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Re-examination of the spatial distribution of landslides triggered by the Manjil-Iran 1990 earthquake

A.M. Rajabi (1), J. Wasowski (2), D. Capolongo (3), V. Del Gaudio (3), M.R. Mahdavifar (4), and M. Khamehchiyan (1)

(1) Engineering Geology Dept., Tarbiat Modares University, Tehran, I.R. Iran., (2) Istituto di Ricerca per la Protezione Idrogeologica, Consiglio Nazionale delle Ricerche, Bari, Italy, (3) Dipartimento di Geologia e Geofisica - Università di Bari, Italy, (4) Geotechnical Engineering Research Center, International Institute of Earthquake Engineering and Seismology (IIEES), Tehran, Iran.

The Iranian Plateau, one of the most seismically active regions of the world, has a long history of catastrophic earthquakes. One of the recent destructive events that affected good part of Iran, was the large magnitude (MS =7.7, MW=7.3, Mb =6.4) Manjil earthquake of June 20, 1990, 21:00:10.9 UT. It completely destroyed 700 villages in the Sefidrud river valley and also the cities of Rudbar, Manjil and Loshan, killing more than 40,000 people, injuring 60,000 and rendering 500,000 homeless. Many landslides were triggered by the earthquake and some of them were catastrophic causing numerous fatalities and damage to infrastructure.
In this paper the spatial distribution of 51 major landslides triggered by the Manjil earthquake is examined to assess the susceptibility to seismically induced landsliding of an area located in the middle of Alborz mountain range in the northern part of Iran. The study area, which covers 310 km2 is characterized by high relief (including elevations ranging between 1960 and 160 meters a.s.l.) and generaly steep slopes. From the lithological point of view, the study area contains Eocene age volcanic tuffs and andesites, Alborz magmatic assemblage (Karaj Formation, Eocene) consisting of porphyritic and nonporphyritic, andesitic and andesite-basaltic compositions, rhyodacites, calcareous and non-calcareous pyroclastics such as tuffs and agglomerates, limestone, shale and sandstone (Shamshak Formation), unconsolidated, poorly sorted Quaternary deposits. In this study, topographic data with a 30 m resolution and a digital representation of, geology, relevant geotechnical parameters and seismic shaking (Arias intensity) were ingested into a GIS. Then, using regional attenuation relations, Newmark's permanent-deformation (sliding-block) analysis was applied to estimate coseismic landslide displacements and to predict spatial probability of slope-failures. The modelled displacements were compared with the inventory of landslides triggered by the Manjil earthquake to test the reliability of the identification of the zones susceptible to earthquake-induced landslides. The results show that only 40 percent of major landslides were located in areas where the estimated Newmark displacement is larger than the value (10 cm) generally considered as a critical threshold for slope failure: these landslides are found on steeper slopes made of tuffs, agglomerates and limestones. The remaining 60 percent of landslides (with estimated Newmark displacement below the critical value) were found on shallower slopes mostly including Quaternary deposits and interbedded shales and sandstones (Shamshak Formation), and closely associated with the drainage network. Different causes of the apparent discrepancies between the calculated Newmark displacements and landslide triggering are analysed by examining the influence of the uncertainties in geotechnical parameters, possibility of liquefaction failure, as well as the role of factors like topographic, and lithologic shaking amplification, delayed failure following alteration of hydrogeological conditions, and river erosion.