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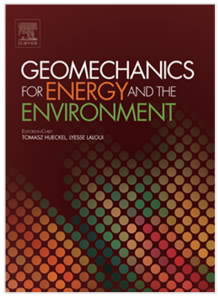


Themed issue on selected papers SEG2015 — Part I

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**Themed Issue on Selected Papers SEG2015 – Part I**

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## Introduction: *SEG-2015*

This themed issue of *Geomechanics for Energy and the Environment* '*SEG-2015-Part I'*, presents papers selected from abstracts submitted to the Symposium on Energy Geotechnics (*SEG-2015*) held in Barcelona, Spain, between June $2^{nd}$ and $4^{th}$, 2015. The Symposium venue was the Civil Engineering School of the Universitat Politècnica de Catalunya in Barcelona.

To organize the growing activity in the area of Energy Geotechnics, the International Society for Soil Mechanics and Geotechnical Engineering (*ISSMGE*) has recently formed the Technical Committee *TC308* on 'Energy Geotechnics'. The *TC308* has several missions, including: i) to disseminate knowledge and practice in the area of soil mechanics and geotechnical engineering associated with Energy Geotechnics; ii) to organize specialty conferences, symposiums and workshops; iii) to assist with technical programs of international and regional conferences organized by the *ISSMGE*, and also iv) to interact with industry and other organizations working in areas related to the *TC308*'s specialist subject.

*SEG-2015* was the first Symposium organized by the *TC308* in this context. The event brought together more than one hundred colleagues from different countries, including internationally recognized experts, young researchers, academics, professionals and representatives of geoengineering companies, who exchanged ideas, discussed current and future investigations and practices in the area of energy geotechnics. The format of the event was singular, comprising two days of track-sessions associated with the eight 'Task Force' areas, in which the *TC308* channels its activities. These Task Forces address: Gas Hydrate Sediments; Unconventional Hydrocarbon & Hydraulic Fracturing; Energy Geo-Structures & Storage of Thermal Energy in the Ground; Energy Geo-storage; High Level Radioactive Waste Disposal; Carbon Dioxide Geological Storage; Fundamentals of Geo-Energy; and Others Geotechnical Activities Related to the Energy Sector. Each session included a 'Position Paper' (delivered by the 'Tasks Force Leaders'), two 'Invited Presentations', plus a 'Technical Panel' composed of recognized experts in the corresponding Tasks Forces. The third day was dedicated to the presentation of the technical works submitted by delegates. In summary, a total of 7 position papers were presented, plus 23 invited lectures and 34 technical presentations.

## Contribution to this *SEG-2015* issue

This special issue consists of eight papers selected from the invited and technical presentations after a peer-review process. A second part of this special issue (to appear later this year) will contain a similar number of contributions selected from this event.

A common conclusion emerging from practically all the presented work associated with Energy Geotechnics is the need of achieving a complete laboratory characterization, a sound understanding of the process involved and a coupled modelling of the thermo-hydro-mechanical and chemical behaviour of soils and rocks. The formation of shear bands in geomaterials is a topic that has been intensely investigated in the last few decades, with special focus on materials' mechanical behaviour. However, hydraulic, thermal and chemical interactions may also play an important role in the triggering and evolution of narrow zones of localized deformation in geomaterials. In this issue, Sulem and Stefanou[1] brought an in-depth review of recent relevant contributions dealing with the effects of temperature, pore-pressure, chemical reactions and microstructure on strain localization in geomaterials. The cases analysed are related to seismic-slip and compaction banding. The Authors proposed a framework for a localized failure applied to earthquake rupture. Based on that framework, they concluded that thermal pressurization (of the pore fluid) and specific chemical reactions (with the associated dissolution softening) could trigger strain localization. They observed that two models based on different constitutive assumptions (i.e. one based on Cauchy continuum, and the other on Cosserat continuum) yield to analogous expressions for the critical wave-length that scale with the thickness of the localized zone.

Robust modelling approach able to deal with the complex coupled multiphysics phenomena generally present in Energy Geotechnics applications is a critical component to advance knowledge and practice in this area. In this issue, Cui et al.[2] demonstrated that the Galerkin's finite element method is capable of dealing with convection-dominated heat transfer problems and the associated strongly coupled thermo-hydraulic interactions. The application under study corresponded to open-loop problems associated with ground source energy systems. Cui et al.[2] upgraded and validated the geomechanical computer software *ICFEP* to tackle this type of coupled hydro-thermal problems. Special attention was paid to the stability condition for the adopted time marching scheme and the selection of an adequate discretization for different boundary conditions to prevent oscillatory solutions. Very satisfactory agreement between numerical and analytical solutions was reached in this contribution for the case a boundary value problem associated with an open-loop system.

The storage of heat and its exchange with the ground to assist the heating and cooling of buildings is perhaps the subject that has developed most in the last few years in the area of Energy Geotechnics. In this issue, the contribution by Bidarmaghz et al.[3] studies the implementation of Ground Heat Exchanger (*GHE*) concept for the air conditioning of buildings using geothermal energy. A constant temperature in depth is generally assumed in studies involving the thermal performance of *GHEs*. This is a fair assumption for deep boreholes (i.e. 50m or deeper). In this work, Bidarmaghz et al.[3] focused their analyses in relatively shallow energy piles, studying the influence of the surface air temperature changes on ground temperature and in the long-term performance of *GHEs*. The numerical simulations were performed with a 3D model developed in *COMSOL* that allowed a detailed representation of the main component of the problem. The model was validated using several full-scale experiments involving vertical GHEs and considering long-term performance (up to 25 years). These simulations have shown that air temperature fluctuations had a significant impact on GHEs behaviour.

Also in this volume, Criollo et al.[4] analysed in detail the effect of both varying surface boundary conditions and material properties (in particular, thermal conductivity) on the collection performance of near-surface interseasonal heat storage systems. To study this problem, they proposed an advanced 2D finite element model, which they validated against field data. The case study is based on the interseasonal heat storage facility investigated by Carder et al.[5]. From the sensitivity analyses presented in this study it was clear that the thermal conductivity played a central role in the ground-heat storage and the associated temperatures. It was also observed that the role of the insulation layers is critical when studying heat losses. As for the climatic conditions, it was observed that warmer climates provided more thermal energy available to be stored. However, changes in the amplitude of seasonal air temperature variations had an effect on the rate of collection of thermal energy. Furthermore, the selection of the proper surface boundary conditions was found to be instrumental when simulating the dynamics of this type of system.

Offshore geotechnics possess significant challenges associated with the design of foundations for oil platforms, wind turbines, and other subsea civil infrastructure. Two papers of this special issue are related to this subject. Lu and Maclaren[6] present numerical analyses associated with the geotechnical stability of offshore foundations in mudmat. The simulations involve analytical solutions and finite element modelling using the commercial geotechnical program *Plaxis*. The case study corresponds to an offshore jacket project in the North Sea characterized by quite complex layered soil conditions, involving very soft clays underlaid by sand immediately underneath the mudmat. This type of ground condition limits the direct use of conventional analytical procedures, therefore the Authors investigated different finite element modelling strategies to cope with such soil conditions. By combining analytical and finite element methods the paper provides bearing capacity graphs for offshore jackets. The procedure proposed in this paper will hopefully serve as a reference for designing foundations in future offshore projects under similar soil conditions.

The work of Labenski and Moormann[7] is also related to offshore geotechnics and it is focused on the design of the monopiles typically used in wind farms. This is an area of energy geotechnics that has been receiving an increased attention in the last few years. This contribution discusses well-established methods (five in total) to determine the axial bearing capacity based on the cone resistance of the soil, but it also explored explores two new approaches recently proposed. The Authors also conducted a sensitivity analysis to identify the key factors and parameters involved in the prediction of the axial bearing capacity of monopiles. The reliability of the different methods to predict the bearing capacity under different conditions is studied using published field data.

Geo-engineers also need to deal with the waste generated by the energy sector. A typical example is the design of repositories for high level radioactive waste. Two contributions of this special issue are related to this type of application, one of them focused on gas migration and the other one on coupled processes associated with water transfer under non-isothermal conditions.

The paper by Gonzalez-Blanco et al.[8] explores gas migration issues through a potential host clay formation for the geological disposal of radioactive waste in Belgium on the basis of laboratory work and its numerical modelling to help in the interpretation of the results. Priority was given to the study of the volume change response along the air injection and dissipation stages that were performed under oedometer conditions, as well as to the analysis of the pore network changes (associated with preferential air pathways). The experimental results were simulated using a fully coupled hydro-mechanical finite element code *Code Bright*, which incorporated an embedded fracture permeability model to deal with gas flow along pathways with variable aperture (that depended on the deformation of the clay).The test results and simulations along the air injection and dissipation stages showed the important effects of these aperture changes, which significantly affected the intrinsic permeability and the water retention properties of the clay.

The contribution by Sanchez et al.[9] focuses on numerical analyses associated with the effect of thermo-osmotic flow in the long term behaviour of barrier materials (both natural/geological and engineered) subjected to hydration under temperature gradients. Advective mass flux (driven by liquid pressure gradients) is the main mechanism of the water movement in porous media, however it is not the only one. For example, thermo-osmosis is a coupled process associated with the movement of mass of liquid water induced by temperature gradients. It may have a relevant effect in the long-term behaviour of repositories. The Authors selected two cases to study this coupled process, one of them explored the behaviour of rock acting as a geological barrier (a case proposed by Pollock[10]), and the other one studied the behaviour of a clay barrier material in the laboratory under controlled conditions. The modelling results are supported by experimental observations.

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