



The transportation and deposition of the 2009 Hsiaolin landslide in Taiwan revealed from 3D granular discrete element simulation

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Typhoon Morakot caused severe damage in south Taiwan in 2009. The most atrocious incident was the Hsiaolin-Hsiandushan landslide, which buried more than 400 victims. Field investigations demonstrated that the geological structure of the source area of the Hsiaolin-Hsiandushan landslide formed an unfavorable wedge by bedding planes on the north side and by E-W trending joints, together with a small fault on the south side, which was overhanging and sloped westward. Several days of torrential rain diverted water into the rock fissures, increasing the pore pressure and reducing the effective stress until the landslide occurred.

Detailed modeling is conducted on the kinematic process of this landslide using the 3-D discrete element method with granular particle assemblage by Particle Flow Code 3D (PFC3D). When the friction coefficient of landslide-mass reaches the critical value of 0.1, the mass begins to slide. The shape of the resulting deposit fits the actual landscape well. The landslide mass proceeded in two paths. The first flowed into the northernmost Gully 2. Since fewer particles enter this way, less energy is dissipated by collision, which generated a maximum slide velocity of 74 m/s with the addition of greater degrees of freedom. The other paths followed the transport zone, splitting further after crashing with the 590 Highland. The branch with the larger mass flowed to Gully 1, reaching a maximum velocity of approximately 40-50 m/s. The other smaller branch followed the potential debris flow river DF006 and rushed into Hsiaolin Village. The maximum velocity was between 45 and 51 m/s. Scraping of the 590 Highland increased the mass flowing into the village. This caused the entire settlement to the north of Hsiaolin Elementary School to be buried under the debris, while the area to the south was spared. The landslide mass formed two natural dams when it reached the Chishan River valley, located at elevations of 410 and 415 m above sea level. After the dam broke, the area to the south of Hsiaolin Elementary School was destroyed by the flood.