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Session Report: Geophysics, 2

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ABSTRACT: This report outlines seven papers presented in the geophysics sessions in the Fifth International Conference on Geotechnical Site Characterisation (ISC'5) held in Gold Coast, Australia on 5 to 9 September 2016. Twenty-five papers were presented in the geophysics sessions and the eight papers selected for this report are in application of the seismic and airborne electromagnetic methods, and development of new equipments. These research, case history and development papers represent recent effort of site characterization using the geophysical methods.

1 INTRODUCTION

The geophysical techniques are applied to all scales of investigation of the earth from large scale such as the interior of the earth and earth's crust to small scale like surface rocks and soil. They are primarily developed for petroleum and minerals exploration because of its economic interest. They are also applied to geotechnical and environmental problems. This engineering geophysics is perhaps the smallest in scale of the geophysical applications (Table 1).

Table 1 Category of Geophysics by scale

Geophysics	Scale	Range
Solid Earth Geophysics	Huge	<6400 km
Crustal Geophysics	Large	10-50 km
Exploration Geophysics	Medium	<10 km
<u>Engineering Geophysics</u>	<u>Small</u>	<u><100m</u>

Geotechnical engineers often address these techniques collectively as “geophysics”, in such a phrase as “we applied geophysics”. Such an expression is vague and it is best to avoid. Geophysics is indeed a group of physical survey techniques to investigate a variety of physical properties of the earth. For example, the magnetic survey investigates distribution of magnetic properties such as magnetic susceptibility and magnetic permeability; the gravity survey for distribution of mass; and seismic survey for velocity of various seismic waves.

A comprehensive manual of geophysics for engineering application by Society of Exploration

Geophysicists of Japan (2014) explains twenty geophysical methods for engineering application including ground, offshore, airborne and downhole surveys.

The geophysical parameters obtained from geophysical surveys are physical properties of the ground. They have physical dimensions and they are analytically interrelated through physical observations and mathematical manipulation. On the other hand, geotechnical parameters are often stand alone, and relationships among them are generally derived empirically. Relationship between the engineering parameters and physical parameters are also deduced empirically, and there are always discrepancy between the parameters inferred from an empirical formula and values from actual measurement. This is because the geotechnical engineering deals with the parameters influenced by multitude of factors, some can be physically quantified and others are impossible to quantify. Therefore an attempt to relate a physical parameter to a geotechnical parameter is like looking at two-dimensional cross section of multi-dimensional space. Yet, geophysics can contribute to geotechnical site characterisation through physical properties.

In the Fifth International Conference on Geotechnical and Geophysical Site Characterisation (ISC'5), twenty-five papers were selected for presentation. Eight of the presentations are accepted to present. However one presenter failed to appear at the conference and it is omitted from the review in this report. The majority of the papers reviewed are on the seismic methods, with which the present author is familiar (Table 2).

Table 2. Papers reviewed in this report by classification of techniques.

Seismic	Surface	onshore	Sathwik, et al.	MASW Parameter study
			Heymann et al.	New inversion algorithm of MASW data - model test
			Lin & Lin	Proposal of data acquisition method for MASW
	Crosshole	offshore	McGrath et al.	Case study of offshore application of MASW
			Sylvain, et al.	Hardware development / test
			von Ketelhodt et al.	development / experiment
Electro-magnetic	Airborne		Look et al.	Testing new equipment
			Pfaffhuber et al.	Application case history

2 SUMMARY OF PAPERS

2.1 Onshore MASW

Heymann, *et al.* (2016) points out inversion of dispersion of surface waves is an ill-posed problem, as is geophysical inversion generally is. In attempt to circumvent the problem and to reach an accurate inversion result the authors proposes a procedure called “partial least squares regression”. They

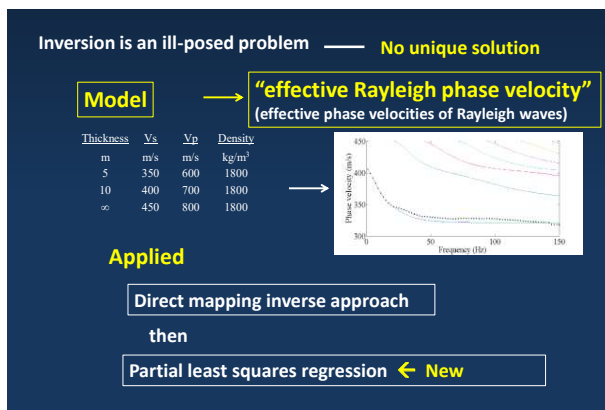


Figure 1. Modelling procedure of Heymann (2016).

examined the process by applying it to a three-layer model using the “direct mapping inverse approach” first, which saves computation time (Figure 1). Their result showed: a) if the thicknesses of the layers of the model is known *a priori*, the S-wave velocities (V_s) of the three layers are predicted within 1% accuracy; b) If the V_s of the layers of the model are known *a priori*, the thicknesses are also predicted to about 5-8% accuracy; while c) both V_s and thicknesses are to be predicted the inversion result presents errors around 5% in V_s and 10% in thickness with right set of inversion parameters.

Lin & Lin (2016) tackles the aliasing problem in SASW data by using the MASW method (Figure 2).

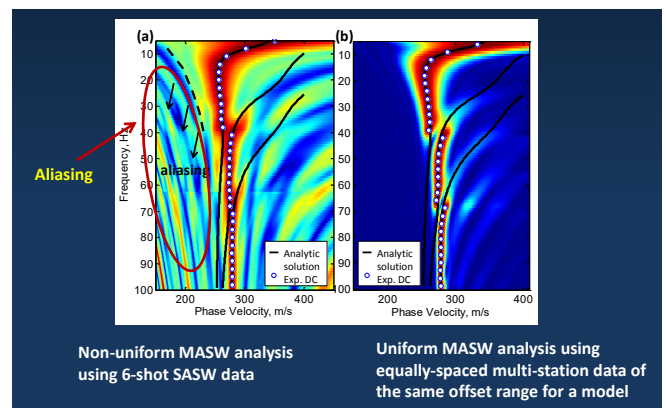


Figure 2. Aliasing problem in SASW in comparison with uniform MASW display in the frequency-velocity domain

This method, while reduces aliasing, trades off the spatial resolution by using a long geophone array. To achieve a good spatial resolution, it is necessary to increase offset range. Their solution is to use multiple shots to a geophone array (Figure 3). This achieves a wide bandwidth necessary to improve probe depth while not compromising the aliasing problem.

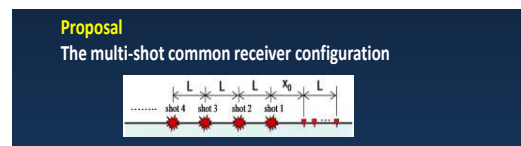


Figure 3. Proposed configuration of multi-shot common receiver survey

2.2 Offshore MASW

McGrath *et al.* (2016) is a case history of an offshore MASW survey near Dublin, Ireland. It deployed a water bottom cable and airgun on the floor (Figure 4).

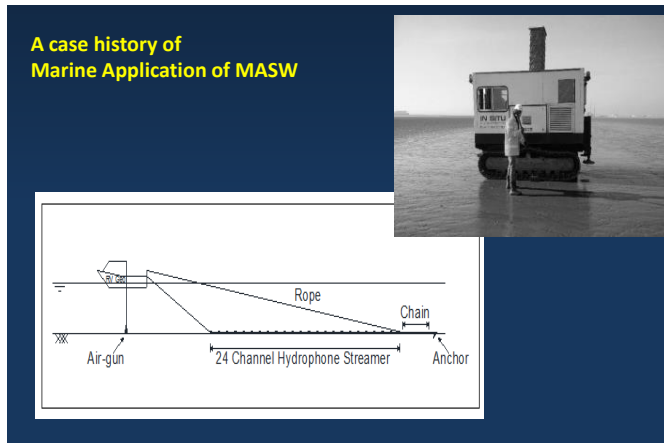


Figure 4. Schematic diagram of marine MASW configuration and field photo

The subsurface is made of 3 to 9.5 metres of alluvium clay, gravels, sands and marine deposits overlying glacial till and bedrock. The result was compared with the CPT and SCPT (Figure 5) and found good correlation with MASW's ability to probe deeper than SCPT can in this situation. The MASW could profile deeper than SCPT. This case study demonstrated validity of MASW survey and repeatability of the results.

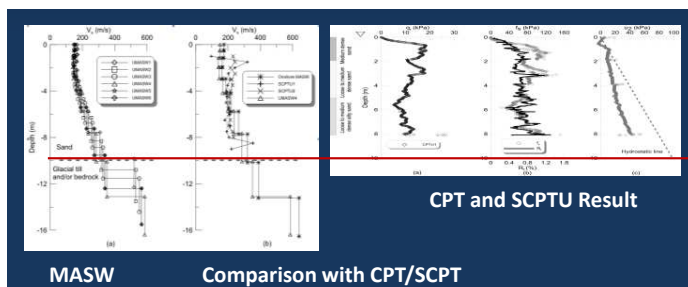


Figure 5. Comparison between under-water MASW and CPT and SCPT

2.3 Crosshole Tomography

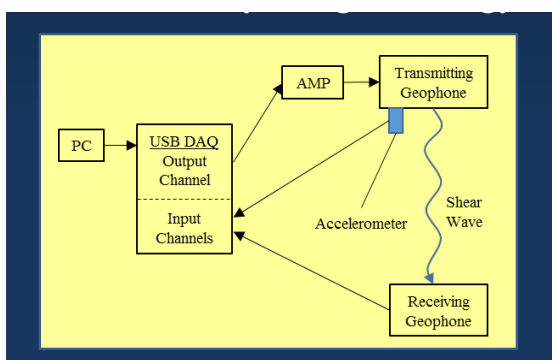


Figure 6. Components of crosshole testing system

Sylvain *et al.* (2016) created a new tool for crosshole tomography (Figure 6). Using the 3D printing technology for its housing of transmitter and receiver and selection of material resulted in a low-cost but reliable system. They tested the system in a backfilled sand pit (Figure 7) and compared with



Figure 7. Backfilled test pit 3m x 3m x 3m

MASW, SCPT and DMT. The result was presented in detail in their extended abstract in this volume (McGrath *et al.*, 2016).

An experiment on crosshole tomography using both P- and S-waves was carried out by von Ketelhodt, *et al.* (2016). They also developed a new three-component data acquisition system. With the velocity data of both P- and S-waves, shear modulus, Young's modulus, bulk modulus and Poisson's ratio can be calculated in the two-dimensional plane between the boreholes. The experiment revealed that S-wave tomography has a better resolution than P-wave tomography.

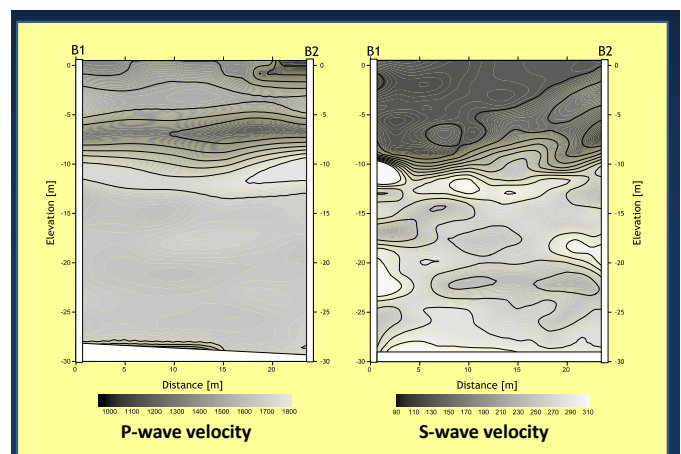


Figure 8. Comparison between P- and S-wave tomography

2.4 Laboratory Measurement

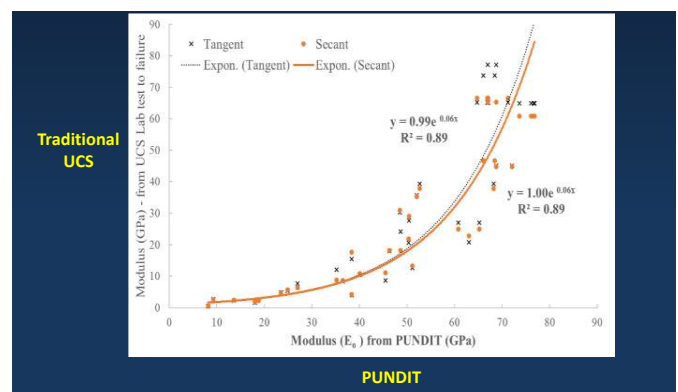


Figure 9. Comparison between results by "traditional" UCS and by PUNDIT.

Look, *et al.* (2016) attempted to improve the conventional method of measuring uniaxial compressive rock strength (UCS) and Young's

modulus (E), which is time-consuming and expensive, by devising ultrasonic pulse velocity testing technique (PUNDIT). This is a non-destructive testing method. They found a significant correlation between the results of this new method and “traditional” UCS testing (Figure 9).

2.5 Application of Airborne Electromagnetic Survey

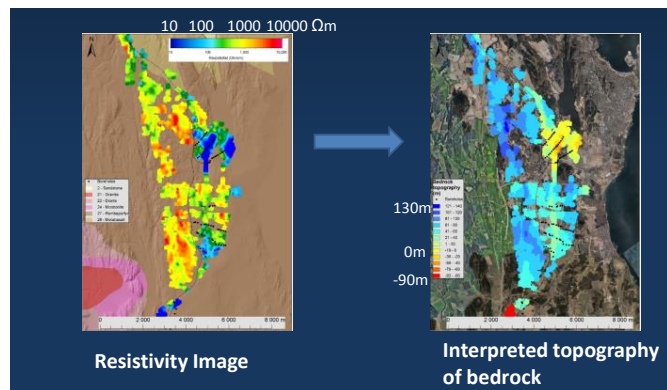


Figure 10. Map image of electric resistivity from AEM and its interpretation to depth of bedrock.

Pfaffhuber *et al.* (2016) presented a case history of application of airborne electromagnetic (AEM) survey to planned railway alignment in Norway. The area is known to have problem of quick clay. As well as relief of the bedrock from AEM data (Figure 10), they managed to detect and map the quick clay (Figure 11).

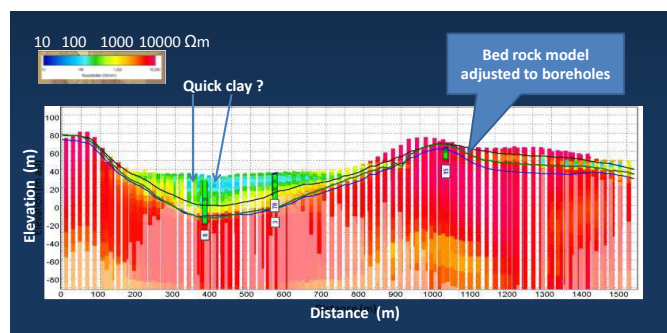


Figure 11. Resistivity cross section along the railway alignment.

3 CONCLUSION

Seven papers presented in geophysics sessions at the Fifth International Conference on Geotechnical Site Characterisation are reviewed. These represent recent efforts all over the world to apply geophysical methods to geotechnical characterization. They include development of algorithm and software, making new hardware, and application case history. These made a significant contribution to site characterisation using geophysical techniques.

4 REFERENCES

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