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Monitoring the geotechnical stability of quarry marble mines of Kurdistan province

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Abstract

In this research, 13 different quarry rubble mines in Kurdistan province are selected as the case study for geotechnical stability monitoring. For this purpose, felid surveys are done and lithological, structural and geometrical properties of mines bench evaluated and recorded. Also, representative block samples are collected form working face of these mines to perform the experimental studies. Then, coring operation is performed over the above-mentioned blocks and cylindrical cores are provided for conducting the unconfined compressive strength and point load testes and preparing input data for slope stability analysis. Finally, the geometrical characteristics, boundary conditions and geo-mechanical properties of mines are designed using AutoCAD software. Then, the actual conditions of the available layers are simulated using Slide software and slope stability analyses are conducted. According to the numerical modeling results, the safety factor of Boghdeh Kkandi mine bench is obtained equal to 0.784. This proved that its bench is unstable and unsafe and slope decreasing and modification of the mine blasting pattern are required immediately. Also, the benches of Halozhan, Khoshkin, Sernjyaneh Olya 2, Babariz 3, Babariz 4, Sman, Kani Pahn and Abbas Abad are stable and the probability of their benches failure and collapse is low in the short term condition. At last, the benches of Zekkryan, Darrebagh, Bilo Arandan and Askaran mines are stable in the current state but they may reach the failure/collapse phase in the near future. Therefore, these mines will need the periodical regular monitoring and control the occurred deformations to ensure the required safety.

Keywords: *Quarry rubble mine, Geotechnical monitoring, Slide software, Slope stability analysis, Safety factor*

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Extended Abstract:

1. Introduction

Sand and gravel are the primary required materials in the civil and building industries. Therefore, the optimum production of these materials is the essential requirements that can reduce the possible problems in this industry. A large part of the required sand and gravels in the Kurdistan province is provided from the marble quarry mines. In fact, quarries are the largest number of under operation mines among the different types of mines in Kurdistan province, which play an important role in the province's mining industry. One of the main problems of these mines is the non-optimum inappropriate extraction of the existing reserves, which can endanger the future supply of these materials in the province. One of the main causing of the aforementioned problems is the existence of geotechnical instabilities due to the non-optimal design of the mines working benches as well as the incorrect design of the drilling and blasting pattern. This can endanger the safety of the personnel and equipment and decrease the mine efficiency and production and lead to the mine closure in critical conditions. Monitoring the geotechnical instability of the Kurdistan marble quarry mines, identifying the origin and influencing factors of instability and suggesting the solutions to solve the problem can help the safety in this mining industry. Also, it leads to prevent the damage of these important materials and guarantee their continuous and safe extraction in the future. This can prevent the possible price fluctuations and provide stability and safety of this industry. According to the practical topic of this research, no extensive theoretical studies have been done on the geotechnical instability of marble quarry mines. However, a lot of general research has been done on various instability factors in open pit mines. For example, various researches have been performed separately on the optimum design of the mine bench and final pit in (Adibi et al., 2015; Arslan et al., 2017; Benjamin et al., 2019) as well as the optimum design of the drilling and blasting pattern in surface mines (Zhang et al., 2016; Rezaei 2018) by different researchers. Reviewing the above-mentioned references showed that by knowing the influencing parameters of the occurred instabilities in the open pit mines, it is possible to identify the source of geotechnical instability in quarries and providing the appropriate solution.

The purpose of this research is to identify the marble quarry mines with geotechnical instability in the Kurdistan province, investigation of the influencing factors causing instability and providing suitable solutions to solve the problem of instability. This can increase the mine efficiency, safety and productivity indices. Also, a suitable database of marble quarry mines with possible geotechnical instability problems is prepared as the basis of future research related to improving the productivity of these mines.

2. Materials and methods

To conduct this research, felid surveys from 13 quarry mines are firstly done and available joints, faults, lithological properties and mine benches characteristics are evaluated and recorded. Then, required demonstrative blocks are collected form the bench face of these mines for conducting the required experimental tests. At the next stage, coring operation is performed, standard cylindrical cores are supplied and unconfined compressive strength and point load testes are implemented. In the following, the numerical model geometry is designed using AutoCAD mine software. Lastly, numerical modeling is perfumed using the Slide software for slope stability analyses of all 13 mines.

3. Tests results

According to the laboratory studies, the mechanical properties of mines slope rock samples including unconfined compressive strength (σ_c), point load index (PLI), tension strength (σ_t), cohesion (C) and friction angle (φ) are measured and given in Table 1. Also, the safety factor values are obtained for all 13 mines based in the conducted numerical modeling and using the Slide software. According to the numerical modeling results, mine stability conditions classified into the main categories i.e., unstable, currently stable and permanent stable as demonstrated in Table 2. Examples of unstable, currently stable and permanent stable categories are demonstrated in Figs. 1 to 3, respectively.

Table 1. Mechanical properties of mines slope rock samples

Mine	σ_c (MPPa)	PLI (MPA)	σ_t (MPa)	C (MPa)	φ (Degree)
Boghdeh kandi	78.57	6.42	8.032	8.31	66.1
Halozhan	23.08	1.44	1.8	3.35	57.66
Zekkryan	26.49	1.68	2.1	3.73	58.54
Khoshkin	18.54	1.16	1.45	3.12	52.75
Bilo Arandan	37.12	2.44	2.8	4.78	61.12
Darrebagh	33.04	3.62	4.52	4.3	60.81
Askaran	63.09	4.36	5.45	6.81	65.62
Sernjyaneh Olya 2	20.4	0.98	1.225	3.21	54.31
Babariz 3	136.93	9.98	12.47	13.16	68.23
Babariz 4	46.02	3.61	4.51	5.5	63.1
Sman	7.8	0.7	0.875	1.93	37.18
Kani Pahn	90.58	6.92	8.65	9.22	66.97
Abbas Abad	75.36	5.96	7.45	7.97	66.1

Table 2. Values of obtained safety factors for the studied mine slopes

Number	Mine	Safety factor	Remarks
1	Boghdeh Kandi	0.784	Unstable: Deed to correct and reduce the slope and optimize the blasting pattern
2	Halozhan	1.32	Permanent stable: Probability of slope failure is low
3	Zekkryan	1.212	Currently stable: Possible future slope failure (needs regular periodic monitoring)
4	Khoshkin	1.525	Permanent stable: Probability of slope failure is low
5	Bilo Arandan	1.123	Currently stable: Possible future slope failure (needs regular periodic monitoring)
6	Darrebagh	1.286	Currently stable: Possible future slope failure (needs regular periodic monitoring)
7	Askaran	1.206	Currently stable: Possible future slope failure (needs regular periodic monitoring)
8	Sernjyaneh Olya 2	1.353	Permanent stable: Probability of slope failure is low
9	Babariz 3	1.511	Permanent stable: Probability of slope failure is low
10	Babariz 4	1.676	Permanent stable: Probability of slope failure is low
11	Sman	1.659	Permanent stable: Probability of slope failure is low
12	Kani Pahn	1.639	Permanent stable: Probability of slope failure is low
13	Abbas Abad	1.593	Permanent stable: Probability of slope failure is low

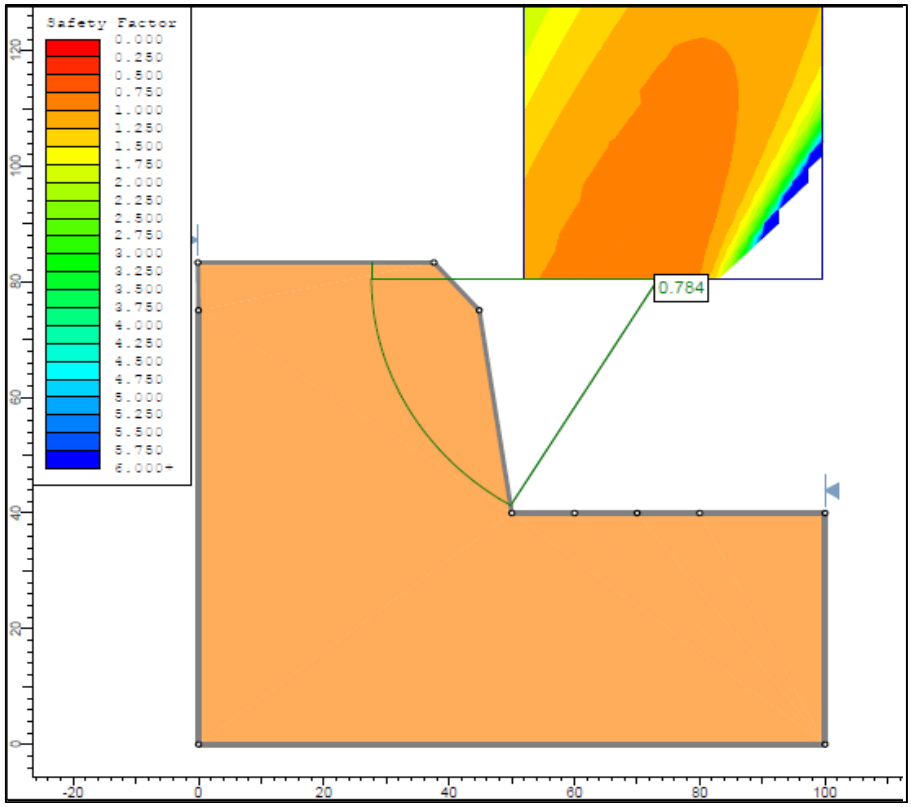

Fig. 1. Numerical slope stability analysis of Boghdeh Kandi mine (Unstable)

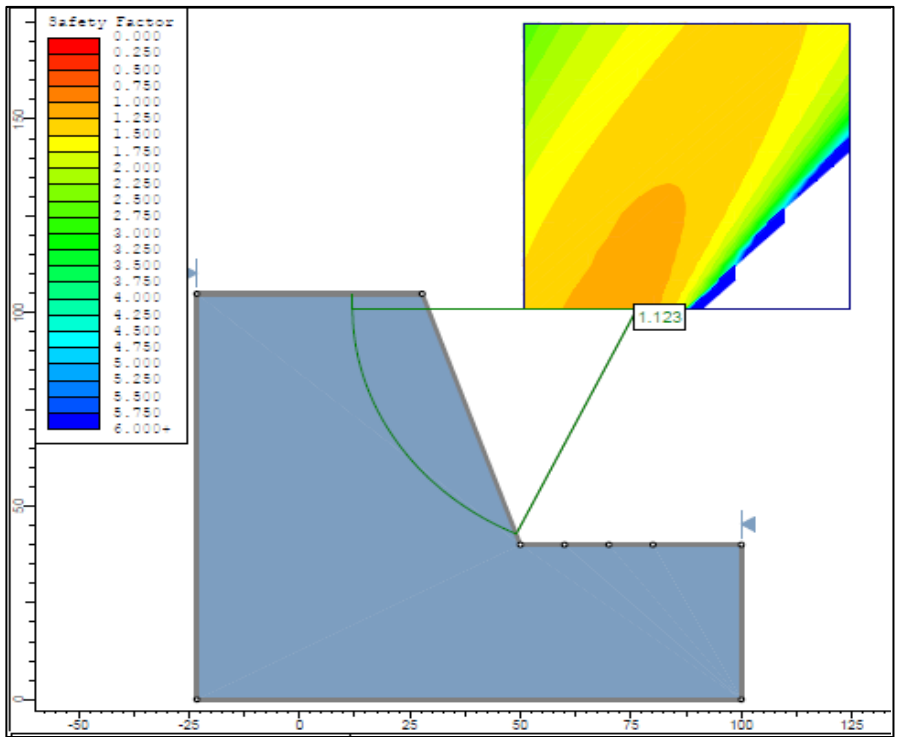

Fig. 2. Numerical slope stability analysis of Bilo Arandan mine (Currently stable)

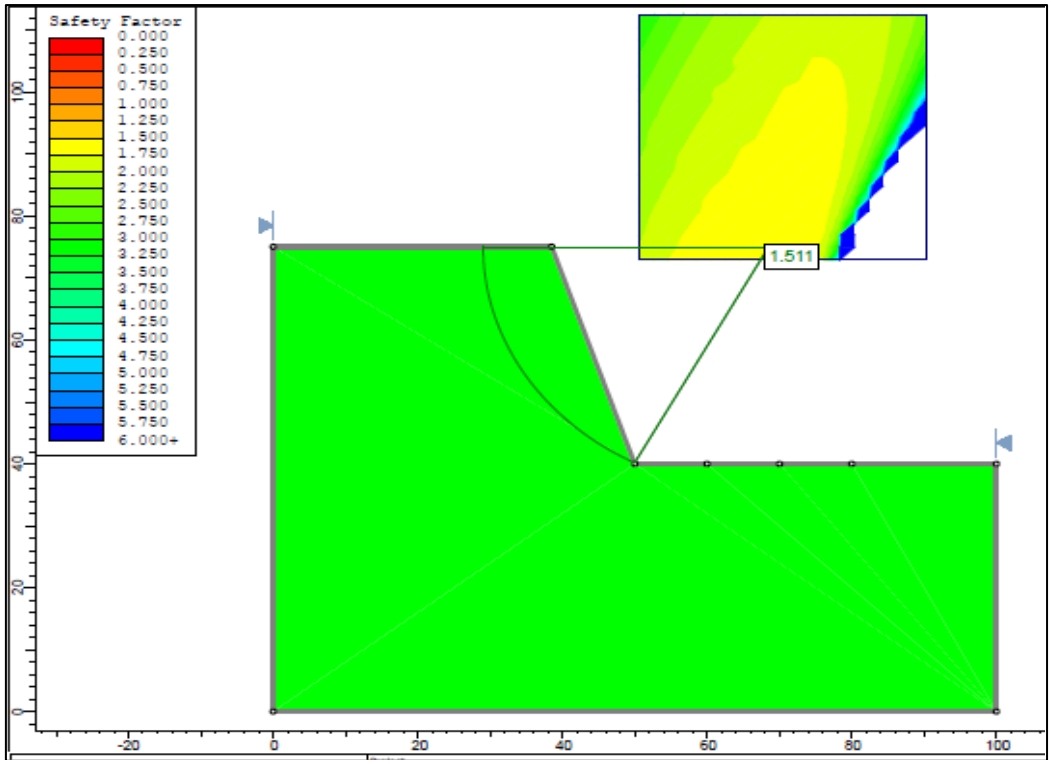

Fig. 3. Numerical slope stability analysis of Babariz 3 mine (Permanent stable)

4. Conclusion

In this research, the geotechnical stability of the quarry rubble mines of the Kurdistan province is monitored based on the combination of the field surveying, experimental studies and numerical modeling using the Slide software. According to the obtained results, the safety factor of Boghdeh Kandi mine was obtained 0.784 which indicated the instability state of this mine. Also, this factor was achieved 1.32, 1.525, 1.353, 1.511, 1.676, 1.659, 1.639 and 1.593 for Halozhan, Khoshkin, Sernjyaneh Olya 2, Babariz 3, Babariz 4, Sman, Kani Pahn and Abbas Abad, respectively. This proved the permanent stability of these mines. Finally, the safety factor for Zekkryan, Bilo Arandan, Darrebagh and Askaran was obtained 1.212, 1.123, 1.268 and 1.206, respectively. These safety factor values showed that the above-mentioned mines are currently in a stable state, but they may enter the failure phase in the near future.

References:

Adibi, N., Ataee-pour, M., Rahmanpour, M., 2015. Integration of sustainable development concepts in open pit mine design. Journal of Cleaner Production, 108: 1037–1049.

Arslan, A.T., Kahraman, B., Özfirat, M.K., Frühwirt, T., Yıldızdağ, K., Köse, H., 2017. A Parametric study using numerical modelling to assess the stability of marble quarries. Procedia Engineering, 191: 646–655.

Benjamin, G., Topal, E., Leenders, B., 2019. Examining system configuration in an open pit mine design. Resources Policy, 63: 101438.

Rezaei, M., 2018. Modeling and optimizing the drilling and blasting pattern of the Boghde-Kandi quarry rubble mine of Saghez. Journal of Iranian Association of Engineering Geology, 11(4): 41-53.

Zhang, K., Cao, P., Ma, G., Fan, W., Meng, J., Li, K., 2016. A new methodology for open pit slope design in Karst-Prone ground conditions based on integrated stochastic-limit equilibrium analysis. Rock Mechanics and Rock Engineering, 49(7): 2737–2752.