# An MASW survey for geotechnical engineering in an urban setting - an application to pre-tunnelling investigation.

**Koya Suto**
*Terra Australis Geophysica Pty Ltd*
*Brisbane, Australia*
*koya@terra-au.com*

## SUMMARY

As a part of the Airport Tunnel project in Brisbane, an MASW survey was carried out to investigate the nature of the fill site of an old rock quarry. The main target of the survey is the depth of the landfill after the quarrying operation to avoid the tunnelling penetrate the fill material. The site is currently used as a shopping centre car park in an inner suburb of Brisbane along one of the main roads. To avoid excessive noise, the survey took place at night.

Some part of the seismic data presented an unusual but consistent noise pattern. External sources of this unusual noise, such as buried electric cables and drainage were considered, but no source could account for it. Therefore the noise was determined to be due to composition of the materials underground.

The analysis of the seismic data outlined the depth and shape of the quarry. The noisy area was identified as a shallow hard rock left in the quarry, perhaps as an access ramp. This was verified a historic photography of the old quarry.

The depth of the quarry was found shallower than the proposed depth of the tunnel to ensure the safety of boring.

**Key words:** MASW, Engineering Application, Landfill, Tunnelling.

## INTRODUCTION

The Multi-Channel Analysis of Surface Waves (Park, *et al.*, 1999; Suto, 2007) is a surface wave seismic method. It is particularly suited to characterisation of the near-surface by S-wave velocity structure. In Australia, its recent application include investigation of depth and nature of landfill (Scott and Suto, 200; Suto and Lacey, 2011; Suto and Cenic, 2012); tailings dam (Suto et al, 2007), search for palaeochannel (Suto, 2012) and determining depth of screw piers (Frederick and Tayler, 2012).

The sites of landfill are typically in the low profile areas in the round, often in the valleys. The material used for landfill may be brought from nearby cutting or domestic and industrial refuge, and not often documented. Even it is documented, the state of the fill after a number of years of fill and compaction is not known until it is surveyed. The MASW applications to these sites are usually for investigation of thickness and strength of the fill material to build structures upon.

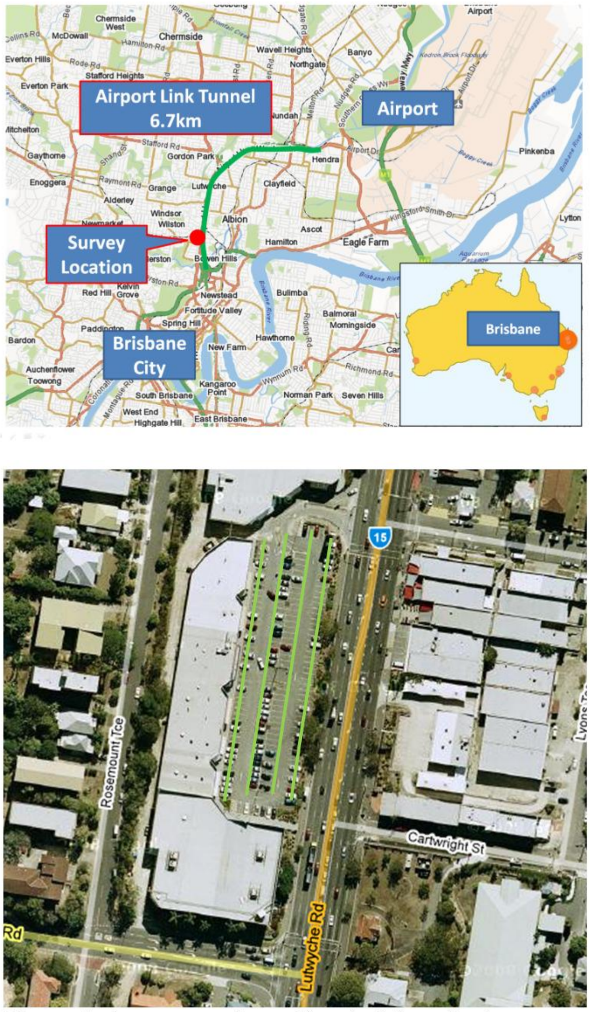


**Figure 1**: **Area maps from Google Maps (top); Site map with approximate location of the seismic survey lines (bottom).**

## SURVEY OUTLINE

Brisbane's Airport Link Tunnel (Figure 1) was planned in 2008 to directly connect Brisbane City and the Airport, and completed in 2012. The 6.7 kilometre tunnel passes under the suburban residential, retail and industrial areas. A part of its passage is a former quarry for rocks. The site was filled and is currently used as a shopping centre and its car park. It is the site of the present study. The bottom of the fill is, therefore, not a natural surface, but the floor of the quarry.

For tunnelling, the depth of this floor is the most of the concern, because if the tunnelling bores this floor through from underneath into the uncontrolled fill material, then there is a severe risk of damaging the structure build on the ground. To ensure the tunnel stays within the competent rock layer, the knowledge of the depth of the floor of the former quarry is essential.

**Table 1. Data Acquisition Parameters**

| | |
|---|---|
| Source: | 50kg weight dropping |
| Recorder: | Seistronix RAS-24 distributed seismic system |
| Channels: | 24 per record x 2 records per array |
| Sampling: | 0.5 ms (2000Hz) |
| Length: | 2 seconds |
| Geophone: | Geospace SD11 4.5 Hz single geophones |
| Receiver | Seismic Landstreamer |
| Offset | 12.5m |
| Geophone interval: | 1m |

## DATA ACQUISITION

Four survey lines are surveyed along the long axis of the car park 120 metres long about 8 metres apart (Figure 1; bottom). The survey took place during the night time, when the retailers' car park is empty, and the noise from the nearby main road traffic is relatively quiet. The lines were surveyed from south to north. The data acquisition parameters are summarised in Table 1.

## DATA QUALITY AND ANALYSIS

Figure 2 shows shot records along one of the survey lines. Particularly noisy traces were noted to the north of the area (between the red and blue dots in Figure 2). These noise areas were apparent on the three eastern lines, but not the western-most line. The nature of this noise did not appear to be related to any surface feature, drainage or buried electric cable.

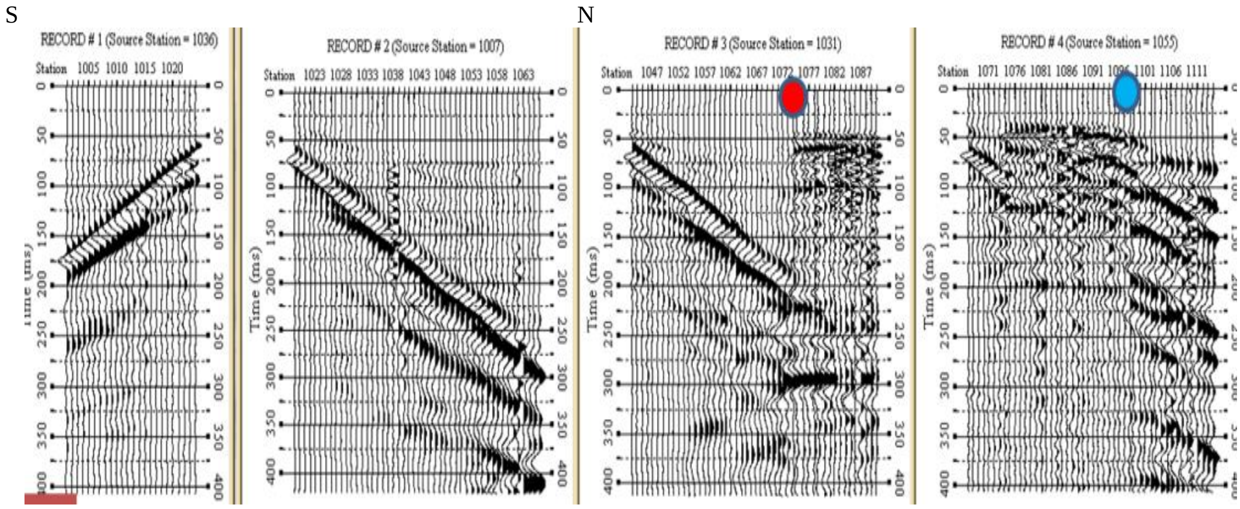


**Figure 2. Seismic records along Line C. Red and Blue dots denote the start and end of the "noisy" area, respectively.**

The data were analysed at every 6 metres using SurfSeis 2.15 software by Kansas Geological Survey. The noisy area showed less coherent dispersion characteristics in the frequency-velocity domain.

## INVERSION RESULT

The dispersion curve extracted in the frequency-velocity domain was inverted to S-wave velocity structure. Figure 3 shows four representative velocity profiles along one of the lines. The points from the "noisy" area presented a very high S-wave velocity from the surface (The third profile in Figure 3). The severe velocity reversal around 20 metre deep of this particular profile is perhaps a processing artefact.

The S-wave velocities are interpolated and colour-coded to make S-wave velocity sections (Figures 4a and 4b). Line D (Figure 5) did not present the "noisy zone" and shows "quiet" section.

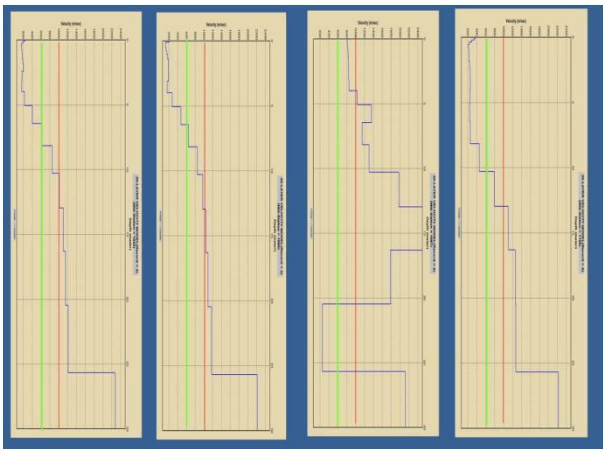

**Figure 3: Examples of 1D inversion; four points on Line B. Vs=600 and 1000m/s are indicated by green and red lines, respectively.**

.

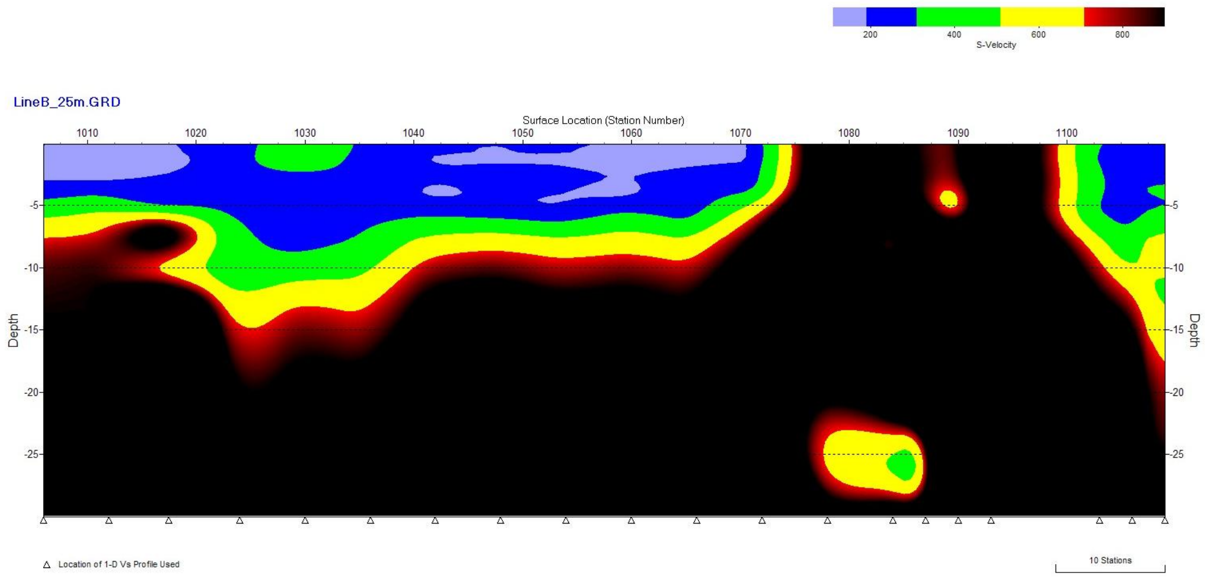


**Figure 4a. S-wave velocity Section Line B**

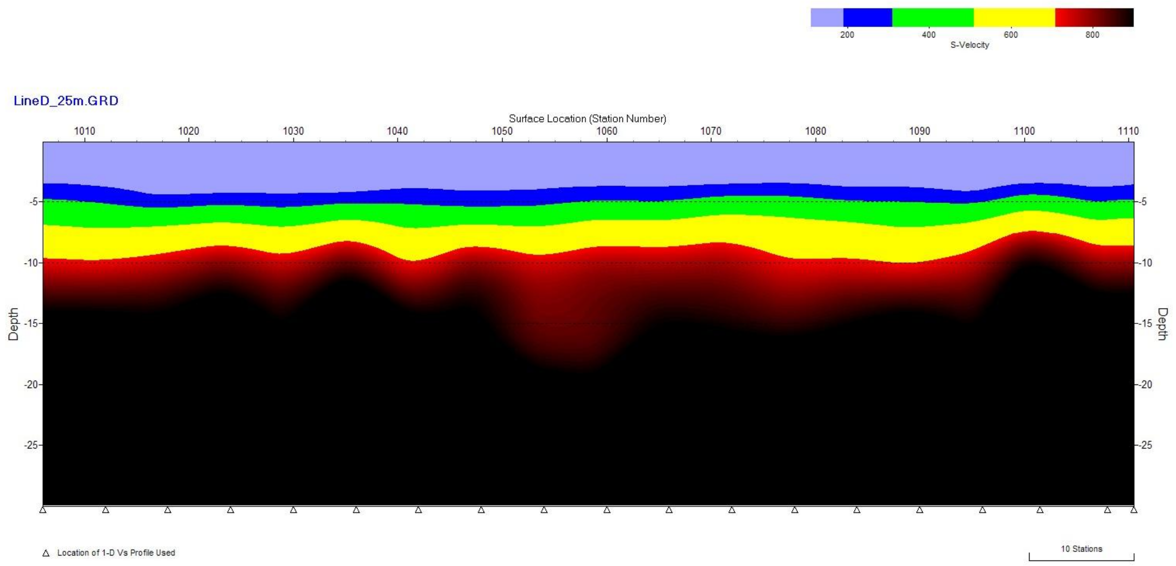


**Figure 4b. S-wave velocity Section Line D**

## HORIZONTAL SLICES

The velocity sections of the four lines are then interpolated 3-dimensionally to create horizontal slices and displayed at every 5 metres from the surface (Figure 5).

Both Figures 4 and 5 show the S-wave velocity reaches 700m/s at the depths 10 to 15 metres (indicated by red in Figures 4 and 5).

## DISCUSSION

The S-wave velocity structure of the site showed a localised shallow high-velocity area. This high-velocity area corresponds to the noisy parts in the seismic record. This is perhaps some hard material left in the quarry unmined. A historical aerial photo of the area from 1955 (Figure 6) shows some storage tanks in the area and some different structure is seen around the area of the shallow high-velocity feature.

A borehole drilled to the north of the site showed hard tuff at around 13 metres deep ((*pers. corr.*) suggesting the depth of the floor of the quarry. The corresponding S-wave velocity at this point is about 500m/s, which is indicated by yellow in the S-wave velocity sections. The depth of the quarry floor appears uneven in places, about 8 metres below surface and over 12 metres to the north of the unmined section.

The S-wave velocity over 700m/s (indicated by red) is considered as rocks hard enough to be stable with some safety factor. The planned depth of the tunnel in this section was more than 20 metres under the ground and it was not considered to interfere the fill. Figure 7 shows perspective views of the S-wave velocity structure. At the designed depth of tunnel deeper than 20 metres, the S-wave velocity is much higher than 700m/s.

## CONCLUSIONS

An MASW survey was carried out in a fill site of old rock quarry to estimate the depth of the fill prior to boring of Airport Link Tunnel in Brisbane's north.

The depth of the quarry floor was estimated around 8m below the surface in the south of the unmined wall; and over 12m to the north. This is well above the planned depth of the tunnel of more than 20 metres.

The S-wave velocity of the rock around the depth of the tunnel was estimated higher than 700m/s, and is considered to be stable for tunnelling.

The tunnel was completed in July 2012. There were no difficulties or safety issues reported during and after drilling this section.

The MASW survey contributed in the geotechnical investigation of the tunnel route.

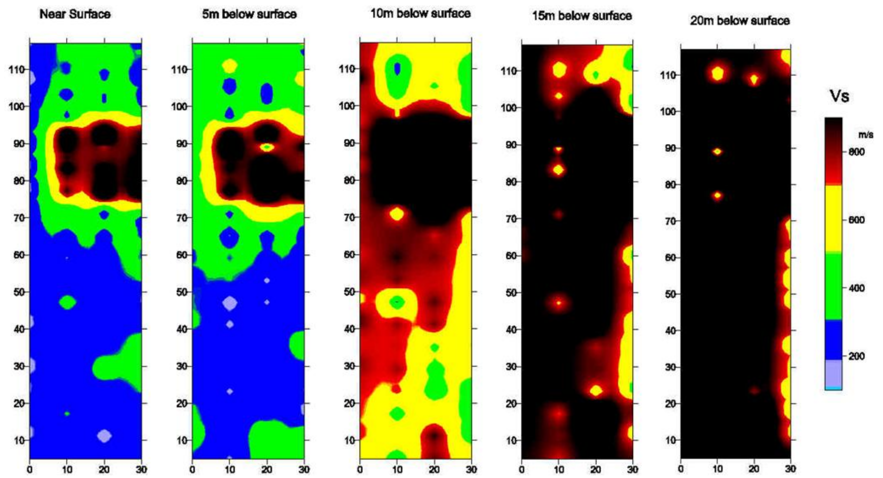


Figure 5. Horizontal slices of the S-wave velocity

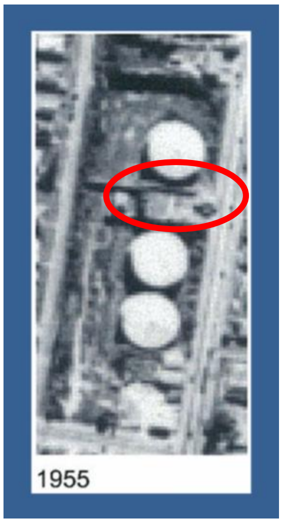


Figure 6. Aerial photo of the site 1955

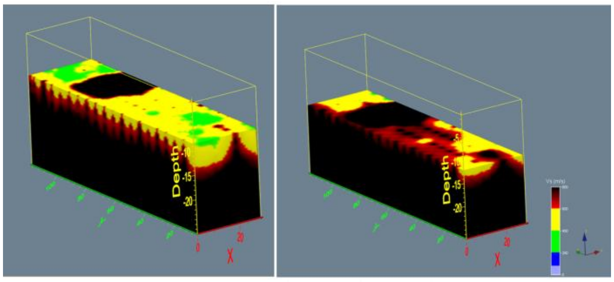


**Figure 7. Perspective view of the S-wave velocity structure sliced at 8m (left) and 12m (right)**

## ACKNOWLEDGMENTS

The author thanks to Mr Joe Leslie of Thiess John Holland for the permission to present this paper. Thanks are also due to Ms Desianne Tjen of TJH and Mr Ronald Bubko who assisted in the field data acquisition.

## REFERENCES

Fredericks, J. and Tayler, 2012: Site control using seismic technology, 11th Australia New Zealand Conference on Geomechanics, Melbourne, pp 1165-1170.

Lacey, D and Griffiths, 2012, Use of geophysical survey and sonic drilling for sitecharacterisation and material property derivation for a municipal waste landfill, 11th Australia New Zealand Conference on Geomechanics, Melbourne, pp 1310-1315

Park, C B, Miller R D and Xia, J 1999, Multichannel analysis of surface waves, Geophysics 64, pp 800-808.

Scott, B and Suto, K, 2007, Case study of ground mprovement at an industrial estate containing uncontrolled fill, 10th Australia New Zealand Conference on Geomechanics, Brisbane, pp150-155.

Suto, K (2007): Multichannel Analysis of Surface Waves (MASW) for Investigation of Ground Competence: An Introduction. Proceedings of the Sydney Chapter 2007 Symposium, Australian Geomechanics Society, pp71-81.

Suto, K, 2012, An application of multi-channel analysis of surface waves (MASW) to hydrological study: A case history, ASEG 22nd International Geophysical Conference and Exhibition, Brisbane, Australia

Suto, K. and Cenic, I., 2012, An MASW Survey at a Site with High Velocity Uncontrolled Fill - A Case History, 74th EAGE Conference & Exhibition incorporating SPE EUROPEC 2012 Copenhagen, Denmark, C031.