Preface

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Twelve papers are published in this special issue, each paper covering a different topic related to Hard Soils–Weak Rocks. These papers are based on papers that have been presented in the 15th European Conference of Soil Mechanics and Geotechnical Engineering which was held in Athens Greece in September 2011 and have been published in the proceedings of that conference (Anagnostopoulos et al. 2011).

All papers were reviewed by the procedure of Geotechnical and Geological Engineering: An International Journal. The Guest Editors were responsible for managing the peer review process of the papers. These papers provide either a new development or an interesting case history or both, on a topic related to hard soils or weak rocks. Therefore, the papers can be considered useful for educators, researchers and practitioners.

No. 1 Determination of the small strain stiffness of hard soils by means of bender elements and accelerometer

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Cr. Ferreira, J.P. Martins and A. Gomes Correia propose a new technique for measuring the shear wave velocity of soil samples in the lab, in order to determine their small strain stiffness. The method uses two side mounted accelerometers (AC) on the sample, in conjunction with bender elements (BE), at the base and top cap of a stress–path triaxial cell. The above technique is proposed as a better alternative to the BE, because: (a) the performance of the AC is not affected by the use of higher frequencies—specially in the case of hard soils—and (b) the interpretation of the acceleration measurements by the AC's are straight forward. An application study of a hard soil, prepared by laboratory compaction of a well graded, coarse grained, clayey sand and tested in drained triaxial compression at different isotropic stresses is presented, in order to observe the differences between BE and AC results, at various stiffnesses.

No. 2 The influence of stiffness anisotropy on the behavior of a stiff natural clay

A. Grammaticopoulou, F.C. Schroeder, A. Gasparre, N. Kovacevic and V. Germano report the use of a cross-anisotropic non-linear elasto-plastic model, to simulate the soil stiffness anisotropy, at small strains, of stiff plastic London Clay. The anisotropic model employed combines a three parameter cross-anisotropic formulation with a non-linear elastic response. The cross anisotropy is defined by three independent param-

eters: The drained Young's modulus in the vertical direction, the drained Poisson's ratio for horizontal strain due to horizontal strain and the anisotropic scale factor α :

$$\alpha = \sqrt{\frac{E'_h}{E'_v}} = \frac{v'_{vh}}{v'_{hh}} = \frac{G_{hh}}{G_{hv}}$$

The anisotropic model is shown to reproduce well the response measured in advanced laboratory triaxial tests. For comparison, the predictions of the above cross-anisotropic model are presented for the ground surface settlement profile at the end of tunnel construction and in the long term, for the case of a single tunnel constructed in the London Clay.

No. 3 25 MPa HyperPac fills the gap between the Ménard pressuremeter and the flexible dilatometer

G. Arsonnet, J.-P. Baud, M. Gambin and R. Heintz in their paper describe the successive development of high pressure Ménard pressuremeter test (PMT). With reference to EN/ISO standard 22476-4, the pressures used in the conventional PMT are restricted to 5 MPa, because mainly the test is addressed to soil mechanics problems. Special probes allow increasing the pressure up to 10 MPa in exceptional cases. There is an increasing need to apply higher stresses to very stiff soils and weathered rocks in order to study the behavior of these materials under radial expansion.

In the paper, the authors present new equipment, the HyperPac 25 MPa, consisting of a new totally controlled unit including a volumetric system, making possible standard pressure holds stable up to 25 MPa, without the help of an operator. With the above apparatus hard soils and weak rocks, presenting initial failure before reaching 25 MPa, may be tested. Comments on the applicability of the new high pressure pressuremeter and the flexible dilatometer, having the same goal of measuring E-moduli are made in the text. Some first test diagrams up to the pressure of 25 MPa in slightly fractured rocks are also given.

No. 4 Soil and rock classification from high pressure borehole expansion tests

J.-P. Baud and M. Gambin, suggest that the data obtained during a borehole expansion test, i.e. the fundamental parameters E_M (the pressuremeter modulus) and P^*_{LM} (the limit pressure) permit a soil classification system, due to the close relationship

between the ratio E_M/P^*_{LM} and the type of the soil behavior, being itself a function of the soil gradation curve from typical sand to typical clay. During the gradual transition from stiff soils to weathered rocks or jointed rocks, the radial expansion behavior of the materials does not suddenly change in nature, but the scale of the associated stresses change gradually by one or two powers of 10.

By the development of pressuremeter equipment, making it possible to apply pressures up to 25 MPa, it is possible to observe the behavior and mode of failure of materials within the range between soils and weak rocks. As a conceptual framework the authors propose the extension of the spectral diagram $\left[\frac{E_M}{P^*_{LM}}, P^*_{LM}\right]$, or pressiorama[®], towards pressures above 10 MPa and up to 25 MPa, provided by the HyperPac control unit. Examples from practice, in hard soils or weak rocks, where pressures can grow during pressuremeter tests, show that they do not exhibit a behavior quite different from that of soils, i.e. a phase of creep and later, one of large deformation. Thus the proposed pressiorama[®] diagram using pressuremeter parameters offers a single soil and weak rock classification system.

No. 5 Retaining structures in expansive clays

A.T. Papagiannakis, S. Bin-Shafique and R.L. Lytton describe a numerical approach for estimating the swelling stresses exerted on retaining structures from swelling clays under increasing moisture conditions. Two wall types were analyzed, a drilled shaft wall and a tie-back wall.

In designing retaining walls, accounting for swelling pressures needs to address the interaction of the retaining wall and the soil. This involves laboratory testing to characterize the swelling properties of the clay, as well as finite element modeling (FEM) of the wall-clay system. The results of the analyses suggest that swelling soils can add substantially to the ordinary stresses exerted on retaining walls and that these stresses follow the pattern of water content decrease with depth. Moreover the soil confinement effected by the wall significantly increases the clay swelling pressures.

No. 6 A new method for the evaluation of the ultimate load of piles by tests not carried to failure

G. Dalerici and R. Bovolenta propose a new method for the estimate of the ultimate load of a single pile, on the basis of data obtained from pile load tests which

were not carried to failure. The method is applicable in the case where full mobilization of the shaft resistance has taken place during the loading.

By suitable analysis the prediction of the complete single pile behavior becomes possible, including the ultimate base and shaft loads for settlements greater than those realized during the load test. The authors validated their method on the basis of results from 44 instrumented pile load tests. Fourteen (14) of the above cases concerned piles in stiff soils or weak rocks.

No. 7 Soil nailing in Dublin Boulder Clay

C.O. Menkiti, M. Long, G.W.E. Milligan and P. Higgins describe an extensive investigation for the design of the temporary support of cut slopes, 7–12 m high, with slope angles between 65° and 80°, for the construction of part of the Dublin Port Tunnel. The required stand-up time was 6 months. In the end, 1,700 m of slope were constructed, with shotcrete facing and 7,460 soil nails. The soil conditions were boulder clay, consisting of low plasticity, very stiff to hard, gravelly sandy clay. In the paper, the results of the nail pull-out tests are presented, as well as the detailed monitoring of the nailed slopes and the quality of the grout and shotcrete used.

The nail pullout tests were executed before and during construction. The nails were installed by rotary drilling, inclined at 10° to the horizontal. The pull out tests revealed the following characteristics: (a) very high skin friction at the soil–grout interface, which was higher than the soil undrained strength (b) The mobilization of the skin friction was rapid, at about 5–10 mm displacement, exhibiting a ductile response, (c) The risk of significant creep was at about 60–70 % of the ultimate skin friction value.

The observed movements of the partly nailed slope were small with a typical horizontal displacement at the top of about 16 mm, i.e. 0.13 % of the slope height. Also the surface settlements adjacent to the nailed slope were modest, not exceeding the 3 to 4 mm. The pore water pressures in the slope were also monitored. Initially, the piezometric readings corresponded to the hydrostatic conditions, while subsequently the values decreased due to the release of the total stresses, as a result of the excavation.

Finally savings of more than 20 % in nail quantities, relative to a fully nailed slope with a long design life, were achieved, due to the optimized design justified by pullout tests.

No. 8 Foundation of a gravity dam on layered soft rock. Shear strength of bedding planes in laboratory and large in situ tests

E. Alonso, N.M. Pinyol and J. Pineda describe the procedure followed in order to select strength parameters for the foundation of a 100 m high gravity dam, founded on a soft Weald claystone with interbedded sandstone strata. The ground structure and strength is dominated by the sedimentation planes, which dip on average at 18°. A series of drained direct shear tests on the sedimentary planes were performed in the laboratory, using a large shear box machine (30 × 30 cm). The types of joints tested were on planes inside the sandstone with mica concentrations, sandstone–claystone contacts and planes inside the claystone. No apparent cohesion was measured in all the above tests. Ring shear tests on the joints' filling were also performed for the estimation of the residual strengths.

Six multistage in situ shear tests (3 in each abutment) were performed on square samples 80 × 80 cm. The maximum applied vertical stresses were 0.62–1.0 MPa, i.e. somewhat smaller than the expected effective stress from the dam under full hydrostatic load.

The shear behavior was ductile in all tests, while the measured failure envelopes were significantly different. Existing relationships between joint roughness and strength envelopes were also considered for comparison with the test results from the shear tests. Finally, the variation of the secant friction angles with the normal stresses, suitable for the design, was given by favoring the results of the in situ tests but disregarding the extreme values.

No. 9 Athens Metro Line 3—Western extension—Trumpet area

S. Schina and A. Charalampidou, report two cases of complex tunnel geometries as part of the Athens Metro lines extensions in Greece. The challenge of the design was the geometry change of metro tunnels within short alignment lengths, creating transition zones between typical cross sections. The so-called “Trumpet Area” describes a horizontal sequence of different tunnel sections and the “Access Gallery” refers to a vertical tunnel complexity.

The first case describes the meeting zone of a single and a double track tunnel towards a triple one. The design particularities in the first part were the narrow

ground pillar between the two tunnels and the construction commitment to start the excavation from the single track tunnel towards the triple one, with all the deriving restrictions, while in the second part, an enlarged tunnel section had to be designed in order to inscribe the two tunnels.

In the second case, a three-storey gallery was designed in full compliance with the construction sequence of the Egaleo Metro Station. Each level provides access to the construction of the upper part of the station through an access chamber. Due to the intersection of tunnels of different geometry, size and elevation, the support measures were uniquely designed to satisfy the aforementioned demands.

Both tunnels are in full operation since 2007. The construction advanced without difficulties, assuring stability, low surface settlements and accepted convergences.

No. 10 Block-in-matrix structure and creeping slope—Tunneling in hard soil and/or weak rock

The paper by **D. Adam, R. Markiewicz and M. Brunner**, deals with the construction of the city bypass road tunnel of Waidhofen an der Ybbs (Austria). The tunnel has a length of 1,485 m and a maximum overburden of 50 m. Its construction started in 2007 and ended in 2011. The tunnel was excavated through a mount ridge with a complex geological environment in which marly limestones, marls and tectonic breccias predominate. The latter rocks constitute a “mélange” presenting a peculiar geotechnical behavior, since they consist of isolated harder blocks embedded in a softer matrix, called in general “block-in-matrix” (BIM) rocks. The complex geological structure and the unstable creeping slopes required the application of a sophisticated monitoring system, the use of empirical methods for the determination of the shear strength characteristics of geomaterials and also the use of various tunneling methods including open cuts, cut-and-cover sections and the New Austrian Tunneling Method (NATM). Based on the results of the additional investigations, conducted during the tunnel construction, appropriate protective and stabilizing measures were taken, such as slope drainage by the construction of gravel piles, extensive slope dowelling by vertical and inclined piles and the reinforcing of the tunnel lining, resulting in significant decrease of slope creep.

No. 11 Slope stability analysis based on autocorrelated shear strength parameters

O. Tietje, P. Fitze and H.R. Schneider, investigate the influence of the shear strength spatial variability on estimating the reliability of slopes. For the purpose of slope stability analyses, it is proposed to correlate the spatial variability of the characteristic value of strength to the length of the slip surface. A series of limit equilibrium slope stability analyses are performed for undrained and effective shear strength conditions, to examine the effect of the length of the slip surface. These included Monte-Carlo analyses that were used to validate the proposed equations for the characteristic strength, which take into account the spatial variability. Furthermore, the analyses were used to demonstrate that the risk of slope failure also depends on the scale of the variation of slope properties.

No. 12 Assessment of failure mechanism and rehabilitation of a landslide within marly formations in NW Greece—From the site investigation to the geotechnical design

The paper by **G. Prountzopoulos, P. Fortsakis, K. Seferoglou, F. Chrysochoidis, I. Vassilopoulou & V. Perleros**, describes the geotechnical interpretation and rehabilitation design of a landslide involving a national road embankment founded on a marly formation in NW Greece. The incident took place 30 years after the construction of the road, due to placement of deposits at the embankment toe that did not act as a stabilizing weight, but caused a progressive failure that reached the embankment crest. The area was extensively investigated and monitored and the available data were used for the assessment of the landslide mechanism via stability analyses and for the rehabilitation design. The “flexible” solution of a reinforced embankment was preferred as the best rehabilitation scheme, due to the general kinematic activity of the area.

The Guest Editors would like to express their appreciation to the authors of the papers for their efforts and the quality of their contributions. Moreover, they thank the reviewers for their thorough reviews and their efforts towards improving the quality of the papers. Their thanks are also extended to Professor Paul Marinos for his constant encouragement, to Ms

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