A Parametric Study for Rockfall by Distributed Contact DEM

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1. Introduction

The movement of rockfall is very complex and variable, leading to the study for anti-fence and preventing property and life. With the development of computers, it is possible to conduct large-scale simulations for geological disasters such as landslides and rockfalls with low economic and time costs, promoting to achieve a reliability-based design on rockfall disasters.

This study focuses on the effect of variation in material properties on rockfall movement.

2. Rockfall model in DCDEM method

Compared to the classic Discrete Element Method (DEM), Distributed Contact Discrete Element Method (DCDEM) [1] has an advantage to handle complex geometries by modelling rigid object with collections of particles. DCDEM computes forces among particles, these forces are then integrated for all particles of a given object, motion equation updates the position and velocity of the object and particle positions get updated accordingly at every iteration. There are 5 material properties as input parameters for the falling rock and 4 material properties as input parameters for the slope. In a contract, the coefficient of restitution (*COR*) and the kinetic friction coefficient (μ_f) are simply taken as an average value, while young's modulus (E) and poisson's ratio (υ) are independent variable parameters. It is assumed that all parameters have a log-normal distribution. The mean and coefficient of variation (*COV*) of input material properties are shown in **Table 1**. The rockfall model is shown in **Fig. 1**, where a sphere (D = 0.50 m) with collections of 97 particles (d = 0.05 m) is used to represent a simple rock shape. The occurrence location is assumed at h/H = 0.8 on a slope with 50 degrees and 15 m height [2]. The initial release height is 2 m from the occurrence location.

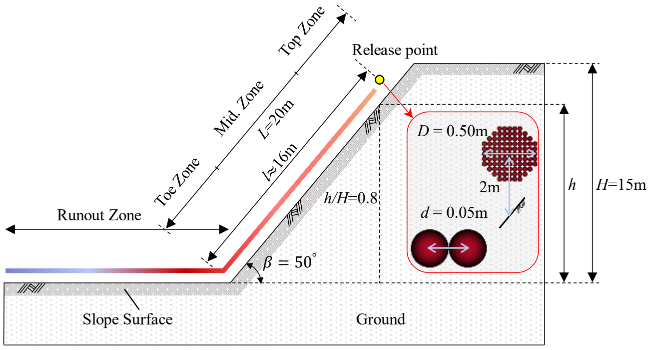

Fig. 1 Rockfall model

Table 1 The material property in DCDEM

	Parameter	Rock	Slope	Distribution
E	Young's modulus (Pa)	60×10^9	3×10^9	Log-normal distribution
υ	Poisson's ratio	0.25	0.35	
μ_f	Kinetic friction coefficient	0.60	0.70 (fixed)	
COR	Coefficient of restitution	0.70	0.30 (fixed)	
ρ	Density (kg/m^3)	2700	-	
-	*COV* for 7 parameters	0.2		

COV: coefficient of variation

3. Analysis result

The 2D analysis is conducted for the parametric study. **Fig. 2** illustrates the relationship between the number of simulations, the mean runout distance, and its standard deviation. It can be judged that the variation decreases after 500 runs, and both become stable at 1000 runs.

Three indexes of the rockfall are analyzed: a) runout distance, b) the max. jumping height and c) the max. kinetic energy.

Fig. 3 illustrates a 20-bin relative frequency histogram of runout distance for 7 material properties. The arrow represents the case when the material properties are mean values (refer to **Table 1**). It is seen that the runout distance of rockfalls is over 20 m and up to 70 m and mostly concentrated between 35 to 45 m.

Fig. 4 shows the mean and *COV* of runout distance, the max. jumping height and the max. kinetic energy. In **Fig. 4(a)**, runout distance for *COR* variation of the rock is 42.57 m, followed by 42.24 m for υ variation of the rock and 41.85 m for E variation of the slope, respectively. In **Fig. 4(b)**, *COR*, υ and E of the rock show a large *COV* in terms of the runout distance, while the max. jumping height, for μ_f variation of the rock exhibits 0.22, followed by *COR* and E of the rock. There is no difference for the max. kinetic energy since all *COV* are 0.06. As a result, the *COV* of the max. jumping height is the largest among the three indexes, showing around 0.30. *COV* of runout distance is similar to the input *COV*, 0.2. *COV* for the max. kinetic energy are 0.06, which indicates largely unaffected by variations of the material properties.

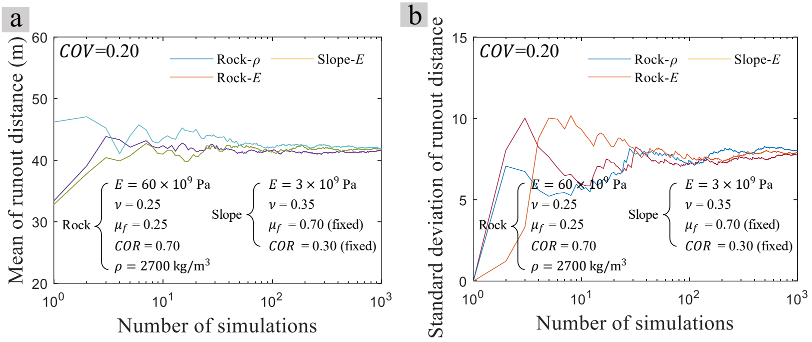

Fig. 2 Runout distance. (a) Mean value against number of simulations. (b) Standard deviation value against number of simulations.

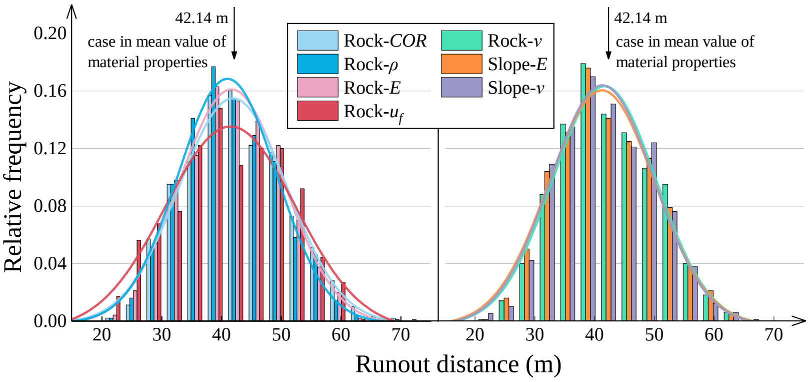

Fig. 3 Histogram of runout distance with *COV* = 0.20.

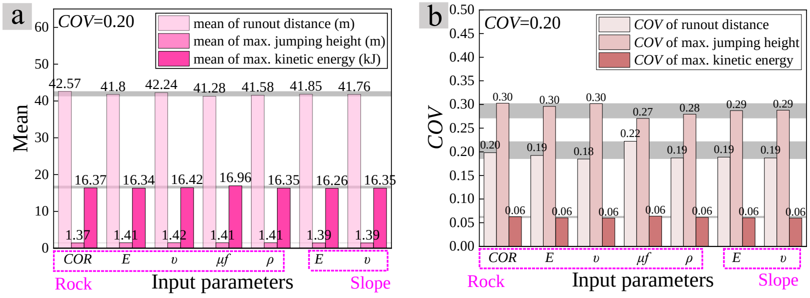

Fig. 4 Statistical results. (a) Mean. (b) *COV*.

In **Fig. 4**, the gray lines with thicknesses show the maximum rate of change, they are 3.0%~4.1% for mean and 6.7%~16.7% for *COV*, respectively.

4. Conclusion

a) The max. jumping height is most affected by the variation of the material properties, followed by runout distance, but the max. kinetic energy is almost unaffected.

b) The variation of all material properties assumed in this study has a non-negligible effect on rockfall movement, namely, we need to consider all parameters variations in DCDEM.

Reference

[1] Ricardo B. Canelas, Alejandro J.C. Crespo, Jose M. Domínguez, Rui M.L. Ferreira, Moncho Gómez-Gesteira: SPH–DCDEM model for arbitrary geometries in free surface solid–fluid flows, *Computer Physics Communications*, Vol. 202, pp. 131-140, 2016.

[2] Nobutomo, O., Yoko, T., Kazuya, A., Tomoaki, M.: Technical note of national institute for land and infrastructure management, *National Institute for Land and Infrastructure Management Ministry of Land, Infrastructure, Transport and Tourism,* Japan, No. 530, 2009.