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3RD EUROPEAN REGIONAL CONFERENCE OF IAEG
ATHENS 2020
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2D and 3D dynamic numerical modelling of seismically induced rock slope failure

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Conference topics/sessions
Analysis and Mitigation of Geo-hazards

Background

The stability of rock slopes is often guided by the structural geology of the rocks composing the slope. Especially, discontinuities can significantly influence slope stability according to their orientation with respect to the one of general slope. Here, we will focus on the triggering of giant rockslides. The final goal is to identify failure characteristics allowing us to distinguish seismic trigger modes from climatic ones, notably on the basis of the source zone rock structures. This study is supported by dynamic numerical modelling. More specifically, we will present results based on a parametric numerical study, using distinct element codes designed for 2D and 3D dynamic analysis. This study was applied to the Balta rockslide in the SE Carpathian Mountains (Romania) that has been extensively studied by Mreyen et al. (2019) during the last years.

Methods

For the numerical modelling, we chose the distinct element codes UDEC and 3DEC (2D and 3D, respectively) developed by Itasca® (2016). This method allows us to quantify the effects of loads and external stresses applied to discontinuous media, such as jointed rock material, taking also into account dynamically changing groundwater pressures.
Both 2D and 3D models consider the ‘observed morphological-structural case’ as well as slopes with lower or steeper inclination and with variously dipping joint orientations. One of the scenarios representing the most realistic slope conditions (jointed anti-dip rock slope) was simulated with 3DEC, accounting for seismic effects, and changing groundwater pressures.

Results

Two results of this back-analysis and parametric study are presented below in terms of along-slope displacements, respectively for the close-to-observed scenarios simulated with UDEC in 2D (Figure 1) and for the one in 3D (Figure 2). For both dynamic numerical models a Ricker wavelet (with energy between 0.5 – 8 Hz) was used as seismic input. Both confirm that the slope modelled with the close-to-observed structure is highly stable in static conditions and affected by minor deformation after seismic loading. Note, the 2D model only includes one bedrock material. Here, dynamic effects are purely influenced by the structure and the topography (with larger shaking in the convex upper part of the slope), while the 2-layer 3D model also produces some material-dependent site amplification.

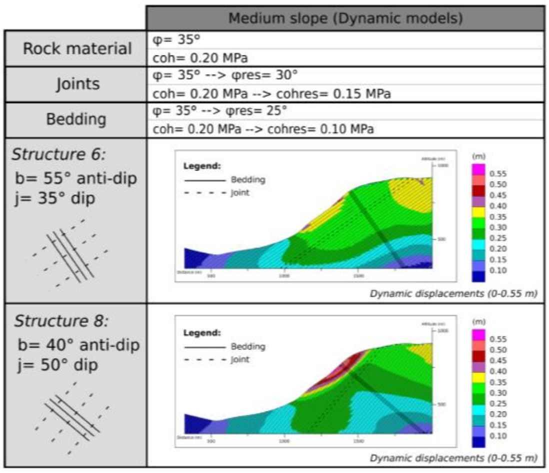

Figure 1. 2D Dynamic modelling results (in terms of displacements, with maximum values close to 0.5 m) for the rock slope conditions closest to the Balta case, with anti-dip slope bedding structure.

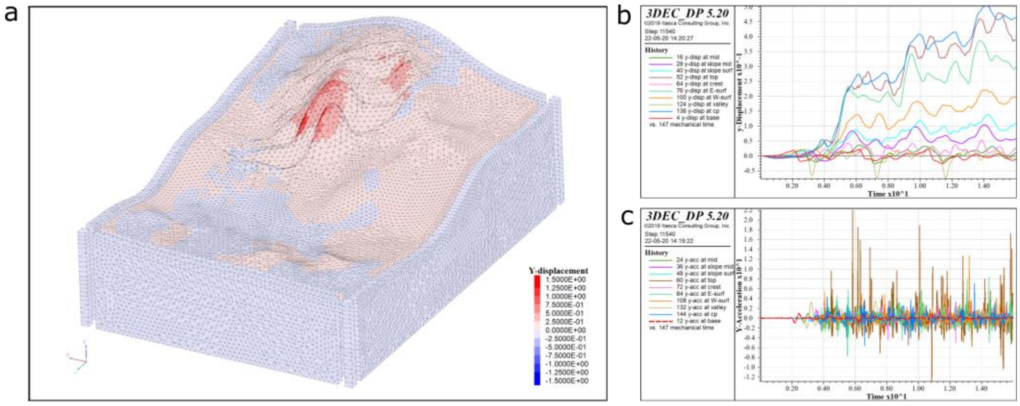

Figure 2. 3D Dynamic loading of the Balta rock slope with 3DEC: a) 3D block model quantifying displacement in y-direction (positive towards the slope foot), y-Displacement (b) and y-Acceleration records (c) for defined history points.

Conclusions

2D and 3D results both confirm that anti-di slope bedding structures are always stable in static conditions. Significant along-slope displacements only occur after simulation of severe shaking (PGA>0.2g). An interesting result was obtained for a bedding structure steeply dipping (> 70° dip) into the slope – actually, this structure revealed to be the most unstable on as affected by flexural toppling (also in the static domain) – even a model with a gentle slope (<15°) presented some displacements of almost 0.5 m after seismic input (while only elastic non-permanent deformation was modelled for all other bedding structures within a gentle slope).

REFERENCES

Itasca (2016). 2- and 3-Dimensional Distinct Element Code Manuals (UDEC version 6.0; 3DEC version 5.2). Minneapolis, Minnesota: Itasca Consulting Group, Inc.

Mreyen A.-S., Cauchie L., Micu M., Cerfontaine P., Havenith H-B. (2019). Multi-technique approach to characterize ancient deep-seated landslides in seismic regions. American Geophysical Union Fall Meeting, 9-13 December, 2019, San Francisco, USA.