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Earthquake-triggered Tsaoling landslide mechanics and dynamic process revealed by discrete element method

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The high-speed large-scaled Tsaoling rock-and-soil avalanche is the largest landslides triggered by the Chi-Chi earthquake (Taiwan, 1999). In order to characterize the landslide mechanics and sliding behavior, this study integrates the geological and morphological features, strong motion seismostation record during block sliding on the sliding surface, and numerical simulation. The morphological analysis was performed by interpreting aerial photos taken before and at several times after the Chi-Chi earthquake. The topography of the landslide was studied by studying several 2m resolution digital elevation models (DEMs) generated from the aerial photos taken at different times. The comparison between the topographies before and after the slide allows precise calculation of the initial volume of rock and soil mobilized in the landslide, as well as the geometry and thickness of the landslide deposit. Field observations at different scales were also carried along the sliding surface and the landslide deposit and gave new insights into the mechanical behavior of the landslide, and the subsequent geomorphologic evolution of the landslide site.

The major sliding surface is situated between two massive sandstones by a metric friable fine layer composing of fine layered shale, silty mudstone and interlayered beds, and is characterizing by a smooth, gentile and planar surface. The major slid mass situated on the upper slope, is an isolated hill and been daylighted. The estimated volume of the initial rocke avalanche is about 125.5 Mm3 and 138 Mm3 for the depleted and accumulation zones, respectively, indicating an increase in volume due to fragmentation. The average thickness was about 150 - 170m, up to 195 m thick of the slid mass. Whereas about 4/5 of the slid mass transport across the river and deposit around the Taochiashan hill. The hill, composed of rock debris generated by the previous events, is about 140 m higher than the Chinshui riverbed before the earthquake. The transported debris was about 30 - 90 m thick, covered on the preexisting debris deposit hill and around the river channel. The debris formed a dammed lake, with a maximum volume of 45 Mm3.

Based on DTMs data sets, field observations, the discrete element method - PFC3D is adapts to analyze the triggering mechanism and sling dynamic process. The presence and the coupling effect from the strong ground excitation and high pore water pressure is the essential factor to triggering the landslide event. The results shows that the best fit between the deposit topography of the post-event DTM and numerical simulations, the fictional coefficient of the sliding surface is as low as 0.087. The maximum sliding speed is as high as 87.2 m/s, the result coincide with the seismic record from the nearby strong motion seismic record.