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Analysis of rock fall and its risk assessment by evolutionary method in rock slopes (Case study: Esfidan village, southeast of Bojnourd city, North Khorasan)

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Abstract

Esfidan village is one of the historical and tourist areas in 45 km southeast of Bojnourd in North Khorasan, which is located in a mountainous area. The rock falls in this area can lead to the closure of the village communication road and also damage to part of the village houses. In this paper, the possible occurrence of rock fall is analyzed by software and also the risk of rock fall in it is evaluated. Field investigations have shown that rock falls in this area are mostly due to the tectonics of rock units, the presence of discontinuities, seasonal precipitation or a combination of these factors. Jointing studies have shown that the main discontinuities in the rock slope consist of three sets of joints with two major layers. Also, sampling of rock layers and performing various physico-mechanical tests indicated that the rock layers are mainly made of high-strength limestone. Software analysis of rock fall in this slope was performed on two selected sections by Rock fall software. Then, by combining the data obtained from the software analysis of rock fall and also the field data collected from the status of the slope activity, using Evolving Rock fall Hazard Assessment (ERHA) method, the potential of rock fall in two selected sections was evaluated. The results showed that the slope is in the middle to high risk category in terms of the risk of rock fall and needs to implement protective measures to prevent damage to roads and residential houses.

Keywords: Rock fall, Geomechanical Properties, Risk Assessment

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Extended Abstract:

1. Introduction

One of the most important geological hazards that have long challenged the minds of engineers and geologists is the instability of rock slopes. There are different types of rock slopes; one of the most common of which is rock fall and it often causes hazards in mountainous areas. The phenomenon of rock fall can lead to serious damage to urban areas, rural settlements as well as engineering structures. In addition, it has caused significant casualties that have been reported in various parts of the world (Chau et al., 2003; Ferrari et al., 2017; San et al., 2020).

In this research, the intention is to study the potential of rock fall in the entrance slope overlooking the Esfidan village in 45 km southeast of Bojnourd in North Khorasan.

2. Materials and methods

To carry out the research, in the first step, the geological condition and environmental characteristics of the study area were determined. Then, during field studies and local visits, different rock layers in the study area were sampled, and a number of mechanical and physical tests were performed on them. Finally, the potential of rock fall in the study slope was determined using two-dimensional rock fall analysis with Rock fall software version 0.4, and the results were discussed. In addition, based on the results, the risk assessment of rock fall potential was performed using the Evolving Rock fall Hazard Assessment (ERHA) method.

3. Results and Discussion

Based on the studies performed on the results of 16 samples of limestone, the average density in the dry and saturated state is equal to 2.50 and 2.55 g/cm^3, respectively. The average water absorption in this sample is 2.2% and the range of its changes is significant. The value of uniaxial compressive strength is 95.4 MPa and the range of changes is significant, which can be attributed to the presence of clay impurities and porosity in this samples. Based on the results obtained from the direct shear test performed on the samples, the average internal friction angle and cohesive are 46.5° and 1.5 MPa, respectively. It should be noted that the degree of homogeneity of the rock, the presence of clay impurities, the presence of fine cracks, the intensity of weathering, the size of the crystals and the test conditions are among the factors affecting the strength properties of the rock.

As shown in Table 1, for section A-A′, the maximum kinetic energy for rock blocks with weights of 10, 100, and 500 kg is 0.84, 7.4, and 37 kJ, respectively, while for section B-B′, the amount of kinetic energy for the same weights is calculated to be equal to 1.7, 17.9 and 88 kJ, respectively. Due to the steeper topography and greater dip of the slope in the B-B′ section, the velocity of the rock blocks increases and as a result, their kinetic energy is higher than that of the A-A′ section.

Table 1. Results of the two-dimensional analysis of rock fall by Rock fall software

Maximum velocity (m/s)	Maximum kinetic energy (J)	Maximum height of the jump (m)	Weight of rock pieces (kg)	Cross section name
12.4	840	1.53	10	**A-A′**
13.9	7467	2.34	100	
12.7	37051	2.21	500	
16.8	1723	1.64	10	**B-B′**
17.1	17964	1.83	100	
16.9	88006	1.78	500	

Based on the presence of signs of instability in the studied sections, the final activity status of both sections was determined. According to Table 2, the activity status of both sections is in the high activity category, which is confirmed by the field signs and the history of rock fall in the study area.

Table 2. Determining the final activity status of the rock slopes (Ferrari et al., 2017)

Preliminary score	Preliminary class	Without signs of activity	With signs of activity
0–3	Low	Low	Medium
4–7	Medium	Medium	High
8–11	High	High	High

4. Conclusions

Rock fall analysis was performed on two selected sections of the slope by Rock fall software which has the ability of two-dimensional statistical analysis of rock fall. The results of software analysis showed that in section B-B′, the main parameters related to rock fall such as jump height of rock blocks, energy and their velocity are more than section A-A′. Also, the results of indicated that the presence of a retaining wall downstream of the road was able to effectively prevent falling blocks to the village.

In general, the passage of traffic, both pedestrians and machinery, in the study area can be associated with hazards of the rock falls. Also, the results of software analysis showed that in case of falling rock blocks weighing more than 500 kg, these blocks may cross the retaining wall of the road and reach to the village, leading to financial and human losses.

Finally, in order to reduce the risk of the rock falls, it is recommended that the current retaining wall be raised and that the gap between the slope and the road be created by rock blocks removal.

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