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1-DIMENSIONAL SHEAR WAVE VELOCITY ANALYSIS OF THE PHASE II SITE, AHMADU BELLO UNIVERSITY, ZARIA USING MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

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ABSTRACT

The Multichannel Analysis of Surface Waves (MASW) is an effective method for near-surface analysis. The method was employed at the Ahmadu Bello University, Zaria (Phase II site) to determine the shear wave velocity of the site. The dispersive characteristics of Rayleigh type of the surface waves was used to infer the shear wave velocity of the site down to 30 m (V_{s30}). The average V_{s30} obtained of the site varies between 236.6 m/s to 294.5 m/s. Therefore, the soil of the site is stiff.

Keywords: Dispersion Spectrum, Fundamental Mode, Rayleigh wave, Fourier Transformation

INTRODUCTION

Geophysical method of investigation such as the Multichannel Analysis of Surface Waves (MASW) involves taking measurements on the earth's surface. These measurements are influenced by variation of physical properties within the earth's subsurface. The obtained measurements are analyzed to reveal how this variation occur (Kearey and Vine, 1996). The MASW method have been used to provide reliable results for near-surface analysis (Park *et al*., 1997; Xia *et al*., 2002). It uses the dispersive characteristics of the Rayleigh wave to infer the shear wave velocity of the site to be investigated, which in turn, is the stiffness of the soil (Park *et al*., 1999; Yilmaz, 2015).

The MASW is a low-cost and non-invasive method (i.e. it neither require heavy machinery nor leave lasting marks on the earth's surface) (Park *et al.*, 1999). It involves generation of Rayleigh-type surface waves for estimating the shear wave velocity (V_s) profile of the site to be investigated as a function of depth. The V_s of soil layers is directly proportional to their shear modulus, which in turn is their stiffness (Yilmaz, 2015). Although, the reliability of the method depends on the accuracy in picking the Rayleigh wave fundamental mode from the dispersion spectrum (Park *et al*., 1999). However, the method has proven to be the most effective tool for site characterization (Yilmaz, 2015; Anand and Parul, 2018; Ashraf *et al*., 2017; Long and Donohue, 2007; Neelima and Rao, 2008).

Structural failure assessment has become imperative to geoscientist and engineers all over the world. Within the Zaria area, structural failures have been attributed to be as a result of poor subsurface conditions, which have sometimes resulted to the collapse of buildings (Egwuonwu and Osazuwa, 2011). In order to ensure a good foundation, the stiffness properties (i.e. shear wave velocity) of the site is an important parameter required by a geotechnical engineer. Therefore, the shear wave velocity of the site is evaluated to a depth of 30 m, a depth of interest to a geotechnical engineer, which is also considered the depth to geotechnical bedrock (Yilmaz, 2015).

Geologic Settings

The study area is predominated by Biotite Gneiss (Figure 1) which is occasionally broken up eastwards by older granites (McCurry, 1970) and extends westward forming a gradational contact with Quartz-Mica Schist. The outcrops of this rock unit are found mainly at the stream valleys, of which they are intensively weathered. They are medium to coarse grained and moderately to weakly foliated rocks. They are mostly composed of quartz, turbid oligoclase and accessory apatite (Truswell and Cope, 1963).

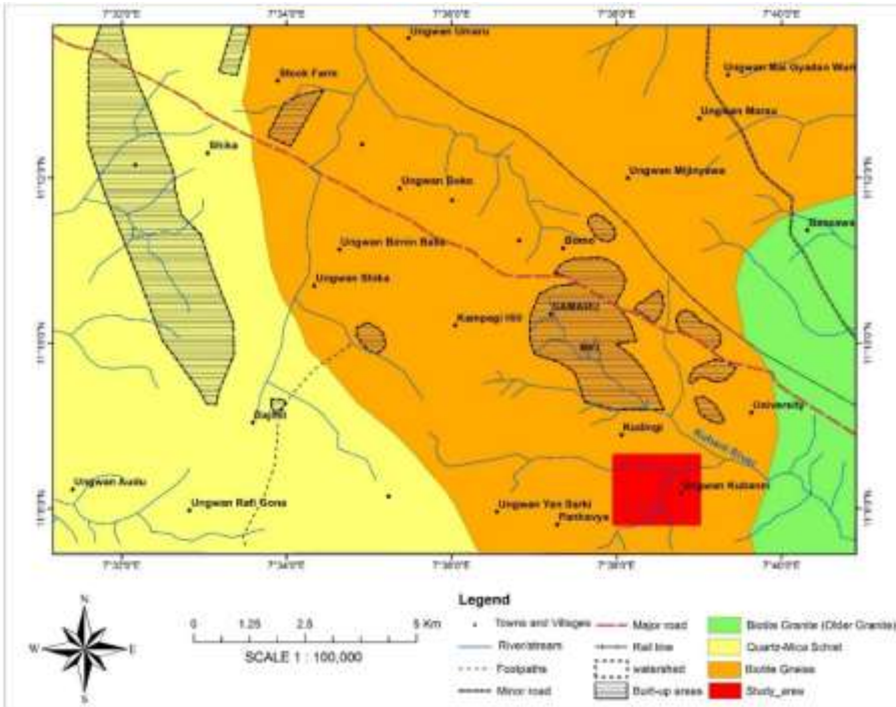

Fig. 2: Geological Map Showing the Study Area (After McCurry, 1970).

The area forms part of the Kubanni river basin (Figure 2). The superficial deposits are the Quarternary deposits and Older Laterites which constitute the sporadically distributed Older and Younger Alluviums (Eigbefo, 1978). The Biotite Gneiss in the site has been weathered to lateritic soil. Some sections of this lateritic soil, measuring up to 3m in thickness, are exposed around the study area.

Data Acquisition

The overall setup for the MASW survey is presented schematically in figure 2. A 24-Channel seismograph was used for data acquisition in various locations of the site (Figure 3). The aim of estimating the shear wave velocity profile of the subsurface layers. In order to probe to a depth of about 30 m, a low frequency geophone of 10 Hz was used, which can investigate up to depth of 30 m (as stipulated by Park *et al*., 2002). The record length depends on the number of samples and sampling interval, the higher the number of samples and the shorter the sampling interval yield good result. Therefore, a length of 1024 ms and sampling interval of 1 ms was employed for the survey.

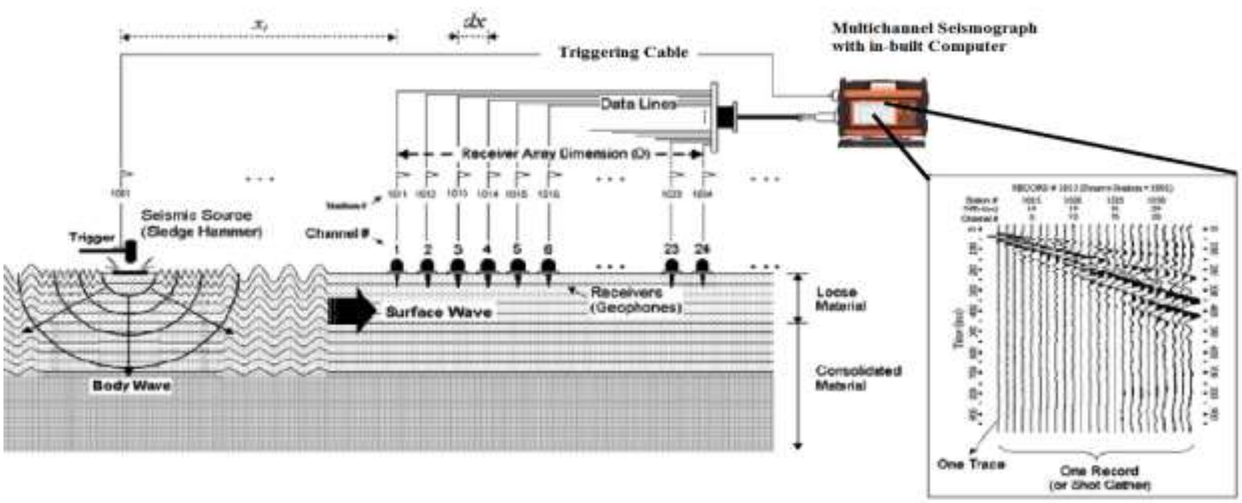

Fig. 2: Schematic illustration for the 1D Multichannel Analysis of Surface Waves (MASW) data acquisition.

The acquisition parameters are of necessity to achieving the desired objectives. This includes, the receiver spacing, the offset distance and the source. The surface waves becomes planar after traveling a certain distance from the source (i.e. the offset distance), which is a function of the wavelength. An offset distance of 10 m allows the plane wave propagation for a wavelength of about 60 m (Park *et al*., 2002) which in turn influences the depth of propagation. The depth of propagation is approximately half the wavelength (Park *et al*., 1999). Receiver spacing of 2 m was adopted. 14lb sledgehammer impacted on a rubber plate was used as the seismic source stacking of 4 was maintained throughout the acquisition to improve the quality of the data. The shot gather obtained was saved in a file

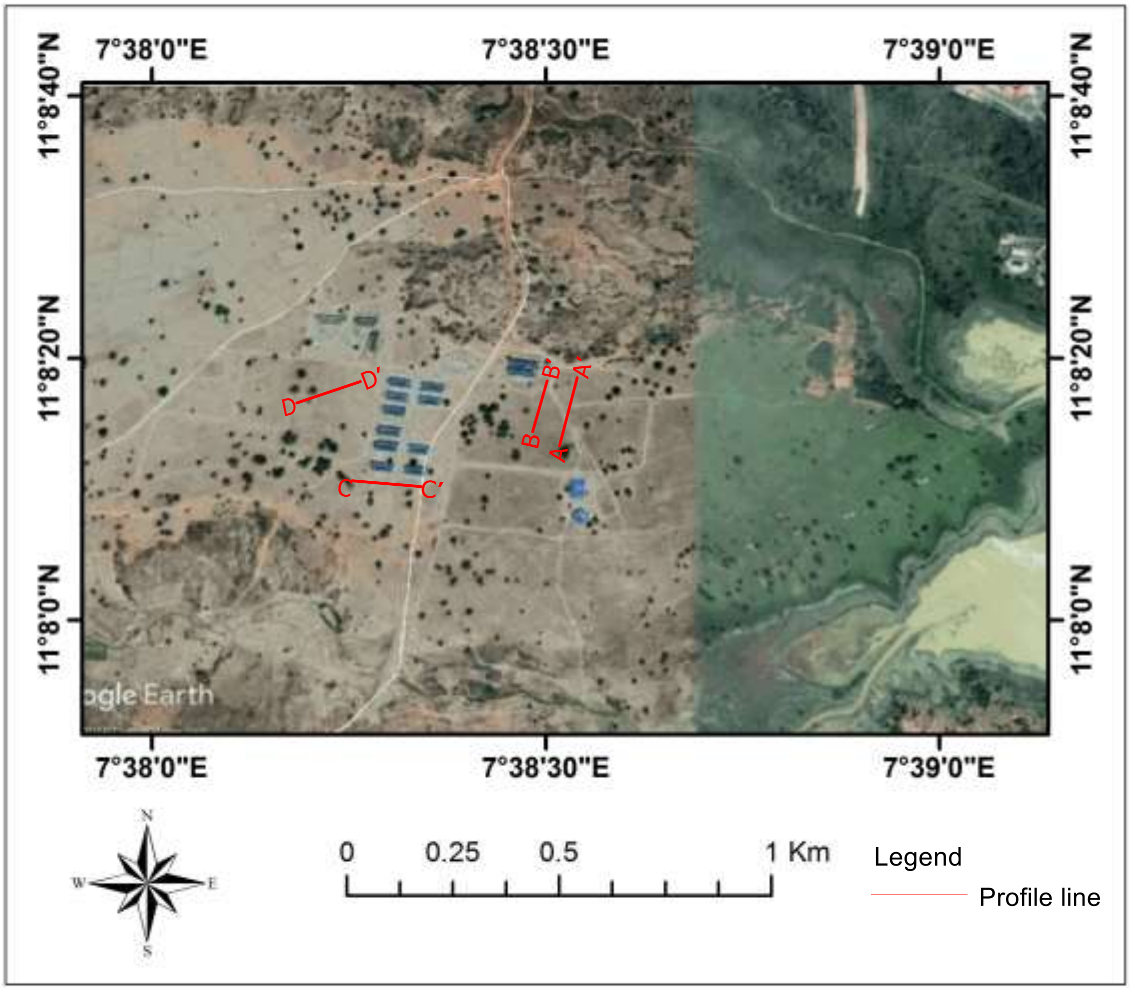

Fig. 3: Google Earth image of the ABU phase II site showing the profiling for the survey

Data processing

The Data was processed using the seisimager/Sw software. The shot gather was inputed into the software and processed into a dispersion spectrum using fourier transformation. The dispersion spectrum is a plot of phase velocity against frequency.

Mathematically,

$$U(x,w) = \int u(x,t)e^{iwt}dt$$

where $U(x,t)$ represents the shot gather in the time domain, $U(x,w)$ represents the shot gather in the frequency domain after applying the transform. According to Xia *et al*. (2000), $U(x,w)$ can be expressed as the multiplication of the amplitude spectrum and the phase:

$$U(x,w) = e^{-i\Phi x}A(x,w)$$
$$\Phi = w/c_w$$

w represents the frequency in radian and c_w represents phase velocity for frequency (w).

The Next procedure is the picking of the fundamental mode from the dispersion spectrum. The fundamental mode of the Rayleigh wave is of interest, as it will be inverted to generate the shear wave velocity of the site. The inversion analysis (Xia *et al*., 1999) was employed in order to generate the 1 D shear wave velocity model.

Result and Interpretation

The shot gather analysis (Figures 4,5,6 and 7) shows how the Rayleigh wave decay rapidly as the depth increases. The fundamental mode picked represent the dispersion curve selected for inversion. This represents the lowest frequency and the areas of higher amplitudes. The average shear wave velocity down to 30 m in the profile A-A[1], B-B[1], C-C[1] and D-D[1] is 290.5 m/sec, 294.5 m/sec, 287.8 m/sec and 236.6 m/sec respectively. This implies that the soil is stiff according to the NEHRP seismic site classification.

Table 1: NEHRP seismic site classification based on shear-wave velocity (V_s) ranges (BSSC, 2003)

Site Class	S-velocity (V_s) (m/s)
A (Hard rock)	>1500
B (Rock)	760-1500
C (Very dense soil and soft rock)	360-760
D (Stiff soil)	180-360
E (Soft clay soil)	<180
F (Soils requiring additional response)	< 180, and meeting some additional conditions

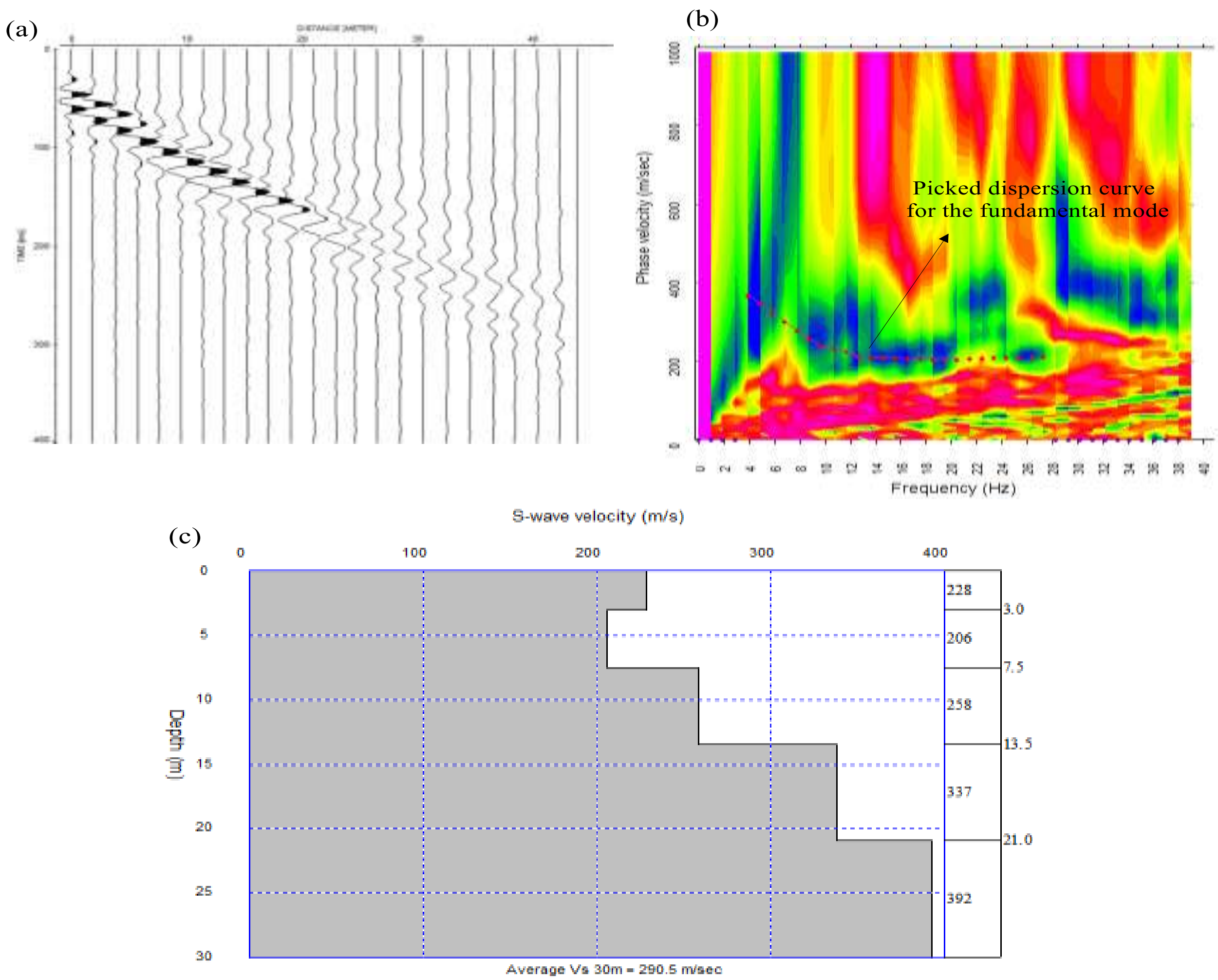

Fig. 4: Profile A-A[1], A shot gather analysis. (a) 24-channel shot gathers recorded using 10-Hz vertical component geophones. (b) Dispersion spectrum (c) 1D S-wave velocity model estimated by inversion of the dispersion curves picked in (b)

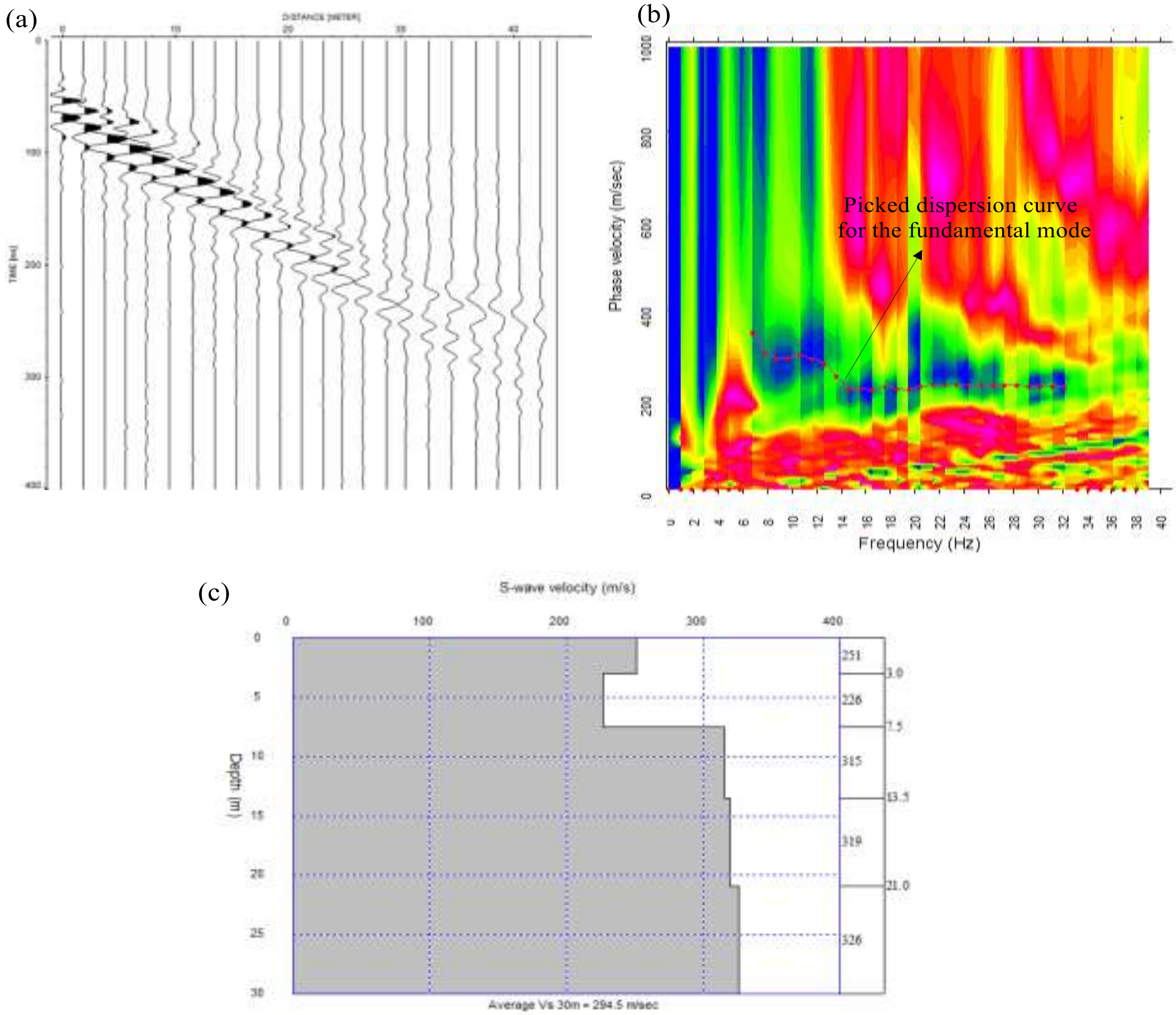

Fig. 5: Profile B-B[1], A shot gather analysis. (a) 24-channel shot gathers recorded using 10-Hz vertical component geophones. (b) Dispersion spectrum. (c) 1D S-wave velocity model estimated by inversion of the dispersion curves picked in (b)

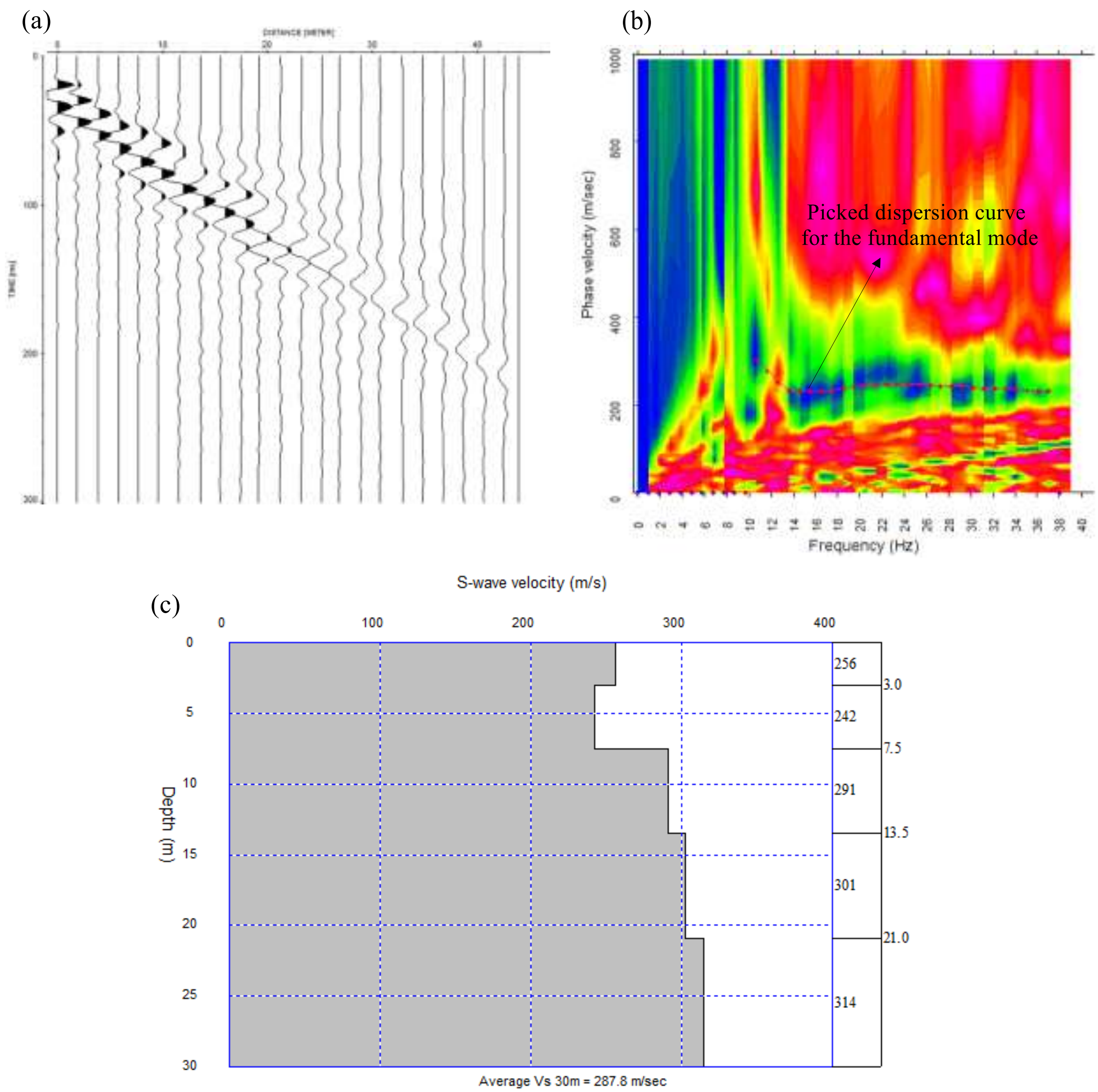

Fig. 6: Profile C-C[1], A shot gather analysis. (a) 24-channel shot gathers recorded using 10-Hz vertical component geophones. (b) Dispersion spectrum (c) 1D S-wave velocity model estimated by inversion of the dispersion curves picked in (b)

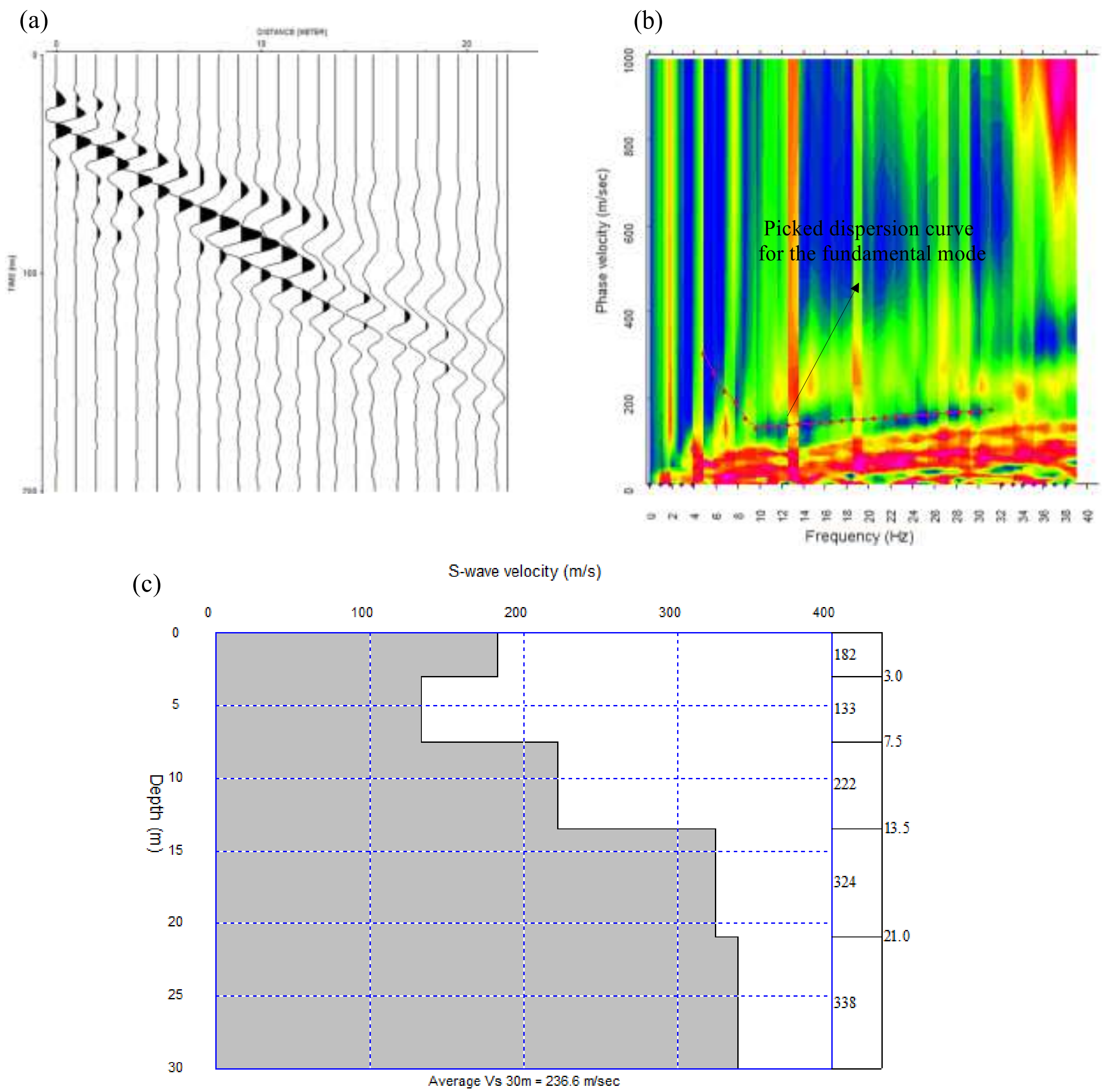

Fig. 7: Profile D-D[1], A shot gather analysis. (a) 24-channel shot gathers recorded using 10-Hz vertical component geophones. (b) Dispersion spectrum (c) 1D S-wave velocity model estimated by inversion of the dispersion curves picked in (b)

CONCLUSION

The MASW method is a non-invasive geophysical method. It is an effective tool in analyzing near surface properties. The MASW method reveals the shear wave velocity of the phase II site, Ahmadu Bello University ranges between 236.6 to 294.5 m/s. This implies that the soil of the site is stiff.

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