Coupled hydro-mechanical landslide simulation

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In collaboration with:

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Terre+, Bevaix (www.terreplus.ch)
Overview

• Intro
  – Goal of landslide simulations
  – Included physics

• Case study
  – Modeling approach, physics, simplifications
  – Calibration of model
  – Integration of FEFLOW with ZSoil
Introduction (1)

• Goals of landslide simulation
  – Risk assessment (safety factor SF), $\Delta$SF due to construction
  – Evaluation of mitigation measures
  – Understanding driving mechanisms
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• Goals of landslide simulation
  – Risk assessment (safety factor SF), $\Delta$SF due to construction
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• Lack of reliable data: Back-analyses are often used for parameter estimation ($\phi'$, $c'$)
Introduction (2)

• Included physics

- Geomechanics: \( \nabla \cdot \sigma + b = 0 \)
- Continuity: \( \frac{d}{dt} (\phi \rho) + \nabla \cdot q = Q \)
- Constitutive relations: \( \sigma(\varepsilon), q(\nabla \rho) \)
Introduction (2)

- Included physics

  - Geomechanics: $\nabla \cdot \sigma + b = 0$
  - Continuity: $\frac{d}{dt} (\phi \rho) + \nabla \cdot q = Q$
  - Constitutive relations: $\sigma(\varepsilon), q(\nabla \rho)$

- Multiple fluid phases (water, air)
- Heat equation
- Chemistry (phase changes)
Case study: Large landslide

Surface: 3-4km²
Velocity: 2-3cm/year (calm phase) decimeters/year (crisis)
Goal: Evaluate mitigation solutions
Case study:

Modeling approach (1)

- Slow moving slide $\rightarrow$ neglect inertial forces
- Driving mechanism: Pore water pressure

1. Hydrological model simulates water pressures
2. Introduce pressures into geomechanical model
3. Compute displacements
Case study:

Modeling approach (2)

• One-way coupling

• Deformation localized in one thin shear layer (slip surface)

• Purely Mohr-Coulomb material (no creep)
Case study:

**Modeling steps (1)**

- Geological model, based on Geol. Atlas, boreholes and interpretation (Terre+).
Case study:

Modeling steps (3)

• Hydro-geological model
  – FEFLOW (Terre+)
Case study:

Modeling steps (4)

• Creation of geomechanical model:
  – 2D quad model in Zsoil
  – Extrude in vertical direction, intersect with layers of hydrological model
Case study:

Hydromechanical one-way coupling

• Compute pressures with FEFLOW
• Insert pressures into ZSoil:
  – Read pressures from FEFLOW
  – Interpolate pressures on ZSoil mesh
  – Export to ZSoil as load-time functions for each node
  – All procedures coded in python
Calibration

- Calibration of hydro and geomechanical models:
  - Water levels in boreholes
  - Displacements in inclinometers and GPS-points
Conclusions

• Coupled 2-software approach
• Insight in slide mechanics, structure
• Benefits of using ZSoil for this project:
  – Allows interaction/manipulation of *all* input data (.inp file contains everything)
  – Results can be processed outside PostPro (binary output file structure is documented)
    • Automation of output using e.g. python
    • Using alternative post-processors (e.g. vtk in Paraview)