General report – Parallel session: ISP6 Pressuremeter test last innovations

Rapport général – Session parallèle : ISP6 dernières innovations autour du pressiomètre

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ABSTRACT: Thirty seven papers dealing with various aspects of pressuremeter test and its applications are reviewed. The discussion focuses on: apparatuses and *in situ* procedures, test programs and interpretation, soil classifications and correlations, special soils and rocks, foundation design and on site quality control. Some recent developments in the area are highlighted. Some questions are raised and few topics for further research are suggested.

RÉSUMÉ : Trente sept articles traitant de différents aspects de l'essai pressiométrique et ses applications sont examinés. La discussion porte sur : les appareillages et les procédures de mise en œuvre, les programmes d'essai et l'interprétation, la classification des sols et les corrélations, le comportement particulier de certains sols et des roches, la conception des fondations et le contrôle de la qualité sur site. Certains développements récents dans le domaine sont mis en exergue. Certaines questions sont soulevées et quelques sujets de recherches futures sont proposés.

KEYWORDS: Pressuremeter, apparatus, rheology, soil classification, foundation design

MOTS-CLES : Pressiomètre, appareillage, rhéologie, classification des sols, calcul de fondation

INTRODUCTION

The ISP6 international symposium host by the 18th ICSMGE, gives the opportunity to gather engineers and researcher from 17 countries to exchange about the last evolutions and developments of the pressuremeter in engineering practice.

The reviewed papers deal with very different topics which show the very broad field of application of this *in situ* testing technique. Table 1 gives a brief description of the topic of each paper and the main subject addressed.

The discussion focuses on the following aspects: apparatuses and *in situ* procedures (A+B), test programs and interpretation (C), soil classifications and correlations (D+H), special soils and rocks (E), foundation design (F) and on site quality control (G).

1APPARATUSES AND *IN SITU* PROCEDURES (A)

Three papers describe the developments of specific parts of the apparatus. The first one (**Jacquard et al.**) presents a new type of sheath with aramid weaves incorporated in an elastomeric tube having a cylindrical shape at rest, which permits to reach a final volume with a suitable geometry. The main property of this material is to have a very low inertia (pressure loss) until reaching the final volume (sized to be much higher than the volume corresponding to a doubling of the cylindrical cavity volume) and then presenting a final resistance of 6 bars. This innovation overcomes the limitation of Menard type pressuremeter tests that meet some difficulties to reach large expansion volumes and high pressures without exposing to significant risks of bursting. Comparative tests on different sites are presented demonstrating the technical and operational contribution of the new concept. The uncertainties for the assessment of the Menard limit pressure p_{LM} are thus reduced.

The second paper proposed by **Tezel et al.** compares the results obtained with a high pressure apparatus to standard 5 MPa range one. Applications are presented for the calculation of settlement for the recent project of high-rise building. The measures allows the determination of geotechnical parameters for sandstone, mudstone intercalation with intrusive dyke (diabasic, basaltic, andesitic, dasitic) and thick fracture zones with clay interfiling.

The two last papers proposed by **Arsonnet et al.** present the principles of an electronically regulated piston chamber for automatic pressure controlled MPT. This apparatus can be associated with a slotted tube with inside disintegrating tool and mud circulation. This type of technique allows an accurate characterization of the soil due to the lowest disturbance of the ground in place. Further developments can be made in order to determine the whole constitutive law of the soil investigated.

2TYPE OF TESTS (B)

The four papers dealing with type of tests show that a wide range of testing program is used in practice: constant volume rate, cyclic, creep in order to investigate soil behavior in small strains, under cyclic loading or subjected to time dependant behavior. The comparisons proposed by Benoit and concerning the comparison between pressuremeter tests and other in situ tests are presented at the end of this paper.

For **Hughes et al.,** estimation of the *in situ* lateral stresses close to tunnel was a primary focus of ground investigation. Due to the hard consistency of glacial clay materials and the potential for cobbles, neither self-boring pressuremeter nor dilatometer testing was feasible and therefore pre-bored pressuremeter testing was used. Hughes et al. describe the test procedure (called balance pressure method) investigating the effect of time at different specific pressure holds during the final unload loop (Figure 1). The interpretation leading to the definition of lateral stress is illustrated on several tests.

The main concern of **Lambert et al.** deals with the surface storage of low and medium-level radioactive wastes. In order to predict settlements accurately, a large-scale loading test has been performed. The geotechnical properties of the ground had been predetermined from field and laboratory tests and have been refined through the calibration process of finite-element models considering the results of embankment monitoring. Self-boring pressuremeter has been used during this process for a first determination of the small-strain characteristics of the soil layers.

Reiffsteck et al. summarize several results of cyclic expansion tests carried out on different experimental sites. The quality of these results allows the derivation of stress-strain parameters at low strain level. These cyclic tests were carried out using Menard and self-boring pressuremeters and consist of several phases of cycles of variable amplitude. One can observe a shift of the module depending on several factors: the number of cycles, the nature of the soil and the ratio of the amplitude and the mean position compared to the horizontal earth pressure stress at rest.

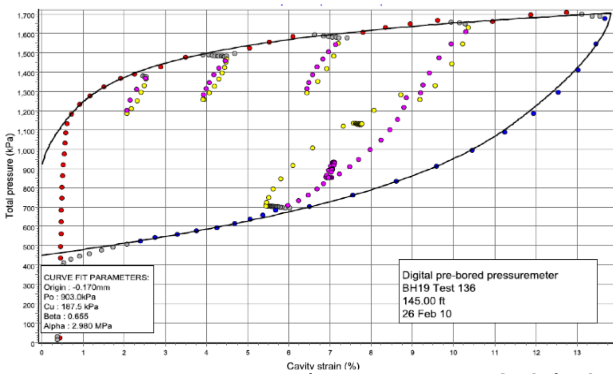

Figure 1. Pressure expansion curve for Test 136 at 44m. depth for the Seattle SR 99 Tunnel compared with the ideal pressure expansion model.

Table 1. List of paper (Keys: (A) apparatuses, (B) Test program, (C) interpretation, (D) classification and correlations, (E) Special soils and rocks, (F) Foundation design, (G) On site quality control, (H) correlation).

Paper N°	First author	Brief description of content	Main subject
43	Jacquard C.	Presentation and test of a new type of sheath	A
52	Tezel G.	High pressure and prebored pressuremeter tests results for foundation design	A
8	Arsonnet G.	Automated pressure volume controller	A
9	Arsonnet G.	Preparation of MPT borehole with slotted tube with eccentric overburden tool	A
3	Hughes J.	Measure of lateral stress in Glacial materials	B
20	Lambert N.	Calibration of settlement calculation of a test embankment using SBPT results	B
44	Reiffsteck P.	Cyclic expansion tests (MPT and SBPT) used to define small strain modulus	B
54	Benoit J.	Current status of pressuremeter testing in the USA	B
35	Mecsi J.	Soil shear strength and deformation characteristics	C
41	Baud J.P.	Stress strain hyperbolic law fitted on MPT placed using slotted tube	C
25	Caquineau X.	Reliability and representativeness of pressuremeter modulus	C
21	Retamosa M.	Undrained shear strength of overconsolidated clays based on creep pressure results	C
7	Whittle R.	A method for describing the stress and strain dependency of stiffness in sand	C
55	Failmezger R.A.	Method to compute reload and unload pressuremeter moduli abstract	C
38	Silvestri V.	Analysis of SBPT in a sensitive clay of Quebec	C
10	Baud J.P.	50 MPa Ménard MPT help linking soil and rock classifications	D/A
42	Baud J.P.	Determination of Menard rheological coefficient α by means of Pressiorama chart	D
5	Reiffsteck P.	Soil behavior classification chart based on MPT results	D
4	Ritsos A	Pressiorama classification chart in several geological formations encountered in Greece	D
27	Monnet J.	Charts for mechanical characterization of soils based on cyclic MPT results	D
51	Frikha W.	Estimation of soil characteristics from pressuremeter data	D
12	Esta J.B.	Applicability SPT/p_{LM} et q_c/p_{LM} correlation to compute settlement	H
31	Perez N.	Comparative performance of pressiometric and non-pressiometric tools on a silty deposit	H
15	Sedran G.	Menard modulus and Young modulus relationship for cohesionless soils	H/D
37	Tarnawski M.	Characterization tool for very dense sands	E
34	Marcil L.	Measurement of rock deformability with high pressure pressuremeter	E/A
16	Menéndez M.M.	Deformation modulus of Algeciras flysch unit, correlation of MPT results with RMR	E
18	Lapeña P.	Mechanical characterization of MSW using MPT and other field tests	E
39	Heintz R.	Use of MPT to investigate toarcian pyritic black shales able to induce swell.	E
28	Cao L.F.	Rock modulus from MPT and laboratory tests	E
29	Bohn C.	Foundations settlement calculation after pressuremeter method	F/D
11	Savatier V.	Improvement of usual pressiometric method for consolidation settlement calculation	F/B
24	Hai N.M.	Analysis of MPT results for evaluation of O-cell tests results	F
26	Bahar R.	Using the MPT in Algerian clays: interpretation and application	F
36	Khalid R.	Bearing capacity of cast-in concrete piles in expansive soils, based on pressuremeter tests	F
50	Guler E.	Deep foundation design using MPT and comparison with instrumented pile load tests	F
2	Varaksin S.	Design, quality assurance and acceptance method for ground improvement projects	G
19	Debats J.M.	Quality control of stone columns for an LNG tank in south east Asia	G

3 TEST INTERPRETATION (C)

Interpretation of pressuremeter test results obtained with Ménard test procedure or others with or without cycle is covered by seven papers. Either empirical such as hyperbolic curve fitting or theoretical as application of the cavity expansion theory for the determination of soil strengths and nonlinear deformation parameters these effort are a key point in the use of this test for application in design with method such as finite element method.

Mecsi presents the development of a cavity expansion theory to take into consideration anisotropy of soils and compaction occurring during expansion. A power law is assumed between modulus and radial deformations. The paper presents an example and shows that the measured diagram is well approximated by the computed values for different basic combinations: cohesion – deformation modulus.

The need to calibrate the hyperbolic model often implemented in finite element softwares leads **Baud et al.** to develop an original equation of the radial borehole expansion ε as $\varepsilon = f(G_0, p_0, p_{LM}, P_L)$ in which P_L is the true "limit pressure" value of the vertical asymptote. A very good agreement of the normalized tangent modulus G_t/G_0 ratio as a function of ε with usual hyperbolic model is obtained, except for very small initial strains.

Caquineau and Dumolard makes a review of several methods to define the characteristic points of the pressure volume curve. They put forward that the secant modulus curve deduced from adjacent pressure data points can be a good solution to be added to each test analysis and report. They suggest two additional indicators to determine Ménard modulus and limit pressure based on the creep curve founded on empirical observations.

For overconsolidated clays, the sampling disturbance leads to the underestimation of undrained shear strength values (c_U) in laboratory. To overcome this problem especially for deep foundation design, **Retamosa** proposes an alternative interpretation based on creep pressure. The author discusses why the rejection of this interpretation is too restrictive for overconsolidated soils. A case study reveals optimistic results, much higher than those obtained from laboratory tests, but in accordance with overconsolidated clays nature and their effective stress history.

Whittle and Liu report that stiffness parameters derived from unload-reload loops in sands show a strain and stress dependency. They propose a single expression that describes the strain and stress development of stiffness by combining a power law approach with a widely used stress level adjustment. The only requirement from the test is that there should be at least three unload/reload cycles (Figure 2).

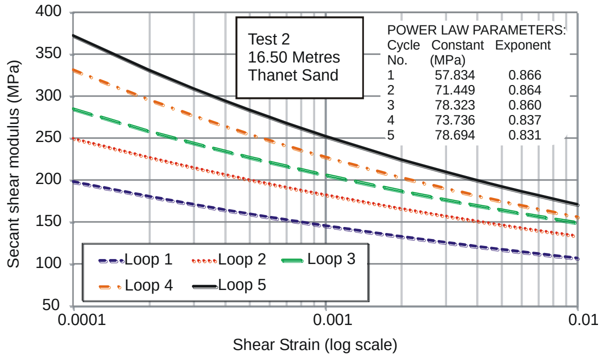

Figure 2. Variation of secant stiffness with stress level.

The last paper on this topic deals with cyclic expansion tests. **Failmezger and Sedran** analyze multiple cycles of unload-reload stress-strain loops during pressuremeter test. They observe increasing values of the corresponding unload and reload moduli during cycling and identify a linear relationship. However close to the yield stress, typically, the first loop, does not follow those best fit lines and are lower. In-situ MPT test data from three case studies are presented demonstrating these relationships.

Self-boring pressuremeter test results obtained in a clay deposit of Quebec have been used by **Silvestri and Tabib** to fit modified Camclay model parameters with linearly elastic perfectly plastic law and a nonlinear plastic model law on total stress analysis. Effective stress paths deduced from tests results do not compare well with modified Camclay-derived effective stress paths but allows to determine the distribution of effective stresses and excess pore pressures generated in the soil surrounding the cavity.

4 SOIL CLASSIFICATIONS AND CORRELATIONS (D+H)

Soil profiling chart based on SPT and CPT results have a great success among practitioners. One resistance parameter is figured versus another one dimensional or normalized (by the first one) and zones of specific behavior are delimitated by curves. As these parameters are not independent, logarithmic scale are often used to linearize hyperbolic trend. Recently the same development was initiated for pressuremeter tests results. Four papers present the practical application of this soils classification chart on various projects. A fifth one proposes an alternative classification based on theoretical relation between friction angle and MPT parameters.

Baud and Gambin give in two papers an update of previous development of their soil behavior chart called Pressiorama. This tool defines soil classes or mechanical properties, in a plane constructed with the normalized limit pressure versus the ratio of the Ménard modulus to the limit pressure. The new version presented skip from limit pressure to rheological factor α invented by Louis Ménard. In order to complete the Pressiorama diagram with a α values axis, the authors used a calibration mostly based on MPT tests performed in various soil types from soft clay to rock. Application to hard soils soft rocks is detailed in a second paper based on tests results obtained in Stampian sandstone with a high pressure MPT.

Reiffsteck et al. test the soil behavior chart proposed by Baud on a large database of pressuremeter test results collected during site investigation performed for the fourteenth metropolitan line of Paris area. This paper shows the difficulties to classify hard soil/soft rocks using this tool and proposes a modified version taking into account initial state of the ground and a classification index similar to the one propose by Jefferies and Been (2006).

Ritsos et al. analyze pressuremeter tests results carried out within four geological formations that can be found in Greece, using also Baud's soil behavior chart (Figure 3). They conclude that the evaluation of pressuremeter results and derived parameters, in accordance with laboratory tests for the determination mainly of the physical properties in characteristic samples, is much more accurate and gives the possibility to determine more precisely the ground strength and geotechnical engineering parameters needed for design purposes.

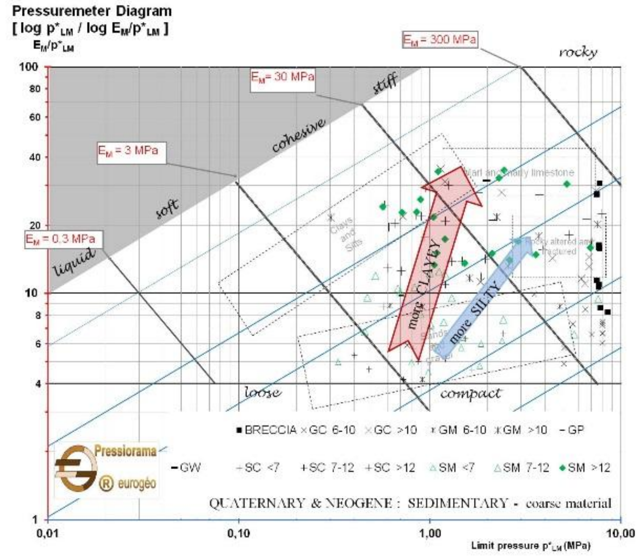

Figure 3. Classification of coarse material from Thessaloniki (Greece).

Monnet presents a classification of friction soils based on dimensionless measurements G^e/p'_0 (G^e: elastic shear modulus derived from cyclic MPT, p'_0 horizontal earth pressure at rest) and p'_{LM}/p'_0 (p'_{LM} standard limit pressure). In the case of purely cohesive soil, the paper proposes identification from the logarithm of G^e and net limit pressure $p_{LM} - p_0$. An application of these methods of identification is carried out on several pressuremeter soil surveys.

Other authors focus on correlation between MPT results and *in situ* or laboratory tests results. It seems that the main concern is to expand information on soil stiffness deduced from MPT with the help of other type of test to the site size.

Frikha et al. focuse on the prediction of the undrained cohesion form the limit pressure p_{LM}. A database comparing these two parameters is presented as soon as several empirical relations.

In many countries the soil survey is realized by executing boreholes and SPT test with a collection of more or less undisturbed samples or CPT. As raised by **Esta,** these tests do not permit the calculation of a reliable settlement as in the pressuremeter method. The author proposes correlations between SPT and cone resistance q_c related to the limit pressure pl and the deformation modulus E_M. In this publication he presents three cases where the measured settlements are in concordance with those obtained by correlations.

Pérez et al. paper's describes results of an experimental program including pressiometric, (flexible dilatometer and cone pressuremeter) as well as non pressiometric tools (CPTu, SDMT) on a test site of fluviomarine interbedded silt, clay and sand deposits. A comparative analysis is given of the stiffness and undrained shear strength of the materials for the different tests performed.

Difference between Ménard modulus and Young modulus makes difficult the use of this first to define real elastic modulus for design purpose. **Sedran et al.**, investigates in a parametric study if a relation between E_M and E_Y for cohesionless soils can be proposed. The authors have back-calculated E_M of cohesionless soils knowing a priori values of E, with the help of a finite element analysis. These numerical predictions are then used to reconstruct pressure vs. radial deformation curves from which E_M is back-calculated. The relation between E_M and E_Y was plotted for a range of soil stiffness E_Y values, and a range of values of the in-situ horizontal stresses p_0.

5SPECIAL SOILS AND ROCKS (E)

As pressuremeter tests (MPT) consist in inserting a probe containing a cylindrical flexible membrane into the ground either into a pre-borehole or by driving inside a slotted tube, they permit the investigation of ground in which cone penetration tests (CPT) or standard penetration tests (SPT) meet refusal. Four papers have been proposed to illustrate the application of MPT in special soils and rocks: the first deals with the characterisation of very dense sands, two other paper present the measurement of the rock deformability and the last one is related to the behaviour of municipal solid wastes (MSW).

In the case where it is necessary to recognise in details very deep soil layers, CPT and SPT cannot be sufficient due to refusals. **Tarnawski et al.** show an example where the use of MPT permits the differentiation between dense sands and very sands. A correlation between Menard pressure limit p_{LM} and relative density I_D is established (Figure 4). This correlation remains relevant for high values of I_D since the MPT allows the precise measurement of the mechanical strength for very dense soils. Menard pressure limit can be measured both in loose and very dense soils.

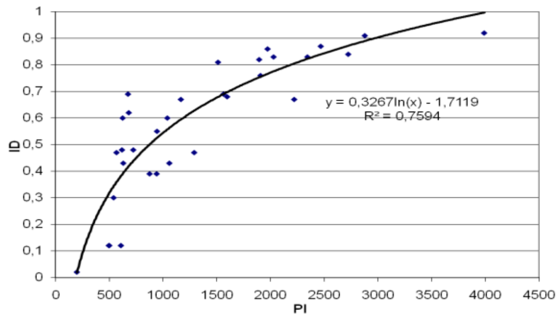

Figure 4. Correlation between Menard pressure limit p_{LM} and relative density I_D for sands in Świnoujście (Poland).

Principles of MPT can be applied to characterize rock properties. The Probex rock dilatometer used as a pressuremeter is an example. The pressure can reach 30 MPa. **Marcil et al.** show, all over the world, different applications of this apparatus which can be very useful when it is difficult to obtain samples for laboratory testing. The process permits the measurement of deformation modulus until 3 GPa. Cyclic tests are performed and give the evolution of the deformation modulus with the cycle number. They indicate that the response of rock masses can be inelastic with very few plastic strains. This type of measurements seems to be very interesting to characterize cracks into rock masses. **Menéndez et al.** present some results about the characterization of rocks for the construction of a tunnel in the Strait of Gibraltar. Comparisons in terms of rock deformability are given between the Menard pressuremeter modulus and geomechanical indexes (RMR) (Figure 5).

Pressuremeter test can be used in very special soils as MSW. **Lapeña et al.** explain how the measurement of shear stiffness parameters with pressuremeter is possible. Unload and reload cycles have been performed with correct results. Nevertheless, usage of soft membranes is strongly recommended in this case.

Swelling Toarcian pyritic shales are very special soils cause of many damages on foundations and retaining walls. **Heintz et al.** have collected results of pressuremeter tests in pre-cored boreholes, using the cores to assess the risk of pyritic swelling by geochemical and mineralogical analyses. They established a statistical correlation between laboratory and pressuremeter results identifying hard pyritic shale (figure 6). This method could be applied to investigate similar facies known stratigraphically since the Paleozoic era, which can be found all over the world.

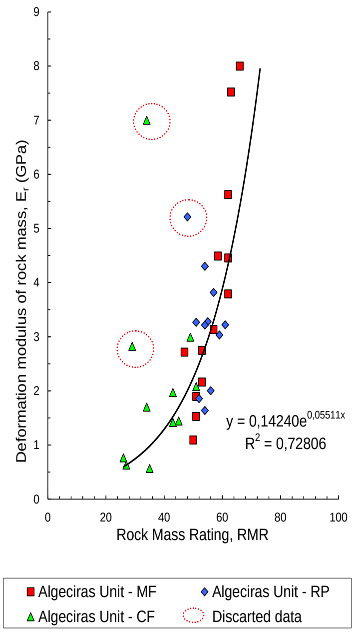

Figure 5. Proposed correlation between rock mass deformation moduli of Algeciras Unit and RMR

6FOUNDATION DESIGN (F)

Pressuremeter test provides both a failure parameter and a deformation parameter, which enables to tackle with the same *in situ* test the problems of bearing capacity of foundations (using the limit pressure p_{LM}), as well as the problems of displacements of foundations (using the pressuremeter modulus E_M). In France, design codes for shallow and deep foundations are based on the use of pressuremeter parameters. Recent developments and new experiments have been performed and show that improvements are possible.

Concerning the settlement of foundations, **Bohn et al.** present a synthesis of different calculation methods. For shallow foundation, a comparison between three methods using respectively pressuremeter data penetrometer data and oedometer data is presented. The authors highlight the problem of the estimation of the soil deformation modulus. Different correlations are proposed. For deep foundations, several t-z curves are presented and are compared for the estimation of the settlement of a bored pile submitted to axial load. Pressuremeter and penetrometer data are used and results are analyzed.

Savatier and Deluzarche present a new method to predict consolidations settlements. They use the classical method proposed by Menard with the rheological coefficient α. Values for this last coefficient are proposed analysing the results from oedometer tests. The new values take into account the OCR and the ratio C_s/C_c.

Bahar et al. present the results of Ménard pressuremeter tests carried out on various Algerian clayey sites in order to establish correlations between the parameters derived from this test, and to predict the behaviour of a single bored pile subjected to an axial load. MPT test results were analysed by a numerical method taking into account the Duncan and Chang model called "Pressident" and the method developed by Bahar and Olivari based on the generalised elastoplastic Prager's model with the Von Mises criterion which is suitable to describe the behaviour of saturated clays under undrained conditions. The prediction of the bearing capacity and the settlement of bored piles is also presented with a comparison to the loading test results.

Parasitic additionnal loads on deep foundation due to expansive soil is a major concern in Mediterranean country and especially in Morocco. To justify the use of pressumeter direct design method to this case, **Khalid and Choukaili** compare this method with other methods, and especially those based on laboratory tests, like Alpha and Beta methods. This paper summarises the local geology, the physical and mechanical properties of soils, the loading test setup and loading test programs.

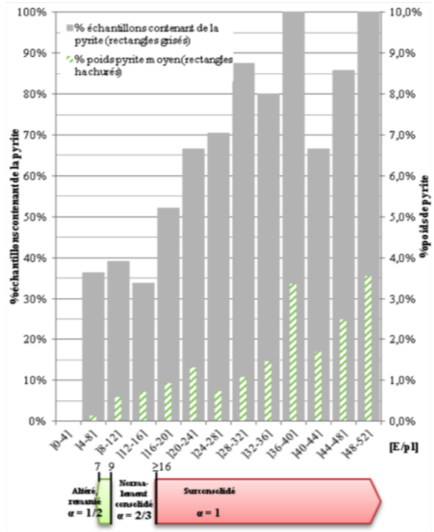

Figure 6. Evolution of the pyrite content depending on the density of massive pyritic shale, expressed by the E / pl ratio.

Hai et al. report experimental results with O-cell test failures on two bored piles of respectively 76 and 91 m depth and 1,500 and 1,800 mm diameter have been reported. Experimental shaft mobilization curves are compared to empirical t-z curves developed by Frank and Zhao (1982) and to unit shaft friction values proposed by Bustamante et al. (2009). Unit shaft friction values from the chart of Bustamante and Gianeselli are underestimated whereas t-z curves show a good agreement for the mobilization of shaft friction (Figure 7).

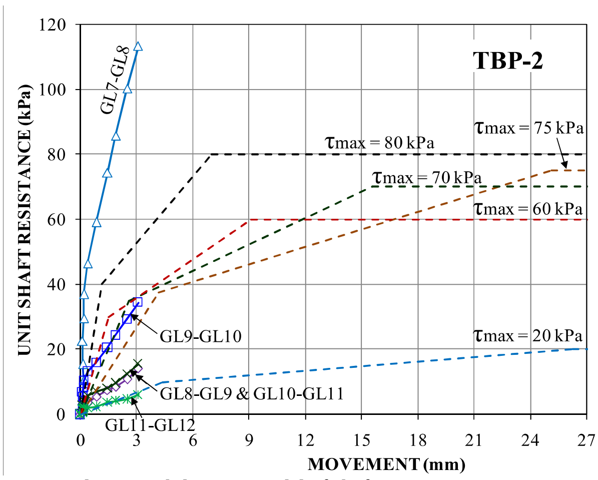

Figure 7. Tri-linear mobilization model of shaft resistances.

For the construction of high buildings in Turkey, **Güler et al.** show the results from more than 100 pressuremeter test results. Several static pile load tests have been performed and unit shaft friction have been measured by means of extensometers. The comparison between these values and those obtained from the application of the design rules presented in the Annex E of the Eurocode 7 – Part 2 show a very good agreement.

7ON SITE QUALITY CONTROL (G)

Varaskin and Hamidi present different applications of the pressuremeter on different sites all over the world: characterization of creep in loose soils, soil classification, correlation with cohesion c and friction angle φ.

Quality control for soil improvement such as stone columns asks to check the continuity of inclusions in the ground and their mechanical characteristics and thus relies on in-situ testing. **Debats and Pardessus** describe an example of the use of the Menard pressuremeter for the foundation of LNG tank, the difficulties encountered and the solutions adopted. They show that, rather than specifying a given Young's modulus to be achieved in the stone columns it is preferable to look for a minimum ratio of the modulus of the improvement to the one of the soil.

8DISCUSSION AND FURTHER DEVELOPEMENTS

All papers presented in this symposium show that pressuremeter has still a great interest for practice in basic application such as classification of ground mass or quality control but also for deriving parameters or to develop and fit behavior law needed for finite element modeling. For this purpose as pointed out by **Briaud** in his Ménard lecture and **Baud and Gambin**, simple techniques can be used to recreate the small strain early part of the curve lost by the decompression-recompression process associated with the preparation of the MPT borehole. The use of the MPT unload-reload modulus can be also a reliable way to derive small strain modulus (**Whittle and Liu**).

The most successful application of the pressuremeter achieved is foundation design. This method based on a large database has shown in projects and benchmarks, his reliability. There still remains potential improvement by using the entire expansion curve to predict the load settlement behavior of shallow foundations, the load displacement behavior of deep foundations under horizontal loading, foundation design of very tall structures, long term creep loading (**Briaud**, **Bohn et al., Hai et al.**).

SPT, CPT and WST have been used extensively for estimating, by correlation, the influence of seismic events on soil (module degradation, liquefaction, etc.) probably because they were the only tests available close to the most threatened zones. The pressuremeter is the only tool allowing, by multicycle testing, to observe without the help of correlation, these phenomena (**Reiffsteck et al., Whittle and Liu, Failmezger and Sedran**). **Briaud** proposes an attempt to generate preliminary soil liquefaction curves based on the normalized MPT limit pressure.

However, whereas it is present in most country worldwide, the pressuremeter is not used in the day-to-day practice but more often for high added value investigation. This can be explained by two main factors: on the one hand the availability of suitable drilling tools and the practical training by operators and on the other hand the knowledge by the engineers of dedicated and recognized design methods (**Briaud, Benoit**).

Benoit has gauged the degree that pressuremeter testing and design methods are being taught at both undergraduate and graduate level courses in civil and geotechnical engineering courses at US academic institutions. The results from the survey provide a current status of pressuremeter testing instruction in the US which is far from what is done for other tests such as the SPT and CPT and allow the development of a framework for broader use and dissemination of pressuremeter testing technology in practice and in academia.

9CONCLUSION

Pressuremeter soil tests constitute a specific tool within géotechnique with a high potential to answer to fundamental questions related the soil deformability in undisturbed state and its failure mechanism. This interest raises an important number of presentations made at the most significant international conferences and symposia on soil mechanics and foundations and of papers published in internationally recognized journals on the practical, theoretical and instrument development aspects.

This symposium ISP6 succeeds to five international symposiums. This cycle was initiated in 1982 in Paris by the symposium on pressuremeter and its marine applications. In 1986, Texas A&M University (College Station, Texas, USA) organized a symposium on pressuremeter tests and the application of their results followed by the symposium and seminar on the theoretical and practical aspects of pressuremeter tests organized by the British Geotechnical Society in l990. The pressuremeter and its new avenues took place in Canada in 1995 and a decade later, the 50 year anniversary of the invention of the pressuremeter by Ménard was the opportunity in 2005 to organize a symposium under the title ISP5 about the theoretical and practical aspects of pressuremeter tests.

More than 30 years after this first symposium, the 37 papers show that this technique has reached a maturity in all the fields of application but that there is still a need for revisiting:

- the techniques to prepare the MPT borehole to have the same quality in most soils and rocks,
- apparatus to give more rich information on the test and latitude to the operator to vary the test procedure,
- test procedure to be more adapted to the needs for engineers to feed geotechnical parameters into discrete or finite element softwares,
- databases similar to those developed for deep foundation for shallow foundation and retaining walls.

10ACKNOWLEDGEMENTS

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11REFERENCES

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Arsonnet G., Baud J.P., Gambin M. une amélioration déterminante de l'autoforage du pressiométre Ménard

Bahar R. Utilisation du pressiomètre Menard dans les argiles Algérienne: interprétation et application

Baud J.P. and Gambin M. 50 MPa Ménard PMTs Help Linking Soil and Rock Classifications

Benoit J. Current Status of Pressuremeter Testing in the USA

Bohn C., Frank R. and Lambert S. Foundation settlement calculations with pressuremeter method compared to other methods and resulting correlations

Cao L. F., Peaker S. M. and Sirati A. Rock Modulus from In-Situ Pressuremeter and Laboratory Tests

Caquineau X. et Dumolard B. Module pressiométrique : aides pratiques à l'interprétation

Debats J.M., Pardessus N., Fearon R., Use of the pressuremeter in the quality control of stone columns for an LNG tank in south east Asia

Esta J.B. Utilisation de corrélation (SPT ou q_c)/p_l pour le calcul de tassement

Failmezger R.A. and Sedran G. New method to compute reload and unload pressuremeter moduli abstract

Frikha W., Ben Salem Z. and Bouassida M. Estimation of Tunis soft soil undrained shear strength from pressuremeter data

Guler E., Koc M., Bakilar GS and Osmanoglu U. A Case Study of Deep Foundation Design Using PMT and Comparison with Instrumented Pile Load Tests
Hai N. M., Dao D.H. and Tien N.T., Analysis by the Menard direct designmethod of O-cell instrumented pile load tests
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