Analysis of Collision Behavior in Rockfall: An Investigation of DDA and UDEC Results

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1. Introduction

Rockfall is frequent major hazard in mountainous areas, potentially threat in both property and life. Precise estimation of the rockfall's displacement is very important for disaster mitigation. It was indicated by both outdoor experiments and numerical simulations that the front facing blocks were accelerated and reached farther by internal collision between blocks①. Further, the field data indicated that during 2008 Wenchuan Earthquake (Ms. 8.0) there was a common phenomenon of rockmass thrown out by the ground motion after structural plane was made run though②. Thus, it is important to investigate the collision behavior during rockfall for more appropriate estimation.

In previous studies, two different discrete element methods (DDA and UDEC) were usually used to characterize the kinematics of blocky rockmass. Before applying the numerical methods to complicated problems, it is necessary to verify the applicability of the methods and how varying parameters affect the collision behavior by some simple model with analytical solutions.

2. Colliding Blocks

The model used in the investigation study is a single block colliding another block of same mass with no friction (Fig. 1). We address the accuracy of simulation by the velocity exchange ratio (VTR):

$$VTR = V_2' / V_1 \qquad (1)$$

It can be analytically solved by eq.2 from the conversation of both momentum and energy for a perfect elastic collision:

$$\begin{aligned} M_1V_1 + M_2V_2 &= M_1V_1' + M_2V_2' \\ \frac{1}{2}M_1V_1^2 + \frac{1}{2}M_2V_2^2 &= \frac{1}{2}M_1V_1'^2 + \frac{1}{2}M_2V_2'^2 \end{aligned} \qquad (2)$$

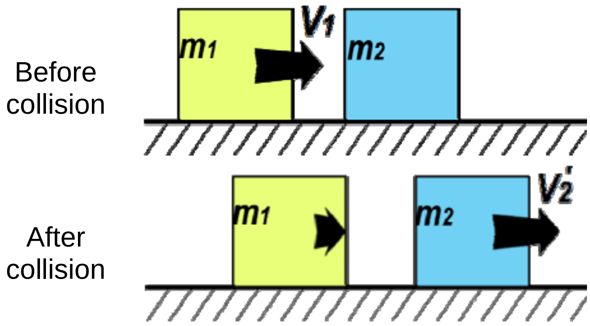

Figure 1 Collision blocks with no friction

Where, M_1 is the mass of block1 and V_1, V'_1 are its velocities before and after collision respectively; M_2 is the mass of block2 and V_2, V'_2 are its velocities too; denoted mass ratio as $MR = M_1/M_2$

$$VTR = 2MR / (MR + 1) \qquad (3)$$

The values used in the analyses are, unit weight of 20kN/m^3; initial velocity 10m/s; Poisson ratio 0.1 and Young's modulus (E) from 10^7pa to 10^{13}pa; mass ratio from 1 to 30; time step 10^{-3}s (DDA only) and penalty/contact stiffness (P) from 10^6N/m to 10^{12}N/m.

3. Results of DDA and UDEC

Fig. 2 illustrates the DDA results of mass ratio 1 with time step 10^{-3}s. The data of penalty spring stiffness 10^6N/m is not shown because its velocity exchange action is not completed till the end. As shown in Fig. 2, the results are

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mainly affected by penalty stiffness. The VTR decreases rapidly with penalty spring stiffness increasing. Contrary to static problems, relatively small penalty stiffness is suggested. It should be pointed out that the results do not change when mass, initial velocity or mass ratio varied.

Fig. 3 shows the UDEC results of mass ratio 1. Spring stiffness less than 10^9N/m doesn't work because large overlapping. It shows the results converge to a minimum value when p / e > 10 and converge to analytical solution when p / e < 0.1. It also shows the accuracy decreases with contact stiffness increasing. Fig. 4 indicates that the UDEC results degrades when mass ratio increasing. It should be also noted that the UDEC results also affect by mass and initial velocity.

4. Discussion

In static problems, to avoid relatively obvious spring displacement, usually the penalty stiffness is set as 20~100 Young's modulus[3]. But during velocity exchange action of collision problems the spring displacement is unavoidable, the error increases rapidly with penalty stiffness increasing.

DDA is energy based and using implicit solution. But during open-close iteration at the set and release of the spring, there is perturbation on the equilibrium of energy. Larger stiffness brings larger perturbation.

UDEC is force based and using explicit solution. Artificial springs are required to absorb the energy generated from the relaxation analysis so as to maintain equilibrium. The accuracy is controlled by the value p/e.

5. Conclusion

For collision problems, relatively small penalty/contact stiffness 10^8N/m for DDA and 10^9N/m for UDEC are suggested. The accuracy of DDA is controlled by p only and UDEC by p/e. Although both works well with material of high strength, DDA is more appropriate with engineer rock masses.

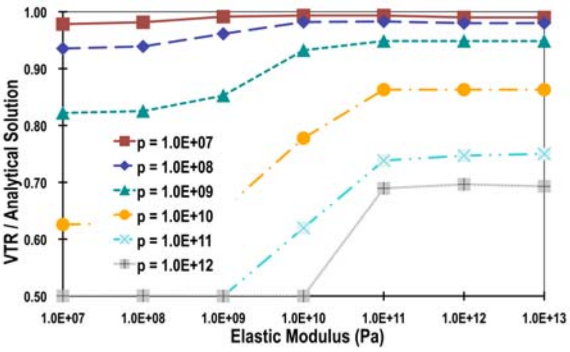

Figure 2 Results of DDA, MR = 1

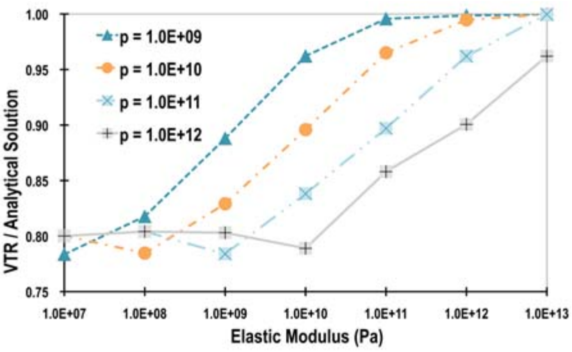

Figure 3 Results of UDEC, MR = 1

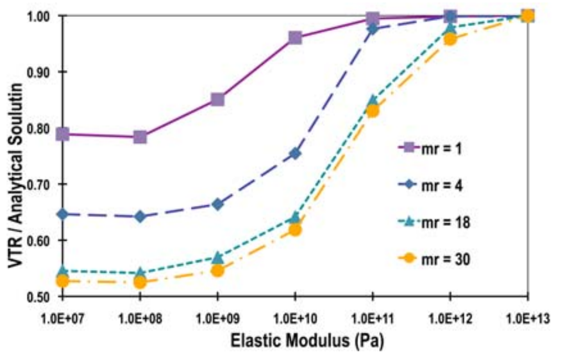

Figure 4 Results of UDEC, MR varied

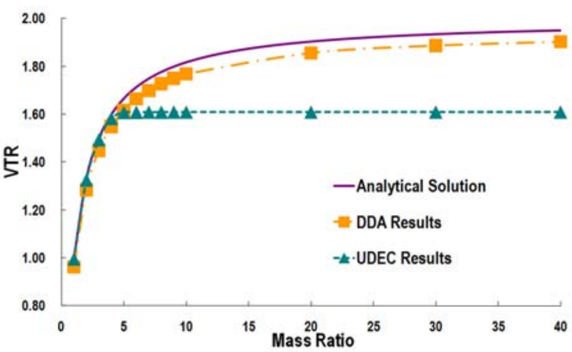

Figure 5 VTR versus MR of DDA and UDEC, E 10^{13}pa, P 10^9N/m

References

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