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The Tsaoling 1941 Landslide, New Insight of Numerical Simulation of Discrete Element Model

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Large earthquakes in the southeastern Taiwan are not rare in the historical catalogue. Tsaoling, located southeast of Taiwan, last five large landslides occurred in the 19th and 20th centuries. According to the literature about the Tsaoling landslide, we concluded four characteristics of the Tsaoling landslide, (1) repeated (2) multi-landslide surface, (3) huge landslide block, and (4) some people survived after sliding a long distance (>2 km). This is the reason why we want to understand the causes of the repeated landslides in Tsaoling and its mechanisms. However, there is not any record about the landslide in 1862 and the most of the landslide evidence disappeared. Hence, we aim at the landslide dynamics of the 1941 landslide in this study. Tsaoling area is located in a large dipping towards the south-southwest monocline. The dip of strata toward the SSW is similar to the both sides of the Chinshui River valley. The bedrock of the Tsaoling area is Pliocene in age and belongs to the upper Chinshui Shale and the lower Cholan Formation. The plane failure analysis and Newmark displacement method are common for slope stability in recent years. However, the plane failure analysis can only provide a safety factor. When the safe factor (FS) is less than 1, it can only indicate that the slope is unstable. The result of Newmark displacement method is a value of displacement length. Both assumptions of the analysis are based on a rigid body. For the large landslide, like the Tsaoling landslide, the volume of landslide masses are over 108 m3, and the landslide block cannot be considered a rigid body. We considered the block as a quasi-rigid body, because the blocks are deformable and jointed. The original version of Distinct Element Method (DEM) was devoted to the modeling of rock-block systems and it was lately applied to the modeling of granular material. The calculation cycle in PFC2D is a time-stepping algorithm that consists of the repeated application of the law of motion to each particle, a force-displacement law to each contact, and a constant updating of wall positions. The physical properties of the particles in the model can be traced in time dominant (i.e. velocity, displacement, force, and stress). During the simulating, we can get the variation of physical properties, so the inter-block change of displacement, force, and stress could be monitored. After the seismic shaking, the result of the PFC model can be divided into three portions, upper (thick), middle (transitional) and lower (thin). The shear displacements of the three parts on the sliding plane are not agreement. The displacement of the lower part block is large than the upper and middle part of the blocks. The shear displacement of middle part is between upper and lower part. During the shaking of the earthquake, the different parts in the block collide with each other, and the upper part of the block was hit back and stayed in origin position or slid a short distance, but the lower part of the block was hit down by the upper block. The collision pushed down a certain length to the lower part of the block. The shear length just lost the strength of the sliding plane and induced the landslide during the 1941 earthquake. The upper part of the block stayed on the slope but revealed unstable. Eight months later, the upper part of the block slid down was induced by a 700 mm downpour in three days.