A review of effects of water level variation on slope stability analysis

Advisor: Chuen-Fa Ni
Speaker: Tran, Thi Kim Tu
Date: 2019/10/31
Review: effects of water level variation on slope stability analysis

An example: the influence of groundwater table variation on slope stability
• **Sources**

(A) Flowing water  
(B) Water level drawdown  
(C) Raised water level  
(D) Fluctuating water level.

In the pictures principle water loads (WL), as well as the positions of the ground-water table (GWT) and the external water level (EWL) are shown.

Figure: Basic modes of water level change  
*K. Zhang et al., 2004*

Natural water-level variations are related to meteorological and geological phenomena.
Effects

Drawdown of an external water level is usually impairing the stability of a slope. (e.g. Lane & Griffiths, 2000; J. M. Duncan & Wright, 2005; Yang et al., 2010; Pinyol, Alonso, Corominas, & Moya, 2011).

Fig. Stability charts subjected to water level drawdown
• Considerations

Limit-equilibrium (LE) methods for expression of safety factors (Lane & Griffiths, 2000; Huang & Jia, 2009).

Finite-element (FE) tools (e.g. Lane & Griffiths, 2000; Pinyol et al., 2011)

To describe this interaction, and for proper consideration of the behavior of unsaturated soils, fully coupled hydro-mechanical computations are needed (e.g. Galavi, 2010)
Slope-stability analysis

Strength of different material

......

Soil

Shear strength

Presence of pore water
• Mohr-Coulomb Failure Criterion

\[ \tau_f = c' + \sigma' \tan \phi' \]

Failure envelope in terms of effective stresses

Failure envelope in terms of total stresses

\( \sigma \) or \( \sigma' \)
## Modeling

<table>
<thead>
<tr>
<th>Model</th>
<th>Application</th>
<th>Application Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified HBV model (Hydrologiska Byrans Vattenavdelning)</td>
<td>a well-established conceptual rainfall-runoff model, developed by Bergström (1976)</td>
<td>simulate the observed groundwater level fluctuations</td>
</tr>
<tr>
<td>SEEP model</td>
<td>a commercial two-dimensional groundwater modelling tool developed by GEO-SLOPE (2008)</td>
<td>analyzing groundwater seepage and excess pore-water pressure dissipation problems within porous materials such as soil and rock</td>
</tr>
<tr>
<td>Chalmers model</td>
<td>developed by Svensson (1984), is a statistical model for calculating the maximum groundwater levels expected at a specific site within a certain design period</td>
<td>predictions of maximum pore pressures in slope stability calculations (CoSS, 1995)</td>
</tr>
</tbody>
</table>
To understand the importance of the impact of water level variation on slope stability.

To determine the suitable model of computing pore pressure which can combine with an approach of previous research in real case
Stochastic modeling workflow based on numerical Monte Carlo Simulation.

- Generation of random fields
  - $k$ fields
  - $n$ fields
  - $\gamma$ fields

- FLAC3D simulations
- Pressure head/Displacement/Shear strain rate distribution
- Finish all the Monte Carlo realizations
  - Yes
  - No

- Calculate mean/variance of pressure head, displacement, shear strain rate

$k$: permeability
$n$: porosity
$\gamma$: unit weight
Hydraulic and mechanical boundary conditions

Figure. Conceptual model
Soil properties used in the example

<table>
<thead>
<tr>
<th>Soil property</th>
<th>Value</th>
<th>Unit</th>
<th>Variance $\sigma_{ln}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit weight ($\gamma$)</td>
<td>1600</td>
<td>kg/m$^3$</td>
<td>0.01</td>
</tr>
<tr>
<td>Water density ($\rho_w$)</td>
<td>1000</td>
<td>kg/m$^3$</td>
<td></td>
</tr>
<tr>
<td>Water bulk modulus ($K_f$)</td>
<td>1000</td>
<td>Pa</td>
<td></td>
</tr>
<tr>
<td>Porosity ($n$)</td>
<td>0.3</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>$10^{-5}$</td>
<td>(m/s)</td>
<td>0.5</td>
</tr>
<tr>
<td>Gravity ($g$)</td>
<td>10</td>
<td>m/sec$^2$</td>
<td></td>
</tr>
<tr>
<td>Effective friction angle ($\varphi'$)</td>
<td>27</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Elastic modulus ($E_s$)</td>
<td>5.5</td>
<td>MPa</td>
<td></td>
</tr>
<tr>
<td>Cohesion ($c$)</td>
<td>7</td>
<td>kPa</td>
<td></td>
</tr>
<tr>
<td>Poisson ratio</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(McCarthy and David 1998, Naderi 2013, Amr 2016)*
• Water table variation

Figure. Water table variation in heterogeneity
• Factor of safety

Figure. Factor of safety distribution
Water-level changes have been shown to significantly influence slope stability; effects of rapidly increased water pressures

It is not reasonable to use simple conservative methods for analysis of slopes subjected to water-level fluctuations.

It is necessary to develop an approach using numerical modeling which implements the pore pressure distribution in a realistic case in the future.

Future work

• Determine the suitable model for computing the water level variation
• Try to establish an approach to develop the current research for the real case
Thank you for your attention