Science World Journal Vol. 20(No 4) 2025 https://dx.doi.org/10.4314/swj.v20i4.13
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

Full Length Research Article

IMPACT OF GEOPHONE SPACING ON SOIL STIFFNESS EVALUATION AT KASU, NEW SITE

*[1]Lawal Mustapha Tanimu, [1]Abdullahi Nasir Khalid, [1]Hycienth O. Aboh, [2]Abdulhadi Danlami, [2]Ango Abubakar, [1]Ahmad Muhammad Sani, [1]Hussaini Abdulkarim

[1]Department of Physics, Kaduna State University, Kaduna State, Nigeria
[2]Department of Physics with Electronics, Nuhu Bamalli Polytechnic, Zaria, Kaduna State, Nigeria

*Corresponding Author Email Address: mustaphatanimulawal@gmail.com

ABSTRACT
Multichannel Analysis of Surface Waves (MASW) Measurement was conducted at Kaduna State University, New site, Rigachikun Ward, Igabi Local Government Area, Kaduna State, Nigeria, in order to characterize the study area and to study the ability of different geophone configurations. MASW was conducted at five (5) profiles with geophone spacings of 1m, 2m, and 3m for each profile, which covered a maximum of 108m profile length with the aid of ABEM TERRALOCK PRO seismographs, and the field data obtained was analyzed using SeisImager Computer software. The 1m, 2m, and 3m geophones spacing results show a maximum of five (5) layers and both revealed heterogeneous nature of the subsurface geological sequence. The geological sequence beneath the study area for all profiles shows an average shear velocity ranging from 180m/s to 528.50m/s from the velocity profiles and the site is classified as class C (very dense soil and soft rock) and Class D (stiff soil) as the depths of the layers differ from one location to other ranging from 1.5m to 24m. Quantitative interpretation indicates that, the study area is dominated by three major types of soil; clay, sand and gravel as revealed by the 2D model with shear velocity ranging from 215m/s to 610m/s and at depth ranging from 0 to 37m. At 1m geophone spacing about 50% indicates soil class C (Very dense soil and soft rock) and 50% class D (stiff soil) while at 2m geophone spacing about 33% revealed soil class C while 67% revealed soil class D. At 3m geophone spacing, the soil type was 100% at class D.

Keywords: MASW, Surface Waves, Geophones spacing, Shear Velocity, Site class

INTRODUCTION
Multichannel analysis of surface waves (MASW) as an important method for investigating shallow geologic structures and evaluating the relative shear velocity of subsurface materials is one of the method apply to solve the problem that lead to building collapse (Joseph et al 2022). The issue of building collapse is a global challenge that significantly impacts the construction industry, especially within the urban settlement, with insufficient measures taken to address the problem (Joseph *et al*., 2022). Nigeria Similar to numerous other nations is experiencing a worrying increasing in the collapse of engineering structures across various urban areas (Ebekozien and Samsurijan, 2023). Properly constructed buildings are anticipated to serve their intended purposes for extended periods (Joseph *et al.,* 2022). Key consideration in the construction of buildings comprises durability, sufficient stability to prevent failure or discomfort for users, and the ability to withstand weather conditions, fire, and other potential hazards (Oloyede *et al*., 2017). Thus, performing a comprehensive evaluation of the subsurface materials at the site selected for construction is an essential measure to avoid foundation failures and prevent damage to lives and properties (Mittal *et al*.,2023).This research work is set to evaluate the effectiveness of geophones spacing at Kaduna State University, New Site, Rigachikun Ward, Igabi Local Government, Kaduna, Kaduna State, using MASW in order to address the issue of space constrain in conducting seismic survey for site characterization. The research has evaluated an effective geophone spacing for site characterization using MASW especially in the urban settlement for geotechnical investigations.

Location of the Study Area
Rigachikun is an area located in the humid, wet-dry tropics, in the northern region of the guinea savannah and lie within latitude 10^0 37'17.27''N, longitude 7^0 28'47.83''E and latitude 10^0 37'17.60''N, longitude 7^0 28'51.05''E in Igabi Local government area of Kaduna state, Nigeria.

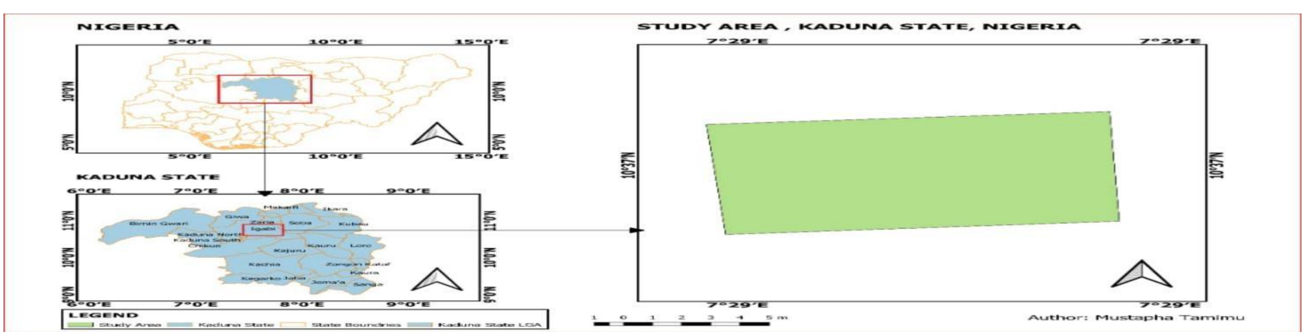

Figure 1. Map of the study area (Google Earth, 2024)

Science World Journal Vol. 20(No 4) 2025
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
https://dx.doi.org/10.4314/swj.v20i4.13

Geology of the Study Area

The geological mapping of the study area reveals that the most dominant rock type in this area is Migmatite-Gneiss and Biotite-Granite and some few pegmatitic veins towards the north-eastern area of Mando, Igabi Local government area of Kaduna State (Offodile, 1992)

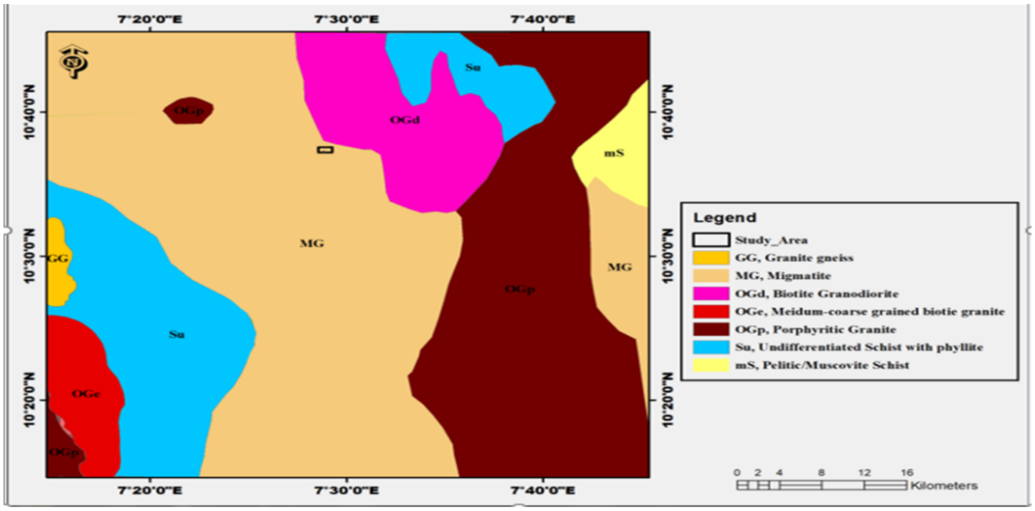

Figure 2. Geology Map of the study area (NGSA, 2019)

MATERIALS AND METHODS

Abem Terralock seismograph and accessories were used to acquired field data using active parameters as shown in table 1 below:

Table 1: data acquisition parameters (Sies imager/SW manual,2009)

Parameter	**Settings**
Spread configuration	Linear
Geophone's spacing	1m,2m, and 3m
Total number of geophones	24 geophones
Geophone type	10 Hz (vertical)
Nearest offset	½ of geophone spacing in meters
Source equipment	16Lb sledgehammer
Sample interval	0.5 milliseconds
Record length	1 second
Stacking limit	5 stacking

Figure 3. Abem Terralock Seismograph and Accessories

Other materials used include; takeout cable, triggered cable, 24 set of 10Hz vertical geophone, 16LB sledge hammer, shot plate, measuring tape, GPS and Dc power source.

Data Collection/ Field Procedure

Data was collected along Five (5) profiles at interval of twenty meters (20m) with three spacing intervals, namely 1m, 2m and 3m for each profile, data were collected at the spacing of 1m. Twenty-four (24) geophones were planted on the earth surface at interval of 1meter which covers 24m. The offset was set at 0.5m while the first shot was taken in-between the first and second geophones. Other shots were also taken in-between next two geophones until when the triggered geophone was in-between geophone twelve (12) and thirteen (13) whereby the first twelve geophones were uprooted and moved forward (Roll along). The same procedure was repeated for more six (6) times until 96m was covered. The same procedure was followed to obtained data for 2m and 3m with an offset set at 1m and 1.5m respectively at which a distance of 96m and 108m was covered.

https://dx.doi.org/10.4314/swj.v20i4.13
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

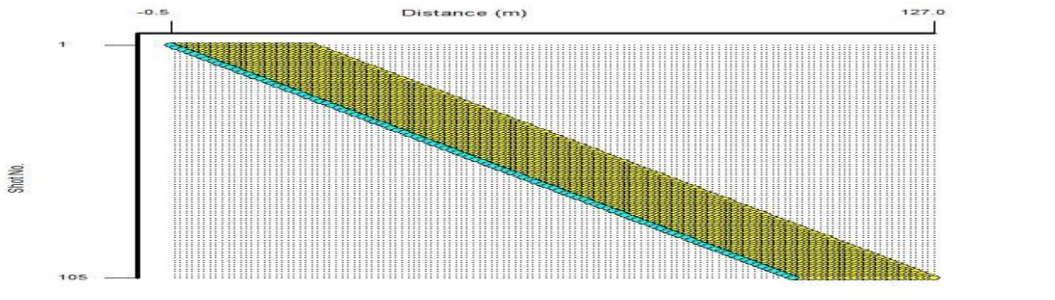

Figure 4. Showing Shot points for profile 1 at 1m

RESULTS AND DISCUSSION

For this research, the data analysis for the seismic MASW was performed using computer software called SeisImager. The seismic surveys give a picture of the subsurface wave's distribution. The S-waves vary from one point to another. As result of the variation, measuring the S-waves of an unknown material has potential for being useful in identifying that material which provides further information. Furthermore, to convert seismic picture to a geological picture, some knowledge of a typical seismic values for different subsurface material is useful (Al-Shuhail and Mousa, 2017).

Table 2. Site classification based on site-specific conditions established by the International Building Code (IBC) 2012 (Abdallatif et al 2022).

Site class	Soil profile Name	V_{S30} (ft/s)	V_{S30} (m/s)
A	Hard Rock	V_{S30}>5000	V_{S30}>1524
B	Rock	2500< V_{S30} ≤5000	762< V_{S30}≤1524
C	Very Dense soil and soft Rock	1200< V_{S30}≤2500	366< V_{S30}≤762
D	Stiff soil	600≤ V_{S30}≤1200	183< V_{S30}≤366
E	Soft soil	V_{S30}<600	V_{S30}<183

Interpretation of profile 1 at 1m

Figure 5 displays a typical velocity profile of profile 1 at 1m, the near-surface soils of the study area revealed five layers with an average shear velocity of 379.80m/s and depth ranging from 1.5m to 24m which is classified based on the Vs30 as site class C (stiff soil and soft rock) according to the International Building Code (IBC) 2012.

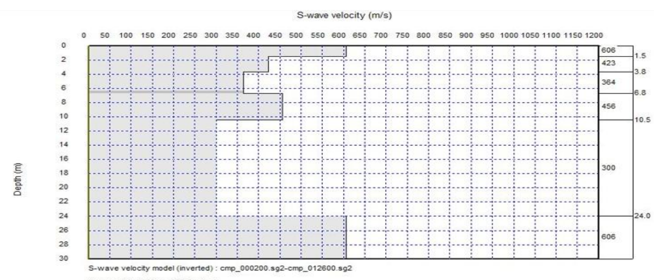

Figure 5: Typical Velocity profile for profile 1 at 1m

Figure 6 presents a 2D model of profile 1 at 1m, the shear wave velocity model generated revealed a general increase of velocity with depth down to 35m. The model shows variation of the subsurface from one place to another which consist of clay, sand and gravel. The portion that consists of clay has a lower velocity range. The portion that consists of sand has an intermediate velocity range. The layer which consists of gravel composed of the higher velocity with shear velocity ranging from 215m/s to 569m/s.

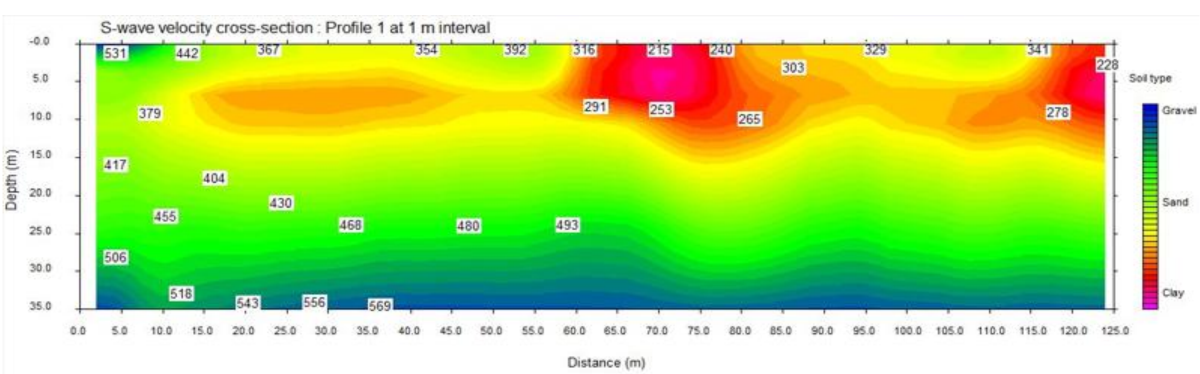

Figure: 6 2D model for profile 1 at 1m

Interpretation of profile 2 at 1m

Figure 7 is the typical velocity profile of the sub-surface of the study area with an average shear velocity of 347.81m/s and depth ranges from 1.5m to 24m thereby classified as class D (Stiff soil).

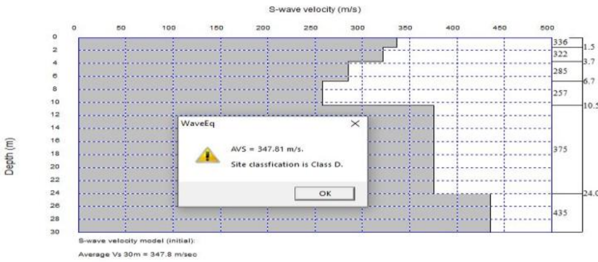

Figure 7: Typical Velocity profile for profile 2 at 1m

Figure 8 displays 2D model, the shear wave velocity model produced revealed an over-all increase of velocity with depth down to a depth of 35m. The model shows difference of the subsurface from one place to another which consist of clay, sand and gravel with shear velocity ranging from 215m/s to 569m/s.

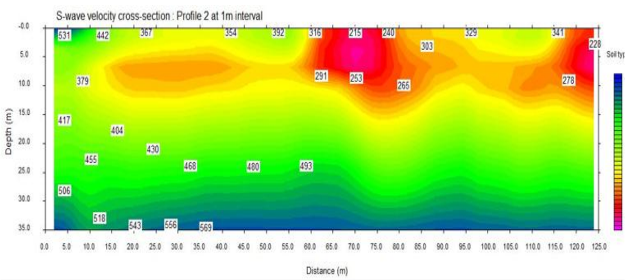

Figure 8: 2D model for profile 2 at 1m

Interpretation of profile 3 at 1m

Figure 9 gives a typical velocity profile of the sub-surface soils of the study area similarly revealed five layers with an average shear velocity of 310m/s and depth ranging from 1.5m to 24m therefore is interpreted as class D (Stiff soil).

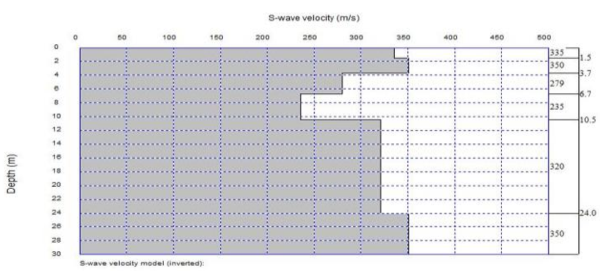

Figure 9: Typical Velocity profile for profile 3 at 1m

Figure 10 displays a 2D model, the shear wave velocity model generated show an increase of velocity with depth down 38m. The model shows disparity of the near-surface from one position to another which comprises of clay, sand and gravel with their respective velocities with shear velocity ranging from 230m/s to 380m/s.

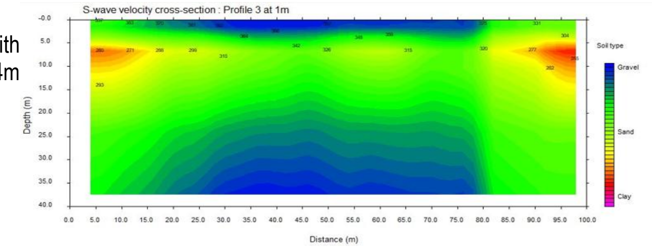

Figure 10: 2D model for profile 3 at 1m

Interpretation of profile 4 at 1m

Figure 11 demonstrates a typical velocity profile of the near-surface soils of the study area revealed nine layers with an average shear velocity of 314.0m/s and depth ranges from 1.5m to 24m and is classified as class D (Stiff soil).

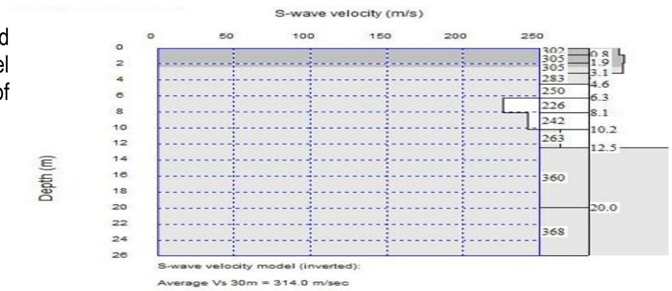

Figure 11: Typical Velocity profile for profile 4 at 1m

Figure 12 is a 2D model, the shear wave velocity model produced shows an increase of velocity with depth down to 28m. The model shows transformation of the subsurface from one point to another which consist of clay, sand and gravel with shear velocity ranging from 202m/s to 398m/s.

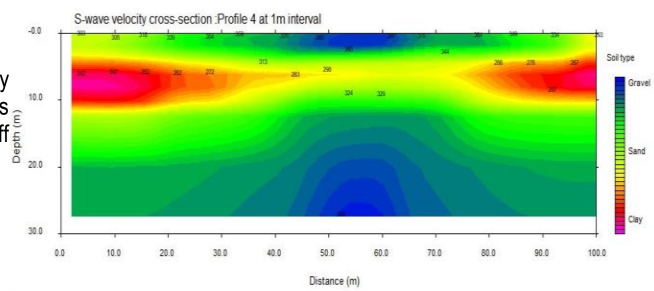

Figure 12: 2D model for profile 4 at 1m

Interpretation of profile 5 at 1m

Figure 13 exhibits a typical velocity profile of the sub-surface soils of the study area with an average shear velocity of 434.4m/s and depth ranges from 1.5m to 24m and is categorized based on the Vs30 as site class D (Stiff soil).

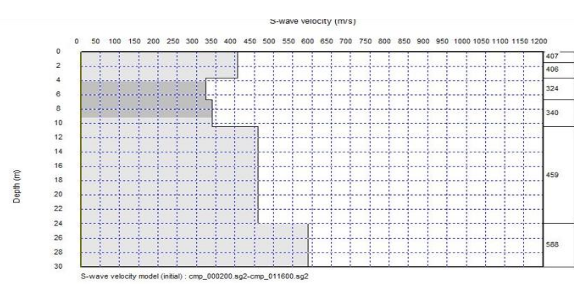

Figure 13: Typical Velocity profile for profile 5 at 1m

Science World Journal Vol. 20(No 4) 2025 https://dx.doi.org/10.4314/swj.v20i4.13
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

Figure 14 unveils the 2D shear wave velocity model which revealed a general rise in velocity with depth down to a depth of 38m. The model shows dissimilarity of the subsurface from one part to another which consist of clay, sand and gravel with shear velocity ranging from 259m/s to 580m/s.

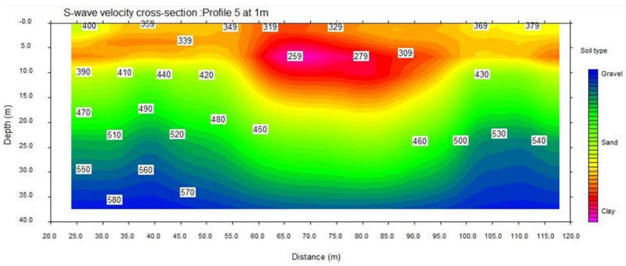

Figure 14: 2D model for profile 5 at 1m

Interpretation of profile 1 at 2m
Figure 15 displays a typical velocity profile of the near-surface soils of the study area that consists five layers with an average shear velocity of 360.60m/s with depth ranging from 1.5m to 24m, the site is therefore categorized as class D (Stiff soil).

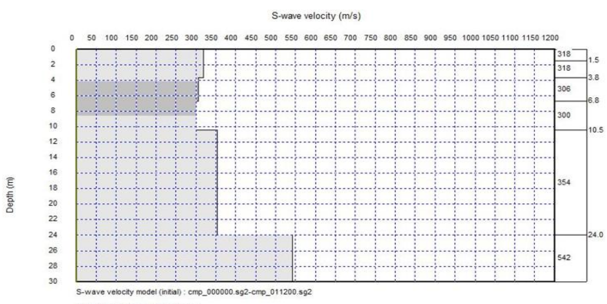

Figure 15: Typical Velocity profile for profile 1 at 2m

Figure 16 shows a 2D shear wave velocity model, the model produced gives a general increase of velocity with depth down to 30m. This model shows inequality of the subsurface from one point to another which consist of clay, sand and gravel. The model has velocity range from 308m/s to 493m/s.

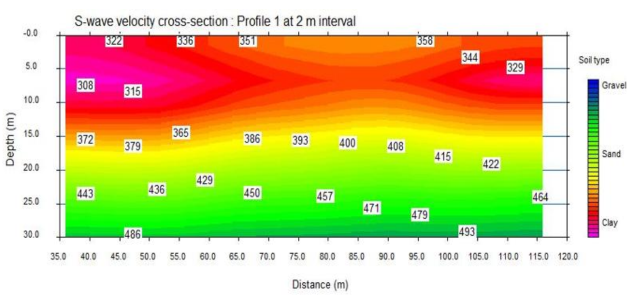

Figure 16: 2D model for profile 1 at 2m

Interpretation of profile 2 at 2m
Figure 17 illustrates a typical velocity profile of the sub-surface soils of the study area with an average shear velocity of 319.50m/s and depth ranging from 1.5m to 24m. The site is then classified as class D (Stiff soil).

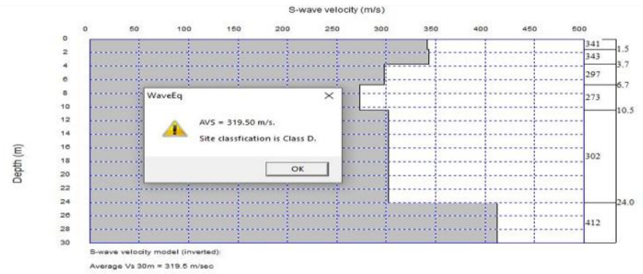

Figure 17: Typical Velocity profile for profile 2 at 2m

Figure 18 demonstrates a 2D shear wave velocity model, the model created shows an increase of velocity with depth down to a depth of 37m. This model shows difference of the subsurface from one portion to another which consist of clay, sand and gravel. The model shows velocity ranging from 304m/s to 525m/s.

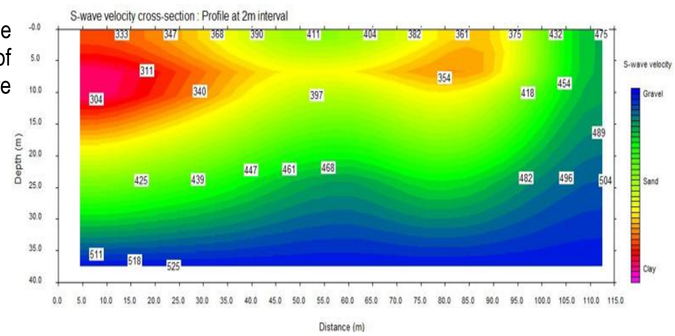

Figure 18: 2D model for profile 2 at 2m

Interpretation of profile 3 at 2m
Figure 19 exhibits the typical velocity profile of the sub-surface soils of the study area with an average shear velocity of 371.60m/s and depth ranges from 1.5m to 24m and then classified based on the Vs30 as class D.

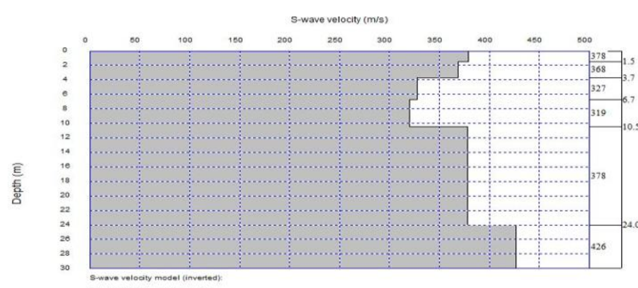

Figure 19: Typical Velocity profile for profile 3 at 2m

Figure 20 gives the 2D shear wave velocity model, the generated model established a general increase of velocity with depth down to of 37m. This model shows disparity of the subsurface from one place to another which consist of clay, sand and gravel. The model has velocity range from 322m/s to 600m/s.

Science World Journal Vol. 20(No 4) 2025
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
https://dx.doi.org/10.4314/swj.v20i4.13

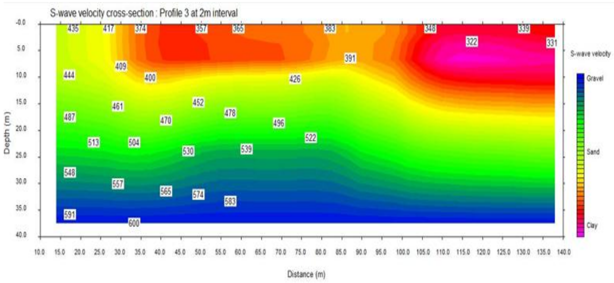

Figure 20: 2D model for profile 3 at 2m

Interpretation of profile 4 at 2m
Figure 21 demonstrates a typical velocity profile of the near-surface soils of the study with an average shear velocity of 347.67m/s and depth ranging from 1.5m to 24m and is interpreted based on the Vs30 as class D (Stiff soil).

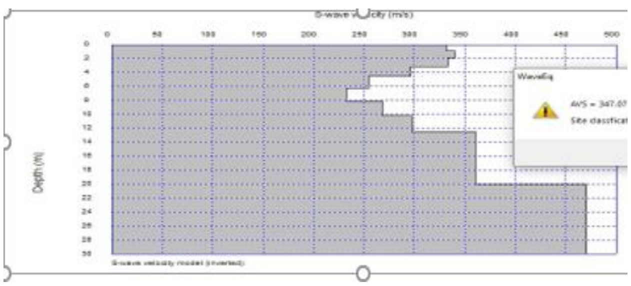

Figure 21: Typical Velocity profile for profile 4 at 2m

Figure 22 displays a 2D shear wave velocity model generated revealed a general increase of velocity with depth down to a depth of 37m. This model shows discrepancy of the subsurface from one place to another which consist of clay, sand and gravel. The model unveils velocity range from 296m/s to 575m/s.

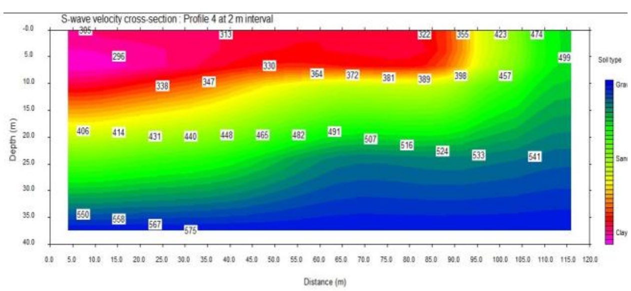

Figure 22: 2D model for profile 4 at 2m

Interpretation of profile 5 at 2m
Figure 23 picture-out a typical velocity profile of the sub-surface soils of the study area with an average shear velocity of 528.50m/s and depth ranging from 1.5m to 24m, this point is categorized as class D (Stiff soil).

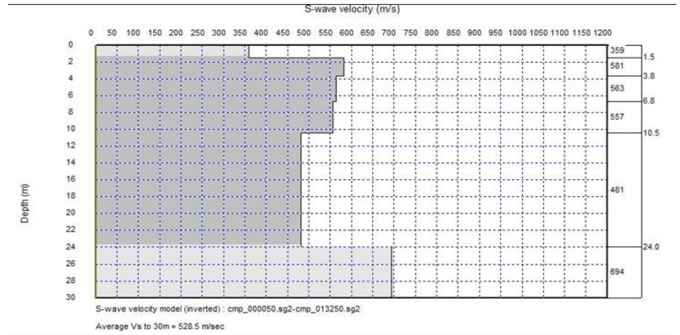

Figure 23: Typical Velocity profile for profile 5 at 2m

Figure 24 gives a 2D shear wave velocity model, the generated model showed an increase of velocity with depth down to a depth of 30m. The model shows distinction of the subsurface from one place to another which consist of clay, sand and gravel. The model points out velocity ranging from 332m/s to 752m/s.

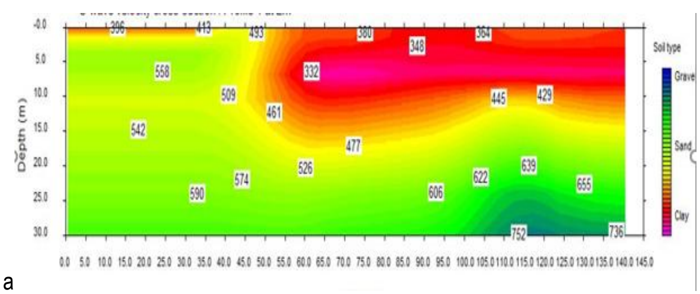

Figure 24: 2D model for profile 5 at 2m

Interpretation of profile 1 at 3m
Figure 25 gives a typical velocity profile of the sub-surface soils of the study area with an average shear velocity of 346.5m/s and depth ranges from 1.5m to 24m and is also interpreted based on the Vs30 as site class D (Stiff soil).

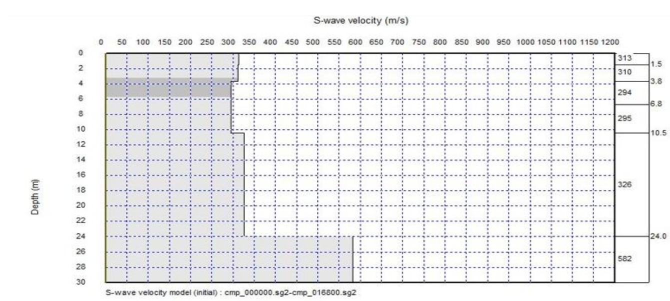

Figure 25: Typical Velocity profile for profile 1 at 3m

Figure 26 establishes a 2D shear wave velocity model, the generated model displays a general increase of velocity with depth down to a depth of 37m. This model shows deviation of the subsurface from one point to another which consist of clay, sand and gravel. The model shows velocity range from 303m/s to 582m/s.

https://dx.doi.org/10.4314/swj.v20i4.13

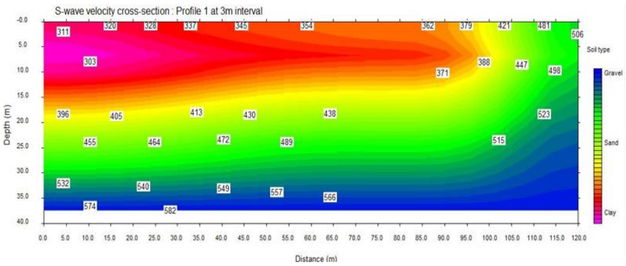

Figure 26: 2D model for profile 1 at 3m

Interpretation of profile 2 at 3m

Figure 27 demonstrates a typical velocity profile of the near-surface soils of the study area with an average shear velocity of 363.50m/s and depth ranges from 1.5m to 24m which is interpreted based on the Vs30 as class D (Stiff soil).

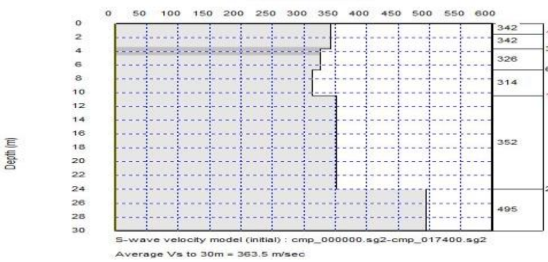

Figure 27: Typical Velocity profile for profile 2 at 3m

Figure 28 presents a 2D shear wave velocity model generated revealed a general increase of velocity with depth down to a depth of 37m. This model shows variation of the subsurface from one place to another which consist of clay, sand and gravel. The model shows velocity ranging from 330m/s to 495m/s.

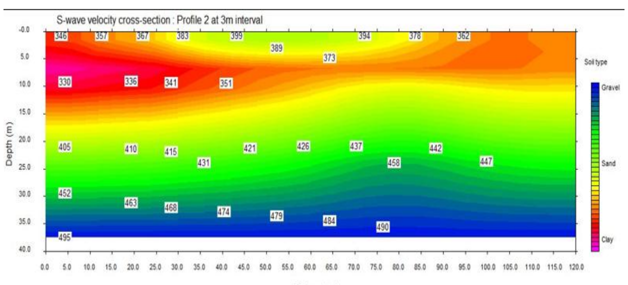

Figure 28 2D model for profile 2 at 3m

Interpretation of profile 3 at 3m

Figure 29 shows a typical velocity profile of the sub-surface soils of the study area with an average shear velocity of 336.60m/s and depth ranges from 1.5m to 24m which is categorized based on the Vs30 as site class D (Stiff soil).

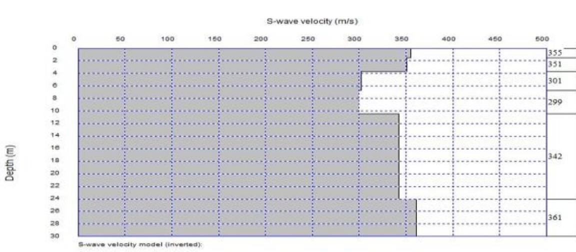

Figure 29: Typical Velocity profile for profile 3 at 3m

Figure 30 demonstrates a 2D shear wave velocity model, the model generated gives a general increase of velocity with depth down to a depth of 37m. This model shows disparity of the subsurface from one point to another which consist of clay, sand and gravel. The model has velocity ranging from 317m to 495m/s.

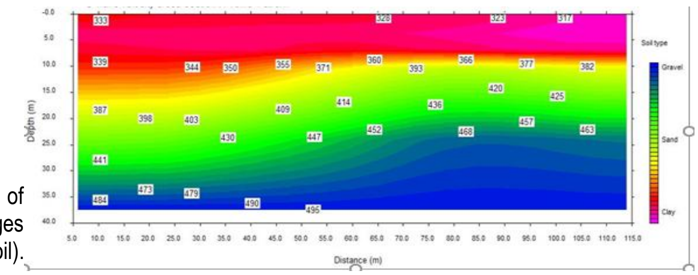

Figure 30: 2D model for profile 3 at 3m

Interpretation of profile 4 at 3m

Figure 31 shows the typical velocity profile of the near-surface soils of the study area with an average shear velocity of 180.11m/s and depth ranges from 1.5m to 24m and is classified based on the Vs30 as site class D (Stiff soil).

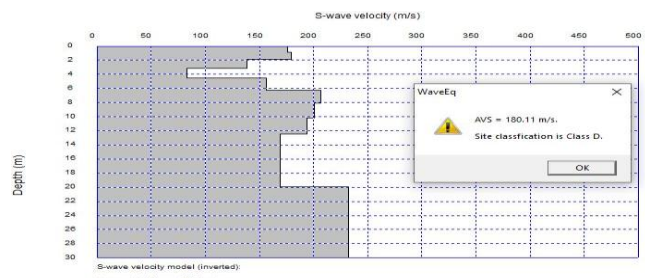

Figure 31: Typical Velocity profile for profile 4 at 3m

Figure 32 reveals the 2D shear wave velocity model generated revealed a general increase of velocity with depth down to a depth of 37m. This model shows difference of the subsurface from one portion to another which consist of clay, sand and gravel. The model gives velocity ranging from 317m/s to 495m/s.

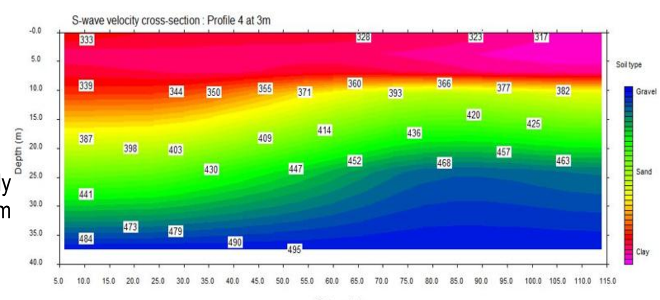

Figure 32: 2D model for profile 4 at 3m

Interpretation of profile 5 at 3m

Figure 33 illustrates a typical velocity profile of the near-surface soils of the study area with an average shear velocity of 342.5m/s and depth ranges from 1.5m to 24m as such is classified based on the Vs30 as site class D (Stiff soil).

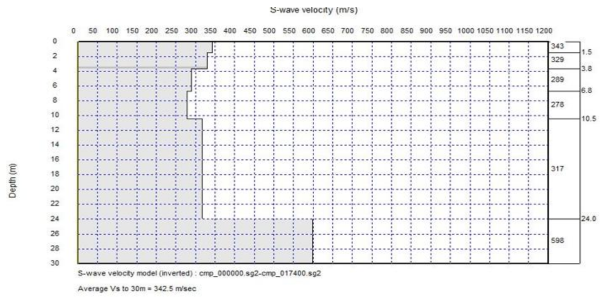

Figure 33 Typical Velocity profile for profile 5 at 3m

Figure 34 establishes the 2D shear wave velocity model, the generated model revealed a general increase of velocity with depth down to a depth of 37m. This model shows dissimilarity of the subsurface from one place to another which consist of clay, sand and gravel. The model has velocity ranging from 338m/s to 610m/s.

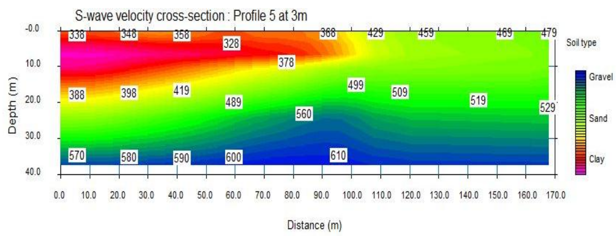

Figure 34: 2D model for profile 5 at 3m

Conclusion

From the results of the MASW conducted, it is concluded that 3m geophone spacing is the most effective configuration that can be used for geotechnical surveys, as the spacing gives the same interpretation of soil type D. Out of the three geophone spacing field data acquired, 3m gives 100% uniform results and therefore recommended for any geotechnical investigation especially at the urban settlement where there is space constrain.

REFERENCES

Abdallatif. T.F, A. A. Khozym & A.A. Ghandour (2022). Determination of Seismic Site Class and Potential Geologic Hazards using Multi-Channel Analysis of Surface Waves (MASW) at the Industrial City of Abu Dhabi, UAE. NRIAG Journal of Astronomy and Geophysics, ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjag20.

Al-Shuhail, A. A., Al-Dossary, S. A., & Mousa, W. A. (2017). *Seismic data interpretation using digital image processing*. John Wiley & Sons.

Ebekozien, A., Aigbavboa, C., & Samsurijan, M. S. (2023). Social sustainability under threat: a case of two collapsed buildings in Lagos, Nigeria. *Property Management*, *41*(3), 431-453.

Google Earth. (2024). Location *map of Igabi, Kaduna State Nigeria* https://earth.google.com/.

Joseph Taye Adegbite , Lukumon Adeoti, Olawole Johnson Allo ,Osazee Omofonmwan and Kelechi Anthony Aharaumunna (2022). Building Distress Evaluation Using Seismic Refraction and Multichannel Analysis of Surface Waves: A Case Study of Millennium Estate Araromi, Gbagada, Lagos, South-Western, Nigeria. FUPRE JOURNAL 6(3): 26-36 (2022), ISSN: 2578-1129.

Mittal, V., Samanta, M., Dash, R. K., Falae, P. O., & Kanungo, D. P. (2023). Subsurface explorations and investigation of foundation performance for distress assessment of a building. *Journal of Performance of Constructed Facilities*, *37*(2), 04023011.

Nigerian Geological Survey Agency (2019). *Geological report on sheet 102, Zaria, Kaduna State, North-western Nigeria.*

Offodile, M. E. (1992). "Ground Water Resources of Nigeria". Medico Limited, Jos, Nigeria.

Oloyede, S.A., Omoogun, C.B., Akinjare, O.A., (2017). Tackling causes of frequent building collapse in Nigeria. Journal of sustainable Development, 3(3), p.127.

Sies imager/SW manual Version 3.0 October, (2009).