Slope Stability Analysis and Prevention Measures in D Area of South Part of Baiyun'ebo Open-pit Iron Mine

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Abstract

Landslide is one of the most common disasters of open-pit mine because of the characteristics of high slope body, large gradient and frequent blasting vibration. This paper takes the main field of Baiyun'ebo iron mine as an example. The engineering geological conditions and rock mass structure characteristics and parameters were obtained by field investigation, and the rationality of rock and soil strength parameters was verified by numerical inversion analysis. The 3D data of 2# slip mass was obtained by three-dimensional laser scanning technique, then the numerical model of slip mass was established based on the three-dimensional data. The current stability of slip mass was analyzed by FLAC3D numerical calculation software. It is concluded that the slip mass is in the unstable state. In order to ensure the mine mining construction and safety of personnel in the future, this paper intends to study the control measure of the slip mass which is cutting slope and reducing load, and analyses the stability of the slope with the control measure. It is concluded that the slope is in steady state after the the control measure.

Key words: three-dimensional laser scanning, stability analysis, management

Introduction

One of the most common kind of geological disasters in open-pit mine is a landslide which is caused due to the height and gradient of the slope of open-pit mines coupled with the influence of fracture zone, dikes and blasting vibrations. The sliding mass has physical and mechanical properties of a wide grading and high degree of loose, which makes the stability of the sliding mass poorer. As a result, the stability of the sliding mass should be analyzed, and some reasonable measures should be put forward to reduce the influence of safety production of mine area.

Baiyun'ebo iron mine area is located in 150km north of Baotou, Inner Mongolia. The main mine is nearly east-west distribution, 3.5km in length, 1.9km in width, covering 4.8 km^2, it is shown in Figure 1.The horizontal layer stripping method is adopted to improve the mining in the main mine of Baiyun'ebo. Now it is mining to 1556m elevation. There is a great deal of difference between the ultimate goal of mining main mine to 1230m elevation which is put forward by Anshan mining design and research institute in 1987 and current 1556m elevation. As the exposed stope slope condition shown, in the south of main mine, the lithology and structure is complex. Fault fracture zones and dikes are wide and large, and their strike is similar to the strike of the slope, tend to be vertical or tilting. It is harmful to the stability of the slope, and the step close to boundary obvious slide and collapse[1]. The 2# slope in D area studied in this paper is located in the south part, as shown in Figure 2.The altitude of the area where the slope located in is 100m, and the area was divided into 5 working platform which is +1650,+1626.+1598,+1570.+1556, the general slope angle is 41°- 44°. The landslide occurred in +1570-+1650 working platform, the typical profiles and photos of landslide mass was respectively shown in Figure 3,Figure4. According to Baiyun'ebo main mine ultimate design, the second installed ore crushing plant will be built in the lower part of the sliding body within the elevation of 1480-1514m. Therefore it is necessary to study the stability analysis and control measure of the slip mass.

Figure 1 Baiyun'ebo iron main mine, mirror image 50°

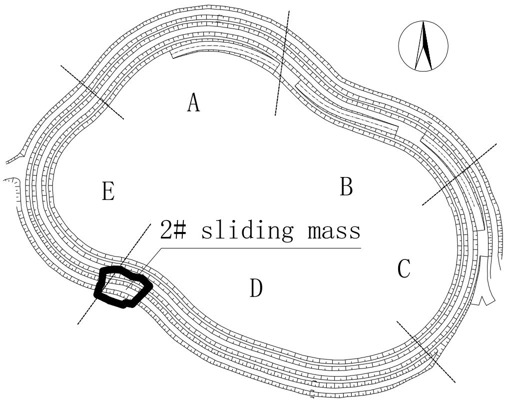

Figure 2 Baiyun’ebo iron main mine stope partition map

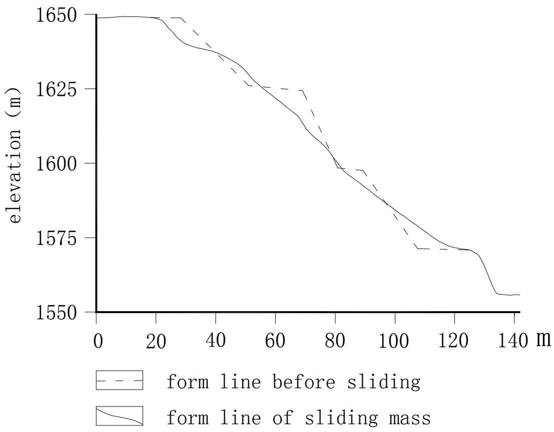

Figure 3 Profile of 2# slope in D area of main mine

Figure 4 picture of 2# slope，mirror image 300°

1. The engineering geological conditions

The tectonic structure of Baiyun’ebo region belongs to the cohesive zone of northern margin of north China platform and Inner Mongolia-the greater hinggan mountain fold system. It is belong to the northern margin of north China landmass range as a whole. There are two nearly east-west trending big fault in this area: Wulanbogeli fault and Baiyun’ebo-Baiyijiaolake fault. Baiyun’ebo group is a set of low greenschist facies volcanic and terrigenous sedimentary rock. It is mainly composed of metamorphic glutenite, feldspar quartz sandstone, slate and crystalline limestone. According to the Inner Mongolia regional geology data[2], Baiyun’ebo group is divided into six formation-complexes, as shown in fihure 5.

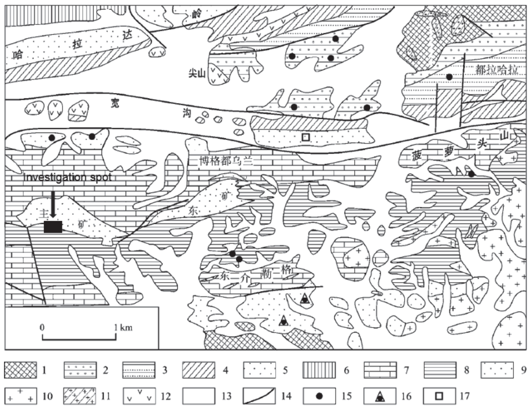

Figure 5 geologic map of Baiyun’ebo mine area

1-Early Proterozoic basement complex 2-Baiyun’ebo group H2 quartz sand conglomerate 3- Baiyun’ebo group H2 White quartzite 4-Baiyun’ebo group H3 dark slate 5-Baiyun’ebo group H4 dark quartzite 6-Baiyun’ebo group H5 dark slate 7-Baiyun’ebo group H8 domolite 8-Baiyun’ebo group H9 feldspar slate 9-REE-Nb-Fe ore body 10-Hercynian granite 11-alkaline dikes 12-basic dikes 13-Tertiary sedimentary rock 14-main fault 15-the exposure point of igneous carbonates dikes 16-sampling location of carbonatite dyke; 17-sampling location of sodium hornblende rock

2. Landslide stability analysis

In this paper, Fast Lagrangian Analysis of Continua software FLAC3D was used to analyze stability of the slope before landslide, current slip body and slope under governance measures.

2.1 Building model

With the constant expansion of application of FLAC3D in the geotechnical engineering, people realized that the accuracy of the model will affect the results of numerical simulation[3]. The reason of inaccuracy modeling of FLAC3D includes: 1. Pretreatment of FLAC3D have problem of big work load, complicated process and low degree of visual. As a result, the model had to be simplified to reduce the workload of modeling. 2. Geotechnical engineering geological survey information is the original data of building model. Its accuracy directly affects the accuracy of the model. To improve the inadequateness of FLAC3D pretreatment, the domestic and foreign experts have tried a lot of explorations: such as developing FLAC3D pretreatment program by programming statements, using the function of pretreatment of Three-dimensional modeling software or finite element software(such as MIDAS , ANASY) in modeling complex terrain[4-6].But there are few studies about how to improve the accuracy of the geological survey data which is used to establish numerical model. In this paper, three-dimensional laser scanning technology was used to solve the problem. Three-dimensionallaser scanner is shown in Figure 6. Three-dimensionallaser data can be collected from object fast through this technology. Every one of Three-dimensionallaser data in the laser point cloud is real data which are directly collected form target. It makes the post-processing of data completely reliable. This technology have characteristics of non-contact measurement, high data sampling rate, active emission of scanning light source, high resolution, high precision, the digital acquisition, good compatibility, etc.[7]

Figure 6 three dimensional laser scanner

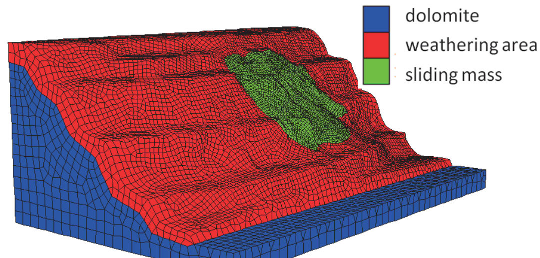

Figure 7 3D model of 2# slope of Baiyun’ebo

2.2 Parameter selection

Joint fissures and large faults are developed in Baiyuebo main mine slope. The slope rock mass are eluvial layer or fully weathered rock stratum, with structure of bulk solid and fragmentation. Considering the factor of unloading rebound and blasting vibration during excavation of the mine, about 30m cover layer of the slope surface are identified as dolomite fracture zone in the stability analysis(i.e., weathered zone). Mechanical parameters of weathered zone decrease comparing with dolomite bedrock. Rock physics index values can be seen as rock mass physical index standard values; Internal friction angle of rock mass standard values can be determined by Internal friction angle of rock multiply by reduction factor 0.80-0.95 according to the integrity of rock mass; cohesion standard values of rock mass are determined by cohesion standard values of rock multiply by reduction factor 0.20-0.30[8]. Combined with investigation report of Study of over 1598m slope stability and comprehensive management measures in Baogang Baiyuebo main iron mine, parameters are selected as Table 1.

Table 1 The sliding body material parameters

material	volume-weight γ（kN/m^3）	cohesion（C/MPa）	Internal friction Angle φ
Weathered dolomite	28.0	0.07	29.0
Fresh dolomite	29.0	0.435	38.0
Slip accumulation body	26.0	0.01	15.0

2.3 Stability Analysis

2.3.1 Stability Analysis of the Slope before Sliding

In order to verify the parameters given by Form 1, this paper calculates the stability of the slope before sliding. According to the Slope design information which is provided by the Final Boundary Map of the Main Orebody of Baiyun’ebo, the three-dimensional (3D) model of this slope can be modeled (Fig. 8). The 3D size of this calculation model is 188m×240m×118m. This paper uses solid elements and mixed meshes (include four-node tetrahedron units, five-node pyramid units, 6-node triangular prism units and 8-node hexahedron units) to simulating the rock soil mass. The calculation model has 91171 units and 56738 nodes in all. Its computational accuracy is 1×10-5.

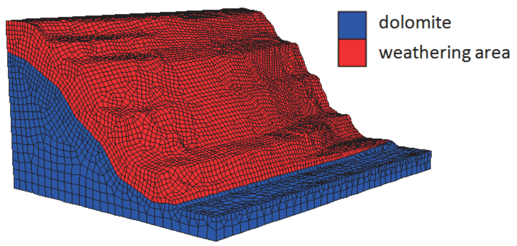

Figure 8 3D model of Slope terrain before sliding

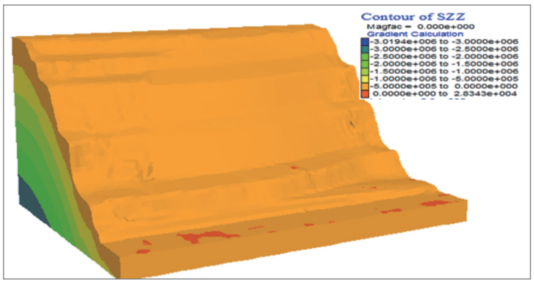

Figure 9 Slope stress distribution nephogram before sliding

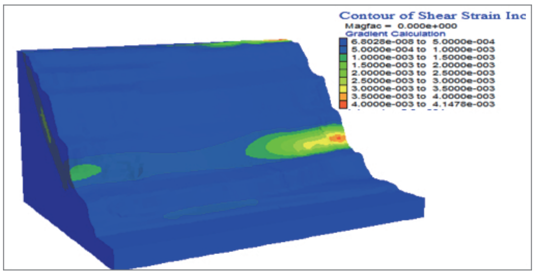

Figure 10 Slope shear strain increment nephogram before sliding

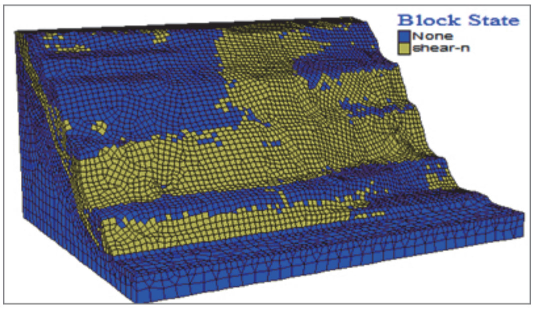

Figure 11 Slope plastic zone map before sliding

The data of shear strain increment in Figure 10 show that the shear zone has a breakthrough point on the surface. At the same time, big plastic zones can be found above the formation region of the shear zone and all of them have a shear failure (Fig. 11). Considering the shear zone and the plastic zones, this slope is most likely to sliding along the connecting plastic zone. This conclusion is in conformity with the actually happened phenomenon of the side slope slippage (2# landslide). It means that the parameters of the slip mass are accordant with the real situation.

2.3.2 Stability Analysis of Slip Mass

By analyzing the stability of the slip mass, the possibility of its continued sliding can be judged. The calculation model is shown by Figure 7. The 3D size of this calculation model is 188m×300m×118m. This paper uses solid elements and mixed meshes (include four-node tetrahedron units, five-node pyramid units, 6-node triangular prism units and 8-node hexahedron units) to simulating the rock soil mass. The calculation model has 91448 units and 47852 nodes in all. Its computational accuracy is 1×10-5.

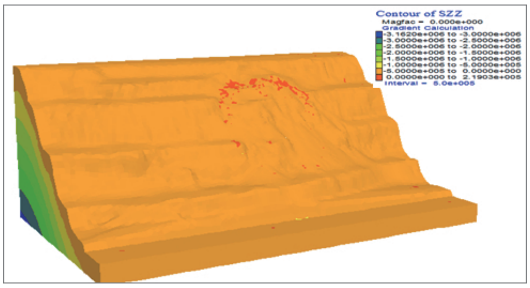

Figure 12 Slope stress distribution nephogram after sliding

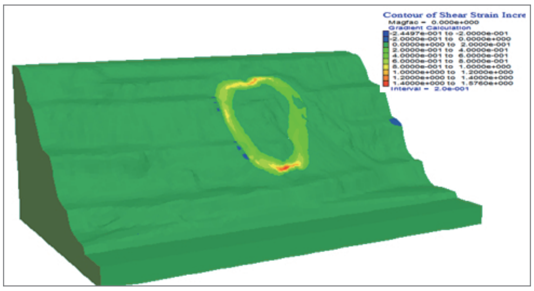

Figure 13 Slope shear strain increment nephogram after sliding

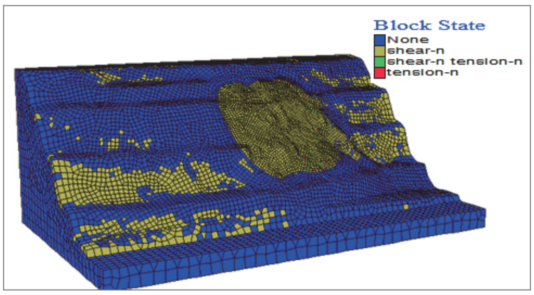

Figure 14 Slope plastic zone map after sliding

The data of shear strain increment in Figure 13 show that there is a connecting shear zone around the slipping zone. So the slipping zone is in danger of continued sliding. The fully plastic distribution appears in the slipping zone. The failure of the most part of it is shear failure and the small part of it belongs to tensile failure. (Fig. 14) Considering the shear zone and the plastic zones, a conclusion is obtained: this slope is most likely to sliding along the slipping zone. Furthermore, there is a connecting shear zone at the step of the right side (west side) of the slipping zone. There is a huge possibility that the continued sliding of the slipping zone would drive the surrounding weathered zone sliding.

2.3.3 Stability Analysis of the Slope after Cutting

Now this slip mass is in a state of flux. It might slip and become a landslide at any time. The landslide will not only affect the safety of mining and threat to the life safety of the staffs who work in the mine area, but also directly influence the construction of the second phase of ore crushing plant which is below the landslide. Therefore, it is necessary to take effective measures to prevent and control the side slope. This paper proposes a control plan by cutting slope and analyzes the stability of the slope after cutting by using numerical simulation method. The typical cross-sections of the slip mass before and after governance are shown by Figure 15. As can be seen from the cross-sections in Figure 15, the overall slope angle is decreased roughly from 47° to 41° after slope cutting. The calculation model of the side slope after cutting is shown by Figure 16. Its 3D size is 188m×300m×118m and totally has 154681 units and 98940 nodes. The computational accuracy of the model is 1×10-5.

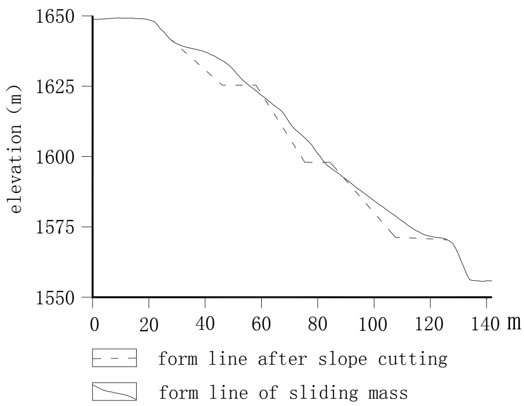

Figure 15 Typical profile before and after treatment of landslide

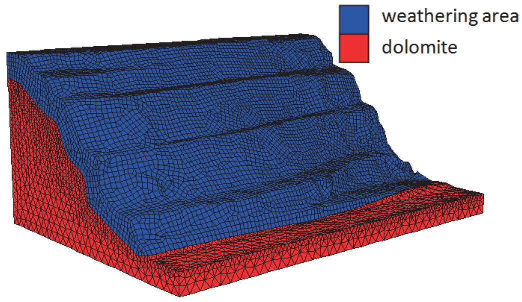

Figure 16 3D model of slope terrain after cutting slope

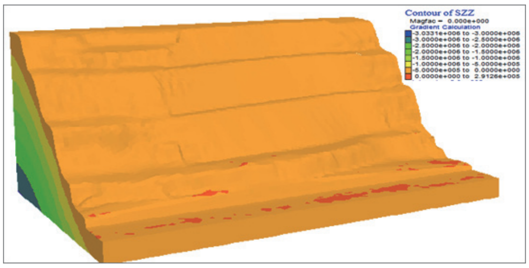

Figure 17 Slope stress distribution nephogram after cutting slope

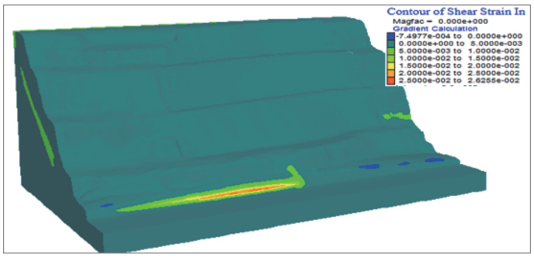

Figure 18 Slope shear strain increment nephogram after cutting slope

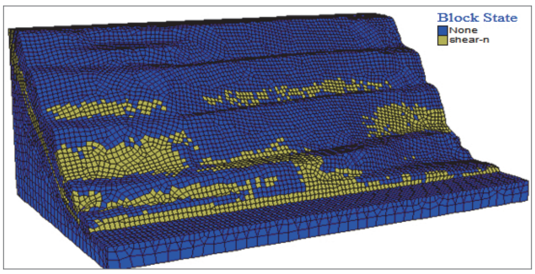

Figure 19 Slope plastic zone map after cutting slope

The shear strain increment nephogram in Figure 18 shows that there is no connecting shear zone in this side slope. Even though there are some shear zones, they do not link to each others. The distributions of plastic zones in Figure 19 shows that most of them are located in the bottom of the side slope. And all the failure of the plastic zones are shear failure. However, there is no obvious plastic zone appeared in the cutting area. Considering the shear zone and the plastic zones, it can be said that the side slope is more stable after cutting.

3 Conclusion

After the 2# side slope of Baiyun'ebo Main Orebody slipping, the representation of its geological structure becomes more complex. Using the traditional modeling method can not meet the requirement of accuracy. This paper uses 3D laser scan technology to get the 3D data of geological representation structure, and then, establishes the calculation model by using FLAC3D according to the 3D data. This method possesses the advantages of fast modeling and reflecting the 3D topographic and geologic shape accurately. In addition, the mathematical calculate model can provide guarantee for getting the more reliable result of numerical simulation.

Using FLAC3D combined with 3D laser scanning technology builds the calculation model of the 2# slip mass of Baiyun'ebo Main Orebody and does the simulate calculation.

Combined with the 3D laser scan technology, the calculation model of the 2# slip mass of Baiyun'ebo Main Orebody is built by FLAC3D program. Doing the simulate calculation, the result shows that this slip mass is in a state of flux and the relevant control measures need to be taken. This paper proposes a control plan by cutting slope. Using numerical simulation method to analyze the condition after taking the control plan, it can be found that the stability of the slope is increased.

Acknowledgements

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