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Session report – General site characterisation

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ABSTRACT: This paper presents highlights from 8 papers submitted to the General Site Characterisation session of the ISC'5 Conference. The general findings of all papers are presented and these are subsequently compared with experience from previous research.

1 INTRODUCTION

The General Site Characterization session (GSC), as its title itself indicates, refers to a very wide range of issues. It applies to both the scope of the research methods used, as well as the subject of research itself, that is soil. The expression "General" can be understood in two ways; it can refer to a general view on a research issue, but it can also specify versatility of identification of a given matter. It also applies to 8 articles submitted for this session. This, perhaps, a small number of works does not, in any way, affect limitation of research topics covered by the authors. Most of the works address a few significant research themes which are often mutually permeant. Therefore, this paper identifies five main research areas on the basis of which the results obtained by particular authors have been discussed.

As Figure 1 shows, the most common theme addressed in the GSC session works is research on soft and organic soils. Most of the research focused on reference test sites, thus its objective was to characterise typical in some respects soils in a given area and it did not refer to specific project cases. In case of three papers, a crucial element of the research problem was accessibility difficulties of the studied area, which, in turn, did not necessarily mean the presence of soft and organic soils. The subject of seismic areas was also clearly addressed, although it was not always the focus of the paper. Unlike previous, intersecting research themes, identification of the subsoil within non-standard investments presented in the one work, formed a slightly different problem.

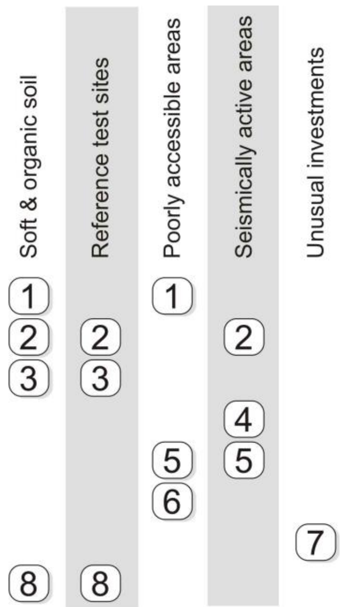

Figure 1. Main research topics addressed in the GSC session works: [1] Geophysical and Geotechnical Characterisation of the Saltwater Creek Bridge Site, Morten Bay Rail Link, Queensland, Australia -. Purwodiharjo A., Rahiman T., Parsons M., Kruger J.; [2] The Phase of Geotechnical Study for a new construction in Albania - Allkja S., Bozo L., Malaj A., Harizaj L., Kosho A., Xhagolli B.; [3] Geotechnical characterization of Ballina clay – Pineda J.A., Kelly R.B., Suwal L., Bates L. & Solan S.W.; [4] Site characterization and seismic response analysis in the area of Collemaggio, L'Aquila (Italy) - Totani G., Monaco P., Totani F., lanzo G., Pagliaroli A., Amoroso S., Marchetti D.; [5] Using Multi-Channel Analysis of Surface Waves and Cone Penetrometer Tests to delineate an in-filled palaeochannel during routine investigations – A Christchurch Earthquake Case Study - Kaumuhangire R., Plunket T., Ruegg C.; [6] Geophysical and in situ testing applied to site characterisation for non-engineered structures in developing regions - Ortiz-Palacio S.; [7] Geotechnical and geophysical site characterization of a nuclear power plant site in United Arab Emirates - Parashar S., Rice R., Asprouda P., Al Hammadi H.; [8] Characterisation of Halden silt - Blaker Ø.

2 SOFT AND ORGANIC SOILS

Studies conducted on soft and organic soils are an integral part of contemporary geotechnics. The intense development of infrastructure is increasingly creating a need for investments in areas with problematical soils in terms of foundation of buildings. The need to utilise soft and organic soils as construction grounds usually poses two kinds of problems. One of them is a difficulty in obtaining a valuable outcome of in situ (Long, 2008) or laboratory (de Groot & Landon, 2007) studies. Another one, related to design itself, is narrowing the absolute margin of error in the assessment of geotechnical parameter value, which derives from numerically low parameter values with standard measurement accuracy. For obvious reasons, works presented within the GSC session mainly refer to the first issue. In this case, due to technical and economic difficulties in obtaining high-quality undisturbed samples, in situ studies dominate in identification of geotechnical conditions. In typical, commercial studies [1] sampling is mainly limited to enable assessment of fundamental physical properties. It is even worse if such a situation applies to areas considered to be reference test sites [2]. The need for calibration of in situ test results to local conditions is particularly important in the case of soft and organic soils, where the aforementioned margin of error gradually narrows (e.g., Młynarek et al., 2014). It is finely proven by test results of [3] which show how a specific structure of soft marine illitic clays affect strong non-linearity of deformation characteristics of such soils (Fig. 2). High values of peak friction angle reaching up to 42 degrees may be somewhat perplexing in case of sediments with high plasticity (PI > 34%) and presence of organic matter reaching 3%. In the context of strong non-linearity of deformation characteristic of these soils it can be assumed that, in this case, its cause may be preliminary sediment cementation. A similar effect of disproportionately high values of peak friction angle and constrained moduli caused by carbonate cementation of alluvial soils was identified e.g., by Stefaniak (2014).

Domination of in situ methods in identifying soft and organic soils, as it has already been mentioned, is in some ways understandable. However, very economical use of penetration techniques dedicated, in a sense, to the soft and organic soils testing, such as the Field Vane Test, the T-bar or Ball penetrometer (Colreavy et al. 2010) is puzzling. Only in the case of tests carried out by [3] the FVT was used, confirming that undrained shear strength measured in situ conditions is higher than the one specified in the triaxial compression test, even on samples of a documented high quality. In this context, correlation attempts of simple methods based on dynamic penetration with advanced techniques of surface wave measurement can be explained by being accustomed to typical test methods. Nonetheless, it is difficult to expect in this case satisfactory results of such analyses (Fig. 3) [1], which has been already indicated by, inter alia, Schnaid 2010.

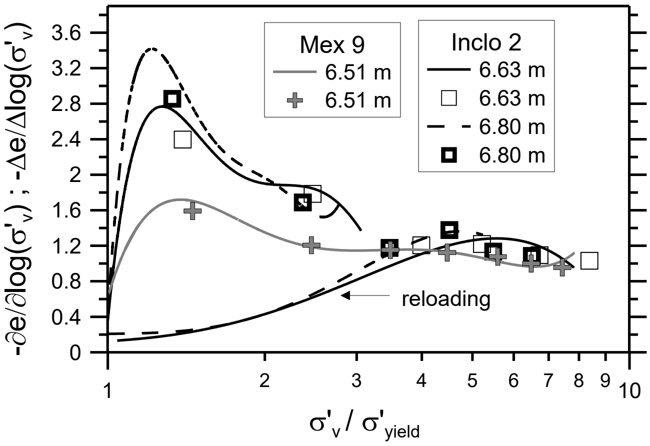

Figure 2. Variation of C_c with the stress level in the case of Balina clay (Pineda et al.).

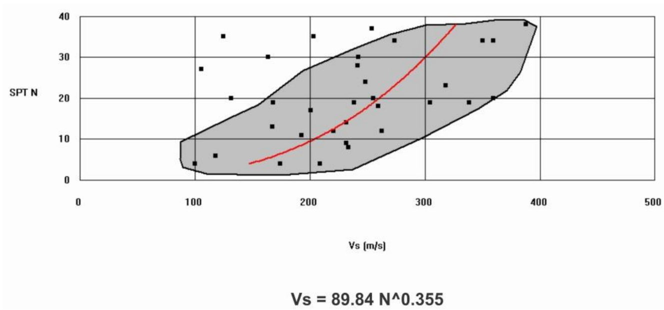

Figure 3. Regression analysis of SPT data and V_s measurements for the Saltwater Creek Bridges sediments (Puwodihardjo et al.).

3 REFERENCE TEST SITES

The location of reference test sites is usually decided, on one hand, by typicality of soils tested for a given area and by geotechnical "problematic nature" of these soils on the other. The same applies to the works presented in the GSC session which mainly analyse intermediate soils deposited in offshore and alluvial environment and organic soils. A common feature of tests conducted on test sites is a comprehensive identification of soil, often far beyond the scope of typical commercial research. Tests conducted by NGI can be a good role model leading to a comprehensive characteristic of the tested sediments and examining correlations between the results obtained using different test methods (Lunne et al. 2003). In general, however, these results are not the effect of a one-time research campaign, but rather the sum of perennial, complementary studies conducted even in the span of 30 years (Wierzbicki & Lunne 1999). In this context, among the works presented in the GSC session one can underline both the ones that are more signal in nature [2] and referring to an almost full characteristic of soils [3] and [8]. Multi-faceted substrate studies, mainly in terms of in situ tests, were conducted notably by [3]. A rather rarely found in practice push-in pressure cells and direct assessment of horizontal stress values are noteworthy. The obtained results remind us how different they can be if they are obtained using different methods, (up to 30-70% reassessment of K_0value specified in the DMT study). As it was noted by [3], in this case dissipation of horizontal stress was not analysed after installation of the device in the soil. Such phenomenon takes place, however, its time depends on the local soil conditions and installation method. In this context, it would be useful to include information about details of the performed measurements with the help of the PIPC. Studies conducted on reference test sites also reflect an increased interest in surface wave measurement methods. As it was earlier noticed by different authors (inter alia, Foti 2013, Vanneste et al. 2014) this method provides a very valuable complement to penetration testing and facilitates creating geotechnical models of substrate structure. [3] and [1] used the results of the MASW test to identify the position of a boundary between the soft and organic soils and the bearing subsoil. In both cases, the criteria value of V_s wave was adopted following the correlation between the CPTU tests results (Fig. 4). As a complement to this theme one can indicate opportunities offered by the use of statistical methods, cluster analysis in particular, in a complementary use of various geotechnical data (Smaga 2014). On the other hand, [8] drew attention to the problem of identification of geotechnical layers in intermediate soils. In terms of lithology, a seemingly homogeneous substrate may often require a more detailed breakdown into layers resulting from significant differences in strength properties. As one of the explanations for this state of affairs, the author provides small, but statistically significant, differences in the content of organic parts. Although the difference of the content of organic parts expressed in per milles seems to be almost imperceptible, in this particular case it may have a decisive impact on the increase of moisture and simultaneously decrease of soil strength parameters. An interesting and important observation of [8] is the need for a cautious approach to the interpretation of intermediate soils using common CPTU classification charts. These conclusions are confirmed by works of other authors (inter alia, Stefaniak 2014) is to draw attention to the opportunities offered by the combination of two classification charts - SBT Robertson (1990) and Schneider et al. (2008) (Fig. 5).

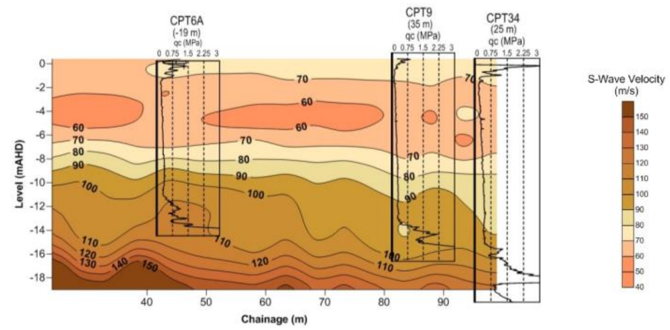

Figure 4. Shear wave velocity profiles obtained from MASW1 alongside East-West direction on the Balina Clay test site (Pineda et al.).

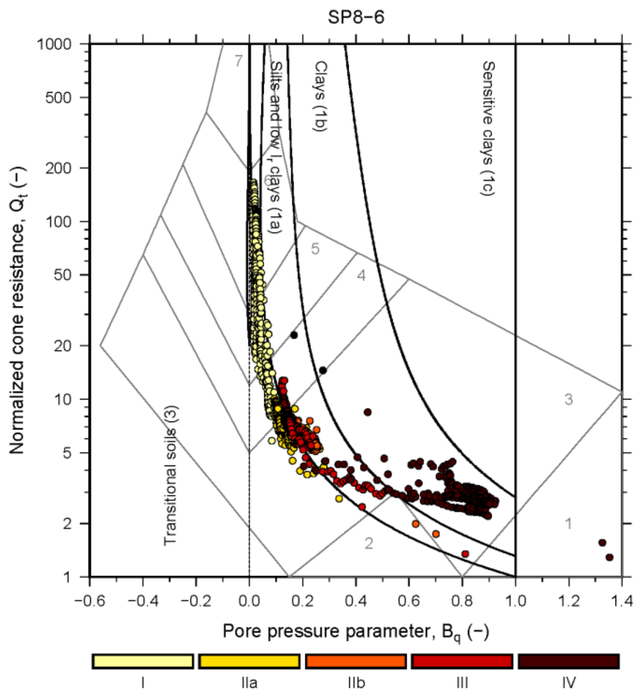

Figure 5. Robertson (1990) soil behaviour type chart combined with the Schneider et al. (2008) classification chart for the Halden silt deposits (Blaker Ø.).

A frequent lack of information on the soil sample quality, unfortunately, leaves a deficiency in the description of the laboratory tests of reference test sites. Sample quality, especially in cases of soft and organic soils, can have a significant impact on the results obtained (Lacasse et al. 2008). It seems that sample quality assessment should be a certain standard in case of reference tests e.g., the one accomplished by [8] based on the criteria of Lunne et al. (1997).

4 POORLY ACCESSIBLE AREAS

It is not always that a geotechnical engineer can have full access to the area of research to conduct all theoretically appropriate tests of the substrate. These restrictions may occur as a result of economic and timely pressures of an investor, but also their more common reason is concern for the natural environment. The first possibility is generally associated with local investments and developing countries and is also well known in the Eastern European countries (Młynarek 2008). An interesting article of [6], on one hand, refers to the well-known pattern that indicates the validity of investing funds in soil research in the pre-project phase (Fig. 6), on the other hand, it indicates possible solutions in terms of economically weaker areas. According to [6], economic-technological constraints around the world cause a dynamic penetration tests to be commonly used. Nonetheless, the author does not see a special alternative to this fact in the case of the less developed world party. It correctly assumes that information about a limited credibility is better than its complete absence, which cannot always be agreed upon. Leaving aside the dubious idea of correlation of simple geotechnical tests with the results of the more advanced ones, such as geophysical tests (Schnaid 2010), this approach may be a significant temptation to conduct "shortcut" tests, even when there are possibilities of a complete analysis of the substrate. This situation occurs e.g., in Poland, where after World War II simple rules of evaluating substrate bearing capacity were developed. Over the years, these rules were complemented and developed resulting in the creation of a set of nomograms in the 80s of the 20th century which allowed the assessment of strength and deformation properties of all soils only on the basis of knowledge of the type of soil along with its relative density or liquidity index (PN-82/03020). In spite of technological and economic development of the country, the vast majority of commercial geotechnical analyses uses these simple and not always justified correlations up to this day. It even leads to peculiar situations when according to the current Eurocode more advanced geotechnical research is performed, but the values of geotechnical parameters are determined on the basis of the old rules (Lipiński et al. 2016).

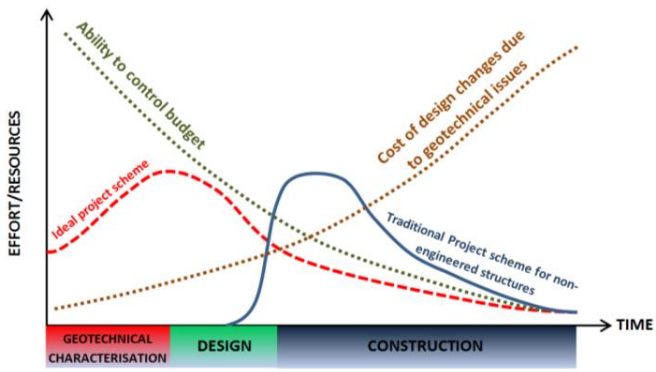

Figure 6. Effort curves in non-engineered buildings projects, adapted from MacLeamy (2004) (Ortiz-Palacio S.).

Another problem is conducting substrate research in areas that are partially protected or densely built-up. In such cases, reducing the number of penetration tests and possibilities of sampling can be successfully compensated with performing surface wave measurements. As shown by the results obtained by [1] and [5], an important part of planned works is a skillful use of penetration test findings and of non-standard measurement techniques, such as Seismic Refraction and LIDAR. Particular attention deserves the result of a joint analysis of geotechnical, geological and geodetic data in the work of [5]. As it emerges, only a summary of these data allowed to present a valid hypothesis for the observed phenomena essential to the building of similar areas (Fig. 7).

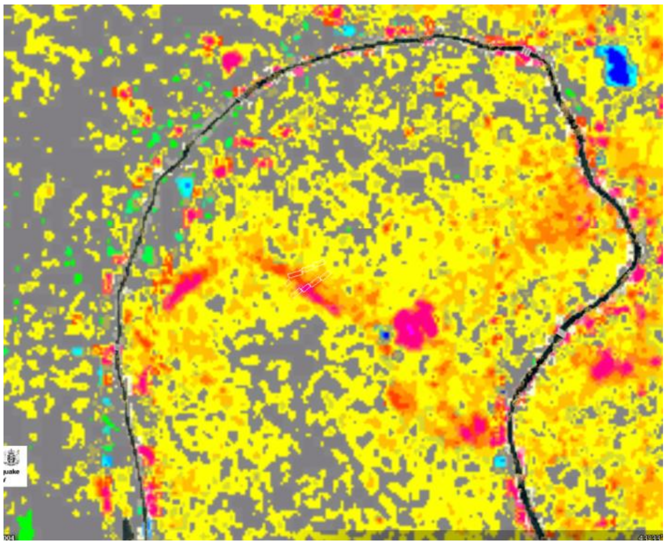

Figure 7. LiDAR vertical movement at the Cresselly Place, St Martins Christchurch test site (Kaumuhangire R. et al.).

5 SEISMICALLY ACTIVE AREAS

Research conducted on seismically active areas pose a separate challenge in geotechnics. Soils that under static load are a stable construction ground, in the case of dynamic loads (e.g. caused by seismic wave propagation) lose their bearing capacity.

For non-lithificated soils, the primary task is to determine liquefaction potential and the extent of occurrence of soils susceptible to this phenomenon. Both penetration (Zhang et al. 2002) and seismic methods are used for this purpose (Andrus et al. 2000). Universality of the results obtained with different methods is obviously a debatable issue. [2] suggest that the correct way in this case is correlation of penetration tests results with a direct shear wave velocity measurement. The differences obtained, however, indicate caution when using these dependents and the need for their calibration to local conditions (Fig. 8). On the other hand, [5] stress commonly observed restrictions in the use of surface wave measurements for a reliable assessment of substrate properties. Ambiguous results derive from geophysical surface prospecting due to the effect of "shadowing" with rigid structures and discontinuities of lower lying layers of the substrate (Godlewski & Szczepański 2015), which is an inherent feature of these studies. As rightly observed by [5], this creates a need for parallel penetration tests, which significantly complement assessment potential of substrate liquefaction (fig. 9).

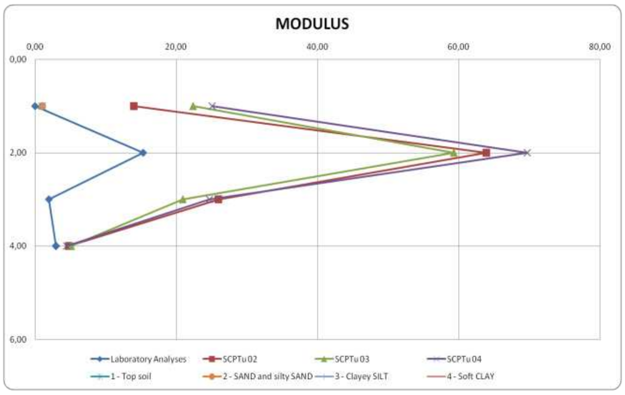

Figure 8. Comparison of constrained modulus obtained from field and laboratory tests for the Fier in Albania test site (Allkja S. et al.).

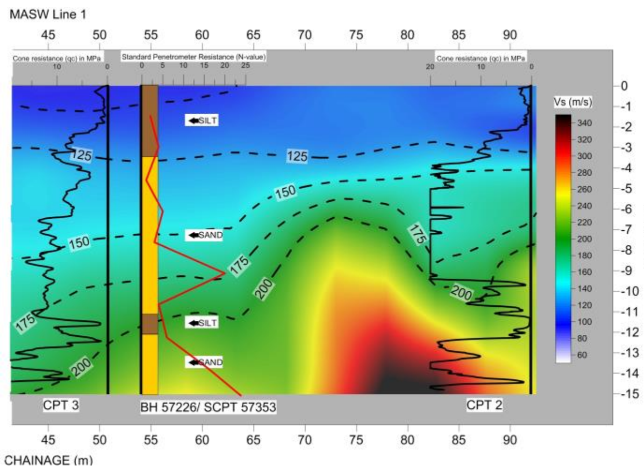

Figure 9. MASW plot superimposed with results of intrusive investigations at the Cresselly Place test site (Kaumuhangire R. et al.).

In turn, [4] represent a very interesting problem of adequacy of modelling subsoil performance wherein the layer susceptible to liquefaction is located between two layers of greater stiffness. Proper restoration of destruction causes and mechanisms caused by an earthquake required in this case employing non-standard SDMT investigations, precise determination of geological structure and topography of the area, but also a detailed analysis of characteristics of historical seismic activity. An important result of the model studies, explaining surprising destruction in the area of the basilica in L'Aquila, as it turns out, is a confirmation of underestimation of seismic action in the range of 2.5-10 Hz (0.1-0.4 s) using data provided by the Italian National Seismic Code (fig. 10).

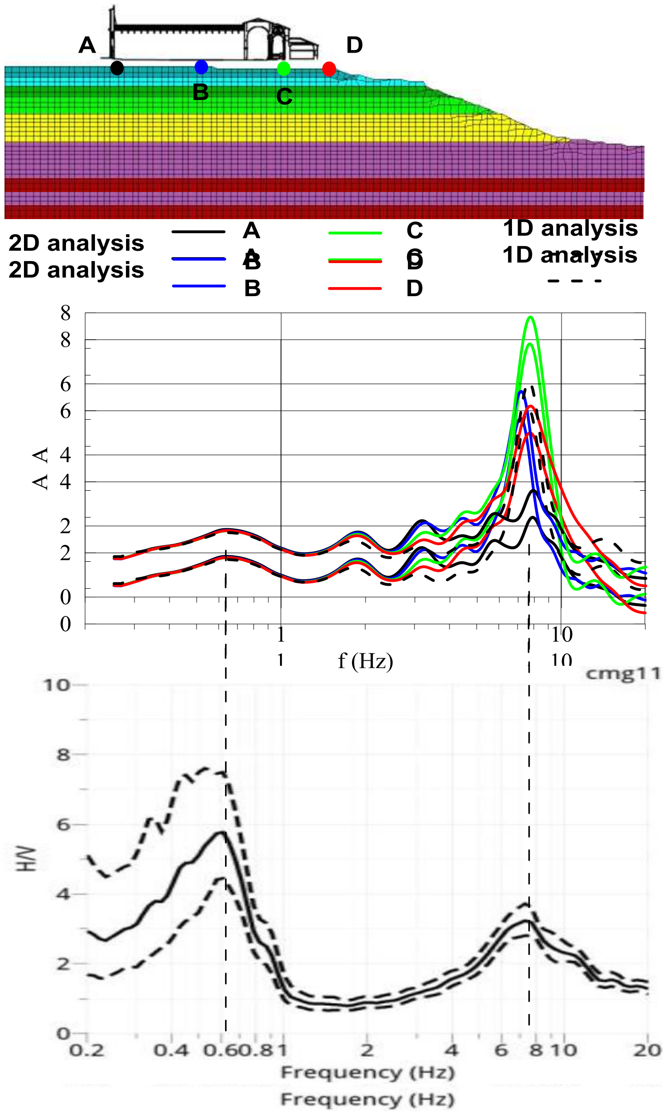

Figure 10. Comparison between transfer functions computed by 1D and 2D visco-elastic linear analyses and representative H/V ratio from noise measurements carried out in the Basilica area (Monaco et al.).

6 UNUSUAL INVESTMENTS

Identifying subsoil for structures such as a nuclear power plant, many problems covered by [6] will not be encountered. The scale of such investment and its significance cause virtual disappearance of economic restrictions in conducting substrate tests resulting in hundreds of test holes, dozens of attempts with undisturbed samples, a full range of in situ and laboratory tests [7]. Against this background, a tenfold reassessment of subsidence calculated based on the results of oedometric tests looks baffling (Tab. 1). Taking into account soils found in the substrate, insufficient quality of samples may have affected such result. As showed by, among others, Landon et al. (2007), the impact of sampling methods may be of critical importance for the results of the analysis of soil compressibility. This hypothesis can also confirm observed by [7] significant differences between the results of geophysical, pressuremeter and laboratory tests.

Table 1. Average Elastic Modulus Values Based on Pressuremeter and Consolidation Tests (Units MPa) for the power plant test site in United Arab Emirates (Parashar S. et al.)

Layer	E (from Pressuremeter Tests)			Ec	Erm, (recommended)
	Initial, Ei	Unload/ Reload E_{ur}	E_{ur} / E_i	(from Consolidation Test)	
2	398	1235	3.1	58	500
3	646	1600	2.5	65	1046
4	2876	3089	1.1	-	1852
5	794	1989	2.5	54	1075
6	1892	4211	2.2	-	1633
7	1599	2567	1.6	107	1580

The importance of non-standard analysis of the subsoil in the case of unusual investments can be well illustrated by the example presented by Jamiolkowski (2014). In that case the large structure of Zelazny Most tailings reservoir, weighted of over 1 giga tons, influences the subsoil much more deeper than was previously expected. The specific geological structure and the enormous load causes that even 80 m below the ground level the horizontal movement can be detected. In such a cases the biggest challenge is to identify such areas in the pre-operational phase.

7 SUMMARY

Review of the works presented in this conference session allows some observations to be made concerning both the current research issues, as well as their likely future in terms of general site characterisation.

Reference test sites are becoming a more and more common practice in geotechnical studies. They provide reference data, allow calibration of commonly used interpretation dependents and understand local specificities of certain soil types. One can wonder whether the right direction would not be a creation of a worldwide register of typical and specific soils and conducting their more coordinated research. A step in this direction could be, for example, adoption of one research standard concerning both the scope and quality control of the conducted research.

Without a doubt, surface wave measurements, especially MASW, are becoming an increasingly more common tool. Results of these studies are an important complement of an image obtained on the basis of penetration tests, however, they require awareness of limitations of physical properties of wave propagation in the subsoil. In this context, parallel use of different tests to create a geotechnical model of ground structure should also be considered. It seems that some of the new possibilities in this regard can provide a wider use of statistical methods e.g., the use of cluster analysis and Bayes' theory.

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