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Analysis of Rockfall Phenomenon in Steep Wall using Modeling by Rocfall Mass-Lump Method and PFC^{3D} Discrete Element Method (A Case Study)

Hadi Fattahi[1] Milad Sadeghi[2] Hossein Ghaedi [3]

1. Introduction

Rockfall refers to the movement of loosened rock blocks on steep slopes under the effect of gravity by free fall, rolling down the slope, and/or bouncing. Blocks may be dislodged due to a combination of factors such as joints, freeze–thaw, root growth and water ingress or by natural events such as earthquakes. This movement may cause significant damage and loss of life as the blocks move very rapidly. Compared to other mass movements, although rockfalls have smaller volumes, they have highly destructive effects. In addition to earthquakes, urban and rural settlements in some regions may experience losses caused by landslide, flood, rockfall, etc. Previous studies of natural disasters within the last 50 years have reported that rockfalls are responsible for a significant proportion (8.26%) of disaster victims. It is therefore important to determine the behaviors of blocks with the potential to fall on the settlements located on steep slopes.

In this paper, in order to assess the risk of falling rocks, using Rocfall and PFC^{3D} softwares, the path of rockfall of isolated blocks was analyzed separately in the most critical section of the northwestern heights of Shahrood.

2. Analysis and Results

The Rockfall V.4.0 (Rocscience2002) software and PFC^{3D} used in the analyses produces surface definitions controlling horizontal and vertical coefficients of normal and tangential restitutions that control energy absorption at the contact points of the falling block according to the topography. These definitions include asphalt, bedrock outcrops, clean hard bedrock, talus cover, soil with vegetation, and talus with vegetation. In these analyses, the surface was defined as ‘‘bedrock outcrops.’’ Friction coefficient is also an input parameter, and varies between zero and the main friction coefficient of the block material. In the analyses, a smaller value was selected in terms of main friction, depending on block shape, and zero for round shaped blocks. The horizontal and vertical velocities of the blocks were considered as 0 m/s due to their locations. Based on these input parameters, the areas of highest potential rockfall risk in the study area were determined. Rockfall trajectory of profile is given in Figure 1. The output of the analyses (location of rock end points, bounce height, kinetic energy, velocity, and graphs of the envelopes) for each profile is presented in Figure 2. Moreover, if the energy of the rocks is not dissipated after their fall, they will continue moving by bouncing.

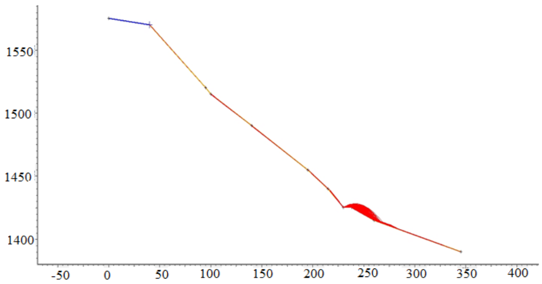
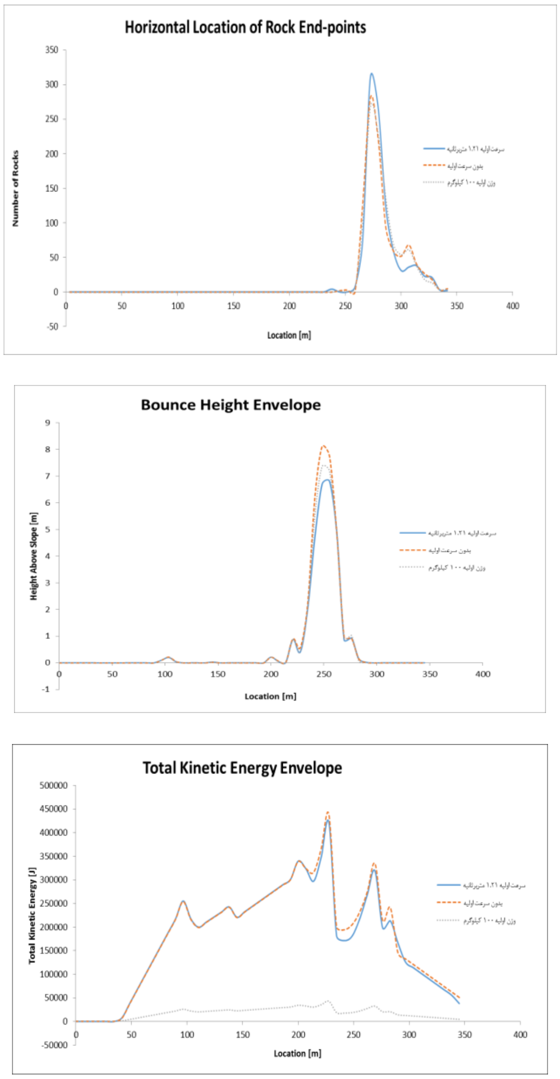


Figure 1. Rockfall trajectory of profile



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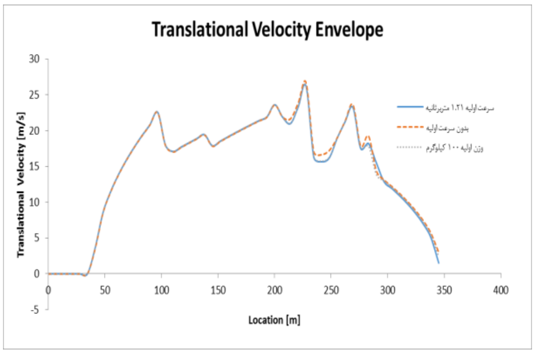
[1]. Corresponding author. Associate Professor in Rock Mechanics Engineering, Arak University of Technology, Iran. Email: h.fattahi@arakut.ac.ir .

[2] MSc Student in Mining Engineering, Faculty of Earth Sciences Engineering, Arak University of Technology, Iran.

[3]MSc Student in Mining Engineering, Faculty of Earth Sciences Engineering, Arak University of Technology, Iran .



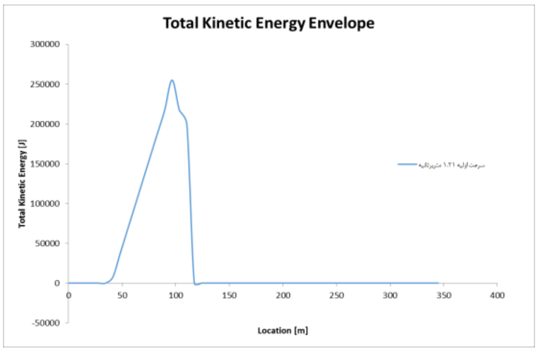


Figure 2. Defined slope and horizontal location of rock end point, bounce height, translational velocity, and total kinetic energy envelope

3. Conclusion

In this paper, in order to assess the risk of falling rocks, first using Rocfall software, the path of rock fall of isolated blocks was analyzed separately in the most critical section of the northwestern heights of Shahrood. In order to consider the interactions between particles in the path, shape, size and weight of the parts, the distinct element method PFC^{3D} was used. Analyzing the simulation results with the help of these two softwares, it was concluded that if the rock falls, a large number of parts will stop in the area of roads and residential areas, which will result in traffic jams and financial and human risks. In other words, considering that the maximum horizontal distance traveled by the plots is 393 meters and the horizontal distance between residential areas is 340 meters, the probability of an accident due to falling rocks is very high. Finally, suggestions such as installation of metal grids, shock absorbers, reduction of kinetic energy in the parts, change in the dimensions of the parts, change of the slope geometry for reducing the risk and damage of falling rocks in the desired section are presented.