Slope stability under dynamic loading including morphological and geological site effect: numerical simulations and back-analysis

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Local site conditions, including topography (slopes, ridges, and canyons) and geology (sedimentary, basins, and faults), have significant influence on ground motion characteristics and seismic intensity. Site effects can increase or sometimes decrease ground motion acceleration, and the presence of a sharp relief can significantly aggravate the disastrous consequences of strong seismic motions. Therefore, topographic site effects play a significant role in triggering landslides and rock falls, which are one of the major causes of land devastation and fatal injuries. Many field investigations have been conducted after earthquakes and have taken seismic damage related to local site conditions into consideration, such as the 1989 Ms=7.1 Loma Prieta earthquake, the 1999 Ms=7.3 Chi-Chi earthquake, the 2008 Ms=8.0 Wenchuan earthquake, the 2009 Ms=5.4 L’Aquila earthquake in Italy and the 2010 Ms=7.0 Haiti earthquake; these earthquakes triggered numerous landslides associated with site effects due to topographic or geological conditions. However, despite of the importance of such risks, earthquake-induced landslides have been rarely studied in a quantitative way by the scientific community specialized in Earthquake Engineering.

The current study mainly focuses on site effect and slope in stability due to geometric and geological factors, also related to hydraulic action. First, a finite difference numerical slope model was employed to identify quantitative effects of geometrical and geological factors, such as slope height, slope dip angle, subsurface geology and impedance contrast, on acceleration amplification. It is also attempted to separate the geological effects from topography amplification effects. In a second stage, landslide movement due to seismic loading will be analyzed, based on numerical slope model. In the course of slope failure, displacement in special measuring points will be observed and analyzed, and will be compared with field test data and results obtained with the pseudo-static calculation method. Subjected to moderate and strong excitations, displacement in fixed spots of slope models for different geometric and geological configurations will be recorded until slope failure. Then statistical analysis will be performed to quantify the effects of geometry, geology and peak ground acceleration on slope displacement or slope failure. Finally, numerical analyses of slope models of configurations for different underground water level will be conducted with the Finn model. The effect of hydraulic action will be evaluated through analyzing displacements of the slope and pore water distribution when the model is subjected to seismic loading.

Numerical analyses have been conducted with the finite difference code FLAC to investigate effects of topographic and subsurface geology on acceleration amplification. Results show that both slope inclination and subsurface geology have significant effects on ground motion amplifications. The maximum acceleration amplification factor reaches up to 1.53. Generally, acceleration amplification increases with increasing slope angle, however, depending on the thickness of subsurface geology which is favorable to acceleration amplification in extent degree. In presence of soft soil deposit (150m), acceleration amplification factor for slope model subject to 1 Hz signal increases as much as 24.9% than acceleration amplification of soil deposit (10m). However, when slope subject to 5Hz signal, acceleration amplification factor for slope configuration of soil deposit (10m) is as large as 118% acceleration amplification for slope configuration of soil deposit (150m). It shows that the coupling effects between signal frequency and soil deposit contribute much more to acceleration amplification. Furthermore, acceleration amplification gets larger with increasing of slope height when slope model is subject to a low frequency excitation (1Hz). However, the effect is much more complicated, when the slope is subjected to a high frequency excitation, especially, when soft soil deposit is locally present.