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Can landslide-prone slope response to strong shaking be inferred from weak motion data? First answer from 2009 L'Aquila earthquake

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The complexity of factors controlling the dynamic response of marginally stable slopes and the scarcity of direct ground motion recordings acquired on landslide-prone areas make it difficult to evaluate the role of site response in seismic landslide triggering. A long term accelerometric monitoring, conducted at a tectonically and geomorphologically active site of Abruzzo in Central Italy (Caramanico Terme) has provided interesting evidence of amplification with a pronounced directional character parallel to the local slope direction on a landslide consisting of colluvial deposits overlying mudstone substratum. However, until 2008, these observations were based only on recordings of events of low to moderate magnitude. The 6.3 Mw earthquake that on 6 April 2009 hit L'Aquila, 60 km from Caramanico, allowed to test whether these previous findings hold true also for the landslide site response at higher shaking levels.

The comparison of the 2009 mainshock recordings of the accelerometric station located on the landslide (CAR2) to those from two nearby stations, one sited on soft soils similar to landslide substratum (CAR1) and the other on colluvial material (CAR5), showed relative amplifications (in terms of peak horizontal acceleration PHA) very close to the average values estimated from smaller events (about 1.5 and 1.0 relatively to CAR1 and CAR5, respectively). The similarity of PHA observed on colluvium, regardless of its involvement in landsliding, confirmed that, in terms of total shaking energy, the main factor controlling amplification is the impedance contrast between colluvium and mudstone substratum. The comparison between the station on landslide and a reference station on rock (CAR4) showed a relative amplification increasing with magnitude, probably because of the stronger response of the rock site to the higher frequencies prevailing in wavetrains coming from nearby small sources. This suggests that in such cases amplification assessments based on weak motion data can lead to considerable underestimates.

On the other hand, the landslide site response directivity showed similar properties for the entire range of the observed magnitudes (1.4 – 6.3). It is possible that in the near field source effects modify the ratio between directional maximum and minimum of shaking energy, without, however, significantly altering the orientation of shaking maxima. In terms of spectral properties, directivity of major peaks in horizontal to spectral ratios (HVSR) was the same at any magnitude, even though at higher magnitudes spectral ratio amplitudes tend to decrease at higher frequencies and increase at lower ones. However the comparison of HVSR with standard spectral ratios (SSR) between the station on landslide and the reference site on rock indicated that the inferences on resonance frequencies derived from single station seismic weak motion measurements (like HVSR) could be unreliable under the complex conditions of a landslide-prone slope. It appears that more reliable indications can be derived from ambient noise measurement acquired with velocimetric instruments.

Thus, overall, weak motion recordings proved to provide useful information on landslide site response characteristics, especially having a dataset sufficiently differentiated in terms of azimuth location, distance, energy and source characteristics. However, the extrapolation of inferences based on recordings of small magnitude events to stronger earthquake scenarios requires some caution.