Study on the slope stability of the mine dumping site in Dailibaoqing village

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Abstract: In this paper, based on the engineering background of the mine dumping site in Dailibaoqing village, the field parameters and indoor rock and soil mechanics tests are used to obtain the mechanical parameters of the slope rock and soil. The FLAC3d software is used to simulate the slope deformation and failure mode, and the soil failure mode is greatly affected by the original topography. The P1 and P2 profiles are in the layered shear failure mode along the basement alluvium, and the P3 profile is in the arc-shaped sliding failure mode. Based on the back analysis of the stability parameters of the mine dumping site slope, the results show that under the condition of heavy rainfall, the recommended value of the saturated waste strength parameter is C=30Kpa, Φ=13°. Under natural conditions, the waste strength parameter value is C=34Kpa, Φ=17°. Through the calculation and analysis of the safety factors of the slopes P1, P2 and P3, the results show that, in the natural state, the slope stability coefficient Fs>1.20, and, in the saturated state, the slope stability coefficient Fs<1.20.

1. Introduction

In open-pit mining, stacking rock and soil on minerals in a mine dumping site forms slopes with several hundred meters high [1]. With the mining of open pit mining, the height of the slope is gradually increasing and the stability is reduced [2-6]. Domestic scholars have carried out a lot of research on slope stability analysis. Chen Peng et al. [7] used finite element method and limit equilibrium method to analyze the slope of dumping site. It is suggested that limit equilibrium analysis method is used to analyze the dumping site slope in the condition of good foundation and no soft layer. Han Yong [8] simplified Bishop method by using several limit equilibrium analysis methods to reveal and evaluate the failure mechanism of the dump slope. Yang Xiaosong et al. [9] compared the Swedish strip method with the simplified Bishop method and obtained the relationship between these two methods. Yang Xiuzhu et al [10] compared the rainfall conditions of different slopes, and compared the safety factors of slopes under different rainfall conditions. Zhang Zhongchao et al [11] analyzed and summarized the influencing factors of slope deformation stability, and quantified the effects of various influencing factors on slope deformation. In this paper, based on the engineering background of the mine dumping site in Dailibaoqing village, the mechanical properties of rock and soil are determined by experiments, and the failure mode and safety factor of open slope are analyzed and studied, which provides technology for the stability of mine dumping site slope. Guarantee.
2. Determination of rock mechanics parameters

2.1 Rock mechanics test

Through the borehole exploration, the main rock distribution characteristics of the slope are determined, including backfill soil, strongly weathered mudstone, silty clay, sandstone, weathered sandstone and weathered slate. Through the physical and mechanical experiments of these six kinds of rock masses, the lithology, composition, structural characteristics, attitude of rock formation and water-bearing state of the basement strata of the dumping site of the Dailibaoqing village dump were found out. It was ascertained that the internal and base of the abandoned material produced a new weak layer (face) or not and its occurrence state and distribution characteristics after the formation of the dumping site; The distribution characteristics of groundwater infiltration surface were obtained, and the different physical and mechanical properties of the groundwater infiltration surface of the excavation ground and the abandoned material were ascertained, which includes various physical and mechanical parameters at different depths and different moisture contents; Through the mechanical experiment of strength parameters of undisturbed rock and soil, basic data for the stability analysis of the boundary rock are provided, and the mechanical parameters of the comprehensive rock and soil are shown in Table 1.

Table 1: Strength parameters of rock mass in the slope of the agent fortification

| Stratigraphic lithology | Elastic Modulus (GPa) | Poisson's ratio | Cohesion (MPa) | Internal friction angle (°) | density (g/cm³) |
|-------------------------|-----------------------|----------------|----------------|----------------------------|----------------|
| Backfill                | 3.50×10⁻³             | 0.18           | 25.66×10⁻³     | 16.90                      | 1.37           |
| Strong weathered mudstone | 6.50×10⁻³             | 0.23           | 30.67×10⁻³     | 23.65                      | 1.47           |
| Silty clay sandstone    | 5.00×10⁻³             | 0.30           | 38.46×10⁻³     | 18.15                      | 1.82           |
| Weathered sandstone     | 17.06                 | 0.20           | 18.77          | 36.7                       | 2.53           |
| Weathered slate         | 13.97                 | 0.25           | 16.81          | 40.6                       | 2.48           |
|                         | 17.21                 | 0.17           | 13.98          | 48.8                       | 2.71           |

3. Numerical simulation analysis

3.1 Model establishment

According to the engineering geological model of the Dailibaoqing village dumping site, the P1, P2 and P3 sections were selected for numerical analysis. The P1 calculation model has a slope length of 1500m along the slope inclination and a maximum vertical height of 295m. The P2 calculation model has a slope length of 1400m along the slope inclination and a maximum vertical height of 325m. The P3 calculation model has a slope length of 1000m along the slope inclination and a maximum vertical height of 263m. The front, back, left and right boundaries of the model are truncated as boundaries. The front and back of the model are constrained by displacement in the Y direction. The left and right directions of the model are constrained by displacement in the X direction, and the bottom of the model is constrained by displacement in the Z direction, thus the displacement boundary conditions are formed to maintain the force balance of the whole system. The geotechnical layers in the model are described by an ideal elastoplastic model. The model calculation parameters are shown in Table 2.1:

3.2 Analysis of results

For the P1 profile, the displacement vector velocity distribution of the slope is shown in Figure 3.1. The displacement vector of the slope develops along the dumping site slope surface from +2250m level to +2400m level, which reflects the sliding trend of the overall slope. The slope shear strain rate cloud diagram is shown in Figure 3.2. The position with the largest shear strain appears at the slope position of +2300m. The stress concentration appears in the slope body. Combined with the displacement vector
velocity distribution diagram, it can be determined that the slope body is mainly the pressure-shear failure mechanism formed by heap load, and the slope presents the bedding shear failure mode along the alluvial basement. The overall instability of the slope will occur in the weak zone or stress concentration zone. The rock and soil unit will produce different degrees of plastic deformation. If the weak zone of plastic deformation or the stress concentration zone is interconnected, the whole instability will occur in the interconnected shear failure surface of the slope. The occurrence and development of plastic strain indicates the occurrence and development degree of yield or failure of rock and soil. The size of plastic strain can describe the process of yield or failure of rock and soil in essence. Therefore, it can be judged whether the plastic zone is penetrated to judge the slope. The overall instability is destroyed. Figure 3.3 is the distribution of the shear yield region of the P1 section of the dump slope of the Dailibaqing village. It can be seen from the distribution of the shear plastic yield region that there is almost no plastic zone in the slope, indicating that the overall slope of the dumping site is in a safe state.

For the P2 section, the slope is mainly the compression-shear failure mechanism formed by the pile load, and the slope is the bedding shear failure mode along the basement alluvium. A small amount of plastic failure occurred at the base of the slope below the level of +2240m, but the plastic zone was not penetrated and the slope was in a safe state. For the P3 section, the slope body is mainly the pressure-shear failure mechanism formed by the pile load, and the slope is in the arc-shaped sliding failure mode.

4. Determination of slope safety factor

4.1 Back analysis of stability parameters of dump slope

In the case of heavy rain in the upper step near the parking lot of the Fortress dump site, there was a partial rib spalling, and the coordinates of the rib spalling range are shown in Table 2 below.
According to the position and range of the rib spalling, the inversion analysis of the strength parameters of the dump is carried out to ensure the reliability of the calculation parameters of the slope stability of the dump. The stability of the local step was examined when the cohesion and internal friction angles were examined separately. According to the definition of slope stability, the slope stability coefficient \( F_s \geq F_{st} \) (allowable safety factor) is stable, \( F_{st} < F_s \leq 1.05 \) is basically stable, \( 1.05 > F_s \geq 1.00 \) is unstable, and \( F_s < 1.0 \) is unstable. Therefore, in the calculation process, the combination of the cohesive force and the internal friction angle in the case of \( F_s < 1.0 \) was examined. The calculation results are shown in Table 3.

From the calculation result map combined with the test results, when the rib spalling occurs, that is, when \( F_s < 1.0 \), when the cohesion force is in the range of (25, 35), the internal friction angle ranges from (11.5°, 15°). In the case of heavy rainfall, the recommended value of the saturated waste strength parameter is \( C=30\text{Kpa}, \Phi=13° \). In the natural state, the waste strength parameter takes \( C=34\text{Kpa} \) and \( \Phi=17° \).

### 4.2 Calculation of slope stability of dumping site

Table 3 Calculation results of FFX-1 profile stability under different cohesive forces/different internal friction angles

| FI=11 | FI=12 | FI=13 | FI=14 | FI=15 | FI=16 | FI=17 |
|-------|-------|-------|-------|-------|-------|-------|
| \( C=34 \) | 0.978 | 1.021 | 1.064 | 1.106 | 1.148 | 1.191 | 1.233 |
| \( C=30 \) | 0.917 | 0.959 | 1.001 | 1.042 | 1.084 | 1.125 | 1.167 |
| \( C=25 \) | 0.838 | 0.879 | 0.92  | 0.961 | 1.001 | 1.042 | 1.082 |

During the calculation and analysis of the slope stability of the Dailibaqing village mine dumping site, three representative sections were selected: dumping section 1 (P1), dumping section 2 (P2), and dumping section 3 (P3). The M-P method and the Bishop method are used to calculate and analyze the
local and overall stability of the slope in the natural state and the possible arc sliding and arc-line combined sliding modes. The calculation results are shown in Table 4.

| Natural state | Part 1 | Part 2 | Part 3 | Part 4 | Part 5 | overall |
|---------------|--------|--------|--------|--------|--------|---------|
| P1            | 2.30   | 1.37   | 1.90   | 1.87   |        | 1.62    |
| P2            | 1.74   | 1.58   | 1.62   | 1.29   | 1.54   | 1.50    |
| P3            | 1.85   | 1.70   | 2.27   |        |        | 1.88    |

| Saturated state | Part 1 | Part 2 | Part 3 | Part 4 | Part 5 | overall |
|-----------------|--------|--------|--------|--------|--------|---------|
| P1              | 1.81   | 1.12   | 1.55   | 1.48   |        | 1.25    |
| P2              | 1.36   | 1.27   | 1.34   | 1.07   | 1.21   | 1.16    |
| P3              | 1.45   | 1.34   | 1.77   |        |        | 1.58    |

It can be seen from the table that in the natural state, the dump slope of the Dailibaoqing village is in full compliance with the slope stability coefficient $F_s > 1.20$; but under the influence of heavy rainfall, the waste will enter the saturation state under the action of rainwater. Therefore, the overall anti-sliding ability of the dump slope is reduced. Under the saturated state, some slopes do not meet the requirements of the slope stability coefficient $F_s > 1.20$.

5. Conclusion

(1) The failure mode of the dumping site is greatly affected by the original topography. The P1 and P2 sections are in the layered shear failure mode along the basement alluvium, and the P3 section is in the arc-shaped sliding failure mode.

(2) In the case of heavy rainfall, the value of the strength of the saturated rejects is taken; in the natural state, the value of the strength of the waste is $C=34$Kpa, $\varphi = 17^\circ$.

(3) In the natural state, after the ascending section, the slope of the dumping site is completely in accordance with the requirements of slope stability coefficient $F_s > 1.20$, under the influence of heavy rainfall, the waste material enters the saturated state under the action of rainwater, which reduces the anti-sliding ability of the slope or step of the dumping site, and some slopes or steps are not in accordance with the requirements of the stability factor $F_s > 1.20$.

References

[1] FU Tian guang. Elastic—plastic FEM Computing Method for Wet Slope Stability of Open—pit Coal Mine[J]. Coal Engineering,2019,51(01):96-100.

[2] CHEN Zan cheng, YU Bin, HU Jian jun, et al. Stability analysis of over size open-pit slope based on numerical simulation using flac3d[J]. Mining and Metallurgy, 2013,22(03):1-6.

[3] Zheng Lujing, Zheng Lulin, Chang Xiaona, et al. Influencing Factor Analysis and Control of Open Pit Slope Stability[J]. Metal Mine,2014(02):131-136.

[4] QIAO Chen, Influencing factors and preventive measures of slope stability in Open-pit Mines[J]. Opencast Mining Technology,2019,34(01):92-94.

[5] Zhang shao xuan, Analysis of Factors Affecting Slope Stability[J].Sichuan Cement,2018(11):284.

[6] Zhang Ziguang, Bai Jiyuan, Analysis on influencing factors of slope stability in external dump of Hongshaquan Coal Mine[J]. Opencast Mining Technology,2018,33(05):51-53+58.

[7] Chen Peng, Chen Pengfei, Slope stability analysis on waste disposal site of opencast[J]. Journal of Liaoning Technical University(Natural Science), 2010, 29(6) :1028-1031.

[8] Han Yong, Study on slope stability of dumping site in Zhundong Open-pit Mine[J]. Opencast Mining Technology, 2010, (5) :63-64, 68.
[9] Yang Xiaosong, GAO Tao. Comparison of Sweden slice method and simplified Bishop method in seawall stability analysis[J]. Port & Waterway Engineering, 2017, (02):27-32.

[10] Yang Xiuzhu, Ye Zhiling, Lei Jinshan, et al. Stability analysis of slope under rainfall infiltration[J]. Journal of Railway Science and Engineering, 2017, 14(05):935-941.

[11] Zhang Zhongchao, LI Wei, Wang Jun, et al. Displacement Disassembly and Monitoring Analysis of Loess Floor Dump Slope Affected by Underground Mining[J]. Safety in Coal Mines, 2017, 48(3):205-208.