth, reflecting moderate compaction;
  3. implication: at this depth, if the foundation collapsed, then there would be a possibility that soil variability (weak spots) or structural load distribution (distribution of forces within the structure) were a part of the failure.
- Greater depths (15-20 m):
  1. the highest resistivity values (50-145 Ωm) indicate denser, well-compacted materials, possibly weathered rock or dry coarse-grained sediments;
  2. seismic refraction confirms a significant increase of P-wave velocity, which indicates capable load bearing strata;
  3. implication: deep foundations at this level would have provided a solid foundation for construction. If failure occurred, it was most likely due to building material faults or design errors, not soil instability.

Implications for soil instability and subsidence risks

- High Risk of Settlement at Shallow Depths
  1. Low seismic velocity combined with low resistivity points to weak, highly compressible, water-saturated sediments in the topmost 5 m.
  2. Excessive settlement and differential movement may create structural damage to buildings relying on shallow foundations in this case.

- Potential for Seismic Liquefaction
  1. Loose, low resistivity sediments at shallow depths indicate high moisture content, thus the possibility of liquefaction under seismic loading.
  2. This is particularly critical for regions with high seismic activity, requiring additional geotechnical reinforcement.
- Improved Stability at Intermediate Depths
  1. Although foundation condition improves in the transition zone (5-15 m depth), the seismic velocity and resistivity variations suggest that there is spatial compaction irregularity.
  2. Additional geotechnical tests (e.g., SPT or CPT) are recommended to confirm load-bearing capacity before construction.
- Deep Layers as the Most Stable Foundation Base
  1. Both ERT and SR results show well-compacted, low-risk material appropriate for deep foundation support at depths more than 15 m.
  2. Structural stability and reduced possibility of settlement or subsidence would be provided by deep pile foundations or deep drilled shafts to this depth.

Recommendations for engineering design and mitigation measures

- Shallow foundations (0-5 m): without soil stabilizing methods like compaction, preloading, or grouting, it is not advised;
- Intermediate depth foundations (5-15 m): suitable for ground improvement, especially in places where resistivity and seismic velocity values are low;
- Deep foundations (15-20 m): these layers are ideal for high-load constructions because they provide stable conditions with low settling danger.

CONCLUSIONS

This study used Electrical Resistivity Tomography (ERT) and Seismic Refraction Technique to conduct a thorough geotechnical and geophysical analysis of the subsurface conditions at Niger Delta University in Amassoma. The integrated technique successfully identified the stratigraphic strata and estimated the N-values, which are critical for understanding the reasons of observed building sinking and creating mitigating strategies. The results of the ERT and Seismic Refraction Technique investigations indicated a 2 to 3-layered soil structure, with each layer having distinct physical qualities. The highest layer, with lower resistivity and shear wave velocities, suggests the presence of softer, more compressible materials such as clays or organic-rich soils. These conditions are prone to settlement under structural loads, which contributes to the university's current subsidence difficulties. In contrast, the deeper strata showed much higher resistivity and shear wave velocities, indicating denser and more solid materials capable of supporting massive constructions.The N-value data revealed a direct measure of soil strength, with measurements confirming the relative compaction of each layer. The increase in N-values with depth supports the Seismic Refraction and ERT findings, emphasizing the possibility of deeper, more compact layers to serve as a secure foundation for new projects, assuming that foundation systems can effectively reach them.

The findings of this study are significant for future construction and infrastructure planning at Niger Delta University. It is suggested that building projects avoid weak foundations that do not extend past the unstable higher layer. Instead, building should use deeper foundation techniques that take advantage of the more stable layers described in this study. Furthermore, if deep foundations are not possible, soil stabilization techniques such as grouting, pilings, or stone columns should be considered to improve the load-bearing capability of poorer soils. This research emphasizes the significance of precise subsurface studies in locations prone to subsidence. The extensive analysis of soil layers and their properties sheds light on soil-structure interaction dynamics in a saturated, soft soil environment. This study's comprehensive data and insights serve not just academic reasons, but also to assist governmental decisions about land use, building codes, and infrastructure development in sensitive areas. This closes the gap between research and practical, policy-oriented applications, improving safety and sustainability in infrastructure development. Niger Delta University may better manage its infrastructure demands by implementing geotechnically informed construction procedures, assuring the long-term stability and safety of its structures in the Niger Delta's tough environmental circumstances.

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