EGU2020-4186
https://doi.org/10.5194/egusphere-egu2020-4186
EGU General Assembly 2020

Numerical modeling of seismically-induced slope displacements: a comparison between 2D and 3D finite difference models and Newmark-Displacements

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The majority of numerical landslide models are designed in 2D. In particular, models based on finite difference methods (FDM) are time-consuming and – as a result – in most cases also cost-intensive. 3D models, therefore, increase the processing time significantly. Another contributing factor to long processing times in the context of modeling of seismically-induced displacements is the fact that mesh grid increments must be small due to the necessity of correct wave propagation through the material. The larger the frequency range of the applied seismic signal should be, the smaller has to be the mesh grid increment. 3D models are, however, considered as more realistic.

In this work, we present a comprehensive study on numerical 2D and 3D models of the Diezma Landslide, Southern Spain. The Landslide is represented in its shape as it appeared at the time of the main rupture on 18th of March in four model layouts: (1) a simplified model in 3D that outlines the landslide body with planar triangular tiles, (2) a longitudinal cross section through this simplified 3D model representing the simplified 2D model, (3) a smooth model in 3D that envelops the landslide body according to the main topographic features, and (4) a longitudinal cross section through this smooth 3D model representing the smooth 2D model.

On both the simplified and the smooth 2D models, a series of 11 seismic scenarios was applied as SV-waves assuming a source sufficiently far for vertical incidence at the model bottoms in order to produce horizontal shear inside the landslide body with respect to the underlying bedrock. All 11 signals are characterized by different frequency contents, Arias Intensities from 0.1 to 1 m/s, moment magnitudes from 5.0 to 7.0 and peak ground accelerations from 0.8 to 1.2 m/s², and therefore correspond to scenarios that represent the local seismicity in Southern Spain.
Because of time-related limitations, only four of these signals were respectively applied to the simplified and smooth 3D model. Newmark-Displacements were calculated using all 11 signals with the classic Newmark-Method that approximates the landslide body in 2D by a rigid block on an inclined plane, and with Newmark's Empirical Law as spatial information covering the landslide area across the slope in regular intervals.

We present a systematic comparison of all models and obtained displacements, showing that the Newmark-Methods deliver very similar results to the maximum displacements obtained by FDM.

Moreover, we discuss on a particular example that – although seeming more accurate in the layout – smooth models lead not necessarily to realistic results.