Numerical Study of Landslides Using an Improved DDA–SPH Method

○Changze LI, Gonghui WANG

1. Introduction

Landslides are among the most widespread and destructive natural hazards in mountainous and tectonically active regions, posing persistent threats to human lives, infrastructure, and socio-economic development. Their mechanical behavior is inherently complex, involving multiple interacting processes, including large deformation, progressive failure, fragmentation, entrainment, and material heterogeneity arising from soil–rock interactions. As a result, accurately capturing landslide dynamics remains challenging for simplified analytical models and laboratory-scale experiments. To address these challenges, this study develops an improved DDA–SPH method to investigate landslide behavior from initiation through post-failure motion, with particular emphasis on multi-material interactions and large-scale processes.

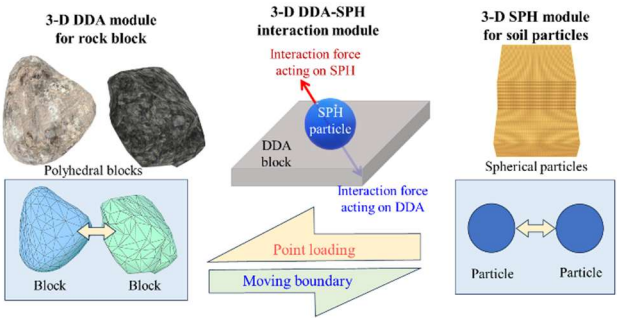

Figure 1. Outline of 3-D DDA–SPH method.

2. Simulation of rockfall and rockslide

The three-dimensional discontinuous deformation analysis (3-D DDA) method has been improved and applied to simulate energy dissipation during collisions in multi-block rockfalls and rockslides. A procedure is proposed to model complex-shaped rock blocks by incorporating three-dimensional scanning techniques to obtain realistic block geometries from natural rock specimens. In addition, surface friction weakening observed in high-speed rotary shear tests is incorporated into the 3-D DDA framework. Simulations of rockfall models at different scales demonstrate that surface friction weakening is a significant contributor to the volume-dependent hypermobility of rock avalanches. The improved 3-D DDA method is further applied to a case study of the Jiweishan rock avalanche. The simulation at the original scale reproduces the observed deposition more accurately than the reduced-scale model.

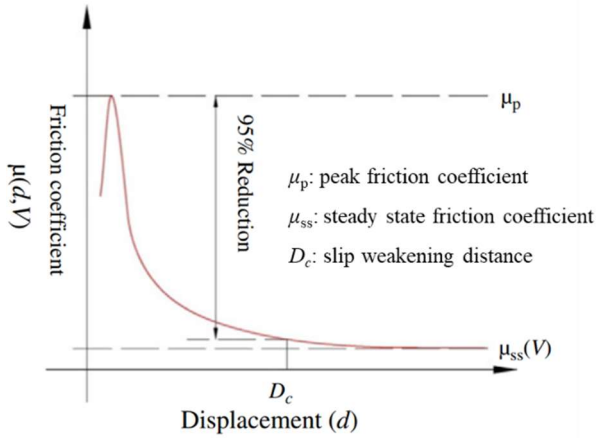

Figure 2. Schematic of the shear displacement dependent friction law.

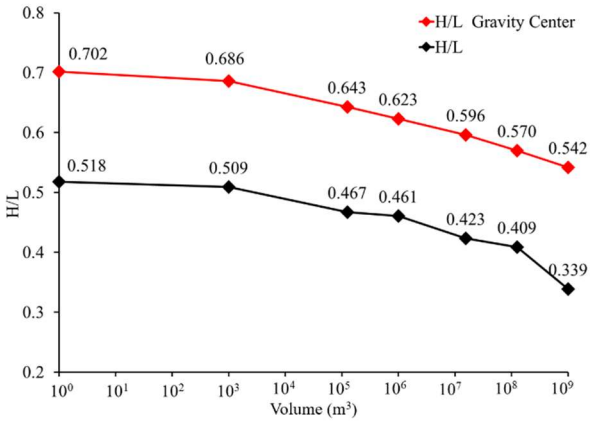

Figure 3. Relationship between the landslide volume and *H*/*L* ratios from 3-D DDA.

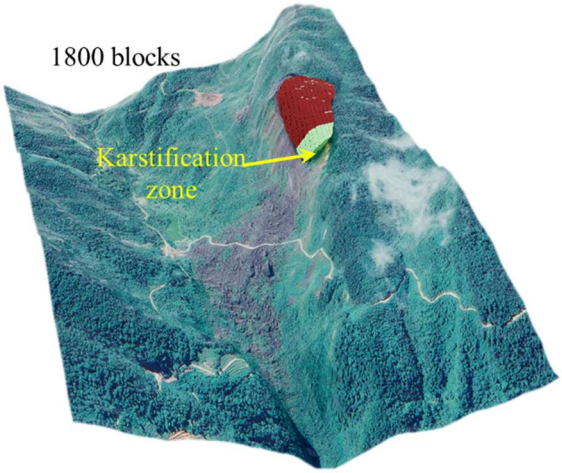

Figure 4. 3-D DDA model of Jiweishan event.

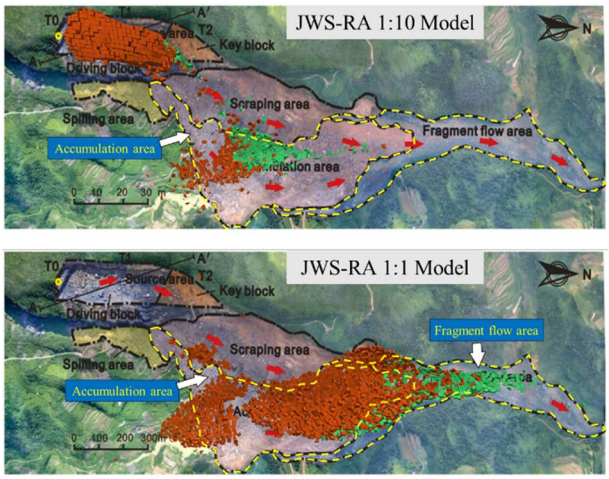

Figure 5. Final deposits of Jiweishan event simulation results at different scales.

3. Simulation of soil-rock interaction

To simulate the interactions between rock and soil, the DDA method is coupled with smoothed particle hydrodynamics (SPH) method. In this coupled method, DDA is used for the simulation of rock and structure, and SPH is used to simulate soil and water. The interaction between the two methods is calculated through a penalty method. Compared with conventional single-phase or single-scale numerical approaches, the coupled DDA–SPH method provides a more advanced and flexible framework for simulating multi-material, multi-scale landslide processes, thereby enhancing its applicability to realistic geohazard simulations. The developed DDA–SPH is applied to the simulation of soil-rock mixture (SRM) landslide, landslide-induced tsunami wave, and interaction between rock avalanche and substrate.

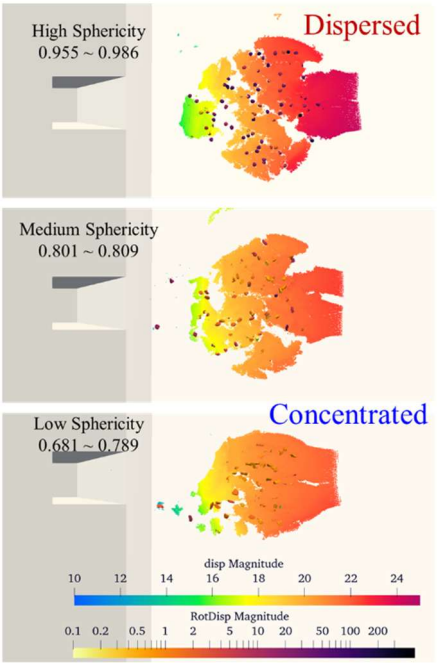

Figure 6. Simulation of SRM landslide with different shapes of rock blocks.

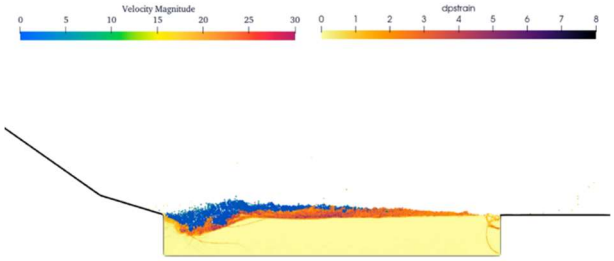

Figure 7. Simulation of interaction between rock avalanche and substrate.

Acknowledgments

This work was partially supported by JSPS KAKENHI, Grant Number 23K23007, JP24KJ1402, and 24K21660.

References

Li Changze, Wang Gonghui, et al., 2025. Dynamic analysis of multi-block rockfalls using improved 3-D discontinuous deformation analysis: Effect of coefficient of restitution. Engineering Geology, 2025

Li Changze, Wang Gonghui, et al., 2025. Dynamic analysis of soil-rock mixtures based on improved 3-D DDA–SPH method. International Journal of Rock Mechanics and Mining Sciences, 2025.