D102

Numerical Study on Multi-block Rockfall with Complex-shaped Block Using Improved 3D Discontinuous Deformation Analysis

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1. Introduction

Instabilities in rock slopes are common in mountainous regions, often resulting in destructive mass movements such as rockfalls and rock avalanches, which pose significant risks to human lives and infrastructure safety. Understanding the dynamics of multi-block systems is essential for engineers to predict and mitigate associated hazards. The shape of a rock block plays a crucial role in determining its behavior during a rockfall event. Different shapes affect the rock's trajectory, bounce height, rotational motion, and energy dissipation. Irregularly shaped blocks tend to have more unpredictable paths and higher rotational energy, which can result in greater damage potential upon impact.

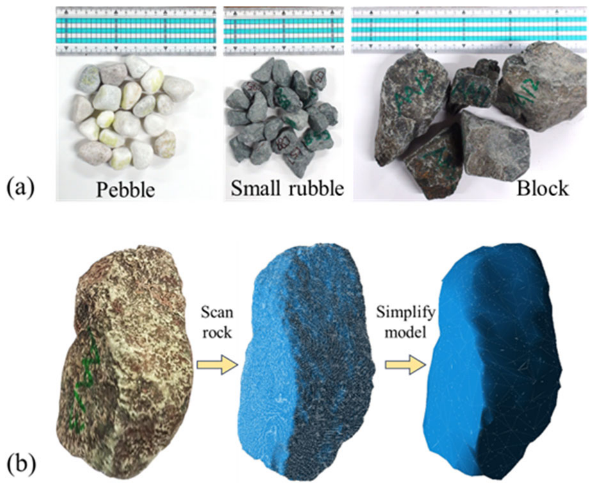

Figure 1. Reconstruction of rock blocks: (a) Representative rock clusters, (b) procedure of reconstruction, (c) sphericity distribution.

In this study, a procedure is proposed for the improved 3-D DDA method, integrating 3-D scanning techniques to obtain 3-D shape information from real rock blocks. Three groups of 70 blocks each, with complex shapes obtained by scanning real rocks, are simulated to investigate the effect of sphericity on rockfall dynamics and post-failure deposits. The obtained results may enhance current understanding of the dynamic behavior of rockfalls, thereby facilitating the prediction and assessment of related hazards.

2. Method and numerical models

The 3-D DDA method has been improved and applied to simulate energy dissipation during collisions in multi-block rockfall. A total of 350 rock blocks with varying shapes and sizes, including pebbles, small rubbles, and block stones, were scanned. A selection of these blocks is shown in Figure 1(a). The scanning procedure is illustrated in Figure 1(b). After data acquisition, the constructed models are converted into the format required for 3-D DDA input files.

Three groups of 70 blocks each are selected from the scanned rock blocks based on their sphericity, as shown in Figure 2. These blocks are initially arranged with sufficient spacing to prevent any penetration between them. Gravity loading is subsequently applied to each block, causing them to settle and densify. After the system stabilizes, the container is removed, and the blocks are relocated to predetermined positions on the slope, as shown in Figure 3.

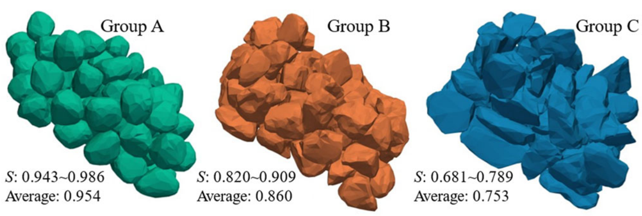

Figure 2. Three groups of rock blocks with different sphericities generated by gravity falling method.

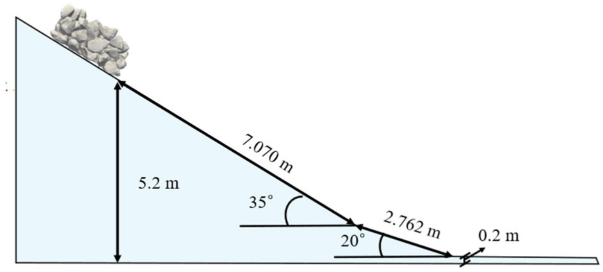

Figure 3. Geometry of rockfall model used for investigating effect of sphericity.

Table 1. Parameters in muti-block rockfall model.

Parameter	Rock Mass	Base Block
Density (kg/m^3)	2500	/
Poisson's ratio	0.2	0.2
Block volume (m^3)	0.12	/
Young's modulus E (GPa)	10	10
Friction ϕ (°)	20	20

3. Results and discussions

Figure 4 illustrates the rotational displacement of each block during the rockfall for the three rock block groups, presented as an example with N-COR =0.35 and T-COR = 0.85. It can be observed that the dynamics and deposition of rock blocks are strongly influenced by their sphericity. As sphericity increases, the deposition becomes more widely scattered, and the rotational displacement also increases.

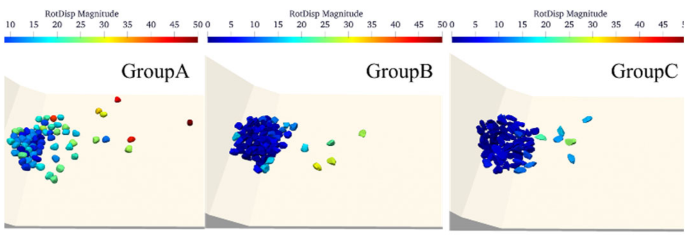

Figure 4. Rotational displacements (unit: rad) during rockfalls for three rock block groups, with N-COR = 0.35 and T-COR = 0.85.

In each model, the blocks at the front of the deposition show relatively greater rotational displacement. However, in the simulation of Group C, only a few blocks display obvious rotational displacement, suggesting that for rock blocks with low sphericity, the dominant motion is sliding and bouncing rather than rotation. This change in dynamic behavior contributes to differences in deposition patterns of the rockfall. Figure 5 shows the relationship between the G-COR and the H_g/L_g ratio for different sphericities. The results demonstrate that sphericity significantly influences H_g/L_g. As sphericity increases, the rotational frictional coefficient decreases, leading to a corresponding decrease in the H_g/L_g ratio.

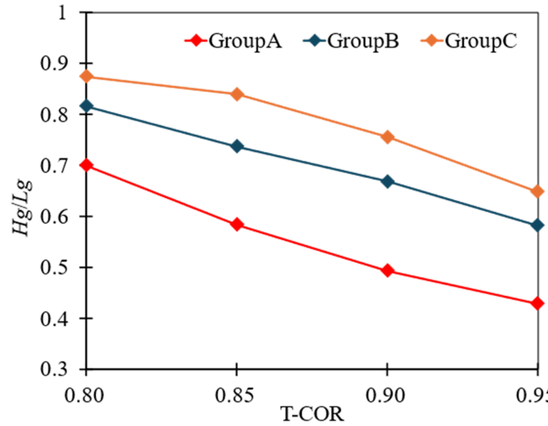

Figure 5. Relationships between H_g/L_g ratio and G-COR with different sphericities.

Summary

The improved 3-D DDA method was employed to analyze multi-block rockfalls, incorporating 3-D scanning technology. It was found that sphericity significantly influences rockfall behavior. As sphericity increases, the runout distance becomes longer, and the deposition becomes more widely scattered. The proposed approach has been demonstrated to serve as a powerful tool for analyzing complex rockfalls.

Acknowledgments

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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.