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Hydromechanical coupling in fractured rock masses: mechanisms and processes of selected case studies

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Hydromechanical (HM) coupling in fractured rock play an important role when events including dam failures, landslides, surface subsidences due to water withdrawal or drainage, injection-induced earthquakes and others are analysed. Generally, hydromechanical coupling occurs when a rock mass contain interconnected pores and fractures which are filled with water and pore/fracture pressures evolves. In the on hand changes in the fluid pressure can lead to stress changes, deformations and failures of the rock mass. In the other hand rock mass stress changes and deformations can alter the hydraulic properties and fluid pressures of the rock mass. Herein well documented case studies focussing on surface subsidence due to water withdrawal, reversible deformations of large-scale valley flanks and failure as well as deformation processes of deep-seated rock slides in fractured rock masses are presented.

Due to pore pressure variations HM coupling can lead to predominantly reversible rock mass deformations. Such processes can be considered by the theory of poroelasticity. Surface subsidence reaching magnitudes of few centimetres and are caused by water drainage into deep tunnels are phenomenas which can be assigned to processes of poroelasticity. Recently, particular focus was given on large tunnelling projects to monitor and predict surface subsidence in fractured rock mass in oder to avoid damage of surface structures such as dams of large reservoirs. It was found that surface subsidence due to tunnel drainage can adversely effect infrastructure when pore pressure drawdown is sufficiently large and spatially extended and differential displacements which can be amplified due to topographical effects e.g. valley closure are occurring.

Reversible surface deformations were also ascertained on large mountain slopes and summits with the help of precise deformation measurements i.e. permanent GPS or episodic levelling/tacheometric methods. These reversible deformations are often in the range of millimetres to a very few centimetres and can be linked to annual groundwater fluctuations.

Due to pore pressure variations HM coupling can influence seepage forces and effective stresses in the rock mass. Effective stress changes can adversely affect the stability and deformation behaviour of deep-seated rock slides by influencing the shear strength or the time dependent (viscous) material behaviour of the basal shear zone. The shear strength of active shear zones is often reasonably well described by Coulomb's law. In Coulomb's law the operative normal stresses to the shear surface/zone are effective stresses and hence pore pressures which should be taken into account reduces the shear strength. According to the time dependent material behaviour a few effective stress based viscous models exists which are able to consider pore pressures. For slowly moving rock slides HM coupling could be highly relevant when low-permeability clayey-silty shear zones (fault gouges) are existing. An important parameters therefore is the hydraulic diffusivity, which is controlled by the permeability and fluid-pore compressibility of the shear zone, and by fluid viscosity. Thus time dependent pore pressure diffusion in the shear zone can either control the stability condition or the viscous behaviour (creep) of the rock slide.

Numerous cases studies show that HM coupling can effect deformability, shear strength and time dependent behaviour of fractured rock masses. A process-based consideration can be important to avoid unexpected impacts on infrastructures and to understand complex rock mass as well rock slide behaviour.