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Modelling dual-permeability hydrological system and slope stability of the Rocca Pitigliana landslide using COMSOL Multiphysics

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The accuracy of using hydrological-slope stability models for rainfall-induced landslide forecasting relies on the identification of realistic landslide triggering mechanisms and the correct mathematical description of these mechanisms. The subsurface hydrological processes in a highly heterogeneous slope are controlled by complex geological conditions. Preferential flow through macropores, fractures and other local high-permeability zones can change the infiltration pattern, resulting in more rapid and deeper water movement. Preferential flow has significant impact on pore water pressure distribution and consequently on slope stability. Increasingly sophisticated theories and models have been developed to simulate preferential flow in various environmental systems. It is necessary to integrate methods of slope stability analysis with preferential flow models, such as dual-permeability models, to investigate the hydrological and soil mechanical response to precipitation in landslide areas.

In this study, a systematic modeling approach is developed by using COMSOL Multiphysics to couple a single-permeability model and a dual-permeability model with a soil mechanical model for slope stability analysis. The dual-permeability model is composed of two Richards equations to describe coupled matrix and preferential flow, which can be used to quantify the influence of preferential flow on distribution and timing of pressure head in a slope. The hydrological models are coupled with a plane-strain elastic soil mechanics model and a local factor of safety method. The factor of safety is evaluated by applying the Mohr-Coulomb failure criterion on the effective stress field.

The method is applied to the Rocca Pitigliana landslide located roughly 50 km south of Bologna. The landslide material consists of weathered clay with a thickness of 2-4m overlying clay-shale bedrock. Three years of field data of pore pressure measurements provide a reliable description of the dynamic hydrological response to transient rainfall intensity. So far, the landslide has been successfully modelled using a diffusion wave approach. In this study, the main focus will be on evaluating the predictive power of different model approaches by inter-comparison of new and existing simulation results. This will make it possible to quantify the influence of preferential flow on subsurface hydrological processes and slope stability in the Rocca Pitigliana landslide.