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Introduction

This themed issue of *Geomechanics for Energy and the Environment* '*SEG-2015-Part II'*, presents papers selected from extended abstracts submitted to the Symposium on Energy Geotechnics (*SEG-2015*) held in the Civil Engineering School of the Universitat Politècnica de Catalunya in Barcelona, Spain, between June 2nd and 4th, 2015. This symposium *SEG-2015* was the first event organized by the Technical Committee *TC308* of the International Society for Soil Mechanics and Geotechnical Engineering, which will have continuity in the next symposium *SEG-2018* to be held in the École Polytechnique Fédérale de Lausanne (Lausanne, Switzerland).

The first issue '*SEG-2015-Part I'* appeared just before the 1st International Conference on Energy Geotechnics (*ICEG-2016*), which was held in Kiel (Germany) at the end of August 2016. The second volume '*SEG-2015-Part II'* on December 2016 will thus close a first cycle of successful conferences and publications along this initial stage of *TC308*.

Contributions to this *SEG-2015* issue

This special issue consists of seven papers selected from the invited and technical presentations of *SEG-2015* after a peer-review process. As with the first issue, the idea was to bring together a series of papers covering different topics and applications within the various 'Task Force' areas, in which sessions of *SEG-2015* were organised and *TC308* has channelled its activities. This way, the papers selected address the following topics: energy geo-storage and geo-structures (three papers); high-level radioactive waste disposal (three papers); and unconventional hydrocarbon (one paper).

The selected papers also cover a wide scope of multi-scale processes, ranging from large-scale reservoir geomechanics, tunnel geothermal plants and geothermal energy piles to lower scale phenomena dealing with thermal conductivity in sedimentary deep host argillaceous rocks, and clay-water interactions in clay-based engineered barriers during hydration. Different coupled phenomena are addressed in the papers, which highlight the need for a sound understanding of the multi-physics process involved and a coupled consideration of the thermo-hydro-mechanical behaviour of soils and rocks, not only from modelling point of view but also from experimental standpoint. Thermo-mechanical aspects are discussed during the hydration of clay-based engineered barriers, heating of deep argillaceous formations, and axial thermal strains and stresses on piles subjected to heating and cooling operations. Coupled thermo-hydraulic phenomena are used to explain pore water pressure increase and loss of shaft friction of geothermal piles placed in low-permeability clays, as well as on the effects of the hydrogeological conditions on the operation of tunnel geothermal plants. Finally, hydro-mechanical issues arise when describing fracture propagation during injection and on reservoir subsidence.

Underground structures (tunnels) with a large surface in contact with the ground provide an excellent opportunity to integrate geothermal plants for renewable energy source. The German experience in two tunnel geothermal plants (Stuttgart Fasanenhof tunnel and Jenbach tunnel in the Tyrol) over several years of operation is presented in the paper by Buhmann *et al.*[1]. The authors describe the geothermal activation of the tunnel to geothermally exploit the lining through an absorber pipework system, in which the tunnel air temperature is a key factor for the heat flux from the tunnel. The authors focus on the energy extraction capacity and the effects that the geothermal activation has on the subsurface temperature.

Shallow geothermal energy piles for heating and cooling of buildings are also an important topic in this issue, in which two contributions are included. The paper by Faizal *et al.* [2] deals with a full-scale experimental investigation to study the influence of different types of operations (intermittent and continuous for 24 hours) on energy extracted, on ground and pile temperatures, as well as on the effects of the thermal loads on the piles (axial thermal strains and stresses). The authors observed that the energy extracted from the ground was higher under lower operating hours. The thermal impact on the piles also induced lower average thermal stresses when using the intermittent operation. The paper by Fuentes *et al.* [3] studies the effects of non-isothermal conditions on low-permeability and saturated clays adjacent to geothermal piles. Numerical simulations, in which soil permeability and compressibility are key parameters, allow estimating the pore pressure increase in these soils during heating that reduces the shaft resistance of the piles. These effects are particularly important in soils that are used as heat sink during sustained periods. The numerical solution is applied to a real case that allows explaining the loss of shaft friction of a heated pile.

Three papers in this volume address particular issues of deep geological disposal for the isolation of high-level radioactive waste. Not only the engineered barriers (made up of compacted swelling clays), but also the host argillaceous rock are subjected to coupled thermal, hydraulic and mechanical phenomena induced by the heat-emitting nature of the nuclear waste and the properties of the multi-barrier isolation system. In this particular context, the paper by Villar *et al.* [4] explores the hydration process of engineered barriers under high temperature field based on laboratory work using highly instrumented cylindrical cells. The aim of the tests is to mimic in the laboratory the conditions of different barrier materials used in a large-scale *in situ* test (HE-E performed at the Mont Terri Underground Laboratory, Switzerland). The authors use new types of sealing materials, namely high-density bentonite pellets and a binary mixture made up of silica sand and bentonite powder (65/35). The reported results are useful for the validation of thermo-hydro-mechanical models and as benchmark exercise. On the other hand, the paper by Jacinto *et al.* [5] deals with a much lower scale of the behaviour of engineered barriers focusing on clay-water interaction during hydration process of compacted bentonite to define water density variations inside small pores. Different laws for the water density are considered to describe the water retention properties. These laws, which depend on the hydration state of the expansive clay, take into account the amount of water in the interlayer space and the adsorbed one on the external surface of clay particles. Model predictions during hydration taking into account the variation of water density compared to simulations at constant water density show that major differences occur at long-term conditions (time for saturation increases substantially with variable water density). The contribution of Romero *et al.* [6] studies another important component of the multi-barrier concept for long-term isolation of high-level radioactive waste: the geological barrier. Particularly it focuses on determining the thermal conductivity of deep sedimentary clay formations using two different laboratory setups (direct thermal conductivity setup and cell for heating pulse tests). Careful sample pre-conditioning protocols to restore rock *in situ* conditions are followed before the heating tests. Heating pulse tests are interpreted with coupled numerical models, which are also used to back-analyse thermal parameters that are consistent with direct measurements. The article discusses the importance of the pre-conditioning protocols to restore sample saturation, particularly on retrieval of deep sedimentary clays that may undergo opening of fissures along bedding planes.

Oil and gas reservoir problems are also another challenge of energy geomechanics. Because of the large scale involved, the information about rock properties is generally very limited. In

addition, the geomechanical properties are affected by the highly heterogeneous character of the formations. The paper by Pereira *et al*. [7] deals with the quantification of uncertainties in reservoir geomechanical problems, particularly with the use of non-probabilistic methods. Two application problems (estimation of the fracture pressure and subsidence) are selected to compare the results obtained by a deterministic study, a probabilistic analysis and a non-probabilistic study based on evidence theory. The authors conclude that the evidence theory is very convenient because the decision making process becomes easier in this case. Furthermore, the evidence theory provides more complete information than the probabilistic method and is very well suited for incorporating additional (new) evidences as they become available, reducing consequently the uncertainty of the results.

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