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General Report of TC103 Numerical Methods in Geomechanics

Rapport général du TC 103 Méthodes numériques en Géomécanique

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ABSTRACT: This paper presents a General Report on 46 contributions, including poster presentations, submitted for the parallel sessions organized by TC 103: Numerical Methods in Geomechanics. The authors come from various regions of the world and the topics of the submitted papers are diverse. These contributions are reviewed from the viewpoint of the current research directions in relation to the numerical schemes and their key results. The overview of the latest work is provided in this general report, dividing the broad paper topics into several important subjects.

RÉSUMÉ : Cet article présente le rapport général sur les 46 contributions, incluant les présentations affichées, soumises aux sessions parallèles organisées par TC 103 : Méthodes numériques en Géomécanique. Les auteurs proviennent de diverses régions du monde et les sujets des articles soumis sont divers. Ces contributions sont examinées du point de vue des orientations de recherche actuelles, en relation avec les schémas numériques et les résultats clés qu'ils produisent. Un aperçu des derniers travaux est fourni dans ce rapport général, en séparant la thématique générale en plusieurs sujets importants.

KEYWORDS: numerical methods, analytical methods, geomechanics.
MOTS-CLÉS : méthodes numériques, méthodes analytiques, géomécanique.

1 INTRODUCTION

The papers submitted to the session organised by TC 103 cover a wide range of topics, touching on all aspects of soil mechanics and geotechnical engineering. The commonality in these contribution is the use of numerical methods to approach the problems, as this is the focus of the technical committee. The papers are quickly reviwed below by general application topics. A variety of techniques is presented, from traditional finite element modeling to most recent developments, such as XFEM, treating soils and rocks as continua or particulate media. A few contributions also favored analytical methods.

2 STABILITY AND PERFORMACE OF FOUNDATIONS

Six papers in this session focus on prediction methods to evaluate the deformation and stability of foundations for various practical design problems. 2D/3D numerical analyses are applied to address the problems directly or to validate the proposed analytical or semi-analytical prediction methods. Commercial software, e.g. Plaxis 3D, FLAC 3D, ANSYS, is gaining prominence as a tool for practical design in the geotechnical field. However, analytical and semi-analytical methods are still useful, as discussed in the papers in this group.

Kristić and Szavits-Nossan propose a direct prediction method to calculate shallow foundation settlement on granular and stiff fine granite soils. The method extends an existing procedure to reproduce the load - settlement curve measured in the field by using SPT N-values as a substitution for the measured settlements in the small strain ranges. This paper uses numerical results by Plaxis 2D to validate the proposed method.

A simplified prediction method using semi-analytical calculations is proposed by *Frattini et al.* for the design of rigid inclusions under a spread footing. The proposed design methodology is mainly based on the determination of stability diagrams for various loading conditions (static or seismic loading, and inclined loads with or without eccentricities), with

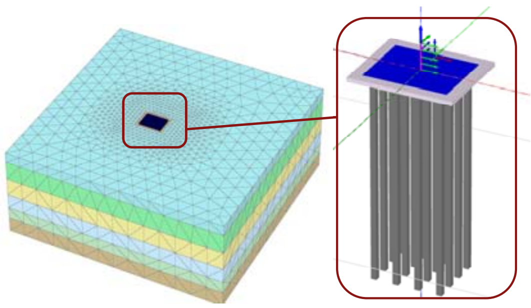

Figure 1. 3-D model of stability problem for a foundation on rigid inclusions. (*Frattini et al.*)

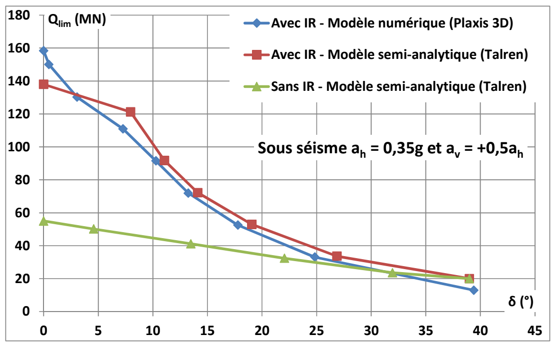

Figure 2. Seismic stability diagram with IR (rigid inclusions). (*Frattini et al.*)

an estimate of post-seismic non-reversible displacements. A 3-D finite element model validates the analytical approach as shown in Figure 1. This simplified approach allows a substantial gain in calculation time, especially when the project requires a high number of inclusions, with results matching those obtained by Plaxis 3D as illustrated in Figure 2.

Matthiesen et al. carry out extensive 2D and 3D numerical simulations to determine the exact location of a newly constructed lock based on predefined allowable deformations of the ship. Finite element analysis by Plaxis 2D is performed to determine the spacing between an existing ship lift and the new lock. Then, extensive 3D finite element analysis is carried out to assess deformations during the construction process as shown in Figure 3. Finite difference analysis by FLAC 3D is also presented in comparison with FEM. This paper is a good example for the use of extensive 3D numerical simulations in practical designs of big construction projects.

Dunne and Martin use 2-D and 3-D finite element limit analysis (FELA) to find the capacity of suction caissons loaded horizontally. The FELA obtains lower and upper bound solutions with adaptive mesh refinement to reduce the gap between solutions in successive iterations. In this paper, the optimum location of the caisson for maximum resistance against horizontal load with various length-to-diameter ratios of the caisson are calculated and shown in charts. An example of the failure mechanism of a caisson simulated by 3D FELA is shown in Figure 4.

Elhuni and Basu develop a closed form analytical solutions for the dynamic response of beams on elastic foundations under

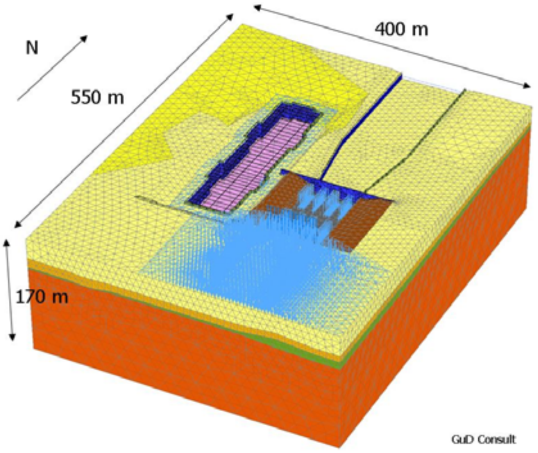

Figure 3. Top view of 3-D FEM model (Plaxis 3D) of existing ship lift (right), lock excavation pit (left) and surroundings. (*Matthiesen et al.*)

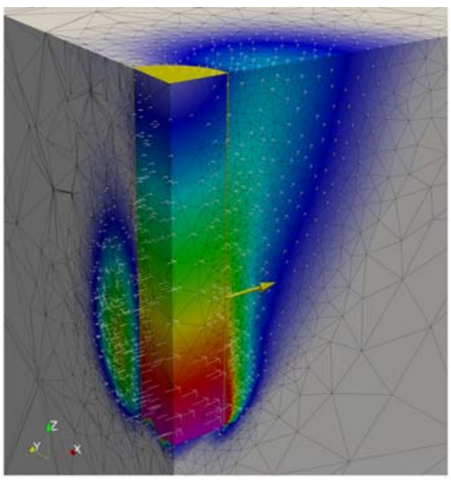

Figure 4. Failure mechanisms of a caisson with length-to-diameter ratio = 3 calculated by 3D FELA. (*Dunne and Martin*)

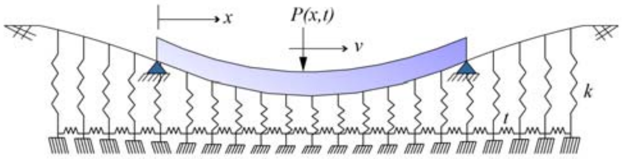

Figure 5. Equilibrium condition of the beam-foundation interactive system. (*Elhuni and Basu*)

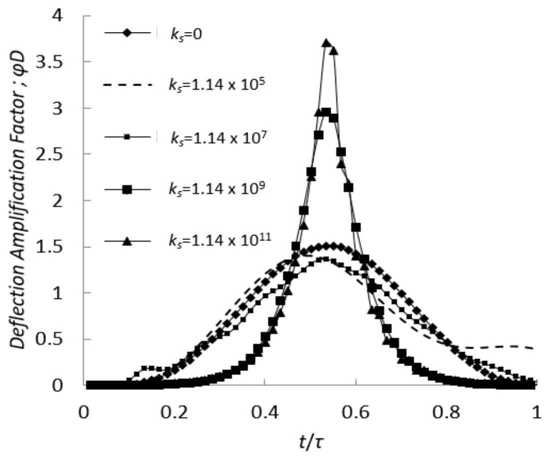

Figure 6. Effect of foundation stiffness-parameters on the mid-span response. (*Elhuni and Basu*)

a moving concentrated load by using the integral transformation methods as illustrated in Figure 5. An equivalent finite element analysis is also carried out to verify the accuracy of the proposed analytical solution. The dynamic amplification factor of mid-span deflections is found to be in direct correlation with the soil compressive resistance as shown in Figure 6. Furthermore, the travelling speed of the moving concentrated load revealed to alter beam response.

Leonid et al. discuss the effect of deformation anisotropy on the stress-strain response of the soil basement. Anisotropic linear elastic materials with various anisotropic coefficients defined by a ratio of vertical and horizontal Young's modulus are assumed. Stress distributions in the ground beneath the rectangular footing are calculated through the numerical experiments by ANSYS FEM software.

Subramanian and Boominathan investigate the effect of batter piles on the dynamic response of 2x2 pile groups. They find that the performance of the pile groups is improved by the inclusion of batter piles, especially where the soil profile includes softer soils closer to the surface. This beneficial effect is particularly pronounced at lower frequencies and become increasingly less important as the frequency of excitation increases beyond the natural frequency of the systems.

A unique study to determine failure modes of soils using Discontinuity Layout Optimization (DLO) for geotechnical limit analyses as a powerful alternative to other numerical methods such as finite element limit analysis approaches is presented in *Smith et al*. The basic concept of DLO is to identify the critical collapse mechanism in the form of discrete slip-lines for any problem geometry using optimization. This paper presents the three approaches in using the dual equilibrium form of the DLO formulation: (a) indicative stress fields, (b) accelerated solution and (c) topology optimization. One of the examples of the stability of a vertically loaded rigid foundation located at the top of clay embankment but offset by one half nodal spacing to the left from the center line in Figure 7.

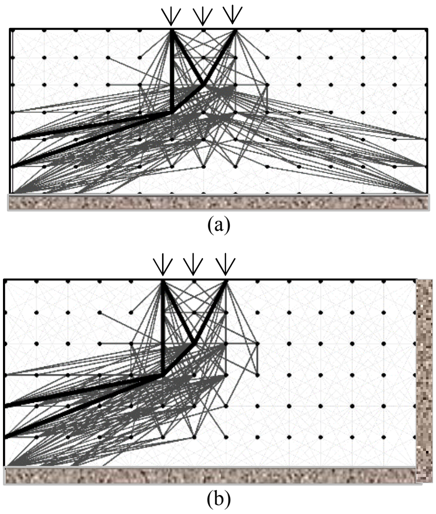

Figure 7. Dual equilibrium output for example problem (a) potential sliplines >80% yield in grey and critical mechanism in black (b) Same problem as (a) with right side constrained. (*Smith et al.*)

3 SLOPE STABILITY

A second group of papers is concerned with different aspects and approaches to slope stability.

Kim et al. develop a design-oriented slope stability program, based on the limit equilibrium method, which can consider the reduction in shear strength induced by rainfall infiltration and the presence of power transmission towers. The code is verified against commercial programs. Parametric studies are performed on rainfall, pile spacing and positions. The use of the program is demonstrated by assessing the optimal transmission tower position for a testbed site in Korea.

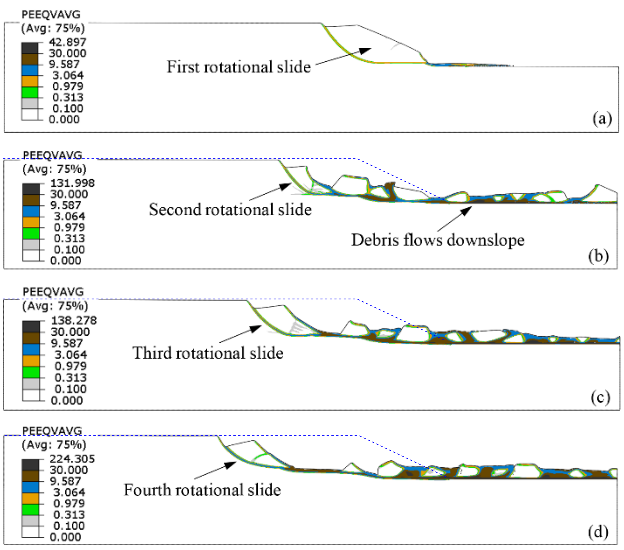

Figure 8. FE simulation of flow-slide. (*Wang and Hawlader*)

In *Wang and Hawlader*, numerical simulations of three major types of large-scale landslides in sensitive clay, i.e., a downhill progressive slide, a flow-slide and a spread, are presented. The initiation of failure, formation of shear bands, global failure of the slopes, and post-failure deformation of the failed soil mass are simulated, as depicted in Figure 8. Due to the strain-softening behavior of sensitive clays, the failure planes develop progressively and significant shear strain localization occurs along the failure planes (shear bands). Moreover, the failed soil mass generally displaces over a large distance. Thus, it is difficult to model using limit equilibrium methods or the typical finite element method developed in Lagrangian framework. Therefore, the coupled Eulerian-Lagrangian technique available in Abaqus FE software is used here.

Fredlund et al. calculate a larger 3D FOS by 12 to 59% compared to the 2D FOS in limit equilibrium analyses. A larger difference is found if unsaturated soil response is considered in the model. Consulting engineers are interested in understanding the potential differences between 2D and 3D analyses. As a result of the sensitivity analysis with typical scenarios, the authors discuss the practical issues related to the application of 3D analysis within the existing design limitations.

4 RETAINING WALLS AND EMBANKMENTS

This group of papers focuses on numerical approaches related to application problems in retaining walls, both in static and dynamic conditions.

de Santos et al. propose the use of genetic algorithms to assess soil properties from back analysis. They focus their study on cases of preloading, where the soil properties are often assessed more fully in the field after construction. An initial synthetic case is used to identify the most effective use of genetic algorithms to optimize the back analysis process. They then apply the method to a field study.

Havinga et al. address the issue of the performance of integrated bridge abutments subjected to cyclic load. They present model test results showing the formation and deepening of the settlement trough behind the wall, as well as the increase in earth pressure with number of cycles. The two experiments are analysed with DEM and FEM with a hypoplastic constitutive model and show very good agreement with the experimental results, validating the use of these numerical techniques for analysing this problem.

Mirmoradi and Ehrlich discuss the effect of toe restraining in the performance of segmental walls, using both experimental and numerical results. Toe restraint reduces the load on wall reinforcement compared to unrestrained toe walls in model experiments. The numerical analyses highlight how the interplay of reinforcing stiffness and facing stiffness can control the distribution of forces in the reinforcement. Overall, neglecting toe restraint during design will increase the margin of safety against overstressing of the reinforcement.

Gunnvard et al. present a valuable study of the effect of deployment pattern, spacing, and bearing mechanism on the performance of geogrid reinforced pile-supported embankments. Their findings support a modest increase in spacing between the piles, which would result in a substantial (35%) reduction in the number of piles used to support a km of road. The pattern of pile installation does not seem to affect the desired outcome.

Szepeshazy and Szep propose a method to derive spring stiffness values to simplify the analysis of complex bridge support conditions using a subgrade reaction approach. Their proposed approach compares well with the results of detailed FEM analysis of a sample problem.

5 EXCAVATIONS

A case history presenting a deep open-cut excavation through thick soft clay deposits in central Shanghai is numerically back analysed in *Bertoldo et al.* The finite element analysis uses the RW plasticity-based constitutive model incorporating progressive degradation of the natural microstructure of the clay due to plastic strains. The overall performance of the excavation model is compared with measured wall displacements and settlements of the ground.

Another back analysis of a deep excavation is carried out in *Kovacevic et al.* using finite element analysis with the modified Cam-clay model. This study investigates the behaviours of an anchored wall in Dublin Boulder Clay during construction the subsequent 6.5 years monitoring period. The numerical analysis reproduces well the short-term wall movements, while the long term results are less successful. This suggests that the wall was heavily stressed and the anchor forces were high, and thus it is concluded that remedial measures are necessary to ensure the long-term wall stability. These back analyses using finite element method give useful insights into mechanism of wall and surface ground behaviours and associated predictions.

Tunnel excavation in 2D versus 3D conditions is numerically investigated in *Equihua-Anguiano et al.* and *Elarabi and Mohamed*. In the former, most of the results are obtained by a finite element analysis in elastic isotropic conditions, using the Mohr-Coulomb model. In the early stages of tunnel excavation, displacement of the tunnel in the 3D analysis is smaller than that in the 2D analysis, although the same maximum displacement is obtained by both approaches at the end of excavation. This indicates 2D-FEM analysis possibly leads to overdesigning of tunnel supports in the early stages of excavation. In addition, the excavation length in the 3D analysis to reach the same displacement as the 2D analysis depends on the radius of tunnel.

In the second paper, finite element analyses of case history of the second Heinenoord Tunnel are performed. Two procedures, the grout pressure method and the contraction method, are used to numerically simulate tunnel excavation. In addition, two constitutive models, Mohr-Coulomb and the Hardening-soil model, are compared. When using the grout pressure method, 3D analysis provides good agreement with the measured ground settlement, while the 2D analysis also gives good results. In contrast, the contraction method overestimates the settlement, and the choice of constitutive model is less sensitive than the choice of the procedures.

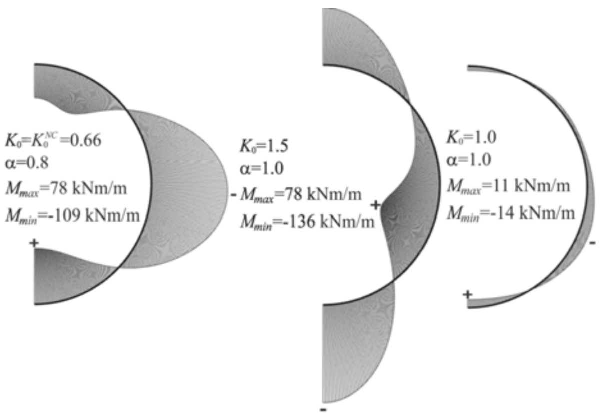

Figure 9. Extreme changes in the distribution of bending moments in the tunnel casing for different conditions of anisotropy with the reference fully isotropic case. (*Cundny and Partyka*)

Cudny and Partyka propose a cross-anisotropic soil model which combines both stress dependent anisotropy and microstructural anisotropy to numerically simulate the influence of anisotropic stiffness of stiff soils on tunneling and excavation problems. Specifically, stress dependency and material microstructure are taken into account for the elastic shear modulus. An example of finite element analysis of a tunnel excavation in a stiff anisotropic soil deposit is shown in Figure 9. Significant differences in the distribution of bending moments in the tunnel casing can be seen for different conditions of anisotropy where K_0 is stress ratio and α is the parameter for the degree of cross-anisotropy. The authors state at the end that anisotropic stiffness of natural soil should be taken into account in numerical analyses of soils, although it is often neglected, and further study is required to standardize the constitutive modelling of anisotropy of soils, particularly in terms of the estimation of material parameters.

6 SEISMIC RESPONSE OF STRUCTURES

This group of papers includes dynamic problems, such as the constitutive modeling of soil liquefaction and the dynamic analyses of dams, cargos, and foundations.

Poli et al. propose a constitutive model developed within the Generalized Plasticity and Critical State frameworks, and simulate the experimental response exhibited in drained and undrained triaxial tests with reconstituted samples of a natural medium-fine to fine sand extracted from the upper layers of a thick granular soil deposit of the Po River Plain (Northern Italy) which experienced extensive liquefaction during the May 2012 Emilia earthquake. The model is able to capture the measured response, although more experimental data and a more sensitive calibration of the parameters would be required. This study can be considered a useful starting point for the modelling of the liquefiable soil deposit and for the proper interpretation of the observed seismic-induced deformation phenomena.

Ülker proposes a new hardening interpolation rule along with a local degradation function for the plastic modulus depending upon the location of the current stress state relative to the one on the bounding surface within the generalized plasticity theory. A set of static and cyclic triaxial shear tests conducted on normally consolidated clays and a loose sand is then simulated. The new interpolation yields slightly better results than the exponential degradation rule proposed in earlier works, which proves the new relation to be useful.

Maghsoudloo et al. focus on evaluation of a generalized elastoplastic model within a multilaminate framework as implemented in the finite element code PLAXIS to simulate large scale experiments of static liquefaction failures in submerged slopes under monotonic loading. The simulations showed that taking into account the time and rate dependent behaviour of some material parameters, along with the stress state, enables more realistic predictions of the stress-strain behaviour. The multilaminate model proves able to simulate the undrained behaviour of loose sands in the available stress range.

Ghahreman-Nejad and Kan present case studies for prediction of seismic deformation of embankment dams by using various numerical approaches, such as empirical methods, simplified Newmark-based methods, and elasto-plastic dynamic analyses. The results of these analyses indicate that semi-empirical methods may not necessarily result in conservative estimates of the deformation for rockfill embankment dams. The authors propose that simplified empirical methods may not necessarily trigger the need for the next stage of analysis and hence may impose significant risks if adequate measures are not employed in design of embankment dams.

Said et al. present simulations of a cargo hold under the effect of swell to elucidate the processes that could occur within the ore pile, subject to the initial conditions of the cargo and accelerations experienced on voyages. The dynamic model results conclude that denser a cargo is more resistant to liquefaction. The numerical simulations also prove that a fully trimmed ore pile is more prone to liquefaction and therefore to cargo shift.

Saeedi Azizkandi et al. discuss the effect of frequency on the response of a piled raft foundation and structure by using shaking table tests. Two different one degree of freedom systems fixed to the piled raft foundation on dry sand soil are examined. The experimental results suggest that the natural frequency of the structure is an important factor for design of the deep foundation.

Nuzhdin describes analytical solutions for the dynamic behavior of foundations. The calculated dependence for the amplitude determination is provided for the foundation vibration constituents from force action and kinematic excitation on the basis of elastic half-space model. The dependence includes only general parameter expressions of hardness and damping of the base, actual load and general parameters of the foundation. They are convenient to use for the foundations of different constructions including special types of foundations for machines with dynamic loads, pile foundations and foundations on reinforced base.

7 PARTICLE METHODS

This category includes four papers concerning particle simulation by DEM and SPH. Two of them both deal with debris flow phenomena by CFD-DEM and SPH. Other two papers use DEM for modeling stone column behavior and evaluating effects of shear direction on the shearing behavior of soils-structural interface, respectively.

Li and Zhao employ a coupled Computational Fluid Dynamics and Discrete Element Method (CFD-DEM) approach to model debris flows as a mixture of fluid and solid phases. They allow for the breakage of aggregates into fines by exchanging mass between the solid phase and fluid phase, resulting in a corresponding change of properties for the two phases. The influence of fine contents added into the fluid phase from the solid phase is carefully examined. It is found that the mobility and impacts of debris flow are enhanced by increased fine contents added to the fluid phase, and the flow patterns and kinematics can be greatly changed as well. Correlation of the obtained empirical coefficient of impact model based on the numerical study agrees well with experimental data.

Chalk et al. report a physical experiment in which a saturated sand mass is released via a trap door in a 220 x 160 mm rectangular channel of length 1.75 m. The inclination of the flume is 31 degrees which meant the sand reached run-out velocities of 1 m/s, approximately. The flow was monitored to obtain its evolving free surface, and the readings are compared to a SPH to discretize the Biot-Zienkiewicz model where two rheological models are implemented, i.e., the frictional Voellmy's model and the viscoplastic Bingham model (Figure 10). The experimental results show that the Voellmy model is better able to simulate the experiment than the Bingham model.

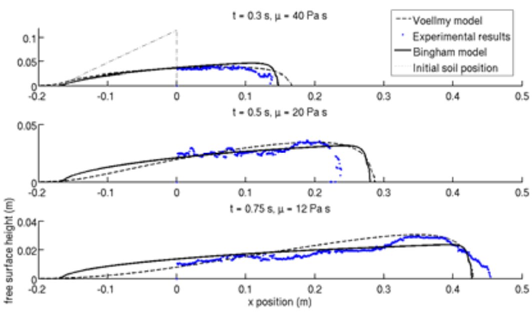

Figure 10. A comparison of the experimental free surface profile with the Voellmy and Bingham numerical models. (*Chalk et al.*)

Shukla and Fuentes model a composite system of both the stone column and the surrounding soil using PFC2D and validate against an experimental model tests on stone columns made of crushed basalt in a clay soil to develop better understanding about the settlement characteristics of stone columns. A brief initial parametric study has been carried out to obtain the correct input parameters for an unreinforced system (clay only sample), using these values the study extends to including a stone column which is then loaded. The clay soil has been correctly calibrated within this study allowing a stone column system to be modelled using DEM only.

In *Chen et al.*, to investigate the effects of shear direction on the shear behavior of a soil-structural interface and the shear banding in it, a series of three-dimensional numerical interface shear tests considering various angles of shear direction, defined as the angle between the shear direction and the direction of a surface's roughness anisotropy, are performed using the discrete element method. Simulation results show that (1) shear stress increases with an increasing of the angle of shear direction, with the elastic perfect-plasticity observed when the angle of shear direction equals zero; (2) all specimens show bulk dilatancy during the shearing process, increasing with the angle of shear direction; and (3) peak stress increases with the angle of shear direction, as does the thickness of the shear band.

8 COUPLED ANALYSES

This group of research has been devoted to numerical modeling of the coupled behavior of saturated and unsaturated porous media. The coupling involves hydro-, mechanical and thermal behaviors. The subjects include analytical solutions to classical problem (*Ho et al.*), numerical solutions to practical problems (*Kim et al.*) as well as developments, verification and implementation of numerical algorithms for geotechnical modeling of both soils and rocks (*Hong et al.*, *Mokhtari et al.*, *Toyoda and Noda*). Numerical schemes developed purposely for calibration and correlation with experimental testing are also presented (*Phangkawira et al.*, *Moldovan et al.*). Formulation which is able to model the mechanical behavior of sand subjected to low initial confining pressure (*Latini et al.*).

Ho et al. develop analytical solutions to the one-dimensional consolidation problem of unsaturated soil deposit with changes in temperature and incremental loading. They considered a one-way drainage boundary system with uniform initial conditions and used Fourier series and Laplace transforms to derive close-form analytical solutions to the governing equations.

Kim et al. perform a coupled hydro-mechanical simulation using FEM to investigate the performance of a shaft seal in a 5-meter-diameter main shaft and demonstrate that their predictions compare well with full-scale tests. Their study further shows that the coupled modeling may help understand the complicated, progressive change in soil behavior during the hydration of the shaft seal components.

Hong et al. present an explicit integration scheme with adaptive time-stepping to implement a class of isotropic multi-surface models based on the subloading surface concept for natural clay. The accuracy and efficiency of the algorithms are evaluated.

Mokhtari et al. investigate the propagation of a cohesive crack in an unsaturated porous media using XFEM. The crack is simulated as a strong discontinuity in the displacement field using XFEM and is treated as internal boundary exchanging water with surrounding porous medium, resulting in changes in suction within the fracture. They further demonstrate their model with application to a L-shaped soil panel subject to mixed-mode loading.

Toyoda and Noda present a fully coupled numerical analysis of saturated soil with high permeability based on full formulation for finite deformation field of soil-water mixture that solves for the pore water pressure, the displacements of both solid and liquid (u-U-p) as independent variables. They demonstrate that their full-formulation analysis enables the observation of pore water flow in highly permeable soil, which is not possible with the commonly used u-p formulation.

Phangkawira et al. develop a numerical methodology to predict the plastic deformations induced by the pressuremeter tests in highly fractured rocks and calibrate relevant model parameters for the Hardening Soil Model (HSM).

Moldovan et al. present a method coupling numerical simulation and experimental tests based on hybrid-Trefftz finite elements to model bender element experiments. They demonstrate that their elements were significantly less sensitive to wavelength than conventional ones, which enables the use of coarse FE meshes for problems with varied wave types and frequencies. The adopted finite elements also exhibit strong physical meanings for direct comparison with experimental results to filter out spurious wave from sample responses.

The objective of paper by *Latini et al.* is to propose a formulation which is able to model the mechanical behavior of sand subjected to low initial confining pressure. Therefore, the formulation aims at introducing a rounded hyperbolic yield surface to eliminate the singular apex from the original yield criterion. Due to this modification, the model is denoted the modified SANISAND (2004) model. Undrained triaxial compression tests on Toyoura sand are performed to show the performance of the proposed formulation.

Santos et al. propose a simple, but very effective, model to describe the nonlinear stiffness of soils. They then illustrate the performance of the constitutive model by applying it to results obtained experimentally on Toyoura Sand.

9 HYDRAULIC FRACTURING, PERMEABILITY, AND CAPILLARY PRESSURE

This small group of papers includes problems related to the modelling of 1) hydraulic fracture, 2) transverse permeability of fibrous geomaterials, and 3) capillary pressure. Sophisticated analytical techniques applicable for each problem are demonstrated by each author.

Youn and Griffiths describe a novel numerical model for investigating pressure leak-off during hydraulic fracturing. The model allows the fluid bottomhole pressure to be observed under different fracturing conditions. To achieve this, a hydro-mechanical coupled model based on an eXtended Finite Element Method (XFEM) is developed and applied. The mechanical behavior of the domain with discontinuities can be estimated without explicitly meshing the discontinuities as would be necessary in a traditional discrete fracture FE model. A sequential coupling scheme using Picard iteration is applied to the XFEM model to reproduce the hydro-mechanical coupling behavior during the hydraulic fracturing. The authors demonstrate with an example how the method can improve the understanding of the influence of pre-existing fractures on pressure leak-off response during hydraulic fracture propagation.

Nguyen et al. propose a coupled numerical approach where fibres are modelled by Discrete Element Method (DEM) and fluid is simulated by Finite Volume Method (FVM). The Parallel Bond Model incorporated in DEM captures the linear stress-strain behaviour of natural fibres such as jute, but unlike previous studies where the fibres are either pre-formed and have an unchanged geometry, the coupling technique provides a good agreement in predicting the hydraulic behaviour of fibrous porous media. The motion of fibres due to fluid flow is also analysed in this study.

Suh et al. describe pore network modeling (PNM), depicted in Figure 11, which is useful to simulate the water retention process of capillary dominated systems. Randomly structured 3D pore geometry can be simplified as the network of pore channels of cylindrical shape. Radii of cylindrical pore channels are determined by inscribed spheres, which leads to the overestimation of capillary pressure in irregularly shaped pore throats. The correct capillary pressure can be obtained by bubble analysis using lattice Boltzmann method (LBM). The authors present a simple shape analysis technique by Euclidean distance transform (EDT) to identify the effective cross-sectional area, which is defined as the expected location of the nonwetting fluid during the invasion into a capillary tube filled with wetting fluid. By extending MS-P theory, the authors calculate capillary pressures of tubes whose effective cross-sections are taken from 3D X-ray CT image compared with LB bubble simulation.

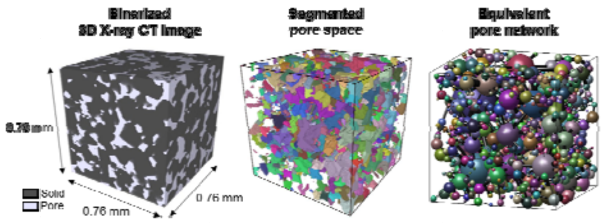

Figure 11. Binary 3D X-ray CT image of Berea sandstone, its segmented pore space and the equivalent pore network. (*Suh et al.*)

10 FIELD MEASUREMENTS FOR COASTAL PERMAFROST AND CREEP CALCULATION

Last group of papers includes two papers both from Norway deal with field measurements for coastal permafrost and creep calculation by satellite data, respectively.

Le contributes to bridge the knowledge gap through an investigation into a typical thermal profile on Pesyakov Island in Varandey, Russia. First, the geological and geomorphological condition of the studied site is described. The paper then discusses the variation of soil temperature measurements at the selected location for study over a period of two years. Finally, a numerical model of the thermal profile calibrated with the measured data at the studied borehole is presented with discussion on important factors influencing the numerical predictions. The numerical models show capability to reproduce quite well the measured data.

In *Gedado and Grimstad*, different ways of evaluating creep parameters are first briefly presented and discussed. In recent years, satellite based remote sensing techniques are shown to monitor ground movements with high precision. A way to supplement evaluation of creep parameters using satellite data is explored in the work presented in this paper. This is further illustrated by using different sets of parameters and along with numerical simulations based on the isotache concept. It is shown that by using such data, there is a huge potential to evaluate and establish the initial creep rate reasonably well and this is illustrated to supplement creep calculations. Additional possible use of satellite data in connection to evaluation of settlement are also discussed.

Appendix

Table 1. List of papers in Numerical Methods in Geomechanics.

STABILITY AND PERFORMACE OF FOUNDATIONS

No.	Authors	Title	Keywords
1	Ivana Lukić Kristić, Vlasta Szavits-Nossan	Direct methods for prediction of shallow foundation settlements in sand and numerical modeling	shallow foundations, settlement, bearing capacity, load tests
2	Nicolas Frattini, Fahd Cuira, Boramy Hor	Simplified approach for the design of rigid inclusions under spread footing using semi-analytical calculations	rigid inclusions, semi-analytical calculations, stability diagram
3	Ulf Matthiesen, Martin Poh, Roland Rother, Sascha Henke	Geotechnical challenges in the design of the new Lueneburg lock next to the existing ship lift	lock, ship lift, numerical modelling, FEM, FDM
4	Helen P. Dunne, Chris M. Martin	Capacity analysis of suction caissons used in catenary mooring systems	limit analysis; finite element modelling; caissons; capacity analysis
5	Hesham Elhuni, Dipanjan Basu	Dynamic Response of Simply Supported Beams on Two-parameter Foundations	analytical solution, beams, elastic foundation, dynamic, Pasternak
6	N. Leonid, N. Matvey, K. Askar, K. Zohir, P. Kseniya	Investigation of the effect of the deformation anisotropy on the stress-strain state of the of soil basement	stress-strain state, anisotropic soils, foundation settlements
7	Subramanian RM, Boominathan A	Behaviour of batter piles under dynamic loads	batter piles, inclined piles, finite element, dynamic.
8	Colin Smith, Javier González-Castejón, Jared Charles	Enhanced interpretation of geotechnical limit analysis solutions using Discontinuity Layout Optimization	limit analysis, DLO, optimization

SLOPE STABILITY

No.	Authors	Title	Keywords
9	Jung-Tae Kim, Ah-Ram Kim, Gye-Chun Cho, Dae-Hong Kim	The development of slope stability program considering rainfall and presence of transmission tower	unsaturated slope stability program, rainfall infiltration
10	Chen Wang, Bipul Hawlader	Numerical Modeling of Three Types of Sensitive Clay Slope Failures	large-scale landslides, finite element modeling and sensitive clay
11	Murray Fredlund, HaiHua Lu, Del Fredlund	Practical Application of 3-D Stability Analysis	3D slope stability, shear strength reduction, 2D stability analysis

RETAINING WALLS AND EMBANKMENTS

No.	Authors	Title	Keywords
12	Cristian de Santos, Alberto Ledesma, Antonio Gens	Backanalysis of preloading	backanalysis, adaptive genetic algorithm and preloading
13	M. Havinga, F. Tschuchnigg, R. Marte, H. F. Schweiger	Small scale experiments and numerical analysis of integral bridge abutments	integral abutment bridge, earth pressure, small scale experiment
14	S.H. Mirmoradi, M. Ehrlich	Reinforced soil walls: Experimental and numerical investigation of the effect of toe resistance on the performance	reinforced soil (RS) walls; toe restraint; segmental block facing; working stress conditions
15	Per Gunnvard, Hans Mattsson, Jan Laue	Numerical Analysis of the Mechanical Behaviour of Light Embankment Piling	piled embankment, timber piles, triangular arrangement, sulphide soil
16	Róbert Szepesházi, János Szép	Modeling of soil-structure interaction in bridge design	FEM-model, bridge design, separated and integrated modeling

EXCAVATIONS

No.	Authors	Title	Keywords
17	Fabiano Bertoldo, Luigi Callisto, Jian-Gu Qian	An interpretation of the behaviour of a deep excavation in Shanghai based on numerical analysis	case history, excavation
18	N. Kovacevic, C. Menkiti, M. Long, D. Potts	Finite element back-analysis of an anchored wall in Dublin Boulder Clay	FEM, excavation, anchored retaining wall, stiff boulder clay
19	L. N. E.-Anguiano, F. V.-Viveros, J. R. P.-Cruz, C. C.-Negrete, E. A.-Rocha, M. O.-Calderón	Displacement nomograph from two (2D) to three (3D) dimensions applied to circular tunnels in clay using finite element	displacements, nomograph, tunnel, clay, finite element method
20	Hussein Elarabi, Anas Mohamed	The Effect of Installation Procedures and Constitutive Laws for Numerical Simulation of Closed Face Tunnelling	numerical simulation, tunnelling, ground deformations
21	Marcin Cudny, Ewelina Partyka	Influence of anisotropic stiffness in numerical analyses of tunneling and excavation problems in stiff soils	soil stiffness, anisotropy, constitutive modelling, overconsolidated soils

SEISMIC RESPONSE OF STRUCTURES

No.	Authors	Title	Keywords
22	Arianna Poli, Irene Rocchi, Laura Tonni	Modelling the experimental behaviour of a liquefaction-prone fine sand	fine sand, soil liquefaction, Generalized Plasticity, state parameter
23	Mehmet Barış Can Ülker	A new hardening interpolation rule for the dynamic behavior of soils using Generalized Plasticity framework	cyclic behavior, Generalized Plasticity, Hardening law
24	A. Maghsoudloo, V. Galavi, M. A. Hicks, A. Askarinejad	Finite element simulation of static liquefaction of submerged sand slopes using a multilaminate model.	Static liquefaction, submarine landslides, multilaminate framework, finite element, sands
25	Behrooz Ghahreman-Nejad, Mojtaba E. Kan	Seismic Deformation Analysis of Embankment Dams: A Comparison between Simplified and Non-Linear Numerical Methods	deformation analysis, embankment dams, FLAC, numerical simulation, SHAKE, simplified methods
26	Imen Said, Samar Daoud, Samir	Dynamic numerical assessment of cargo liquefaction	liquefaction, numerical modeling,

	Ennour, Mounir Bouassida	under the swell effect	dynamic motion, maritime transport
27	A. Saeedi Azizkandi, Mohammad Hassan Baziar, Boshra Razmi	Experimental study on seismic response of structure with Piled raft foundation	piled raft, shaking table test , structure's stiffness ,pile moment
28	Nuzhdin Leonid V.	The analysis of the foundations vibrations on wave models in general case of dynamic loading	vibration amplitudes, elastic half-space model

PARTICLE METHODS

No.	Authors	Title	Keywords
29	Xingyue Li, Jidong Zhao	A coupled CFD-DEM study of debris flow impacts: the influence of mass exchange	coupled CFD-DEM, debris flow, mass exchange, impacting
30	Caitlin Chalk *et al.*	A numerical comparison of a frictional and viscoplastic debris flow model	SPH, debris flow, voellmy, bingham
31	Palak Shukla, Raul Fuentes	Modelling stone column behaviour using the discrete element method	discrete element method, stone columns
32	Wei-Bin Chen, Wan-Huan Zhou, Xue-Ying Jing	Effects of shear direction on the shearing behavior of a soil-structural interface using discrete element method	soil-structure interface, discrete element method

COUPLED ANALYSES

No.	Authors	Title	Keywords
33	Liem Ho, Dan Li, Behzad Fatahi, Hadi Khabbaz	Analytical solution to one-dimensional consolidation in unsaturated soil due to time-dependent exponential temperature and external step loading	1D consolidation, unsaturated soil deposit
34	Chang Seok Kim, Marolo Alfaro, James Blatz	Evaluation of coupled hydro-mechanical behaviour of in-situ shaft sealing components	shaft seal, coupled hydro-mechanical modelling
35	P.Y. Hong, R.P. Chen, W. Chen, Y.J. Cui	Explicit integration for isotropic two-surface plasticity model based on the subloading surface concept	constitutive models, subloading plasticity
36	Alireza Mokhtari, Behrouz Gatmiri, Ehsan Motevalli Haghighi	Propagation of cohesive crack in unsaturated porous media in mixed mode	unsaturated porous media, cohesive crack, XFEM, J integral
37	Tomohiro Toyoda, Toshihiro Noda	A full formulation-based soil-water coupled finite deformation analysis on undrained compression tests on highly permeable soil specimen	full formulation, soil-water coupled finite deformation analysis
38	Fredrik Phangkawira, Dominic E.L. Ong, Chung-Siung Choo	Numerical Prediction of Plastic Behavior of Highly Fractured and Weathered Phyllite Subjected to Pressuremeter Testing	pressuremeter, hardening soil model
39	Ionut Dragos Moldovan, António Gomes Correia, Cláudio Pereira	A coupled numerical–experimental approach for bender-based G_0 measurements in geomaterials	small strain shear modulus
40	Chiara Latini, Varvara Zania, Claudio Tamagnini	Modelling of constitutive behavior of sand in the low stress regime: an implementation of SANISAND	anisotropy, sand, constitutive relations
41	J. Santos, J. C. Lourenço, A. Modaressi-Farahmand Razavi	Calibration of hardening rules of an elastoplastic model to simulate experimental behaviour of natural soils	elastoplastic model, shear hardening, volumetric strain

HYDRAULIC FRACTURING, PERMEABILITY, AND CAPILLARY PRESSURE

No.	Authors	Title	Keywords
42	D.-J. Youn, D.V. Griffiths	A model for numerical analysis of pressure leak-off response during hydraulic fracturing within naturally fractured formations	XFEM, hydraulic fracturing, pressure leak-off
43	T. T. Nguyen, B. Indraratna, C. Rujikiatkamjorn	A numerical investigation into the transverse permeability of fibrous geomaterials	CFD-DEM coupling, natural fibres, geomaterials
44	Hyoung Suk Suh, Dong Hun Kang, Tae Sup Yun	Capillary pressure correction in irregularly shaped pore channel under fully wetting condition	capillary pressure, Pore throat geometry

FIELD MEASUREMENTS FOR COASTAL PERMAFROST AND CREEP CALCULATION

No.	Authors	Title	Keywords
45	Thi Minh Hue Le	A thermal profile of coastal permafrost at Varandey, Russia	permafrost, erosion, coastal, thermal
46	Samson Abate Degago, Gustav Grimstad	Potential application of satellite data in evaluation of field creep calculation	settlement, creep, secondary consolidation