HIDROMECHANICAL SIMULATION IN A FRACTURED ROCK MASS: THE EXPERIMENTAL SITE OF COARAZE (SOUTHERN-ALPS, FRANCE)

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Hydromechanical processes in large permeable jointed rock masses have been poorly studied due to the difficulties in determining boundary conditions in such large sites. To study this type of problems, *in situ* field experiments have been carried out since 1997 on a small fractured calcareous rock mass in Southern France, near Coaraze (limestone aquifer).

The present work is intended to enhance understanding of hydromechanics in rock masses by testing the stress and strain state of the rock matrix and its discontinuities at the experimental site of Coaraze subjected to a stationary water flow introduced between the discontinuities. This stationary water flow is controlled by a floodgate located on the downstream spring, inducing a hydrostatic water pressure, which is directly opposed to the normal component of the stress in the joint. The water flow directly reduces the frictional strength by dropping the effective stress. The effects of water pressure and lithostatic stress on the deformations are simulated by the application of a two-dimensional computational model called DRAC. The program package DRAC is based on the Finite Element Method (FEM) and it has been developed by the Dept. of Geotechnical Engineering and Geosciences, of the Technical University of Catalonia, and designed for the analysis of rock mechanics and other geotechnical problems. In the present work, its functionability and applicability as a *discontinuous method* is demonstrated, taking into account separately the behaviour of both the rock (solid elements) and the discontinuities (interface elements). DRAC seems to be a good approach when simulating hydromechanical rock mass processes in large and permeable jointed rock masses.

The definition of the geometrical model is based on the characterization of the discontinuities at the Coaraze site. An accurate identification and location of the joints is of maximum importance to predict the flow circulation through the discontinuity network and how it affects the internal stresses, strength and deformability. This geometrical model consists of the definition of nodal coordinates, connectivity of the elements (continuum and interfaces) as well as the determination of the constraints (displacement and geometrical boundary conditions) applied to the domain for the posterior use in the FEM process (numerical model). In the present work, a higher discretisation of the finite element mesh is applied next to the joints and geometrical boundaries to obtain more precise numerical results in order to improve previous numerical analysis carried out at the Dipartimento di Ingegneria Strutturale e Geotechnia, Politecnico di Torino.

A cross section of the small valley located near the floodgate controlling the hydraulic flow has been modelled differentiating three discretisation zones. The current test is applied in the section A, where a higher refinement of the mesh is established. Five oblique joints and two vertical joints are defined and modelled by the development of a "zero thickness" joint element. Only one material type and a linear elasticity constitutive law have been used for the continuum (limestone) and two different stiffness values (oblique and vertical joints) have been defined for the interfaces. For both joints, a perfect elastoplasticity constitutive law has been used, establishing a null stiffness under tensile stresses. The stiffness values have been hypothesized due to the lack of information available, while mechanical parameters for the continuum have been extracted from previous numerical analysis of the experimental site. The analysis has been carried out under the assumption of plane strain and small strain/displacement. When simulating the stationary flow, one stage with two loading steps is used. The first step only takes into account the self-weight load of the rock mass; in this manner, the code evaluates the *in situ* initial state of stress. In the second step, a hydrostatic water pressure is introduced by a water head of 7.5 m, simulating stationary water flow by the closure of the gate. The stress state of the continuum as well as the relative normal displacement of the joints at the end of each step are hence calculated and later visualized with the use of the post-processor DRAC*VIU*.

The numerical analysis of the Coaraze site gives comforting values for the stress state of the continuum and aperture/closure of the joints subjected to the water pressure. Relative normal displacements of joints present a μm order of magnitude, fitting the initial hypothesis of small deformations and the experimental values. It is also demonstrated that joint deformation remains in the elastic field. Nevertheless, a sudden anomalous aperture/closure is developed in the joint intersections zones.

The present work should be considered as a first investigation of a much complex problem. Future researches could deal, for example, with deeper investigations on the mechanical parameters for the discontinuities and on joint intersection numerical behaviour, sensitivity analysis of the joint stiffness and the application of a numerical methodology (coupled solution problem) that might be attempted by the use of DRAC and other codes for the study the hydromechanical coupling in the rock mass subjected to a transient flow.