Geophysical Research Abstracts
Vol. 21, EGU2019-6867, 2019
EGU General Assembly 2019

# Integrating rock mass heterogeneities in damage-based, continuum hydro-mechanical models of large landslides

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The hydro-mechanical properties of rock masses in slopes vary in space and time alongside with progressive failure processes, modulating the mechanism, timing and collapse of large rock slope instabilities. A reliable assessment of initial properties in large rock slopes is elusive and further complicate by rock mass heterogeneity related to lithology, fracture network properties and discrete structures (e.g. fault zones). Thus, modelling tools able to properly account for the heterogeneity and damage dependence of rock properties are needed to obtain realistic simulations and predictions of rock slope evolution.

In this perspective, we integrate the ability of stochastic Discrete Fracture Networks (DFN) to realistically represent the heterogeneity of rock mass permeability and deformability within a damage-based, time-dependent 2D FEM model. DaDyn-RS (Riva et al. 2018) simulates the long-term creep and collapse of rock slopes and is able to account for spatially and temporally variable fluid pressure distribution, based on damage-dependent dilatancy and fracture connectivity in a continuum simulation framework. Here we incorporate in DaDyn-RS initial hydro-mechanical properties of rock slopes derived by DFN fracture volumetric intensity (P32), through upscaling techniques.

Starting from field or borehole fracture data (e.g. orientation, intensity, size) we generate DFN models. Then, through grid-based analyses, fracture network properties are upscaled to volumetric fracture intensity (P32) and extracted on representative 2D cross-sections for integration in DaDyn-RS. Depending on the model scale, small fractures are not explicitly represented by the DFN, yet they affect the geomechanical properties of “intact rock”. Thus, we account for the effect of fracture-related heterogeneity on rock mass strength and permeability in three different ways: a) small fractures, not represented in the DFN, are taken into account by assigning initial values of Geological Strength Index (Hoek et al. 1995) to mesh elements corresponding to “rock” blocks in the DFN, according to field-based probability distributions; b) fractures explicitly described by DFN are included by reducing the GSI of relative mesh elements depending on the upscaled P32 of each cell; c) slope-scale structures (e.g. faults or master fractures) are included deterministically in the model. Finally, at each mesh element, the obtained GSI values are used to derive initial values of deformation modulus E0 and damage D0 (i.e. a proxy of element-scale initial permeability as a function of crack density). The model can also be divided into mesh subdomains, characterized by different property distributions and representing different slope-forming materials.

We validated the capability of the approach by the back-analysis of real complex rock slope failures and compared the simulations of conceptual large rock slopes characterized with DFN-derived rock mass properties with those obtained with an equivalent standard GSI-derived distribution (e.g. normal distribution, mean value and standard deviation for the entire slope).