Hydro-mechanical Coupling around Galleries in low permeable Media

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In saturated porous media, the excavation of galleries leads to both mechanical and hydraulic disturbances in their surroundings, namely a de-stressed damaged zone and a significant drop in pore water pressures. This not very known phenomenon of instantaneous pore pressure decrease has already been observed in centrifuge tests and around openings in London clay, Boom clay and Opalinus clay formations. It is brought about by hydro-mechanical coupling in the saturated media. Beyond this stage of excavation assumed to be instantaneous, it is as well worthwhile to study the redistribution of pore pressures as a function of time, in particular because these are responsible for time dependent effects around the tunnels (essentially variations of convergence and/or support pressure).

The aim of the presentation is precisely to clarify the up-to-now misappreciated role taken by pore water on the short and long term stability of tunnels in low permeable saturated media. The following points will be discussed:

- The influence of the pre-existing pore water pressure,
- The change in pore water pressure generated during the excavation as a result of hydro-mechanical coupling,
- The fluid flow occurring during the gallery construction and after its completion, inducing time-dependent changes for both the structure and the medium: variation of the total pressure acting on the lining and redistribution of stresses and displacements in the medium,
- The influence on those delayed effects of the nature of the hydraulic boundary condition at the gallery wall (permeable or impermeable lining).

The discussion will be based on two modelling approaches:

- First, in the framework of the classical convergence-confinement method, semi-analytical relationships are established for the design of tunnels excavated in saturated porous elasto-plastic media. With these developments, it is expected that engineers will be given the means to carry out rapid preliminary studies and to appreciate the influence of the parameters relative to pore water on the design of tunnels.
- Then, to enlarge the rather restrictive domain of application of the closed-form solutions, two-dimensional numerical modelling is carried out. It allows to raise the question of the constitutive model that should be used to represent the hydro-mechanical response of stiff clays. It is shown that the response depends not only on the failure criterion (Tresca, Mohr-Coulomb, Cam-clay, ...), but as well on the stress-strain relationship of the soil matrix (linear or non-linear elasticity, associated or non-associated plasticity). Finally, the influence of non-isotropic initial stress conditions is as well discussed.