

3D TREATMENT OF MASW DATA FOR MONITORING GROUND IMPROVEMENT AT AN UNCONTROLLED FILL SITE

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INTRODUCTION

The Multichannel Analysis of Surface Waves, or MASW in short (Park, et al, 1999; Suto, 2007) analyses seismic data in the frequency-velocity domain and estimates the S-wave velocity structure under the seismic receiver array. Its application range varies, commonly from only a few metres to tens of metres, depending on the wavelengths of the surface waves used for analysis.

The output from an MASW survey and analysis is essentially a series of 1-dimensional S-wave velocity profiles, generating spatially discrete data points similar to borehole data. As the data are collected along a line and sampled at closely spaced intervals, it is common to present the data in the form of a 2-dimensional section of S-wave velocities along the survey line, rather than a 1-dimensional profile with depth. If an MASW survey consists of closely spaced survey lines, it is possible to present the output of the surveyed area as a 3-dimensional data set.



Figure 2. The landstreamer

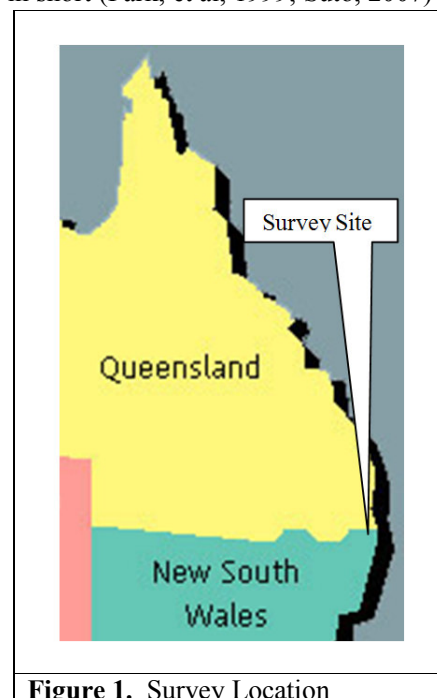


Figure 1. Survey Location

This paper presents an example of an

application of the MASW survey method at a landfill site, with data presented in plan view with a number of depth slices.

SCOPE AND SURVEY SPECIFICATION

An MASW survey was carried out at an industrial development site in northern New South Wales, (Figure 1). The 1.5 hectare site typically consisted of 1.5 to 2 metres of uncontrolled fill including building rubble, old trees and large quantities of other organic matter. The land had been left undeveloped for many years due to geotechnical challenges posed by the fill material, but was now considered worthy of development.

The purpose of the MASW survey was to monitor the compaction and uniformity of the fill material after ground surface compaction using a 4-sided impact roller. An additional aim of the survey was to map the spatial distribution of areas of insufficient compaction by calibrating the survey with geotechnical testing to determine where further ground improvement or excavation and replacement was required. Reliance solely on geotechnical testing was considered too risky given the variable nature of the fill material.

The MASW survey used a purpose-built 24-channel land streamer with 4.5Hz geophones spaced at 1-metre geophone intervals (Figure 2). The source used was a 50kg weight (Figure 3) falling from a height of approximately 1 metre. Two shots were recorded from a source point into two consecutive arrays, and data were merged to form a 48-metre (48-channel) record. This procedure was repeated along each of the survey lines, which were spaced approximately 15 metres apart (Figure 4).



Figure 3. The weight dropping system

Data were recorded by Seistronix RAS-24® 24-bit seismograph, with a sampling interval of 0.5 milliseconds and a recording length of 2 seconds.

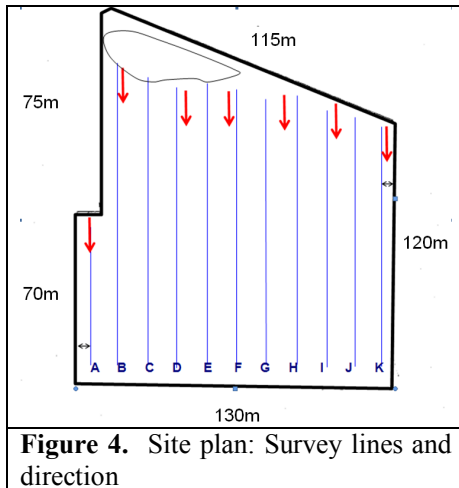


Figure 4. Site plan: Survey lines and direction

The data were analysed using the SurfSeis® software by Kansas Geological Survey. By using the sub-array method (Suto and Wake-Dyster, 2006), 1-dimensional S-wave velocities were analysed every 12 metres along the survey lines.

The geotechnical testing at the site included field density tests, Dynamic Cone Penetration (DCP) testing and the excavation and logging of trial pits.

OVERVIEW OF THE METHOD AND DATA

The quality of the seismic data collected was generally good. Figure 5 shows a typical seismic record in the distance-time domain (left) and its expression in the frequency-velocity domain (right) through the overtone analysis by SurfSeis®. Note the dominant dispersion trend of the fundamental mode Rayleigh wave clearly visible over 10Hz.

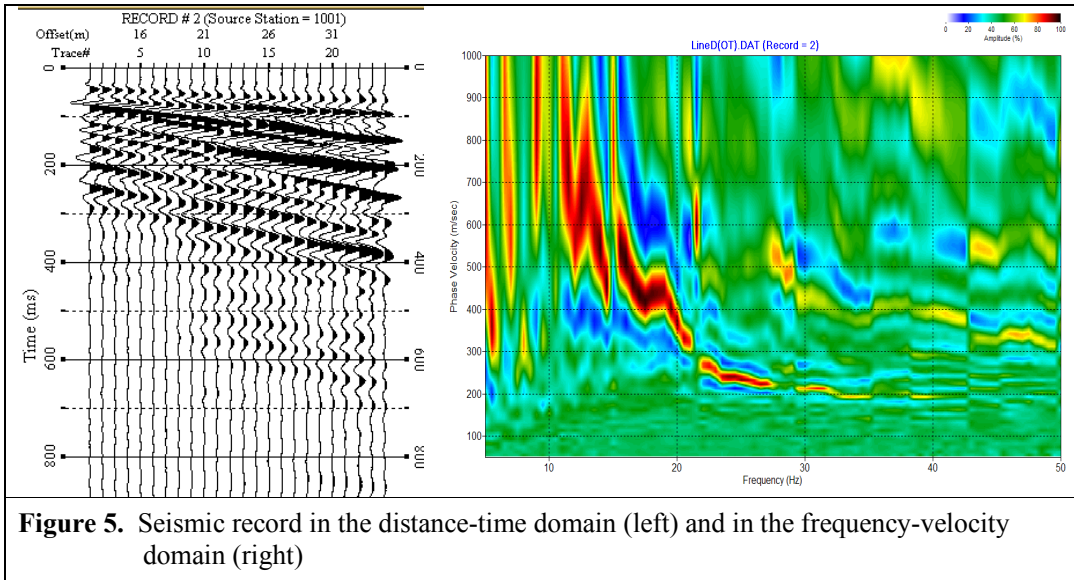


Figure 5. Seismic record in the distance-time domain (left) and in the frequency-velocity domain (right)

1-DIMENSIONAL S-WAVE VELOCITY PROFILE

Figure 6 shows a typical 1-dimensional S-wave profile from the MASW survey. The MASW inversion is limited to the number of layers used. The maximum number of layers currently available is twenty. The thickness of the deepest layer is assumed to be infinity (half-space), and its depth is specified as input. The iterative inversion matches the dispersion curve with the theoretical modes.

2-DIMENSIONAL S-WAVE VELOCITY SECTION

A series of the 1-dimensional profiles along a survey line were arranged and S-wave velocities are expressed in colour, with interpolation used between analysis points. Figure 7 illustrates an S-wave velocity section along one of the survey lines. The triangles at the bottom of the section indicate points where 1-dimensional inversions were performed. A velocity reversal is observed at around 2 metres below the ground level,

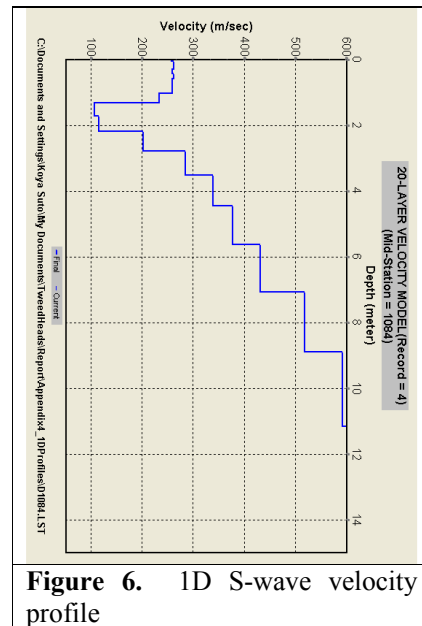


Figure 6. 1D S-wave velocity profile

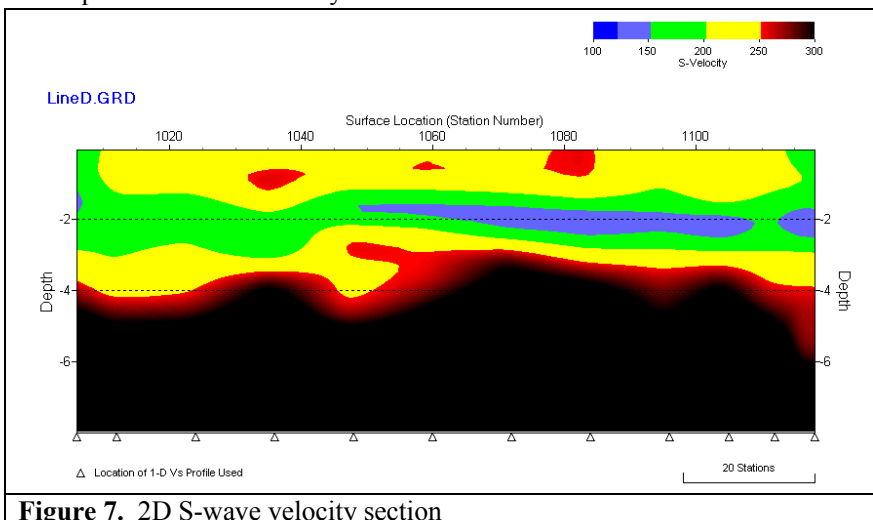
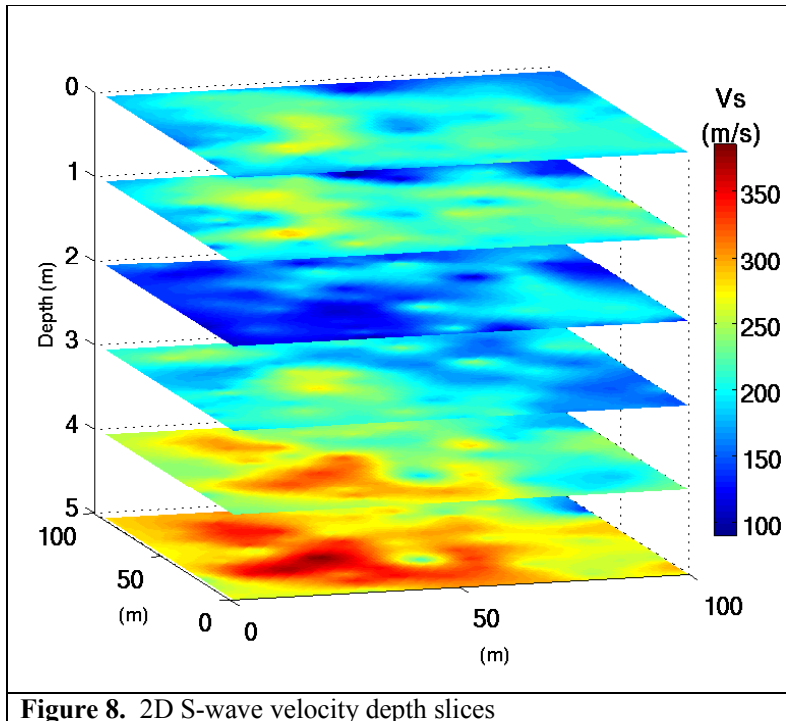


Figure 7. 2D S-wave velocity section

suggesting that the insitu compaction was effective to this depth.

DEPTH SLICES

Incorporating the surface coordinates of each analysis point, all the 1-dimensional S-wave velocity profiles were compiled into one table.



This enabled the S-wave velocities at the analysis points to be interpolated into constant depths. The data were then gridded and displayed in plan view as depth slices.

Figure 8 shows S-wave velocity depth slices from the surface to 5 metres below the ground level. The spatial structure of S-wave velocity is clearly observed in this format.

Figure 8. 2D S-wave velocity depth slices

DISCUSSION

Results from the MASW survey were compared with field density tests, DCP testing and the excavation and logging of trial pits. Good correlation was achieved between the different testing methods, and the MASW survey data when presented in 1-, 2-, or 3-dimensional formats.

In Figure 9, the results of geotechnical (DCP) testing have been superimposed on a depth slice at 1m below ground level (Scott and Suto, 2007). The black dots indicate points where Young's modulus (E) was estimated to be higher than 100MPa, whereas white dots indicate lower values. Good correlation between the estimated Young's modulus and S-wave velocity from MASW was found as indicated by the boundary at around 220m/s (yellow to green). The four points in the

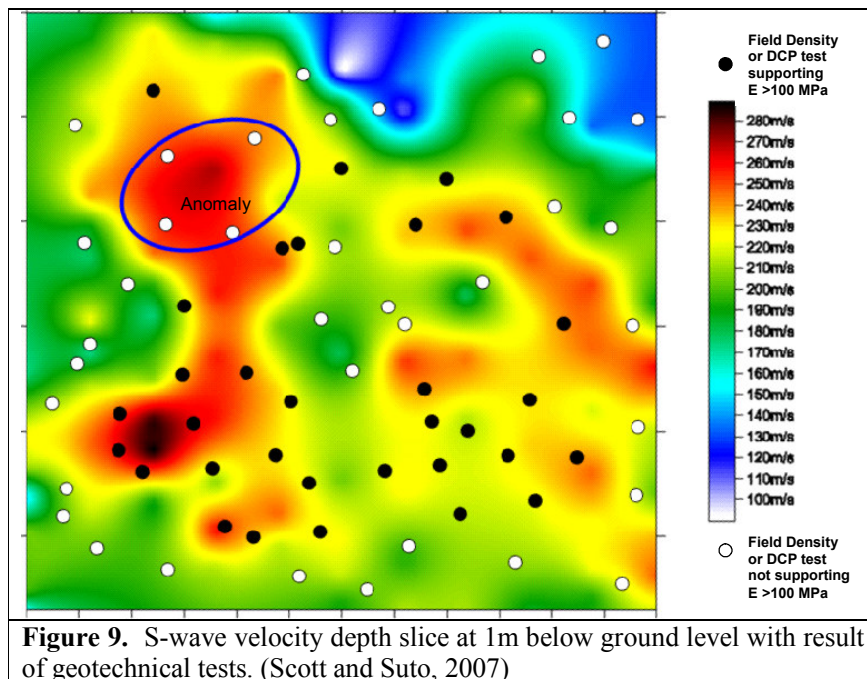


Figure 9. S-wave velocity depth slice at 1m below ground level with result of geotechnical tests. (Scott and Suto, 2007)

Figure 9 shows the results of geotechnical (DCP) testing superimposed on a depth slice at 1m below ground level (Scott and Suto, 2007). The black dots indicate points where Young's modulus (E) was estimated to be higher than 100MPa, whereas white dots indicate lower values. Good correlation between the estimated Young's modulus and S-wave velocity from MASW was found as indicated by the boundary at around 220m/s (yellow to green). The four points in the

blue circle annotated “anomaly” indicated where the MASW result was inconsistent with the geotechnical tests. Later excavation found organic matters such as tree roots in this area at a depth of 0.4 metres.

The MASW survey was used to distinguish between areas of site that were deemed satisfactory and other areas where further ground improvement was needed to facilitate future development at the site. An advantage of the survey results presented in a plan view format is that they can be easily understood, making communication and instruction to excavator or bulldozer operators easy and uncomplicated.

The dense sampling frequency of the MASW survey enabled loose fill layers at depth to be identified and quantified in 3-dimensional space, which lead to timely and cost-effective project outcomes.

This sort of treatment is commonplace in the 3D seismic reflection survey, where data are sampled and presented in a 3-dimensional space. The MASW data can be interpolated into boxils to use with such software, which may improve geotechnical understanding of the distribution of the anomalies. However, such software is very expensive for small-scale operations such as construction sites. A series of depth slices is considered to be an economical and effective compromise for such application.

CONCLUSION

This report presented a 3-dimensional treatment of the MASW data. It is essentially a manipulation of densely distributed 1-dimensional profiles. The survey result presented in plan view could be easily understood improved communication between geotechnical engineer and earthwork operators. The MASW result also helped overall understanding of the site leading to identifying areas of insufficient compaction. These areas were then re-compacted or excavated and replaced.

Development of simple inexpensive software for 3-dimensional interpolation and presentation of the MASW dataset is eagerly sought.

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