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Slope stability analysis of Southern slope of Chengmenshan copper mine, China

Mohammed Mnzool [a,b,*], Wan Ling [a,c], Wei Zuo'an [a,b]

[a] State Key Laboratory of Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing 400030, China
[b] College of Resource and Environmental Science, Chongqing University, Chongqing 400030, China
[c] College of Aerospace Engineering, Chongqing University, Chongqing 400030, China

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ABSTRACT

The engineering geology and hydrogeology in the southern slope of Chengmenshan copper mine are very complicated, because there is a soft-weak layer between two kinds of sandstones. Field investigations demonstrate that some instability problems might occur in the slope. In this research, the southern slope, which is divided into six sections (I-0, I-1, I-2, II-0, II-1 and II-2), is selected for slope stability analysis using limit equilibrium and numerical method. Stability results show that the values of factor of safety (FOS) of sections I-0, I-1 and I-2 are very low and slope failure is likely to happen. Therefore reinforcement subjected to seismic, water and weak layer according to sections were carried out to increase the factor of safety of the three sections, two methods were used; grouting with hydration of cement and water to increase the cohesion (c) and pre-stressed anchor. Results of reinforcement showed that factor of safety increased more than 1.15.

1. Introduction

As the mining methods turning from open pit mining to sag by mining, vertical height of open-pit mine slope continues to increase the slope deformation and failure mode has close relationship with regional geological structure characteristics and the rock mass structures feature [1–4]. The stability is influenced largely by rock mass, joints and fissures, and blasting vibration [5]. Landslide is a typical geological disaster in the worldwide, and causes a huge threat to the human life and property [6,7]. Currently, the slope stability analysis methods include the geo-mechanical method (such as stereographic projection), limit equilibrium method, finite element method, discrete element method, and Lagrange differential method [8,9].

Chengmenshan copper mine as shown in Fig. 1 is located in Jiujiang county which lies about 18 km far from the west-south of Jiujiang city, Jiangxi province and 6 km far from Yangtze River. It is a large-scale copper sulfur open pit mine of Jiangxi Copper Industry Company. The reserves are about 1.65 Mt copper, 69 t gold and 35.66 Mt sulfur, the production is 0.2 Mt of ore (mining volume) and 1.25 Mt of waste (stripping volume) per year. The pit was designed with a width of 1250 m, length of 1400 m and depth of 430 m. The height of the bench is 24 m and the overall slope angle is about 50°.

The east, west and north sides of Chengmenshan copper mine are surrounded by a lake; the south side has a transportation road which has been used for mines production for many years. The engineering geology and hydrogeology in the southern mine area are very complicated and there are F_1 faults which run from east to west and anti-dip against the open pit near the southern slope. The slope consists mainly of two sandstone formations, named Shamao formation (S_3s) and Wutong formation (D_3s). Paralleling to the dip of slope surface, there is a soft-weak layer which is formed by altered limestone and mineralized zones filling material. Due to weathering and erosion of the weak layer, the strength of soft weak layer is very low, which seriously threatens the stability of the slope.

2. Engineering geological characteristics of the southern slope

2.1. Characteristics of the exposed rock in the region

Chengmenshan mining area is about 550 km^2, the geotectonic position of the mining area is part of Yangtze met platform, Yangtze–Qiantang downward, Jiujiang platform caved area as shown in Fig. 2.

The main rocks in the mining area are divided into six types as follows: granodiorite porphyry ($\gamma\delta\pi$), charty-limestone (Ch_1s),

* Corresponding author. Tel.: +86 18602307442.
E-mail address: mnzool2006@gmail.com (M. Mohammed).

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Fig. 1. View of Chengmenshan copper mine.

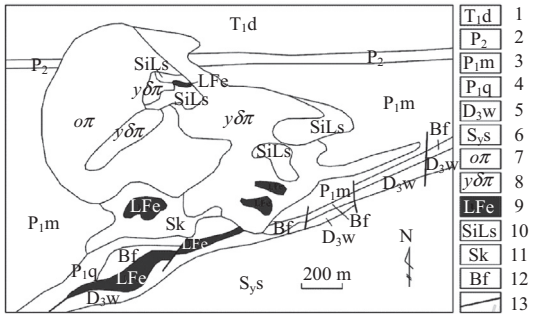

Fig. 2. Regional geology map of Chengmenshan copper mine.

purplish-red sandstone (S_3s), sandstone of Wutong formation (D_3w), carbonate limestone and dolomitic limestone. The engineering data of the six types of rocks are collected from different parts and depths of the early developed, such results are tabulated in Table 1.

The southern slope consists of two rocks of Silurian period, named top series Shamao formation (S_3s) and Devonian period, top series Wutong formation. There is a limestone formation in the deep formation. Because of the weathering effect, the contact plane between two type sandstones has formed soft-weak layers with very low strength. The soft-weak layer is basically parallel to the dip of slope, and seriously threats the stability of slope.

2.2. Structural geology

The benefits of using geotechnical databases to manage collected data as input for mine feasibility studies, initial slope design and ongoing slope optimization have been documented in [10,11]. Based on the distribution of structural properties, the mine is divided into six structural zones as illustrated in Fig. 3. The southern slope of the Chengmenshan is located at the north side of Chengmenshan mountain which belongs to zones I and II, and is in the slope engineering geological structural zones. Wutong set of Pliocene series of Devoniau system (D_3w) is the southern side of F_1 fault. This formation forms the southern slope of south pit which is quartzose sandstone. There are many sets of fissure structures in mining area. The main joint system nearby F_1 reverse thrust zone of Wutong sets rock near the fault zone, the joint fissures can be divided into five sets as shown in Table 2. These joints vary to some extent in different tectonic positions. The joints system of the intrusive body's in the top part in the rock alteration zone is always comparatively dispersed, the direction deflects at different positions.

Table 1
Determination of cohesion (c) and friction angle (ϕ).

Lithology	Protolith		Weak surface	
	c (MPa)	ϕ (°)	c (MPa)	ϕ (°)
Granodiorite porphyry ($\gamma\delta\pi$)	0.63	32	0.030	26
Charty-limestone (Ch_1s)	0.48	40	0.018	29
Purplish-red sandstone (S_3s)	0.46	35	0.040	29
Sandstone of Wutong formation (D_3w)	0.08	44	0.060	29
Carbonate limestone			0.020	27
Dolomitic limestone			0.042	26

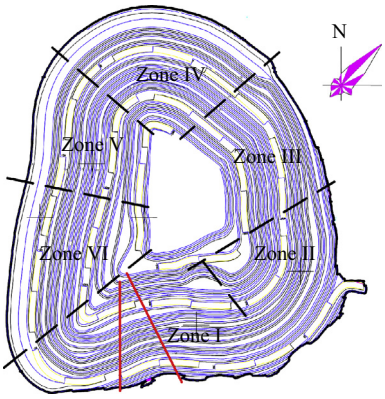

Fig. 3. Structural zones and sections of southern slope of Chengmenshan copper mine.

Table 2
Characteristics of discontinuities.

Sets	Dip (°)	Dip direction (°)	Mechanical property	Features
JS1	50–85	150–170	Compression	The joint surface is straight and filled with pyrite
JS2	50–70	330–350	Compression	The joint surface is straight and filled with pyrite
JS3	60/70–80	240/70–80	Tensional	The joint surface is pectoral and the fissure is wide but not long and filled with pyrite
JS4	50–80/50–80	290–300/110–120	Contorted	The joint is straight and filled a little
JS5	50–80/50–80	60–88/240–268	Contorted	The joint is straight and filled a little

2.3. Hydrogeology

The mining area is surrounded by a lake, only the south side is land, the southern slope is the only out trance of the mine, which has serviced the mine for many years. The mining area is situated in Ruichang river basin of Yangtze River, middle-lower Saihu lake's area. The highest annual precipitation is 2165.7 mm, and the least