Journal of Basic Physical Research ISSN: 2141-8403 Prints, 2141-8411 Online
Vol.14, Issue 1, March, 2025, pp. 1 - 8. Available online at https://journals.unizik.edu.ng/jbpr/

APPLICATION OF SEISMIC REFRACTION TOMOGRAPHY TO PROFFER SOLUTION TO BUILDING COLLAPSE IN AMAWBIA AND ITS ENVIRONS, SOUTH EAST, NIGERIA.

[1]Obiajulu, O. O. [2]Olisa, N. C, [3]Obiabunmo, O. C and [4]Nwaka, E. G
[1,2,3]Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Nigeria

Abstract
Geophysical method of seismic refraction tomography to evaluate the allowable bearing pressure of Amawbia and its environs, South East, Nigeria with the aim to proffer solution to building collapse was used in this study. A 24- channel seismograph with its accessories were used to acquire data. A total of four profiles were conducted within the area. The interpretation of data was done in order to determine the velocities of the various layers using a software called Reflex w. The interpretation of data revealed that in all the areas investigated, three seismic velocities layers were delineated. The first layer has velocity that ranged between 536 m/sand 854 m/s, the second layer has P-wave velocity ranged between 699 m/s and 1398 m/s while the P-wave velocity of the last layer ranged between 944 m/s and 2214 m/s. The velocities obtained from the interpretation of the data were used to determine the allowable bearing pressure. The allowable bearing pressure of the first layer ranged between 136 N/m^2 and 156 N/m^2, the second layer ranged between 190 N/m^2 and 286 N/m^2 while the allowable bearing pressure of the last layer ranged between 275 N/m^2 and 442 N/m^2 respectively. Finally, the results revealed that high rise buildings in this area is recommended to be founded in the second layer.

Keywords: *Building collapse, P-wave velocity, Reflex w, Allowable bearing pressure and Seismograph*

Introduction

The study area, Amawbia which is in Awka capital territory, South East, Nigeria has witnessed rapid developments especially in infrastructures (housing, road constructions but one of the challenges facing the area like any other areas in developing nations is building collapse which has resulted in loss of lives and properties as well as the displacement of people from their homes. In fact, within the last five years, over ten buildings have collapsed within and around the area. Just recently a building collapsed within the area (fig1). It has therefore been the concern of researchers; (Obiajulu, 2021; Adewoyin *et al, 2017;* Agha *et al*, 2006) to search for the causes in order to proffer solution to the problem. Maunde and Bassey, (2017) used the method to investigate the fracture zones and bedrock configuration for geohydrologic and geotechnical studies in parts of Nigeria's Capital City, Abuja. ASMTL (2018) used cone penetrating test method to investigate the subsurface area of Awka in order to determine the allowable bearing capacity of the area, their results showed that the allowable bearing capacity of the area was 160 N/m^2. The alarming rate of building collapse in Amawbia and its environs and other places has therefore necessitated the knowledge about the structure of the subsurface. This subsurface encompass soil, groundwater, unconsolidated sediment. It can also contain products of our own invention such as buried waste. Understanding of what lies beneath the ground before any structure is sited will go a long way in reducing building collapse. In order to do that, adequate approach of investigation should be employed in order to study the subsurface considering the high number of casualties if the result obtained does not properly represent the condition of the subsurface therefore it becomes imperative to know the allowable bearing capacity of an area before any building or structure is sited.

Seismic refraction tomography being one of the surface geophysical methods used in geotechnical studies was used in this study because the method provides an efficient and cost effective means of collecting information about the subsurface of an area (Azwin *et al*, 2013). It can divide the subsurface structure into different layers and gives information on the engineering properties (allowable bearing pressure) of each layers and their depths and thicknesses. The velocity of seismic waves is the most fundamental parameters in seismic refraction methods. It depends on the elastic properties as well as bulk densities of the media and varies with mineral content, lithology, porosity, pore fluid saturation and degree of compaction.

Fig 1: Collapsed building within the study area.

Description of the Study Area

The study area, Amawbia is located in Awka South Local Government Area of Anambra state, South East Nigeria. The area is along the old Enugu - Onitsha express road. The climate of the study area is tropical with an average daily temperature of 27^{o}C. (NIMET, 2012). Two climatic seasons exists, the wet season which is experienced from the months of April to October and the dry season which is felt from November to March. During the dry season, the influence of the Sahara air mass affects 75% of the country. The air is dry and dusty. The rainy season is characterized by heavy flooding, groundwater infiltration and percolation. The study area lies within the Anambra basin in the lower Benue trough tectonic unit. The geology and regional stratigrapy of the trough has been studied and described in details by many researchers including (Ehirim and Ebeniro, 2010; Ezeigwe, 2015; Obiajulu and Nwaka, 2022). The study area are mainly underlain by the Imo Shale Formation. This consists of thick clayey shale, fine-textured, dark-grey to bluish-grey with occasional admixture of clay ironstone and thin sandstone bands. The Formation becomes sandier towards the top where it may consist of alternating bands of sandstone and shale (Ehirim and Ebeniro,2010).

Materials and Method

Theory of Seismic Waves

The basic principle of all seismic methods is the controlled generation of elastic waves by a seismic source in order to obtain an image of the subsurface. Seismic waves are elastic waves that propagate in solids and fluids. The velocity of seismic waves is the most fundamental parameters in seismic methods. It depends on the elastic properties as well as bulk densities of the media and varies with mineral content, lithology, porosity, pore fluid saturation and degree of compaction. P-waves have principally a higher velocity than S-waves. This wave travels fastest and is the first to arrive at the geophones, making its determination relatively easy.

During their propagation within the subsurface, seismic waves are refracted when elastic contrast occurs at boundaries between layers and rock masses of different rock properties (seismic velocities and/ or bulk densities) or at man-made obstacles. The recording of seismic waves returning from the subsurface to the surface allows drawing conclusions on structures and lithological composition of the substance.

Materials

Seismic refraction tomography makes use of the same instruments used in conventional seismic refraction method except that it requires more shots and geophones. The instrument consists of the followings:

i) Energy source (Sledge hammer and striker plate) used for generating and transmitting seismic waves into the subsurface
ii) Geophones (receivers) converts ground motion into electrical signal. They are also used to detect arrival times.
iii) Geophone cables used to transmit electrical impulses from geophones to seismograph
iv) A-24 channel ES 3000 Seismograph (Fig 2) used for recording the information detected by geophones.
v) 12V battery used for powering the seismograph
vi) Trigger extension used to lengthen the cable that is built into the hammer switch. This allows the distance in between the sledge hammer and the seismograph to be increased.

Other instruments include hammers, measuring tapes and GPS.

Fig 2: ES- 3000 Seismograph

Seismic refraction tomography method is based on the travel time measurements of the first arrivals. The velocity contrast is one of the main parameters controlling the resolution of the method. In this research work, a 24- channel (ES 3000) seismograph was used for the survey. A total of four profiles were taken within the study area. A sledge hammer was used to strike a plate which create and emit waves.

These waves travel at material-specific velocities and are refracted at various interfaces and eventually are received by surface geophones that convert them into an electrical signal that is displayed on a seismograph. Fig 3a is a typical example of data collected from the area.

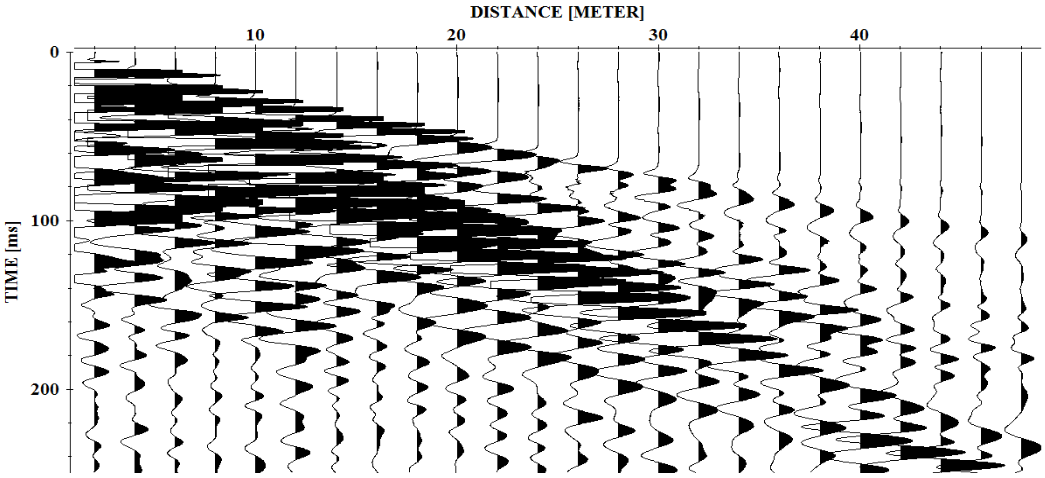

Fig 3 Raw data for forward shooting

Allowable Bearing Pressure

Buildings are supposed to be designed in order to support and withstand loads without any deformity. The loads are the weights of people and objects including rain and other things. With high rise buildings, foundations that support the buildings should be of major consideration as high rise buildings are subject to collapse. Building collapse usually occurs when the structural frame of the building breaks up when the loads on it are beyond its carrying capacity. Obiajulu (2021) noted that one of the major causes of building collapse is poor foundation that is inability to know the allowable bearing capacity of the area. It is therefore important to know the allowable bearing pressure of soil (maximum average contact pressure between the foundation and the soil which should not produce shear failure.

Tezcan *et al.*, 2009 developed a formula for allowable bearing pressure and is given below

$qa = 0.1\gamma Vs / n$

where γ is the unit weight of the soil in $N/m^3 = \gamma_0 + 0.002V_p$, γ_0 is the reference unit weight values in N/m^3, for soil $\gamma_0 =$ 16, n is factor of safety, for soil n =4.0, V_P is the compressional wave velocity and V_s is the shear wave velocity.

The standard value of allowable bearing pressure for Amawbia and its environs is 160 N/m^2 (Obiajulu, 2021)

Interpretation of Data

The interpretation of seismic refraction tomography data was done in order to determine the velocities of various layers. This was achieved by using a software called Reflex w developed by sandmeier (2002). The data collected from the field was subjected to different stages of processing to enhance the signal-to-noise ratio. Fig 4 is a typical example of interpreted data

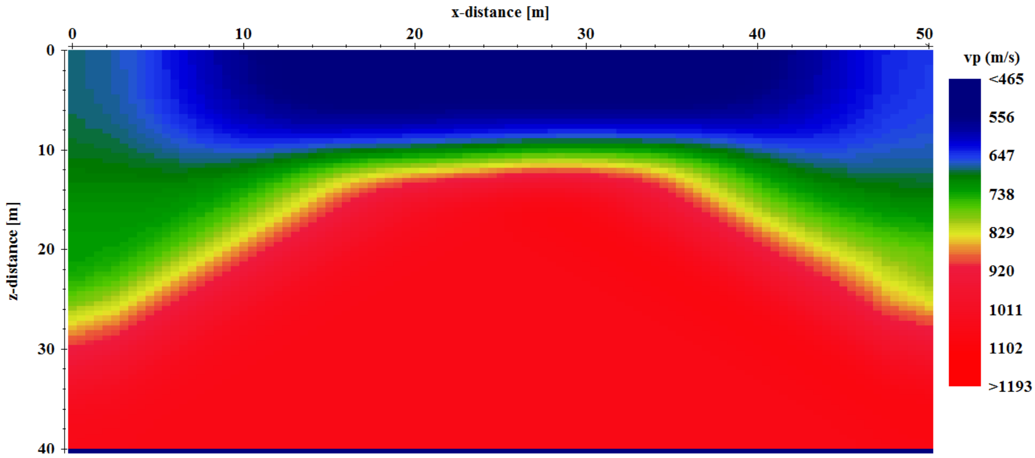

Fig 4 Interpreted seismic refraction tomography data

4. Results and Discussions

Seismic refraction tomography were conducted, the data collected and thereafter interpreted. The results and discussions are presented below.

Profile 1: This profile is located beside Jehova's witness church, Amawbia and there are three seismic layers delineated in this location (Fig 5). The P-wave velocity of the first layer ranged between 465 m/s and 647 m/s, the depth was 5 m and allowable bearing pressure was found to be 136 N/m^2. The second layer has velocity ranged between 647 and 829 m/s, its depth extended from 5 m to 13m with allowable bearing pressure of 190 N/m^2. The last layer whose base could not be reached has velocity greater than 829 m/s and bearing pressure of 276 N/m^2 (Table 1).

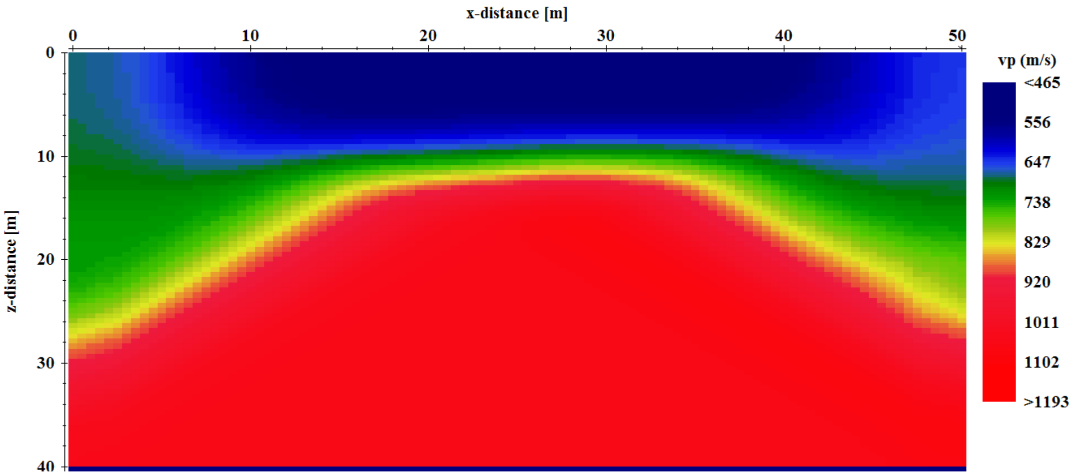

Fig 5 Interpreted SRT data for Profile 1

Profile 2: This profile is situated close to Awka South Local Government Headquarters and three seismic layers were revealed (Fig 6). The P-wave velocity of the first layer was found to be between 454 m/s and 617 m/s and is seated at depth of 7m, the second layer velocity was found to be between 617 m/s and 780 m/s while the third layer has velocity greater than 780 m/s. The allowable bearing pressure of this location were calculated using the P and S waves and was found to be 137 N/m^2,191N/m^2 and 275 N/m^2 respectively for the first, second and third layers respectively (Table 1).

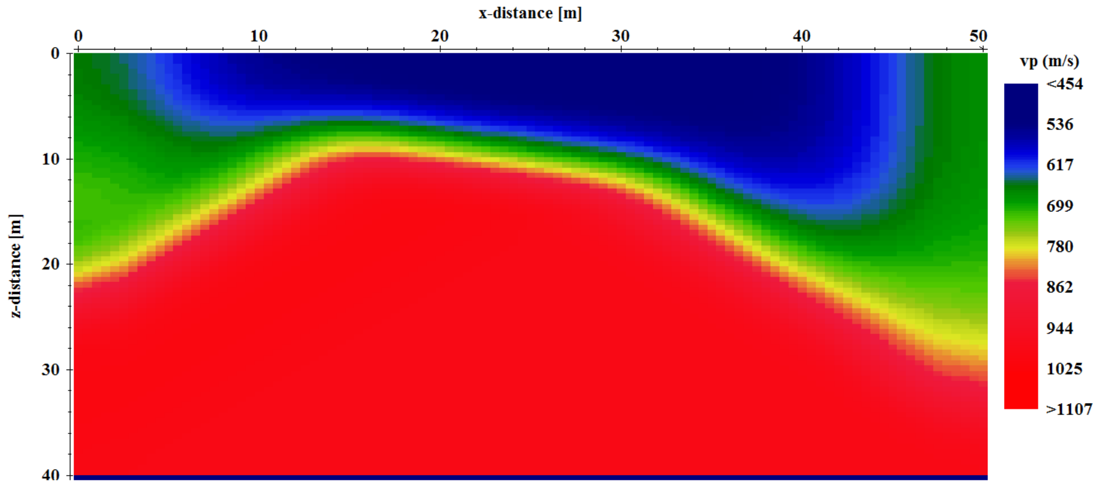

Fig 6 Interpreted SRT data for Profile 2

Profile 3: Seismic refraction tomography revealed three layers in this location (Fig 7) with the first layer having P- wave velocity between 582 m/s and 1126 m/s and allowable bearing pressure of 156 N/m^2. The second layer with velocity between 1126 m/s and 1670 m/s and allowable bearing pressure of 286 N/m^2 is seated at depth that extended from 3 m to 15 m. The third layer whose depth could not be reached has an allowable bearing pressure of 454 N/m^2 (Table 1) with velocity greater than 1670 m/s.

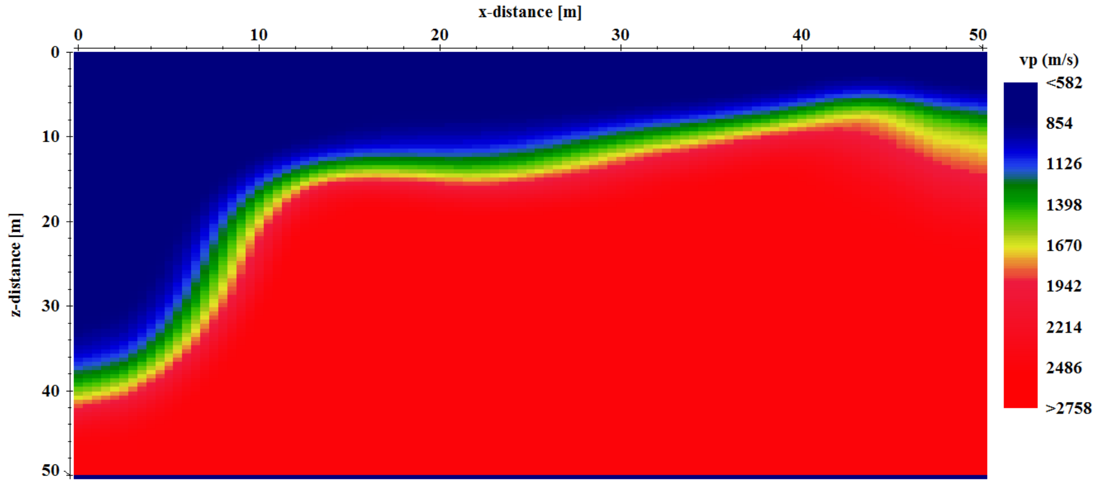

Fig 7 Interpreted SRT data for Profile 3

Profile 4: Three layers were delineated in this location (Fig 8). The P-wave velocity of the first, second and third layers ranged between 623 m/s and 1030 m/s, 1030 m/s and 1436 m/s and greater than 1436 m/s respectively. The P and S waves values that were obtained from the interpretation of seismic data were used to determine the allowable bearing pressure (parameter of interest) of this location. The allowable bearing pressure of this location were 156 N/m^2, 283 N/m^2 and 438 N/m^2 respectively. (Table 1).

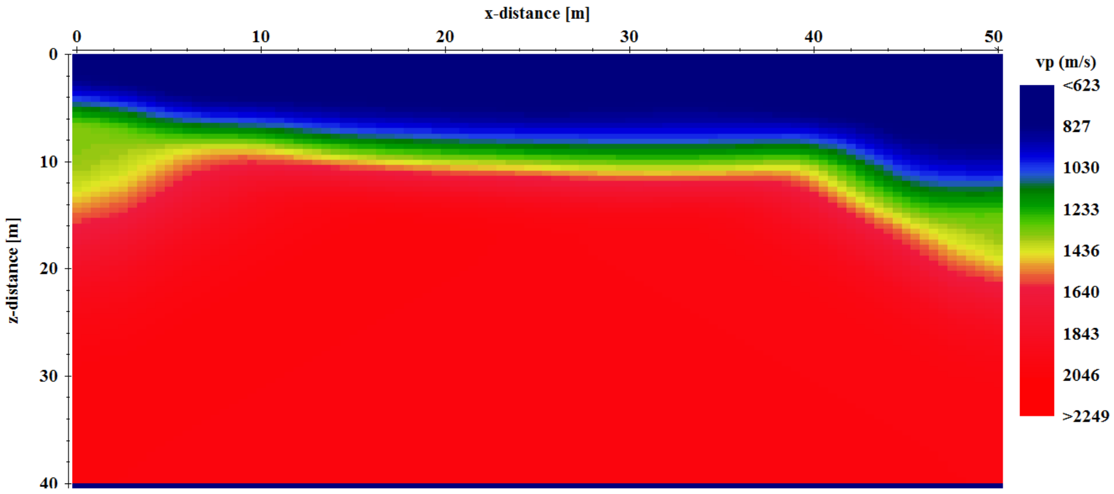

Fig 8 Interpreted SRT data for Profile 4

Table 1: Summary of Results obtained from Seismic Refraction Tomography

Profile	Location	Coordinates	V_p	V_s	$q*10^2$ (N/m^2)
1	Comm. Pri. Sch.	$06^{0}11^{1}427^{11}$N	556	318	1.36
		$07^{1}02^{1}729^{11}$E	738	436	1.90
			1011	612	2.76
2	Beside LGA h/q	$06^{0}10^{1}727^{11}$N	536	320	1.37
		$07^{0}03^{1}838^{11}$ E	699	439	1.91
			944	615	2.75
3	Closeto FSTC	$06^{0}11^{1}887^{11}$N	854	353	1.56
		$07^{0}03^{1}844^{11}$E	1398	609	2.86
			2214	865	4.42
4	Umueze Amawbia	$06^{0}13^{1}132^{11}$N	827	354	1.56
		$007^{0}05^{1}064^{11}$E	1233	614	2.83
			1843	871	4.29

Summary and Conclusion

In the past years, the advancement in imaging techniques used in the acquisition of field has greatly improved the quality of acquired data for resolving complex subsurface features.

In this study, seismic refraction tomography was used in Amawbia, South East, Nigeria to determine the allowable bearing pressure in order to find solution to building collapse in the area. The seismograph was used to collect data. The data obtained were interpreted with a software known as Reflex w. The interpreted data showed that in all the areas under study, three seismic layers were delineated. The first layer has velocity ranged between 536 m/sand 854m/s, the second layer has P-wave velocity ranged between 699 m/s and 1398m/s while the P-wave velocity of the last layer ranged between 944 m/s and 2214m/s.

The velocities obtained from the interpretation of the data helped us to calculate the allowable bearing pressure. The allowable bearing pressure of the first layer ranged between 136 N/m^2 and 156N/m^2, the second layer ranged between 190 N/m^2 and 286N/m^2 while the allowable bearing pressure of the last layer ranged between 275 N/m^2 and 442N/m^2 respectively.

The results obtained have shown a very close semblance with those obtained from Anambra State Materials and Testing Laboratory, Ministry of Works, Awka that used cone penetrating test method.

Using the standard value of allowable bearing capacity for Amawbia which was found to be 160N/m^2 as obtained from Obiajulu, (2021), it can be seen from the results obtained that high rise building will be recommended in the second layer.

Conclusively if government, estate developers and individuals who are involved in building should take the findings into consideration, cases of building collapse in this area will be minimized.

References

Adewoyin, O. O., Joshua, E., Akinyemi, M.L.,Omeje, M. and Joel, E. S. (2017). Investigation to determine the vulnerability of reclaimed land to building collapse using near surface geophysical method. *Journal of physics Conf. Series 852.*

Agha, S. O., Okwueze, E. and Akpan, A.E. (2006). Assessment of the Strength of foundation materials in some parts of Afikpo, Nigeria using seismic refraction. *Nigerian Journal of Physics 18 (1).*

ASMTL, (2018). Anambra State Materials and Testing Laboratory, Ministry of Works, Awka

Azwin, I. N., Rosli Saad and M. Nordiana (2013). Applying the Seismic refraction tomography for site characterization. *APCBEE procedia(5) 227-231.*

Ehirim, C. N. and Ebeniro, J. O. (2010). Evaluation of aquifer characteristics and groundwater potentials in Enugwu-Agidi, Awka, Nigeria Using vertical electrical sounding. *Asian journal of earth Sciences 3(2) 73-81.*

NIMET. (2012). Nigerian Meterological Agency, *Nigeria Climatic data, Abuja, Nigeria.*

Maunde, A. and Bassey, N. E (2017). Seismic refraction investigation of fracture zones and bedrock configuration for geohydrologic and geotechnical studies in part of Nigeria's capital city, Abuja. *Journal of earth sciences and geotechnical engineering 7(2) 91 – 102.*

Obiajulu, O.O. (2021. Geophysical evaluation of hydrogeophysical and engineering properties of crustal materials of Awka, Southeastern, Nigeria. Unpublished Ph.D dissertation. Ebonyi State University, Abakaliki, Nigeria.

Obiajulu, O. O. and Nwaka, E. G. (2022. Aquifer vulnerability assessment in some parts of Awka, South East, Nigeria.

Sandmeier, K. J. (2002). Reflexw 6.0, Manual, Sandmeier software, Zipser Strabe 1, D-76227 Karlsruhe, Germany

Tezcan, S. S., Ozdemir, Z. and Keceli, A. (2009). Seismic technique to determine the allowable bearing pressure for shallow foundations in soils and rocks. *Acta geophysica*57, 400-412.