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A Study of Open-Pit Mine Wall Slope Using Rock Mass Classification Methods: A Case Study of Golbini 7 Bauxite Mine, Jajarm

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ABSTRACT

Slope stability is one of the main and determining parameters in economy and safety in open pit mines. One of the requirements of slope stability analysis is rock mass classification by experimental methods. These methods are widely used for preliminary (pre-design) and feasibility studies. In addition, experimental methods are often used in final designs as well. The main goals of rock mass classifications are to divide the rock mass into groups with similar behavior or classes with different quality, to prepare guidelines and quantitative data for slope engineering design, and to improve engineering judgment and better exchange of opinions regarding open pit mine slope design. The purpose of this article is to classify the rock mass, choose the optimal slope of the single step and choose the slope of the final wall of Golbini 7 Jajarm mine using experimental methods. Therefore, ten engineering geological survey lines with a total length of 432 meters were carried out. In the following, with the help of Dips software and the kinematic analysis method, the optimal single step slope of Golbini Mine 7 was determined. These values for the north wall (Shamshak formation) were equal to 65 degrees and for the south wall (Elika formation) equal to 47 degrees. Finally, by comparing the final slope obtained from the experimental methods of RMR, MRMR and Q-Slope, the value of the final slope of the mine using the experimental method was suggested to be 47 and 49 degrees, respectively, for shamshak and Elika walls. It was found that the use of the MRMR method for mines with a shallow depth provides a favorable answer with high reliability. Definitely, in order to determine the final slope of the mine, especially in deep mines, limit and numerical equilibrium analysis methods should be used in addition to experimental analysis.

KEYWORDS: *DISCONTINUITY STUDY, SLOPE DESIGN, STEP DESIGN, KINEMATICS, STABILITY ANALYSIS, ROCK MASS CLASSIFICATION*

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Extended Abstract:

1. Introduction

Slope stability is a critical parameter for the economics and safety of open-pit mines. A fundamental requirement for slope stability analysis is the empirical classification of the rock mass. This paper aims to select the optimal single-bench slope and the overall pit wall slope for the Golbini 7 mine in Jajarm using empirical methods. The study area comprises two main geological formations: the Elika formation (dolomite, lower seam) and the Shemshak formation (sandstone, siltstone, and shale, upper seam). The necessity of this study arises from the need to design stable slopes for efficient and safe mining operations, particularly given the significant final wall height of up to 290 meters. Empirical methods, while subject to potential error, provide a valuable and relatively straightforward means of initial analysis, especially in early study stages or for shallow mines.

2. Methodology

A comprehensive field investigation was conducted, including four scanlines totaling 230 meters in the Shemshak formation and six scanlines totaling 202 meters in the Elika formation. The data collected encompassed a wide range of geomechanical parameters necessary for rock mass classification, such as RQD, joint orientation, spacing, persistence, roughness, weathering, and groundwater conditions.

The analysis proceeded in two main stages:

1. **Kinematic Analysis for Bench Slope:** Using the Dips software, kinematic analysis was performed to identify potential failure modes (planar, wedge, toppling) and determine the optimal single-bench slope angle. A sensitivity analysis was conducted, considering a maximum acceptable probability of failure (PoF) of 20% for a single bench.
2. **Empirical Slope Design for Overall Pit Wall:** Three established empirical rock mass classification systems were employed to determine the overall pit wall slope:
    - **Rock Mass Rating (RMR):** The basic RMR was calculated and adjusted for joint orientation to obtain RMR89.
    - **Mining Rock Mass Rating (MRMR):** This system, a modification of RMR for open-pit mining, was used as the primary method for final slope design, as recommended by Iranian Publication 538.
    - **Q-Slope:** This recently developed system was used to provide a quality rating directly related to stable slope angles.

A Factor of Safety (FOS) of 1.5 was applied to the MRMR results to account for significant wall heights (up to 100m), sensitive slope angles, geological uncertainties, and potential errors in empirical methods.

3. Results and Discussion

The key results from the analyses are summarized in Table 1 below.

Table 1: Summary of Slope Angle Results for Golbini 7 Mine Walls

Method	Shemshak Wall Slope	Elika Wall Slope
Kinematic (Bench Slope)	65°	47°
RMR	55°	55°
MRMR (H=100 m, FOS=1.5)	47°	49°
MRMR (H=150 m, FOS=1.5)	40-45°	45-50°
Q-Slope (PoF=15%)	69°	70°

- **Kinematic Analysis:** The analysis revealed that wedge failure is the predominant mechanism in the Shemshak formation, while the 45° dip of the bedding in the Elika formation makes it highly susceptible to planar sliding if bench slopes exceed this angle.
- **Rock Mass Classification:** The RMR89 values were calculated as 59.18 (Shemshak) and 60.88 (Elika), classifying both as "Fair" rock masses. The MRMR values were 41.59 (Shemshak) and 43.02 (Elika). The Q-Slope values were 1.17 (Shemshak) and 1.30 (Elika).
- **Final Slope Design:** Based on the MRMR system with an applied FOS of 1.5, the recommended overall stable slope angles are **47° for the Shemshak wall** and **49° for the Elika wall**. These results are more conservative than the initial mine design, which proposed a 39° overall slope for a much higher (260m) Shemshak wall, highlighting the significant scale effect. The proposed slopes ensure a balance between safety and operational efficiency.

4. Conclusion

This study successfully determined stable slope angles for the Golbini 7 open-pit mine through integrated kinematic and empirical analyses. The extensive geomechanical data collection provided a robust basis for the rock mass classifications. The application of the MRMR system, guided by Publication 538 and incorporating a safety factor of 1.5, yielded practical and reliable slope designs of 47° and 49° for the Shemshak and Elika walls, respectively. While empirical methods are highly effective for initial and shallow mine design, the study concludes that for deep mines like Golbini 7 (with a final height of 290m), these results should be supplemented and verified with detailed limit equilibrium and numerical analysis methods in subsequent design phases to ensure long-term stability.

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