DFG RESEARCHERS' GROUP: COUPLING OF FLOW AND DEFORMATION PROCESSES FOR MODELING NATURAL SLOPES' MOVEMENTS

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MOTIVATION

In recent years, the failure of natural slopes or hillslopes has led to catastrophic consequences for population, environment and nature. In cohesive soils, the damage often occurs after a long-lasting creeping which causes a weakening of shear zones, while heavy rainfall can induce a sudden sliding of a natural slope. Runoff, infiltration, interflow, groundwater flow as well as evaporation contribute to a very different measure and on very different space and time scales to the elastic and visco-plastic soil deformations. This superposition of hydrological, subsurface hydraulic and soil mechanical processes over a large bandwith of scales is poorly understood today.
Based on extensive hydrological and hydro-meterological previous investigations carried out by the University of Karlsruhe (Germany; Lindenmaier et al., 2005), the Heumöser slope which is located in Ebnit (close to Dornbirn, Vorarlberg, Austria), represents a 'unique' data base of an intact, however 'moving' (cm … dm / year) natural slope. The measurements indicate that the fast components runoff, macro-pore infiltration and interflow lead to an overall fast infiltration in the upper part of the natural slope, a fast horizontal and downward flow and consequently, a fast pressure increase in the lower part of the natural slope which thus trigger the deformation processes.
As no reliable simulation methods exist today for such purposes, a researchers' group was initiated by the members of the Universities of Stuttgart, Berlin, Potsdam and Karlsruhe to develop prognosis tools which can predict the initiation of a natural slope in the perspective. Their joint project started at the beginning of 2006, for three years, with the possibility of an extension of further three years.

AIM

The overall aim consists of bringing together improved process models with coupling, averaging and upscaling as well as experimental methods while combining deterministical and stochastical approaches to take the complexity of the processes as well as the available data on the different scales into account. At first, two key processes which play an important role for natural slopes' movements and which are running on very different time scales will be numerically and expermentally investigated.
On the one hand, improved process models and coupling methods will be developed to simulate runoff, macro-pore infiltration and the multi-dimensional flow of the water phase in the saturated and unsaturated zone. These processes occur on small time (minutes … days)

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and space scales (millimeter … meters) and they are essential for the fast infiltration in the upper region, the fast downward water flow and the fast pressure increase in the lower region on the large scale of the natural system (kilometers). For the surface runoff, an explicit adaptive Finite Volume Method will be developed to solve the two-dimensional shallow water equations. The flow processes in the saturated and unsaturated zone will be simulated with a three-dimensional model of two-phase flow (phases: water, soil air) in fractured-porous media (MUFTE-UG). Different model concepts will be developed for the macro-pore infiltration (combined approach, coupling porous media and pipe flow, double-continuum approach). Runoff and subsurface flow will be linked by infiltration an exfiltration. Compared to classical hydrological modeling, we suggest a stronger process-based simulation. Model parameters which will be determined by controlled experiments should be upcscaled with geostatistical methods. By these means, we expect to reduce the uncertainty and the event dependency of model parameters to contribute to a more reliable simulation.
On the other hand, the coupling of the subsurface flow with the elastic and visco-plastic deformation processes which are running on larger time scales (days … months) will be investigated. Special averaging techniques which take 'peak loads' into account must be introduced to combine the fast runoff and infiltration processes with the slow deformation processes. The strongly coupled soil mechanical and hydraulic processes will be simulated with the multiphase model PANDAS. At a later stage, MUFTE-UG and PANDAS will be coupled.
The tools which will be developed should first be verified using controlled experiments in the laboratory before being transferred to larger scales. Therefore, two benchmarks will be set up, one for the macro-pore infiltration and the other one for the shear failure. For these purposes, several further developments in the field of non-invasive measurement techniques are required. The validation of the new methods on the laboratory scale will be carried out in the first project period while the transfer to the field scale is planned for the second period. In the first phase, further field investigations will be undertaken. Two core drillings up to about 30 m depths will be installed to measure the pressure dynamics with piezometers and the natural slope's movements with inclinometers. Further geophysical measurements will be made to identify the subsurface structure and soil moisture distribution using STDR technologies. Additionally, a nano-seismic monitoring will be carried out to detect mass movements in the subsurface.

RESULTS

On the symposium, we will present a number of results. Concerning the field measurements, we will show results of tracer experiments, piezometer and inclinometer measurement as well as of the geophysical investigations, especially the nanoseismic monitoring. Concerning the benchmarks, we will show experimental and numerical results. Further we will present a concept how to upscale our laboratory results to the field scale. In the perspective, our new coupled simulation model can be used to design sanitation and precaution measures such as drainage systems, soil nail or steel nets.
Within the project, we also set up an internet-based information system for the project communication. This includes a data management and analysis tool to handle the huge amounts of measurement and simulation data and to serve as a platform for the coupling of models. Further information is found at www.grosshang.de.

Lindenmaier, F., Zehe, E., Dittfurth, A., Ihringer, J. (2005): *Process Identification at a Slow Moving Landslide in the Vorarlberg Alps.* Hydrological Processes, vol. 19, 1635-1651. DOI: 10.1002/hyp.5592.