General Report for TC102
In-Situ Testing

Rapport général du TC102
Essais in-situ

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ABSTRACT: An overview of all the technical papers accepted for the in-situ testing session of the 18th ICSMGE is presented. Forty two papers submitted to this conference were considered as part of this session. The papers were grouped into four major categories: site characterization, technological advances, geotechnical analyses and behavior, and soil and rocks properties. The objective of this report is to present an overview of the theme topics and briefly discuss the major contributions achieved by these papers.

RÉSUMÉ : Un aperçu de tous les articles acceptés à la conférence dans la session «Essais in-situ» du 18e CIMSG est présenté ici. Quarante-deux écrits soumis à cette conférence ont été considérés comme faisant partie de cette session. Les documents ont été regroupés en quatre grandes catégories: la caractérisation du site, les progrès technologiques, les analyses géotechniques, les comportements et enfin les propriétés des sols et des roches. L'objectif de ce rapport est de présenter une vue d'ensemble de tous les sujets et de discuter brièvement des contributions majeures apportées par ces documents.

KEYWORDS: In-situ tests, site characterization, technological advances, geotechnical analysis and behavior, soil and rock properties.

1 INTRODUCTION

Site characterization is the first step on all geotechnical projects and the objectives generally relate to the definition of the stratigraphic profile and groundwater level, estimation of the geotechnical properties from each soil unit, identification of critical layers, definition of geotechnical design parameters and indication of required, if necessary, additional laboratory tests.

The traditional methods for site characterization rely basically on drilling, sampling and laboratory tests. These are usually time consuming and, in some cases, over budget. The "modern" approach, on the other hand, focuses on the rational use of in-situ penetration tools coupled in some cases with geophysical techniques. Of course, the success of an efficient site characterization program depends on clearly defining the scope or objectives of the enterprise and, in some cases, combined site investigation techniques are adopted – as will be demonstrated through the papers of this session.

Hence, TC102 sessions of the conference contain papers with distinct investigative approaches and scopes. Some have presented new testing devices; others new characterization or interpretation methods. Some have described real case studies where the site characterization was a major issue, whereas others discussed the interpreted soil and rock properties to be used as input for routine geotechnical analyses.

Most of the contributions deal purely with in-situ investigation tools, but many have mixed it with laboratory or numerical investigation techniques. As presented in Figure 1, the majority of the papers are "European' in essence, which is expected for the 18th ICSMGE held in this continent.

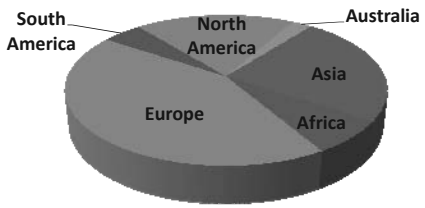

Figure 1. Paper distribution by continents for this conference session.

Figure 2.a shows the distribution of all papers in this session that used any particular in-situ testing technique as a major site investigation tool. Notice that most of the papers used more than one technique. From this, it is possible to realize that CPT and SPT were the more widely-employed tools amongst the published papers. Figure 2.b depicts, from the universe of papers that solely adopted CPT or SPT (or both) as site tool, which interpretation techniques were adopted. It is clearly evident that empirical approaches still form the dominant interpretation group, although in many papers it has been used together with other complementary methods.

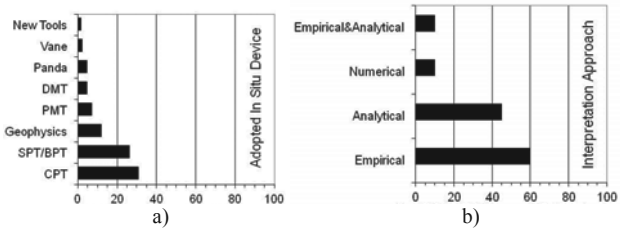

Figure 2. a) Percentage of all papers in the session that used the listed in-situ technique among others site investigation tools and b) Percentage of (only) CPT and/or SPT papers in the session that adopted the listed approach to interpret the data, among other techniques.

Figure 3 shows the types of geotechnical formations that served as the major soil stratum for the employed investigative techniques. It is clear that the great majority of the presented papers are concerned with sedimentary deposits, whereas few of them focused on "less classical" materials such as residual (tropical) soils or man-placed tailings and compacted earth fills.

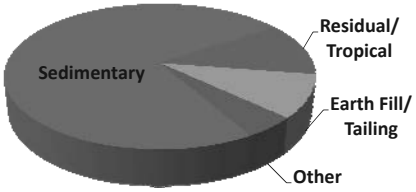

Figure 3. Percentage of geomaterial types addressed in this section.

This report is organized into several major topics and subject areas, as follows: site characterization (4 papers), technological advances (9 papers), geotechnical analyses and behavior (14 papers), and soil and rocks properties (15 papers), leading to a total of 42 papers. The main objective is to present an overview and the advances on the main addressed topics of this Conference Session, hence summarizing and emphasizing the important contributions from the papers.

Table 1 presents a summary with the main topics and subtopics addressed for each of the listed papers, together with the adopted investigation tools (in-situ or laboratory), the main soil type, the investigation approach, and a short 1-line summary of the paper's prime objective & contribution. Given such cited divisions, the papers will be reported under each of the defined topics and subtopics, as it follows next.

2. SITE CHARACTERIZATION

In this Conference Session, four papers dealt with site characterization; two of them are related to soil classification and the other two are more focused on geotechnical modeling.

2.1. Soil classification

The paper written by *Serratrice* proposes a classification method for natural soils based on piezocone test data. Two aspects are considered to classify the soils with liquefaction potential, the drained and undrained strength via triaxial tests and the soil's density. The method is presented and applied in two examples where CPTU data are available in homogeneous clayey deposits.

The paper from *Baud & Gambin* presents a contribution to enhance the Pressiorama® diagram with the extra rheological factor "α", which was originally introduced by Ménard on his design method. The authors used very good quality self-bored PMT tests (STAF technique) in several soil types, from soft clays to rock to obtain E_M/p_{*LM} values. They proposed a re-evaluation of the rheological factor α and the findings are given by an equation graphically expressed in the Pressiorama®.

2.2. Geotechnical modeling

The paper from *Ivšić et al.* discusses the applicability of the RNK-method for spatial engineering & geological and/or geotechnical modeling. This method was tested on many landslides in Croatia and it allows the differentiation of the minimum shear strength zone, or regions of different hydraulic conductivities and varied soil densities. The proposed model was verified by measurements of lateral movements in the landslide area and by results of stability analyses. They concluded that the RNK-method can be used in the study of landslides and slope stability by searching the zone of minimum shear strength.

The paper from *Steenfelt et al.* presents the use of in-situ and laboratory tests for site characterization on an important on-going infrastructure project in China. A very extensive site investigation campaign was carried out comprising geotechnical boreholes, CPTUs and seismic testing with associated advanced laboratory testing. The paper described the results and the interpretation technique used to provide ground stratification and stiffness variations to be used in design. They concluded that the CPTU was a important tool for a clear geological unit delineation, which also allowed a robust and safe design.

3. TECHNOLOGICAL ADVANCES

In this Conference Section, nine papers were selected to be part of the technological advances (main) topic; three of them presented new uses of in-situ testing technologies and six dealt with new types of in-situ testing tools (or apparatuses).

3.1. New uses of in-situ technology

Kim's et al. paper has an environmental appeal since it deals with the geological CO_2 sequestration as an effective mean of reducing the emissions of carbon dioxide. The problem pointed out in the paper is that forward strategies and technologies of CO_2 sequestration in Korea need to be specified depending on the geological conditions of potential sites (in Korea). The authors reviewed the geological characteristics of CO_2 storage projects around the World and also discuss the suitability for CO_2 sequestration. A systematic and quantitative evaluation method to assess the storage and economic efficiencies of sedimentary basins in Korea using dimensionless values between 0 and 1 was applied (Figure 4). The paper also discusses the potential of using geophysical tests to assess the suitability of field strata for CO_2-storing, and to monitor CO_2 movement and possible leakages.

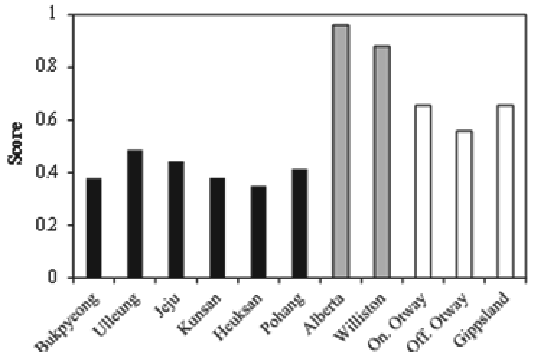

Figure 4. Score for suitability for Korean sedimentary basin *(Kim et al)*.

The paper from *Fenton & Hicks* discusses the uncertainty associated with site characterization and it focused specifically on the effect of number of samples on residual uncertainty. The results can be used to quantitatively select the required number of samples needed to achieve a target maximum residual uncertainty level. A statistical approach was used to study this problem and it was concluded that the accuracy improves as the number of samples and the correlation length increases.

Somasundaram et al. present the characterization and settlement modeling of deep inert debris fills. Inert fills can be considered as a non-text book type geomaterial since they are difficult to characterize and model by current geotechnical methods, due to their inherent heterogeneity, very large particle sizes, and nested and voided structure. The authors presented an approach to characterize a 54 m deep inert debris fill, to model its settlement behavior under seismic loading and groundwater level rise, and to develop remedial measures to render it suitable for development.

3.2. New in-situ tools

Jacquard's et al. paper presents a new probe to overcome the limitation of Menard type pressuremeter tests, i.e., the difficulty of reaching large expansion volumes and pressures. This new device allows for the volume of the hole to be doubled, even under high pressures. The authors described the technological innovations that increased the capabilities (and reliability) of the pressuremeter probe as well as presented comparative tests on different sites to demonstrate the advocated technical advance in this enhanced PMT device.

In *Rito & Emura* paper a new type of sampling method called '*Koken wire line system*' is developed (Figure 5) to retrieve high depth undisturbed samples in deep Pleistocene clay and sand layers at the Kansai International Airport area. The authors also developed two different pore pressure measuring devices, and concluded that both the sample quality and the measured values were respectively of high quality and with reasonably good accuracy to be used in the settlement design of the subsoil of this airport, in Japan.

Table 1. Summary of the general characteristics from each of the papers for Technical Section TC 102 (In-Situ Testing).

Main Topic		Author / Paper	Main Investigation Tool																Studied Soil Type						Investigation Approach							Objective or Major Contribution
			In Situ										Laboratory																			
Site Characterization	Subtopics		SPT / BPT / SWS	CPT	DMT	PMT	Panda/DCP	Geophysics	Borehole Sampling	Permeability	New Device	Other Type	Index	Oedometer	Uniaxial / Triaxial	Simple / Direct Ring Shear	Proctor / CBR	Other Type	Sand / Gravel	Silt / Clay	Residual / Tropical	Earth Fill / Tailing	Rock / Saprolite	Other Type	Empirical	Analytical	Numerical	Instrumentation	Calibration Chamber	Field Data	Probabilistic Statistical	Experimental	
	SC	Serratrice		X											X					X					X					X			Classification of soil sensibility via CPT tests
		Baud & Gambin				X													X	X			X			X						X	Enhancement of soil type interpretation via PMT tests
	GM	Ivsic et al.	X										X			X				X			X		X	X		X					Model for landslide analysis via site correlations
		Steenfelt et al.	X	X				X	X				X	X	X				X	X			X		X	X				X	X		Site characterization for tunnel design
Technological Advances	NU	Kim et al.							X				X					E	X													X	Storage of CO_2 emissions in sedimentary basins
		Fenton & Hicks							X																						X		Technique for optimum soil sampling
		Somasundaram et al.	X					X				LS	X									X				X	X			X			Site techniques to characterize and analyze debris fills
	NI	Jacquard et al.		X		X					X								X	X						X				X		X	Details of a new high volume PMT probe
		Rito & Emura							X		X			X					X	X										X		X	Details of a new high depth sampler and piezometer
		Kayser et al.									X		X					NS	X	X						X			X			X	Scour evaluation for piers via new in-situ probe
		Giacheti et al.	X					X			X										X				X					X		X	Development of seismic SPT for residual soils
		Frost & Martinez		X							X								X	X					X					X		X	CPTu upgrade with a new multi sensor device
		Monnet									X				X			P	X	X						X	X		X	X			Development of a new enhanced PMT probe
Geotechnical Analysis and Behavior	DI	Yasufuku et al.	X						X				X	X	X				X	X						X				X			Rational use of in-situ and lab. tests for foundations
		Cao et al.	X									SS	X					NS	X	X			X			X	X	X					Field instrumentation and results of a pile curtain wall
		Hokmabadi et al.																ST			X						X					X	Dynamic soil-structure analyses for piles
		Amoroso et al.			X			X	X				X			X			X	X			X		X		X			X			Potential use of SDMT in a real case investigation
	FC	Haza-Rozier et al.										SS								X								X					Improvement of the behavior of a soil foundation
		Svinkin										SS							X	X						X							Issues on ground vibration by pile driving
		Matesic et al.	X	X					X			LT						NS	X	X							X	X		X			Field tests to monitor the foundation of oil tanks
		Jeon & Mimura							X										X	X							X	X					Soil foundation deformation of an offshore airport
		Chou et al.																			X									X			Field survey of affected region after Morakot typhoon
		Lin et al.									X										X					X		X		X			Soil erosion via multiscale sediment monitoring tool
		Al-Saoudi et al.											X					NS						GS								X	Geotechnical properties of gypseous soils via lab. test
		Shulyatiev et al.										LT	X					NS		X							X			X			Parameters from field load tests on barrette type piles
		Chen et al.																					X			X		X					Study of cuttability index for tunnel excavation
		Bellato et al.											X			X			X							X						X	Assessment of cutter soil mixing samples in the lab.
Soil and Rock Properties	NT	Baud et al.				X														X			X			X							Shear modulus degradation assessment via PMT tests
		Benz et al.					X							X	X				X	X						X			X			X	New interpretation approach for Panda penetrometer
		Nishimura et al.	X															NS				X			X						X		Earth fill investigation using probability analyses
		Poulsen et al.		X					X											X					X					X			Influence of CPT penetration rate in silty soils
		Galaa et al.							X	X			X						X	X					X	X				X	X		Hyd. conductivity determination of glacial deposits
		Phoon & Ching	X	X								FV			X	X			X	X						X					X		In-situ parameters via reliability-based approach
		Motaghedi et al.		X									X		X	X			X	X						X				X			CPTu strength values via capacity-based equation
	PE	Tumay et al.		X					X				X						X	X										X	X		Organic content assessment for sedimentary soils
		Mulabdic		X	X				X				X	X			X			X		X			X					X			Characterization of a compacted dam via in-situ tests
		Zabielska-Adamska											X				X							FA	X							X	Assessment of a compacted soil via CBR tests
		Chapuis	X						X	X									X	X						X				X	X		Scale effects in the permeability of sandy aquifers
		Mlynarek et al.	X	X				X											X	X					X					X	X		Deformation moduli from jointed CPT & DMT tests
		Liu et al.		X									X	X						X					X					X	X		Practice and correlations of CPTu tests in China
		Espinace et al.					X						X					NS				X			X			X			X		Control of tailing dams with the Panda penetrometer
		Hanza & Shahien		X					X				X	X						X					X					X			Correlations on drained compressibility parameters

SC=Soil Classification, GM=Geotechnical Modeling, NU=New Uses of In-Situ Technology, NI=New In-Situ Tools,, DI=Design Improvement, FC=Field Conditions/Site Performance, NT=New Theoretical Advances, PE=Parameter Evaluation. SPT=Standard Pen. Test, BPT=Becker Pen. Test,, SWS=Swedish Weight Sounding, CPT=Cone Pen. Test, DMT=Dilatometer Pen. Test, DCP=Dynamic Cone Probing, LS=Large Scale Density, FV=Field Vane Test, SS=Stress Strain Sensors, LT=Load Test, CBR=California Bearing Ratio, P=Permeability, ST=Shaking Table, E=Eletroresistivity, G=Geophysics, NS=Lab Test adopted but Non Specified, GS=Gypseous Soil, FA=Fly Ash.

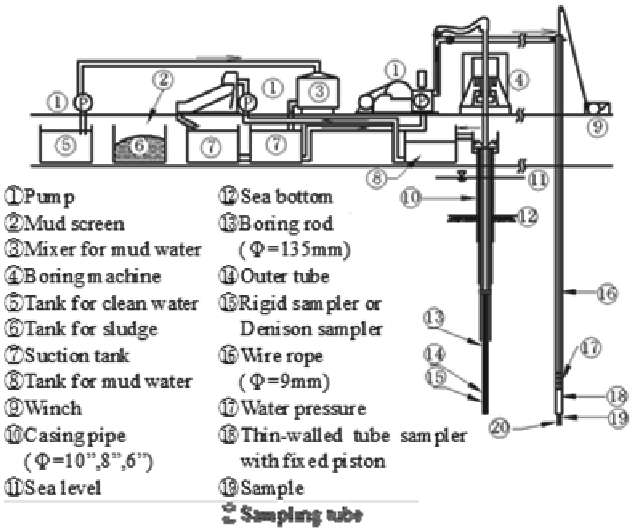

Figure 5. The *Koken wire line* sampling system *(Rito & Emura)*.

The paper from *Kayser et al* describes an approach to assess soil scour potential through the use of the In-Situ Erosion Evaluation Probe (ISEEP), which is advanced by water jetting. Soil erosion parameters were assessed for silty sand in terms of a critical stream power (critical shear stress and detachment rate coefficient). Scour depths around a circular bridge pier were also computed using ISEEP data, and compared with an empirical approach available in literature.

Giacheti et al briefly describes a test which associates the up-hole technique to the SPT, the "seismic SPT" (Figure 6). This hybrid test allows the determination of the maximum shear modulus (G_0) together with the N value in a unique test. The paper also presents and discusses cross-hole, down-hole, SCPT and SPT test data for a Brazilian tropical sandy soil to emphasize the advantage of using the interrelationship between the small strain stiffness (Go) and the ultimate strength (N value) to identify and characterize different soil behaviors.

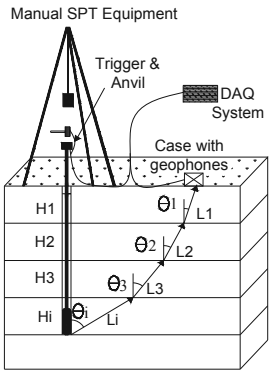

Figure 6. S-SPT test and a seismic refracted path (*Giacheti et al*).

Frost & Martinez enhances the well-established cone penetration test with an extra multi-sleeve penetration attachment (Figure 7). The new CPT probe incorporates a series of friction sleeves with varying surface textures and a torsional load sensing capabilities along with a series of pore pressure sensors, in addition to the standard smooth friction sleeve and pore pressure sensor located behind the tip. They advocate that the multiple measurements made with this device allow it to provide a new insight into the characterization of soil types, besides of establishing relations between stratigraphic variations and in-situ shear strength with the texture height of the sleeves. The authors really consider that the multi-sleeve technology CPT offers significant benefits over other devices to measure the mechanical response of soils.

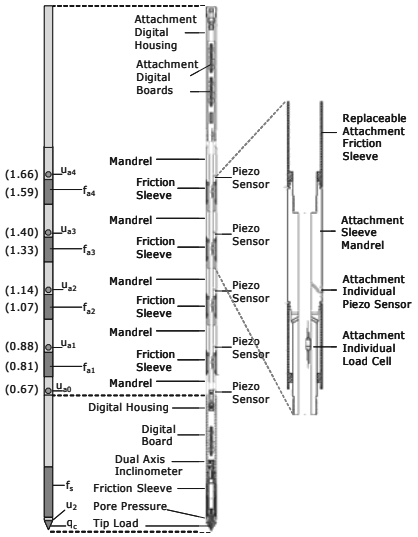

Figure 7. The multi-piezo-sleeve friction penetrometer along with a standard CPT probe (*Frost & Martinez)*.

Monet presents a new in-situ testing device called the "Geomechameter", i.e. an evolution of the pressuremeter. This new device uses the forces generated by water flow around the probe. The hydraulic flow allows the control of the level of vertical stress at the test depth. The influence of this stress is hence taken into account in the test interpretation. The new probe can also evaluate the soil permeability and sensibility to erosion. It was validated by direct comparison with mechanical properties from triaxial tests and permeability values from Lefranc type injection tests.

4. GEOTECHNICAL ANALYSIS AND BEHAVIOR

Fourteen papers in this Conference Session were grouped in the topic of geotechnical analysis and behavior; four of them dealt with design improvement and the other ten addressed field conditions and/or site performance.

4.1. Design improvement

The paper from *Yasufuku et al.* emphasizes the importance of integrating the geotechnical investigations with pile foundation design. Figure 8 shows the policy and concept of geotechnical investigation & design for the studied case, i.e. the construction of the connecting bridge for New-Kitakyushu airport. A rational method for evaluating the pile bearing capacity was presented which reflected the soil characteristic values and the geological environmental history. They concluded that field and laboratory investigations with a reasonable geotechnical consideration sharply decreased the total cost of the bridge in the studied case.

The paper from *Cao et al.* studied the performance of a deep excavation in downtown Toronto. They presented field measurements of soldier pile walls installed into clayey soils and shaly rock. The authors assessed the method of deducing wall bending moments from inclinometer measurements, among other aspects. The paper provides recommendations for such walls when designed in similar geotechnical conditions.

The paper from *Hokmabadi et al.* studies the seismic response of superstructures on soft soils. Shaking table tests and three dimensional numerical simulations using FLAC3D were carried out to investigate the influence of the soil-pile-structure interaction on the seismic response of a 15-storey moment resisting building, supported by end-bearing pile foundations. The authors observed a good agreement between the numerical predictions and the experimental data confirming the reliability of the numerical approach.

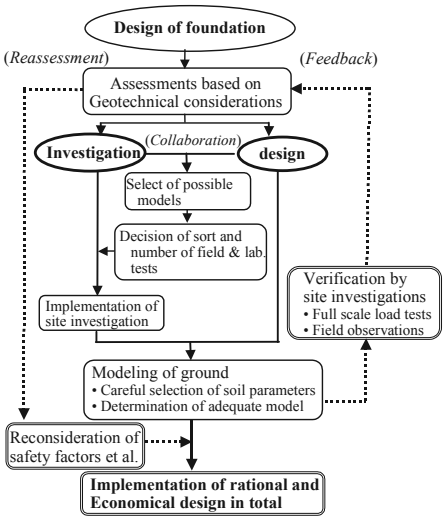

Figure 8. Collaboration of geotechnical investigations with design (*Yasufuku et al*).

Amoroso's et al. paper presents a case history emphasizing the use of the seismic dilatometer (SDMT) as a powerful site investigation tool on the restoration design of an historical building which was damaged by the 2009 L'Aquila earthquake. The investigation of the foundation also included boreholes and laboratory cyclic simple shear tests. The paper presented the interpretation of SDMT for determination of soil profiling, shear wave velocity, constrained modulus and horizontal stress index, which when, combined with lab data, allowed a better understanding of the building's response during the earthquake.

4.2. Field condition and/or site performance

Haza-Rozier et al. study the behavior of a soil foundation improved by rigid columns to support wind turbines. This foundation was fixed on a rigid slab, lying on a granular layer, improved by 84 rigid columns. The authors monitored the structure behavior during excavation, machine construction, and over a period of time for the working service of the wind turbine. They observed that the working platform induced an important confinement of the columns' heads with subsequent small levels of displacement.

Svinkin's paper discusses the controversial and contradictory evaluations of ground vibrations from pile driving theories. He pointed out that pile driving is a powerful and wide-spread source of construction vibrations which may detrimentally affect adjacent or remote structures. The paper thus presented several issues in the assessment of ground vibrations generated by pile driving.

The paper from *Matešić et al.* presents a case history with the use of hydro test results for designing steel tanks on improved ground with 660 stone columns. The authors described the conducted hydro tests as part of a technical monitoring assessment from all elements of the tank structure. The paper presents and discusses all experimental data and states that they could be wisely used to improve the tank design.

Jeon and Mimura present elasto-viscoplastic FEM analyses to assess the long-term deformation of a reclaimed island over a Pleistocene foundation from the adjacent construction of an offshore (twin) airport. It is a numerical modeling paper where simulation was compared to instrumentation results. The authors introduced the concept of "mass permeability" to model the excess pore water pressure dissipation and concluded that it functioned well to assess the long-term deformation of the foundation, including the interactive construction behavior.

Chou´s et al. paper discusses survey results of damaged areas after a flood disaster caused by the 2009 Morakot Typhoon in Taiwan. A comprehensive site survey was conducted after the flood disaster and ten failure mechanisms were identified depending on the different geological environments. The paper presented the site survey observations, analyzed the causes and mechanisms of failures, and drafted strategies and suggestions for the restoration projects.

The paper from *Lin et al.* uses a multi-scale sediment monitoring device to assess the remediation effectiveness on a watershed reservoir after sedimentation processes were originated by the same typhoon cited on *Chou et al*. It is stated that it caused unprecedented landslide and sediment-related disasters in mountain areas of the Tsengwen reservoir watershed, drastically reducing its storage capacity. Hence, the paper describes the method and how to systematically study and analyze soil erosion and landslide areas with the aid of sediment accumulation trapping dams and aforementioned device.

Al-Saudi et al. is another paper that deals with a non-text book type geomaterial: gypseous soils, another "problematic" soil given its intrinsic characteristics. According to the authors, it covers about 20 to 30 % of total Iraq area. An important characteristic of this soil is the collapsibility, a sudden and large volumetric strain when exposed to water. Proposals for soil treatment are presented, focusing on the control of settlement by reducing or even preventing humidity changes within the soil foundation.

Shulyatiev´s et al. paper presents a case study related to the construction of the Okhta-center high-rise tower in St. Petersburg. Static load tests on real scale barrette pile types were carried out to adjust the design soil parameters. The paper also presents a comparison between the derived bearing capacity values and those from Russian and foreign building codes. The authors concluded that pile tests are an effective way to calibrate design parameters for usage in real case designs.

The paper from *Chen et al.* presents a generalized (dimensional analysis type) solution to be used into underground geological-mechanical interaction excavation problems. The model groups the geological characteristics into three categories: brittle (rock-like), ductile (soil-like), and brittle-ductile (gravel-like), with respect to thrust and force cuttings. Two case histories are presented to validate the approach to assess the efficiency of a tunnel cutting machine.

Bellato´s et al. paper presents a case study to discuss the quality control of Cutter Soil Mixing (CSM), i.e., a relatively new deep mixing method suitable for various types of ground improvement. The materials and the testing program were described in the paper. The obtained results under an innovative experimental apparatus underline the influence of the physical, and chemical, characteristics of the natural soil on the strength gain of the stabilized materials.

5. SOIL AND ROCK PROPERTIES

In this Conference Session, fifteen papers were selected to be part of this main topic where seven of them presented new theoretical advances as a major subtopic and eight dealt with the evaluation of geotechnical parameters.

5.1. New theoretical advances

The paper from *Baud et al.* discusses stress-strain hyperbolic curves obtained with a self-boring Ménard PMT test. The authors determined E-moduli values by assimilating the pressure-volume plot of a Ménard PMT to a 2nd degree hyperbolic arc. The self-boring Ménard PMT tests were carried out using a self-bored steel slotted tube implemented either by the STAF® technique, or by the ROTOSTAF® method. The authors derived the hyperbolic best fit of the plotted readings to obtain an original equation of the radial borehole expansion, $\varepsilon = f(G_0, p_o, p_{LM}, P_L)$. After that, they derived the tangent modulus G_t for each reading and the corresponding G_t/G_0 ratio as a

function of ε, and similarly the secant modulus G_s. The authors affirmed that their variation can be well compared with those given by the usual hyperbolic model, except for cases with very small initial strains. They concluded that the results are similar to those obtained by laboratory tests and geophysical surveys.

Benz´s et al. paper presents the recent developments achieved on the Panda 3® dynamic penetrometer to improve its use for site characterization. This new improvement is schematically represented in Figure 9 including a typical test result. According to the authors the load-settlement σ_p-s_p curve can be derived from the measurement and decoupling of sonic waves created by each impact of the penetrometer, which allows the determination of the strength and deformation parameters. The paper presented calibration chamber test data for two different soils to validate the given results. It was observed a good repeatability and sensibility to the soil conditions. The authors compared the results with those obtained by triaxial and oedometer tests and also found a good agreement for sands. This new test is now currently used in the field to improve the derivation of geotechnical soil parameters via site derived load-settlement Panda curves.

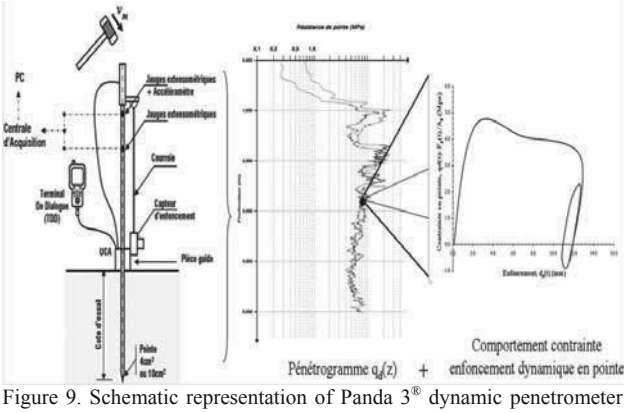

Figure 9. Schematic representation of Panda 3® dynamic penetrometer with a typical test result (*Benz et al*).

The paper from *Nishimura et al.* presents the use of the Swedish Weight Sounding (SWS) test with the objective of making a diagnosis of man made earth-fills, hence increasing their lifetime – especially because their shear strength is generally required for investigations with this scope. The study is justified by the existence of several earth-fill dams for farm ponds in Japan, with some of them under final life stages. Although the strength can also be predicted by the SPT N-values, the authors used the SWS test as a simple method for obtaining the spatial distribution of the N-values in short interval exams. The paper also presented an indicator simulation (geostatistical) method to interpolate the spatial distribution of derived N-values. The results are used to determine degraded regions within existing embankments. The shear strength parameter was derived through the empirical correlation with the N-values, and the reliability analysis of the embankments was conducted considering the variability of the internal friction angle of the material.

The paper from *Poulsen et al.* shows how a change in cone penetration rate affects all cone penetration measurements in a silty soil. The authors emphasized the fact that for the standard rate of penetration (20 mm/s) it is generally accepted that undrained penetration occurs in clay, while it is drained in sands. Data from 15 field cone penetration tests with varying penetration rates were conducted at a sandy silt test site. Figure 10 depicts the pore pressure and cone resistance at depths ranging from 4.5 to 11.4 m for CPTs conducted with variable penetration rates (60 and 0.5 mm/s can be observed). The CPT conducted with a penetration rate of 0.5 mm/s corresponds to fully drained penetration conditions, since the measured pore pressure is close to u_0. On the other hand, the CPT conducted with a penetration rate of 60 mm/s corresponds to undrained or partially drained conditions. The authors did not observe any correlation between sleeve friction and cone penetration rates. They concluded that a correlation between the penetration rate, the cone resistance, and the derived excess pore pressure, do exist. They have also suggested an approach to determine when the penetration is partially drained or not, and how to convert it into a fully drained or undrained condition, hence changing derived geotechnical parameters.

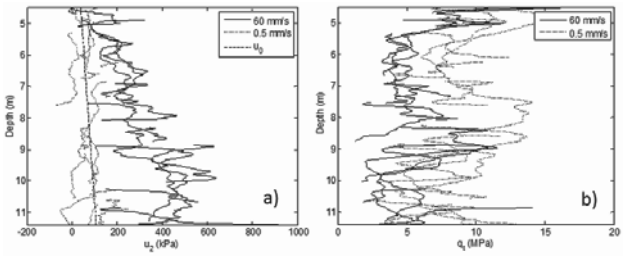

Figure 10. a) Comparison of the pore pressure and b) cone resistance carried out with penetration rates of 60 and 0.5 mm/s, with 3 CPTs test for each rate (*Poulsen et al.*).

Galaa et al. present a paper describing a methodology for establishing more representative design values for the hydraulic conductivity (K) of glacial deposits, particularly when performing large scale subsurface investigations for tunnels. They justify their study given the known glacial deposit heterogeneities and the difficulties to determine proper design values for K. The authors affirm that conventional pumping tests can not provide reliable design parameters due to their small zone of influence, and inherent variable nature of glacial deposits. Hence, the paper describes a subsurface investigation which involved 400 boreholes, 88 slug tests and 16 pumping tests. The authors established a correlation between K from the field tests (K_{field}) and K calculated by the Kozeny-Carman formula (K_{KC}). They observed that the Kozeny-Carmen formula with the incorporation of a site specific correlation factor predicted K values ranging between 1/3 to 3 times the K_{field} values. The calculated and measured K values were used to form a statistical analysis of this parameter, and to provide a more reliable design number for dewatering problems.

Phoon & Ching present a paper using a statistical approach for a better interpretation of the geotechnical data when considering soil variability. The paper presented the concept of a "virtual site" with the purpose of emulating site investigation efforts as realistically as possible. The authors affirmed that in the present time, it is still not possible to emulate every aspect of a real site deposit. So, the scope was to reproduce the information content arising from a typical mix of laboratory and field tests conducted at a site with the aim of estimating undrained shear strengths (s_u) for clays and friction angles (ϕ') for sands. However, the development of a virtual site does not replace the site investigation need, but it quantifies the uncertainty in the derived s_u and ϕ design values by incorporating into the analyses the effect of either higher quality or larger numbers of testing results.

Motaghedi et al. present a new analytical method to predict cohesion (c) and friction angle ($\prod$) using q_c, u and f_s from the piezocone test, considering the bearing capacity mechanism of failure at the cone tip and a direct shear failure along the penetrometer sleeve. The authors state that one of the advantages of this method is the improvement of the accuracy in the case of (eventually) using erroneous data related to all three outputs from the CPTu test. The paper presented laboratory test results, together with two sets of nonlinear equations derived by the proposed approach and existing correlations for both c and parameters. The authors state that the $\prod$ obtained by current techniques is relatively higher than real measured values. However, when adopting the advocated method, the comparisons indicate a good consistency with lower scatter.

5.2. Parameter evaluation

The paper from *Tumay et al.* discusses the challenge for the effective identification of organic content in the soil based on traditional CPT and CPTU methodologies. It is very important to overcome this interpretation limitation since the cone is a popular and handy tool for subsurface investigations and soil characterization. The paper presents a comprehensive CPT/CPTU-based organic content identification method using a probabilistic soil classification system. The paper describes the probabilistic method, which employs a non-traditional modeling approach that takes the uncertainty of the correlation between soil composition and soil behavior into account. The authors affirmed that the use of the compositional soil classification (U) and in-situ behavior (V) indexes for organic profiling improves the capability of determining organic material at any given depth. A detailed description of the proposed methodology and the discussion of its effective application are included in the paper.

Mulabdic´s paper presents the use of penetration testing devices, including the CPT and SDMT, for site characterization of a compacted earth dam. This is a case study of a small earth dam for which the remediation work was necessary given construction errors and the possible damage to the earth structure during the filling stage of the reservoir. The site investigation campaign consisted of drilling boreholes and carrying out in-situ tests (4 CPTs and 3 SDMTs) along the crest of the dam, complemented with laboratory tests. The paper focused on assessing the potential of these in-situ tests in describing physical and mechanical properties of the compacted (man-made) clay strata, since the traditional interpretation methods were developed for natural soils. The authors concluded that both CPT and SDMT clearly detected the inhomogeneous clay conditions. They also showed remarkable repeatability and proved to be valuable tools in characterizing the embankment quality, both in terms of non homogeneity and of physical and mechanical properties.

Zabielska-Adamska & Sulewska present the use of both static (classic) and dynamic CBR methods to establish relationships between the bearing ratio and degree of compaction of fly ash. The objective was the use of the compaction degree, and also the California Bearing Ratio, as an indicator of the soil bearing capacity in compacted material. The dynamic CBR test is described in the paper, where fly ash samples were compacted by the standard and modified Proctor methods without soaking to replicate field conditions during earth structure construction. Test results indicate that both the dynamic CBR as well as the classic CBR are closely connected with the characteristics of compaction, and can therefore be used to assess the compaction of fly ash and cohesive soils. The authors suggested that the dynamic CBR test should be widely used as an alternative way to the classical method of quality control to assess the subgrade capacity of the soil.

The paper from *Chapuis* discusses "scale effects" in the permeability of sandy aquifers. The author's initial hypothesis is that the large-scale tests are more likely to meet preferential flow paths, so yielding larger K values than small-scale tests, which may be viewed as some sort of scale effect. In the paper, the small scale was simulated via lab soil samples, the middle scale from field permeability tests, and the large scale with site pumping tests. The paper presents and discusses some few real case studies, observing that for all of them the K distributions provided consistent images of the aquifers. It was finally concluded that scale effect was not of importance for the test interpretation in such phreatic deposits.

Mlynarek´s et al. paper discusses the interrelationship between deformation moduli from CPTU and SDMT tests in overconsolidated soils. The authors point out that glaciations in Poland overconsolidated its deep soil layers. So, it is imperative to take it into account in calculations of differential settlements of structures. The paper presents deformation characteristics estimated from CPTU and SDMT tests in clays, and focuses on a method to identify soil preconsolidation and to establish relationships between deformation moduli derived from CPTU and SDMT tools. The authors concluded that the simultaneous use of CPTU and SDMT provides a continuous picture of the changes in stiffness of heterogeneous subsoil. They emphasized the need for establishing specific calibration functions for each soil type, which may be a useful tool in the construction of a model for the subsoil's rigidity based on G_0 or M_0 values.

Liu´s et al. paper reports the practice and development of the piezocone test in the geotechnical engineering field of China. In this paper, the history and current development status of CPT and CPTu in China practice were systematically presented. The most used (standard) cone has the 10 cm^2 tip area, but both 15 and 20 cm^2 CPT probes are frequently used in China. The relationship between international standardized CPTu and China's CPT is based on a large data bank of testing results related to a great number of soils. The paper presents a comparison review of the soil characterization methods in China, including the determination of stress history, deformation, consolidation and permeability characteristics.

The paper from *Espinace et al.* presents their 10 years of experience on the use of Panda® penetrometer to assess the stability of Chilean's tailings dams. The authors report around 40 cases of mechanical instability from tailing dams in Chile, which were mainly due to liquefaction, slipping of banks, or settlement. The paper presents the main results that have allowed the proposition of a new methodology to control and diagnose tailing dams. It is based on in-situ determination of the geomechanical parameters (internal friction angle and density index) using the Panda® penetrometer in order to characterize the constituent materials and their variability. The authors also pointed out that this methodology allows taking into account the variability concept for stability and liquefaction risk studies when using a probabilistic approach.

Hamza & Shahien´s paper studies the compressibility parameters of Egyptian cohesive soils via piezocone tests. The major objective was to provide additional data on drained compressibility parameters, focusing on the constrained modulus (M_o) and on the overconsolidation ratio (OCR) for cohesive soils from geotechnical investigations at seven major sites of the Nile delta river deposit in Egypt. Enhanced propositions to estimate the OCR and M_o for the studied clays are presented, allowing settlement analyses to be done with the proposed equations. The authors believe that the presented data and correlations are a valuable contribution, since it improves the current state of the art in estimating the compressibility parameters of sedimentary soils with the CPTU test.

6. FINAL REMARKS

Site characterization using in-situ testing techniques has considerably changed in the last two decades along with the rapid transformation and advances of the technology, either by the development of newer and economical electronic devices operated by laptop computers or by new mathematical and software approaches based on multi-variable, statistical or probabilistic calculations. Besides of such remarkable accomplishments, the traditional "old fashion" (past century….) laboratory and site investigation methods are still widely in use, sometimes as the preferential or unique available method. It was clear from aforementioned review that, on the 21st century, the proper site investigation, material characterization and soil behavior prediction for the geotechnical design cannot solely rely in one isolated test technique, or on simple "local" unadjusted correlations that are probably not universally valid.

Higher sensorial levels of testing tools and combined investigation procedures are surely now available that can be

applied on a more regular basis, especially for large or important jobs. Improved interpretation methods or background geotechnical theories, advanced computer software codes, and more prominent hardware equipment, should further be explored in research as well as in practical in-situ testing settings. This is a challenge for the overall community as a whole, from practitioners to academicians, manufacturers, and designers. Nevertheless it can not be accomplished without a strong change in mentality from the geotechnical field itself, moving from a "*priced-based*" design to perhaps a more expensive and sound "*quality-based*" criteria.

The papers presented in this Conference Session show how in-situ testing technology has developed, matured, and used to tackle several geotechnical problems of difficult order, for instance from the uncertainty in site characterization and understanding of different geomaterials, to the challenging task of retrieving high quality soil samples in a difficult environment. Sometimes, in standard project cases, only traditional tests were required and used for the site characterization. However, in more complex or ambivalent conditions, the usage of today's available technological advances was surely an asset for the design. Although not directly mentioned throughout this review, the human factor, i.e., the good education based on solid concepts of the geotechnical area together with the access to a free flow of technical information and knowledge, will be the key factor for the transformation of our field, and the future society, as we all envisage – with rational use of resources and technology, self-sustained projects, quality based design and environmentally safe site procedures.

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8. REFERENCES

Al-Saoudi N.K.S.; Al-Khafaji A.N., Al-Saoudi N.K.S. Challenging problems of gypseous soils in Iraq.

Amoroso S.; Totani F., Totani G. Site characterization by seismic dilatometer (SDMT): the Justice Court of Chieti.

Baud J.P., Gambin M. Détermination du coefficient rhéologique α de Ménard dans le diagramme Pressiorama®.

Baud J.P.; Gambin M., Schlosser F. Courbes hyperboliques contrainte–déformation au pressiomètre Ménard autoforé.

Bellato D.; Simonini P.; Grisolia M.; Leder E., Marzano I.P. Quality control of Cutter Soil Mixing (CSM) technology – A case study.

Benz M. A.; Escobar E.; Gourvès R.; Haddani Y.; Breul P., Bacconnet C. Mesures dynamiques lors du battage pénétromètrique– Détermination de la courbe charge enfoncement dynamique en pointe.

Cao L.F.; Peaker S.M., Ahmad S. Performance of a deep excavation in downtown Toronto.

Chapuis R.P. Permeability scale effects in sandy aquifers: a few case studies.

Chen L.; Chen Y.C.; Chen W.C., Liu H.W. A study of cuttability Indices for tunnel penetration.

Chou J. C.; Huang C. R., Shou K. J. Survey results of damaged areas in flood disaster of Typhoon Morakot and suggestions for restoration projects.

Espinace R. A.; Villavicencio G. A.; Palma J.; Breul P.; Bacconnet C.; Benz M.A .N, Gourvès R. Stability of Chilean's tailings dams with the Panda® penetrometer. Experiences of the last 10 years.

Fenton G.A.; Hicks M.A. Site sampling: assessing residual uncertainty.

Frost J. D., Martinez A. Multi-sleeve axial-torsional-piezo friction penetration system for subsurface characterization.

Galaa A.; Manzari M., Hamilton B. Hydraulic properties of glacial deposits based on large scale site investigation.

Giacheti H. L.; Pedrini R. A. A., Rocha B. P. The seismic SPT test in a tropical soil and the G_0/N ratio.

Hamza M., Shahien M. Compressibility parameters of cohesive soils From piezocone.

Haza-Rozier E.; Vinceslas G.; Le Kouby A., Crochemore O. Comportement de la structure de sol amélioré par inclusions rigides, supportant une éolienne.

Hokmabadi A.S.; Fatahi B., Samali B. Seismic response of superstructure on soft soil considering soil-pile-structure interaction.

Ivšić T.; Ortolan Ž., Kavur B. Applicability of the RNK-method for geotechnical 3D-modelling in soft rocks.

Jacquard C.; Rispal M.; Puech A.; Geisler J.; Durand F.; Cour F.; Burlon S., Reiffsteck P. Une nouvelle sonde permettant de mesurer sans extrapoler la pression limite pressiométrique des sols.

Jeon B.G., Mimura M. Long-term Deformation of the reclaimed pleistocene foundation of the offshore twin airport.

Kayser M., Gabr M. Assessment of scour potential using in-situ jetting device.

Kim A. R.; Cho G.C.; Kwon T. H., Chang I. H. Practical reviews on CO_2 sequestration in Korean sedimentary basins and geophysical responses of CO_2-injected sediments.

Lin B.S.; Ho H.C.; Hsiao C.Y.; Keck J.; Chen C.Y.; Chi S.Y.; Chien Y.D., Tsai M.F. Using multi-scale sediment monitoring techniques to evaluate remediation effectiveness of the Tsengwen Reservoir watershed after sediment disasters induced by Typhoon Morakot.

Matešić L.; Mihaljević I.; Grget G., Kvasnička P. The use of hydro test results for design of steel tanks on stone column improved ground - a case history.

Młynarek Zb.; Gogolik S., Sanglerat G. Interrelationship between deformation moduli from CPTU and SDMT tests for overconsolidated clays.

Monnet J. Le Géomécamètre, un nouvel essai in-situ adapté à la mesure des caractéristiques hydro-mécaniques du sol.

Motaghedi H.; Eslami A., Shakeran M. Analytical approach for determining soil shear strength parameters from CPT & CPTu data.

Mulabdic M. Use of penetration testing for determination of soil properties in earth dam.

Nishimura S.; Shuku T., Suzuki M. Diagnosis of earth-fills and reliability-based design.

Phoon K.K., Ching J. Construction of virtual sites for reliability-based design.

Poulsen R.; Nielsen B. N., Ibsen L. B. Correlation between cone penetration rate and measured cone penetration parameters in silty soils.

Rito F., Emura T. Sampling method and pore water pressure measurement in the great depth (-400m).

Serratrice J.F. Une méthode de classification de la sensibilité des sols au moyen du piézocône.

Shulyatiev O.; Dzagov A.; Bokov I., Shuliatev S. Correction of soil design parameters for the calculation of the foundation based on the results of barrettes static load test.

Somasundaram S.; Khilnani K.; Shenthan T., Irvine J. Characterization and modeling settlement of deep inert debris fills.

Songyu. L; Guojun. C; Anand J. P., Yanjun D. Practice and development of the piezocone penetration test (CPTu) in geotechnical engineering of China.

Steenfelt J.S.; Yding S.; Rosborg A; Hansen J.G., Yu R. Site characterization of the HZM immersed tunnel.

Svinkin M.R. Controversial and contradictory evaluations in analysis of ground vibrations from pile driving.

Tümay M. T.; Hatipkarasulu Y.; Marx E. R., Cotton B. CPT/PCPT-based organic material profiling.

Yasufuku N.; Ochiai H., Maeda Y. Geotechnical challenge for total cost reduction related to construction of connecting bridge with pile foundations.

Zabielska-Adamska K., Sulewska M.J. CBR as a method of embankment compaction assessment.