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Session Report: Case Histories, 2

M. Arroyo
Department of Civil and Environmental Engineering, UPC, Barcelona, Spain

ABSTRACT: The papers submitted to this session are varied in their methods, scope and in the characterization techniques described or applied. They have in common the need to cope with practical engineering problems and varied ground conditions which is characteristic of geotechnical case histories. There are always interesting lessons to be learned by examining well-documented cases. Sometimes the analogy with other cases makes them directly useful. Sometimes details that may appear secondary to the authors are revealing if considered from a wider, comparative perspective.

1 INTRODUCTION

A total of 9 papers were contributed to this session. While all of them are of high technical quality they lack an obviously unifying subject. Therefore this report will first describe in parallel some the most relevant traits of the different contributions and would then highlight the results that have seemed more relevant from the point of view of the equipment used or the geotechnical property discussed.

2 OVERVIEW

2.1 *Geographical origin*

The majority of the contributors were based in Europe, with a large presence of Italian researchers. As might be expected there was also a large contribution from Oceania. (Figure 1).

2.2 *Characterization techniques*

A fair variety of site investigation techniques are discussed in the contributions to the session (Table 1). The dominant characterization strategy in these cases appears to be based on boreholes and subsequent laboratory testing. Some of the laboratory testing reported was unconventional, for instance the large triaxial tests reported by Pérez & Ale. It is also interesting to note that in two thirds of the papers field monitoring in one guise or another was employed for characterization. There is a significant presence of the (seismic) Marchetti dilatometer, (S)DMT. A variety of geophysical techniques is also employed –apart that is from the seismic measurements that are associated with SDMT.

It is remarkable that, despite its general preeminence in geotechnical site characterization, the cone penetration test (CPT) and its derived techniques (e.g. CPTu, Seismic CPT) feature in only one of the papers contributed to the session. The absence of CPTu may be particularly striking for the Port investigation reported by Jaditager & Sivakugan (2016); this is the kind of job that CPTu seems well adapted to. However the surprise may diminish when it is noted that the investigation reported was conducted almost 25 years ago. At that time there was less availability of CPTu deployment tools for nearshore jobs. This report is thus a useful reminder of the relatively recent maturity of site investigation tools that now seem present everywhere.

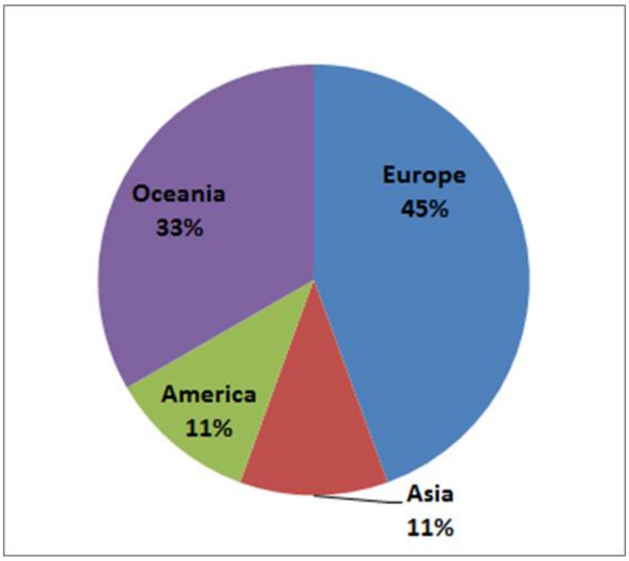


Figure 1 Geographic origin of the session contributions

2.3 *Problem related traits*

By problem related traits (**Error! Reference source not found.**) we make reference to those aspects of the session contributions that were dictated by the nature of the problem discussed by the authors. One first such trait is given by the nature of the driving application. All the papers presented were dealing with some specific application -a case history- rather than with methodological issues. But the driving application differed in nature. Four cases were related with the development of one kind or another of classic civil engineering infrastructures (railways, roads, ports). Three papers dealt with the analysis of different geotechnical related natural risks, seismic in two cases and slope stability in another. Finally two papers were motivated by mining applications, one of them with the post-closure phase of a conventional open pit another with the exploitation phase of a relatively newer mining technique (heap pad leaching).

Another problem-related trait is the nature of the geotechnical materials that are dealt with. In most contributions (6) fine-grained materials are dominant, two deal with granular materials and one (Castellaro, 2016) is surprisingly unspecific in this respect. Of those dealing with fine grained soils, four are about soft clays and silts, and two with stiff overconsolidated clays. Granular soils are also varied, featuring both conventional quartz sand and run-of-mine ore.

Table 1 Characterization techniques employed by the session contributors. CPT(+): CPT and derived techniques. BH+LAB: laboratory tests on recovered soil samples. DMT/SDMT: Flat dilatometer / Seismic flat dilatometer GPHY: geophysical techniques. RC: resonant column

	Characterization techniques					
Authors	CPT(+)	BH + LAB	DMT / SDMT	GPHY	monitoring	other
Castellaro				Y	y	passive seismic survey
Cavallaro et al		Y	Y			RC
Harianto et al.		Y			y	
Iftekhar		Y			Y	physical model
Jaditager & Sivakugan		Y				
Karim & Rahman					Y	
Pérez & Ale		Y		Y		MASW, large TX
Peiffer	Y		Y		Y	
Totani		Y	Y		Y	torpedo DMT

Most contributions describe several properties of the soils under study. However, in many cases it is easy to identify one geotechnical property where the characterization emphasis lies. As can be seen, in a relative majority of contributions (3) the main issue was that of dynamic characterization, with two more contributions dominated other by stiffness-related properties, either operative stiffness or resilient modulus. In the two contributions related with OC clays the issue was one of surface failure detection. One contribution dealt mostly with permeability and, finally, another presented a general stratigraphic picture of a site.

Table 2 Problem-related traits of the different session contributions. OC: over consolidated

Authors	Driving application	Materials	Characterization emphasis
Castellaro	seismic risk	not specified	structural dynamics
Cavallaro et al	seismic risk	OC silty clay	Gmax, damping
Harianto et al.	road embankment	soft clay	settlement
Iftekhar et al.	railtrack	sand	Settlement under cyclyc loading
Jaditager & Sivakugan	dredging	soft soils	Profiling
Karim & Rahman	road embankment /rail cutting	soft clay /glacial till	permeability
Pérez & Ale	heap leach mining	Run-of-mine ore (sandstone)	Gmax, friction
Peiffer	opencast mining	OC clay	failure surface detection
Totani et al.	forensic slope analysis	OC clay	failure surface detection

2.4 *Method related traits*

Several traits of the scientific methodologies employed by the different authors are collected in **Error! Reference source not found.**. The scientific emphasis of the different contributions is quite varied. Groundwater effects are dominant in the cases reported by Totani et al., Karin & Rahman and Jaditager & Sivakukan, generally through its effect on failure properties, although with very different scales at play -from slope stability to dredging. Different aspects of soil-structure interaction are dealt with by Castellaro, whereas Cavallaro and Pérez y Ale deal with seismic site response either of natural soils or of man-made fills.

In three cases there was use of large scale in situ tests or of physical models to aid in the characterization problem. Some are particularly interesting because they represent unique data sources in relatively unexplored corners of geotechnics. This is the case, for instance, of the paper by Iftekhar et al (2016), who present five large scale fatigue model tests on a model railway infrastructure with geogrid reinforcement. The tests reported include careful observations of settlement and stress evolution during hold periods in between cyclic load sequences.

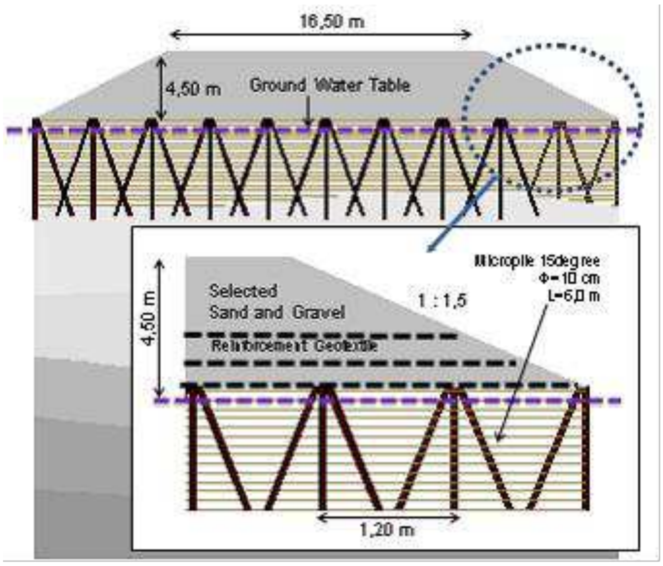


Figure 2 Cross section of wooden pile reinforced embankment tested by Harianto et al. (2016)

Another test, this time full scale, is reported by Harianto et al (2016). They test different configurations of wooden piles for embankment foundation reinforcement (Figure 2). The use of wooden piles for soil reinforcement purposes is a technique that has very ancient precedents. It is infrequent to see reports documenting in detail their benefits for large scale civil engineering projects such as the one presented here.

It is also interesting that in most cases the characterization was linked with numerical analysis of different kinds (Finite Elements, Finite Differences, Limit Equilibrium…). In most cases it was through a direct route in which the geotechnical site investigation produced parameters that were later applied to make different numerical predictions. However there were examples of inverse analysis, in which the numerical tool itself was a key part of the characterization effort. This was particularly the case of the contribution by Karin & Rahman (Figure 3).

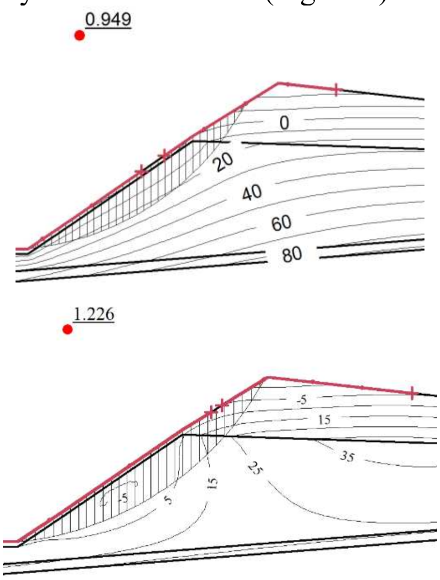


Figure 3 Computed pwp profiles and FoS for slope failure in two hydraulic characterization scenarios (Karin & Rahman, 2016)

Table 3 Method-related traits of the different session contributions. N: no. Y: yes. NE: not explicit. EA: explicitly acknowledged. F: formal treatment. NA: not applicable

Authors	Scientific emphasis	Test site	Analysis method
Castellaro	soil-structure interaction	Y	NA
Cavallaro et al	ground response analysis		Elastic multi-layer transfer function
Harianto et al.	timber piles	Y	NA
Iftekhar et al.	fatigue (cumulative settlement)	Y (scaled)	NA
Jaditager & Sivakugan	dredgeability	N	NA
Karim & Rahman	backanalysis; effects of saturation	N	FEM
Pérez & Ale	stress dependency of properties	N	FDM
Peiffer	Re-consolidation detected via DMT KD	N	FEM
Totani et al.	groundwater controls on slope stability	N	LEQ

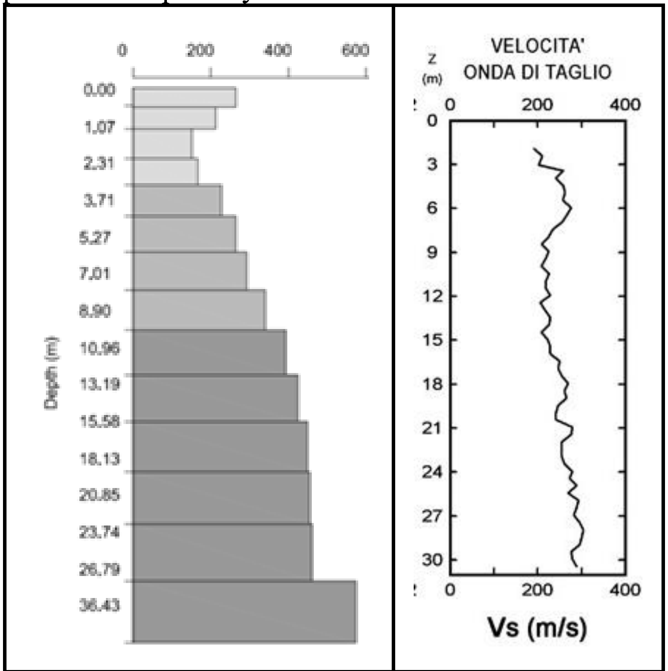
3 SOME HIGHLIGHTS

Many lessons may be extracted from reading the papers presented to the session. What follows are some reflections based on the reporter subjective interests.

3.1 *Shear wave profile: how distinctive?*

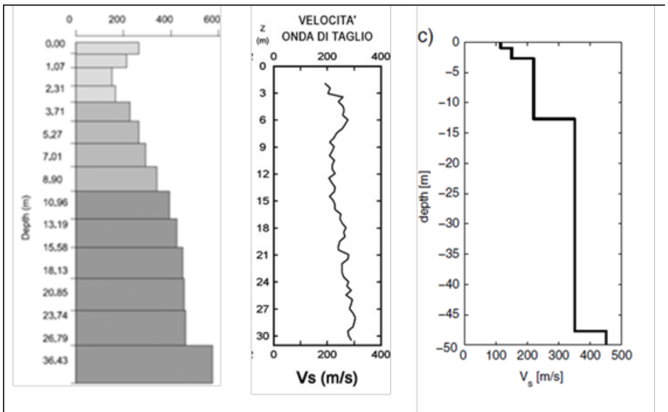
Several papers submitted to the session present profiles of shear wave velocity against depth. It is somewhat surprising to note how very different geotechnical materials may result in similar shear wave velocity profiles. In Figure 4 the profile obtained by Pérez & Ale (2016) on the crushed sandstone that constitutes the heap leach pad they describe is presented side by side with that obtained by Cavallaro et al (2016) in the overconsolidated clay underneath the Bellini gardens in Catania. The medium grain size of these two materials is in a ratio of 2000. The frictional strength is almost in a ratio of 2. The shear wave velocity is roughly within 0.2 of their average.

Even if the comparison between these two profiles may be somewhat distorted by the different technique employed to obtain them, (spectral analysis of surface waves in the pad, downhole SDMT in Catania), it seems that the possibilities of identifying the soil type by its shear wave profile are small. Indeed, the reader is invited to reflect for a second on the profile presented in another session paper by Castellaro (2016). Perhaps inadvertently the type of soil was not precisely identified, although an indication of the location was given (Po river plain). However, that is somewhat too broad: within the Po river plain one may found both profiles dominated by coarse gravels and by clays (Amorosi & Colalongo, 2005). If only the shear wave velocity profile was provided (Figure 5) and the previous examples from the session, it would be hard to decide if that was a gravel or a clay site. In this respect it is instructive the comparison with the work -presented in a different session of the conference- by Sastre et al (2016). There the authors present an -apparently successful- automated method of grain size class soil classification based on the results of a dynamic hand- held probe. Perhaps the success is due to it being a failure test? The reader is left wondering if attempts to relate shear wave stiffness to failure related soil properties (e.g. liquefaction susceptibility) may not be more based in convenience of measurement than in predictive capability



Crushed sandstone $D_{50} \approx 10$ mm φ' = 37 (Pérez & Ale)	OC silty clay $D_{50} \approx 5$ µm φ' = 24 (Cavallaro et al.)

Figure 4 Profiles of shear wave velocity against depth for two cases described in the session: very different soils result in quite similar profiles



Crushed sandstone $D_{50} \approx 10$ mm (Pérez & Ale)	OC silty clay $D_{50} \approx 5$ µm (Cavallaro et al.)	Unknown material $D_{50} \approx$? (Castellaro)

Figure 5 Profiles of shear wave velocity against depth for the two cases above plus one extra profile from a site with unspecified soil type.

3.2 *Dynamic properties: how precise?*

Perhaps the dynamic properties of soils reflect too many factors of soil composition and state to be useful as a stand-alone classificatory. On the other hand enhanced precision in measurement may allow refined discrimination. The need for precision in dynamic property measurement is also well illustrated by the results presented in the paper by Castellaro (2016).

In that paper an interesting case is presented in which two apparently identical buildings, located on the same site responded differently to an earthquake excitation. One of them suffered significant damage, whereas the other did not. Modal analysis based on passive excitation of the buildings is presented revealing some differences in their dynamical response, that are attributed to modest changes in internal structural details. The author rightly emphasizes the importance of soil-structure interaction studies for risk analysis, but, apart from that it is also significant that the back-analyzed eigenfrequencies of the two buildings differ by less than 20% This is a level of precision that is not often requested in other areas of geotechnical analysis.

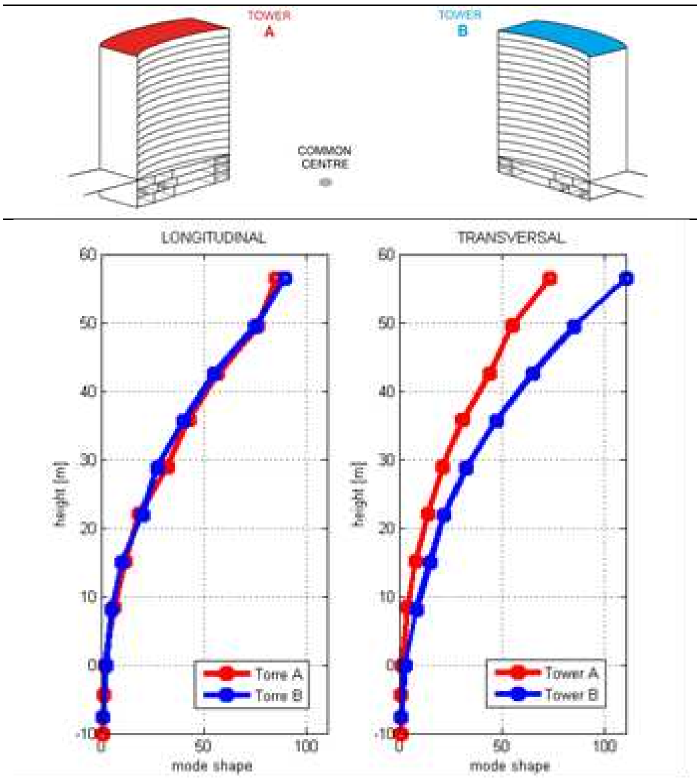


Figure 6 Dynamic response of two apparently identical buildings that responded differently to an earthquake (Castellaro, 2016)

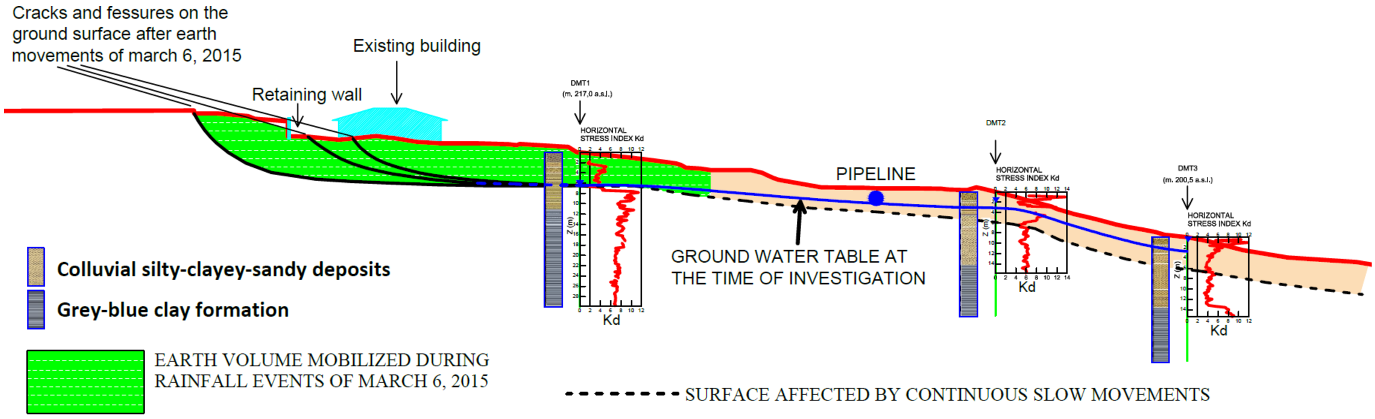


Figure 7 Use of DMT Kd profiles to detect sliding surface location (Totani et al. 2016)

3.3 *SDMT: the multitasking instrument*

It is not always appreciated the variety of purposes that a SDMT profile might serve. We have already mentioned the example in this session in which the instrument is used to obtain a shear wave velocity profile. The other two examples coincide in illustrating a very different application (Figure 5) that of detecting failure shear surfaces, much faster than what is generally possible with inclinometers.

4 FINAL COMMENTS

A large deal of ingenuity is shown in the papers contributed to this session to illustrate, advance and extend the techniques of geotechnical characterisation. The variety of purpose and geotechnical setting of the case histories reported will surely help the readers to extract individual or collective lessons from them.

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