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Investigation of Dam Safety Making Use of Multichannel Analysis of Surface Wave (MASW) Seismic Method

Collins C. Chiemeke

***Abstract*—**Multichannel Analysis of Surface Wave (MASW) seismic method is widely used in geotechnical engineering for the measurement of shear wave velocity and evaluation of material property. This method was recently conducted at a Dam site located in Zaria, within the basement complex of northern Nigeria. The aim of this experiment was to make use of the MASW method in evaluating the strength of material properties of a section of the Dam embankment, which is vital to ascertain the safety of the Dam. The result revealed that, the material embankment showed general increase of shear wave velocity with depth. The range of shear wave velocities and the determined Poisson's ratio falls within the normal range of consolidated rock material, indicating the Dam embankment is still consolidated. The range of shear modulus determined, also shows that the Dam embankment is rigid enough to withstand the shear stress imposed by the impounded water.

***Keywords*—**Dam, MASW, Multichannel Analysis of Surface Wave, Seismic.

I. INTRODUCTION

THE Multichannel Analysis of Surface Wave (MASW) test is non-invasive, expedient, and cost effective. It can be used to produce a single 1-D VS profile as well as 2-D VS profile that covers a wide range of area [9]. In most surface seismic surveys when a compressional wave source is used, more than two-thirds of total seismic energy generated is imparted into Rayleigh waves [3]. Although, ground roll is considered noise on body-wave surveys (i.e., reflection or refraction profiling), its dispersive properties can be utilized to infer near-surface elastic properties [10]. Construction of a shear (S)-wave velocity (Vs) profile through the analysis of plane-wave, fundamental-mode Rayleigh waves is one of the most common ways to use the dispersive properties of surface waves [6]. This type of analysis provides key parameters commonly used to evaluate near-surface stiffness—a critical property for many geotechnical studies [7]. The inversion analysis in this study considered only the dispersion curves associated with the fundamental mode [2]. The aim of this research work is to make use of MASW method in characterizing the material property of a section of the Dam embankment. The major instruments used for this research include: 24 channels Digital Terraloc Mark6 seismograph, vertical Geophone, Reels of cables with takeout points, sledge Hammer and a base plate.

Collins Chiemeke is with Physics Department Federal University Otuoke, Yenagoa, Bayelsa State, Nigeria (Phone: +2348035780638 e-mail: chiemekecc@fuotuoke.edu.ng).

II. LOCATION OF STUDY AREA

The study area is Ahmadu Bello University Dam located in Zaria, bounded by co-ordinate points 11^o 08.041' N, 007^o 39.451' E and 11^o 07.981' N, 007^o 39.470' E, with an average elevation of 650 m above sea level as shown in fig. 1. Zaria is located in the basement complex of North Central Nigeria.

Fig. 1 Image map of the study area, showing the investigated Dam [4]

III. GEOLOGY OF THE AREA

The older granite outcrops in the vicinity of Zaria are exposures of a syntectonics to late-tectonic granite batholiths which intruded a crystalline gneissic basement during the Pan-African Orogeny. This batholith is a north-south oriented body, about 90 x 22km, extending from Zaria southward to the vicinity of Kaduna. The Zaria granite batholiths belong to a suite of syntectonics and late tectonic granites and granodiorites that marked the intrusive phase of the late Precambrian to early Palaeozoic Pan-African Orogeny in Nigeria [8].

IV. METHODOLOGY (DATA ACQUISITION)

During the data acquisition the receivers (Geophones) were placed in a straight line at an interval of 1m. The energy source that was used for the survey is a sledge hammer, with an offset distance of 10m. The common depth point (CDP) profiling method making use of 24 channel seismograph was employed for the survey. After the firing of each shot, the generated seismogram was recorded. The source and the receivers were moved at a predetermine distance of 1m. The firing of the shot was repeated with a stack of five shots at each shot point. The process was continued repeatedly until the end of the profile line was reached. For this particular survey a hundred shot points were sampled. A record length of 1 s was used for the recording. The acquisition and recording parameters used for the data acquisition is shown in Table I. Part of the raw seismic data recorded during the survey is shown in Fig. 2.

TABLE I
ACQUISITION AND RECORDING PARAMETER

Source	Sledge Hammer
Receiver Type	Planted Vertical Geophone
Receiver Interval	1 m
Source Interval	1 m
Source Offset	10 m
Receiver spread length	23 m
Record Length	1 s
Sample Interval	0.25 ms

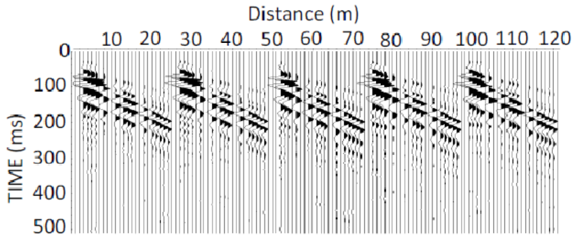

Fig. 2 Raw seismic data recorded during the data acquisition

V. Data Processing

The processing flow started with importing of the raw seismic data recorded in SEG2 format into the geophysical software used for the data processing. Geometry assignment to the seismic data was carried out, so that each trace is given a number of values which were, consequently, saved in the specified header fields of the dataset in the project database. The dispersion image (Fig. 3) which is a plot of phase velocity versus frequency was calculated for the different shot points in the current data sets. The dispersion image was calculated in a range of phase velocities 0 to 500 m/s and in frequency range of 0 to 70 Hz. The fundamental mode was identified in the vicinity of the higher mode and the body waves. The dispersion curve was extracted by clicking on the maximum and the minimum point on the fundamental mode. The dispersion curves were saved for onward processing. The V_s profiles were calculated using an iterative inversion process that involved initial input of poison's ratio and density. At the end of the inversion process, 2D V_s velocity model was generated displayed in station number distance along the surface and depth within the subsurface, as shown in Fig. 4. A 1D shear wave velocity profile was extracted at the 70 station number receiver point, from the 2D V_s model shown in Fig. 4 down to a depth of 12m, at 2m depth interval. The corresponding p wave velocity V_p was also extracted at that point. The extracted V_s and V_p along with an estimated density of 2000 kg/m^3 used during the inversion process were used to compute the Poisson's ratio and shear modulus at various depth as shown in Table II.

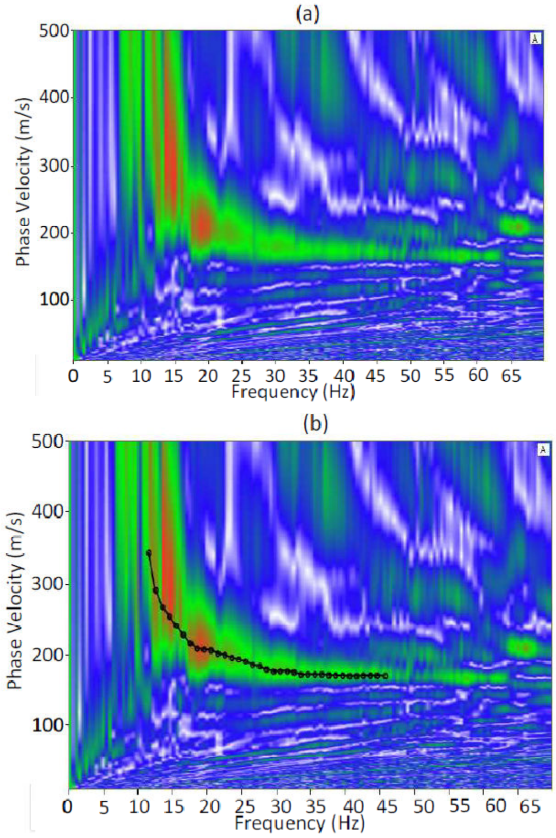

Fig. 3 (a) The generated dispersion image of a shot point (b) Extracted Dispersion curve

VI. Results

The 2D Vs Model with a profile length of 100m and a depth range of 12.5m, generated after 5 iterations is shown in fig. 4. The model depicts the distribution of shear wave velocity within the subsurface. The section showed a general increase of shear wave velocity with depth, without any noticeable region of velocity anisotropy within the section. The shear wave velocity ranges from 200 m/s to 900 m/s. The corresponding extracted 1D p wave velocity at the centre of the profile is shown in Table II. The p wave velocity and the ratio V_p/V_s also showed continuous increase with depth. The calculated Poisson's ratio base on V_s and V_p values extracted from the section also showed a general increase with depth. This confirms evidence of the absence of region of velocity anisotropy, whereby high velocity layer is underlain by low velocity layer that could be detrimental to the Dam. The range of Poisson's ratio determined lies between 0.24 to 0.33, which fall within the normal range of consolidated rock material as reported by [5], is an added evidence that the material embankment of the dam is still very much consolidated. Shear Modulus was also determined to investigate if there are areas of abnormal shear force. The range lies within 0.093 Gpa at the surface to 1.008 Gpa at a depth of 12m. These values are within the normal range of dam embankment, as reported by [1]. This also gives a clear indication that the dam embankment is still very rigid, and can withstand any pressure in the form of shear stress that is imposed on the dam by the impounded water.

TABLE II
EXTRACTED VS AND VP, WITH CALCULATED ELASTIC PARAMETERS

Dept (m)	P wave (m/s)	S wave (m/s)	Ratio of Vp and Vs	Density (kg/m3)	Poisson's ratio	Shear Modulus (Gpa)
2	369	216	1.71	2000	0.24	0.093
4	450	260	1.73	2000	0.25	0.135
6	567	310	1.83	2000	0.29	0.192
8	725	380	1.91	2000	0.31	0.289
10	990	500	1.98	2000	0.33	0.500
12	1420	710	2.00	2000	0.33	1.008

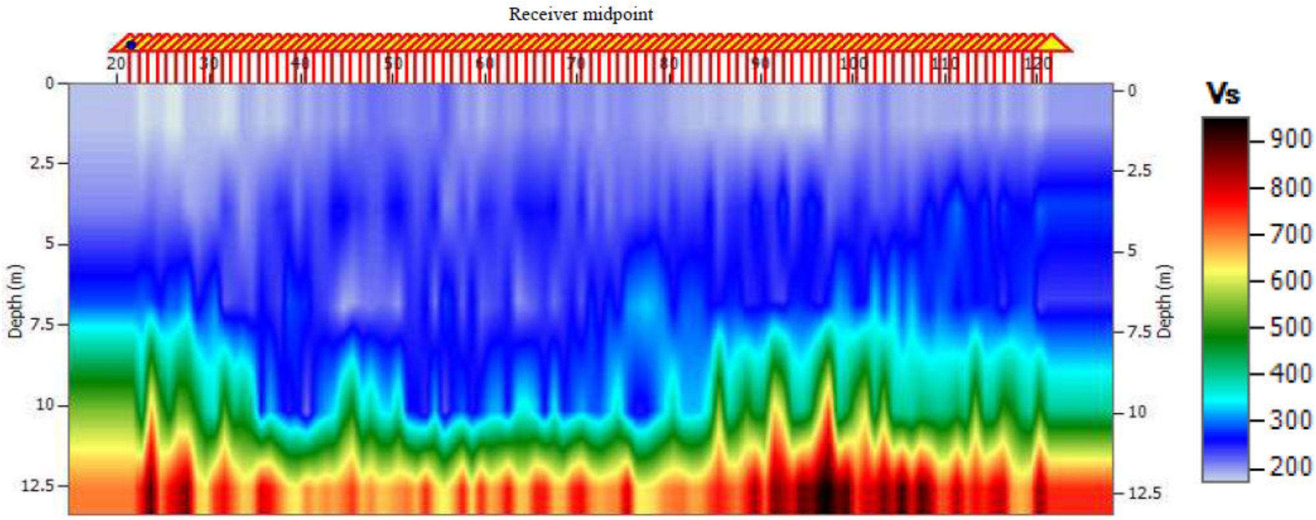

Fig. 4 The 2D Shear wave velocity model, showing the share wave velocity distribution within the subsurface

VII. CONCLUSION

The results of the investigation carried out at Ahmadu Bello University Dam have shown that the material embankment of the Dam is still very much consolidated. There are no regions of weak zones noticed within the investigated area. The elastic properties determined showed that the Dam embankment is in good condition. One can categorically state therefore that Ahmadu Bello University Dam embankment is in stable condition and does not pose any significant threat to the dam and its environ. Therefore Multichannel Analysis of Surface Wave (MASW) seismic method stands as an effective tool in characterizing the strength of material for engineering and geochemical purpose.

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