CAVABILITY CLASSIFICATION MODEL IN BLOCK CAVING[①]

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ABSTRACT The evaluation of an orebody cavability is an important research subject for the application of block caving. Using the RMQC software system, the orebody cavability classification model of Tongkuangyu Copper Mine and its *in situ* practices were studied. Several important problems were discussed, which included the selection and definition of classification designation, the structure analysis of each designation, the estimation of the designation value of each block, the establishment of orebody cavability classification model and the results of classification.

Key words block caving cavability classification of orebody rock mass quality estimation

1 INTRODUCTION

The block caving is a large scale and high intensity mining method, in which the orebody caves by field stress and ore moves by gravity. As the special mechanism in mechanics and technology, an important subject is to estimate the orebody cavability in block caving before determining whether to use this mining method. Most cavability estimation methods in the past were based on the experience analogy. So, to establish a general theory and technique of orebody cavability classification is a major scope in the study of the techniques and equipment in block caving. Based on the theory and techniques which had been established, this paper analyzed the influence factors of orebody cavability in Tongkuangyu copper mine practice and established an orebody cavability classification model of this mine by using RMQC software system.

2 SELECTION OF CAVABALITY CLASSIFICATION DESIGNATION

2.1 Breakage mechanism of rock masses

A large number intact rock mechanical tests in the fields that include rock rheological and fracture mechanics indicate that the rock is higher in strength and lower in rheological in Tongkuangyu mine. The average cohesion force (C) of intact rock equals 18.5 MPa, and its average friction angle (φ) equals 43°. The uniaxial compression strength is about 90 MPa. In the rheological test, when the compression loading is in two levels of 35.81 MPa and 54.92 MPa, and the test time is 192 h, the strain of specimens is almost invariable with time. The joints can be divided into two sets, and its average cohesion force is 0.14 MPa, friction angle is 30°. The uniaxial tension is almost equal to zero for most joints. As the strength of joints is lower than that of the intact rock, so the orebody will break along with the joints surface on the action of caving stress field. The result of similitude material tests also show that most of the damaging starts from the original joints.

The rock masses breakage mechanism in block caving of Tongkuangyu mine can be described as follows: by the action of field caving stress, the original fractures in rock masses were spread and linked each other, it caused the rock block to cave from orebody, and fall to the ore pile. So the joints frequency and its mechanical properties play an important part in both rock

① Received Oct. 20, 1995; accepted Jul. 3, 1996

masses damaging form and the processes of ore caving.

2.2 Selection of estimation parameters

The selection of classification parameters mainly depends on its characteristics that include importance, independence, accuracy and reliability. And the data must be easy to obtain. We selected several parameters to study their influence on orebody cavability. The parameters include the intact rock strength, joints properties, joints space, joints surface condition, joints orientation, underground water conditions and the field stress. According to the analysis results of sensitivity and correlativity, we finally selected four composite parameters as orebody cavability classification designations. These designations are RQD; composite joints space; composite joints set and the composite friction angle of joints.

2.3 Conception of classification designations

RQD means Rock Quality Designation, which was defined by Deere. We can obtain it by drillhole cores or detail-line mapping investigations.

Composite joints space S^* equals the joints space S obtained from field investigation times joints space modification factor K_S, which shows the influence of joints continuity factor K_C in space on rock masses properties in the aspect of strength. The first definition was presented by Amitabha Mukherjee and Ashraf Mahtab[2] in 1987, and the formula is shown as below:

$$K_S = K_C + (1 - K_C) \times \frac{C_r + \sigma_n \cdot \tan \varphi_r}{C_j + \sigma_n \cdot \tan \varphi_j} \quad (1)$$

where C_j is the joint cohesion force, MPa; φ_j, the joint friction angle; C_r, the intact rock cohesion force (MPa); φ_r, the intact rock friction angle; σ_n, the normal stress action on joint surface, it depends on both the field stress and joint orientation.

Composite joint set is the modification result of reality joint set. This modification considers the angle influence between the superiority joint sets on the distribution of ore fragments.

In $\tau = \tan \varphi$, the joints friction angle φ includes both the contributions of joints cohesion force and friction resistance, and so it is called composite friction angle. In the joints shearing tests and joints surface characteristics examination, we found that $\varphi = 18.76 + 1.28i$ can be used to describe the relationship between joints surface characteristics and the composite joints friction angle, where i is root gradient of joints surface. According to the relationship between parameter and joint surface characteristic that obtained in field investigation, we can estimate the composite friction of each investigation points.

In the orebody cavability study of Tongkuangyu Copper Mine, we collected about 5000 m detail-line mapping and 7800 m drillhole rock masses structure data. The data include RQD, joint set number, space, orientation, continuity, opening, filled material properties, as well as joint surface roughness, flatness, weathering degree, underground water condition in investigation points, and intact rock point loading strength. At the same time, we carried out a large number of laboratory tests to determine the uniaxial compression strength, cohesion force, interior friction angle, inferior critical expanding rate of rock fracture, compression loading rheological properties of intact rock, joint mechanical and surface characteristics. All the data are input into computer to create a database. According to the conception of each classification designation, we obtained each classification designation by using RMQC software system. We used the composite samples of classification designation in engineering directions as the data input of the estimation model. The formula of calculating composite sample's value from the original samples is shown as follows:

$$P_C = \frac{\sum_{i=1}^{n} (L_i \cdot P_i)}{\sum_{i=1}^{n} L_i}$$

where P_C is the value of classification designation of composite sample; L_i, the length of composite sample; and P_i, the value of original sample. The sample's compositing conform the following rules:

(1) No value samples are ignored.

(2) The composite samples will be ignored

if its total length is smaller than half of the specified composite sample length.

(3) The position of composite sample is shown by its center coordinate, and the coordinate is calculated by using measurement data that include the position of borehole opening, orientation, dip and borehole survey data.

(4) The rock code of composite samples equals the superior rock code within composite sample length.

3 STRUCTURE ANALYSIS OF DESIGNATION

3.1 Experimental variogram and its theory model

We calculated the experimental semivariogram of both composite joints set and RQD value in three directions. The first direction is orebody strike direction (azimuth 40°, dip 0°), the second, dip direction (azimuth 310°, dip 45°); and the third, dip perpendicular (azimuth 310°, dip 45°). The tolerance of each direction equals 22.5°. The class distance equals composite sample length, 5 m. The theory analysis shows that the experimental semivariogram of composite joints space and RQD can be described with spherical model, and the semivariogram range can be regarded as isotropy in space. The calculation results are shown in Table 1.

3.2 Point validation of semivariogram

In order to ensure the reliability of semivariogram, we used point validation method to test the calculation results of semivariogram. We used the parameters in Table 1 as the Kriging method data input to estimate the values of composite joints space and RQD in point validation. The inverse distance method was used to estimate the composite friction angle and composite joints set, and the data searching range of the former is 80 m, the latter is 85 m. The point validation results of each designation are shown in Table 2.

Table 1 Experimental variogram parameters of composition joints space and RQD

Estimation designation	Nugget	Sill	Semivariogram range/ m
Composite joints space	0.007	0.014	70
RQD	152.0	521.0	103

4 THE MODELS OF CLASSIFICATION DESIGNATION

The original data of estimation model include: the rock masses properties′ data from two main levels (810 m and 870 m) detail-line mapping investigation and 69 downward drillholes data from 930 m level; the composite engineering maps and mine topography map. The model′s parameters are shown in Table 3.

We used three dimension block methods to create estimated models. Both Kriging and inverse distance methods are used to estimate the value. The former was used to estimate the values of composite joints space and RQD in each block, the latter, to estimate the values of composite friction angle and composite joints set.

Table 2 Point validation results of each classification designation

Estimation designation	Original data		Evaluation data		Minus data from original to valuation		Sample number	Correlation factor
	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation		
Joints space	0.2625	0.1174	0.2622	0.0712	0.0003	0.0964	1719	0.57
RQD	58.462	22.741	58.493	16.552	−0.031	15.635	1796	0.73
Composite friction	42.212	1.172	42.205	0.953	0.0064	0.815	279	0.72
Joints set	1.4530	0.1303	1.4527	0.0889	0.0003	0.0992	273	0.653

Table 3 Parameters of cavability classification model in Tongkuangyu mine

Original coordinate of Model			Direction	Range of Model			Block Dimension		
North	East	Elevation of bottom	Rotation angle	Row number	Column number	Level number	Row dimension	Column dimension	Levels dimension
14018.60	59485.70	800.0	310.57	33	75	26	10	10	5

5 OREBODY CAVABILITY CLASSIFICATION MODEL

5.1 The weight of each designation

We used well-distributed function to study the weight of each classification designation from composite samples data. The weight of each classification designation is shown in Table 4.

Table 4 The weight of each classification designation

Designation	Composite joints Space	RQD	Composite friction angle	Composite joints set
Weight	0.4	0.3	0.15	0.15

5.2 Standard samples library of cavability classification

F-ISODATA Class Analysis method was used to create the standard library of cavability classification from composite samples data. The eigenvalue of each classification designation in different classification grade is shown in Table 5.

Table 5 The eigenvalues of each classification designation in standard samples library

Classification grade	Composite joints space	RQD	Composite friction angle	Composite joints set
2nd grade	0.480	68.74	42.04	1.426
3rd grade	0.386	62.32	42.015	1.428
4th grade	0.325	60.40	42.346	1.477

5.3 The model of cavability classification

Combining with the models of composite joints space, RQD, composite friction angle and composite joints set, we used the utmost subjection principle to establish the model of cavability classification. The results of classification are shown in Table 6.

The cumulative frequency analysis of classification model was carried out along with the sections of levels, rows and columns. The variance curves of the cavability grades are shown respectively in Fig. 1, 2, and 3.

6 SUMMARY

(1) The model statistic analysis shows that the percentage of 2nd grade in cavability classification equals 32.38%, 3rd grade equals 58.33%, and 4 th grade only 9.29% in No. 5

Fig. 2 Variance of cavability classification in orebody strike direction

1 —2nd grade; 2 —3rd grade; 3 —4th grade

Fig. 3 Variance of cavability classification in orebody thickness direction
1 —2nd grade; 2 —3rd grade; 3 —4th grade

Table 6 The results of cavability classification

	Blocks number	Percentage/ %
2nd grade	107 009	32. 38
3rd grade	30 635	58. 33
4th grade	4 879	9. 29
Total	525 523	

orebody of Tongkuangyu mine. The orebody cavability belongs to the middle grade.

(2) The percentage of 2nd grade of cavability classification increases at both east and west parts of orebody, and decreases at the middle part of orebody. The percentage of 3rd and 4th grade decreases at both east and west part of orebody, and increases at middle part of orebody. From 800 m level to 930 m level, the percentage of 2nd grade decreases, the 3rd grade increases, and 4th grade is almost invariable. From footwall to hanging wall of orebody, the percentage of 2nd grade increases, 3rd grade is almost invariable, and the 4th grade decreases.

REFERENCES

1 Wang Liguan, Pan Changliang. Journal of Central-South Institute of Mining and Metallurgy, (in Chinese), 1993, 24 (Suppl. 1): 87.
2 Amitabha Mukherjee, Ashraf Mahtab. In: Proc 13th World Mining Congress Thesis, Stockholm Sweden, 1987.
3 Wang Liguan. Joural of Central South University of Technology, (in Chinese), 1996, 27(3): 267.

(Edited by He Xuefeng)