Comprehensive Division of Rock Mass Structure in Granite Area--Taking Tianhu Rock Mass as An Example

YaweiLi*, ZhejiangGuo1

1CNNC Key Laboratory on Geological Disposal of High-level Radioactive Waste, Beijing Research Institute of Uranium Geology, Beijing 100029, China

*Liawei@briug.cn

Abstract. In the stage of sites selection of high-level waste geological repositories, reasonable division of homogeneous zones of rock mass structure is helpful to further analyze the suitability of engineering rock mass quality and construct discontinuous fracture network model. Based on accurate measurement of surface structural planes, the surface rock mass structure in the study area is differentiated by discontinuities spacing, and the homogeneity of rock mass structure is evaluated by linear density index. The results show that the rock mass structure type in the study area is dominated by sub-blocks, and its distribution area accounts for 84% of the total area. The study area belongs to homogeneous rock mass structure with high similarity. Most of the surveying lines in the study area have high correlation and uniform joint density.

1. Introduction

The fractures present in the rock mass cut rock mass into structural bodies or block units with different shapes and scales. In practice, because the spatial distribution of fractures is not uniform, the engineering properties of rock mass in different regions may be quite different. From the point of view of mechanical equivalence, rock mass units with similar combinations and fracture densities often have similar engineering properties[1]. Therefore, the classification of structural types is helpful to determine the geometric and mechanical similarities between rock mass elements. For fractured rock mass, distinguishing different domains according to the similarity of rock mass structure type is the basis for further analysis of rock mass quality classification and discontinuous fracture network modeling in the future[2].

Without considering the difference of lithology, the uniformity of fractures in rock mass is mainly based on the occurrence, density and trace length of fractures. In 1983, Miller divided the homogeneous zone of rock mass structure by using the correlation table of probability theory and Schmidt projection net of equal area, taking the occurrence of structural plane as index[3]. Fan Liuming et al. proposed a density zoning method, which takes the structural surface density as an evaluation index to divide the rock mass structure into different homogeneous regions[4].

Tianhu rock mass is one of the candidate sites for high-level radioactive waste geological disposal in China. Ascertaining the spatial distribution characteristics of the fractures in the site and dividing the rock mass structural provide a basis for judging the suitability of the site. The Tianhu granite body, a candidate site for geological disposal of high-level radioactive waste, is taken as the research object[5]. The surface rock mass structure in the range of 4 km² around the borehole is divided by the spacing of fractures, and the homogeneity of rock mass structure is evaluated by the linear density index.
2. Accurate measurement of fractures

The line measurement method is used to fractures survey. When setting the line, the direction intersecting with the direction of each group of fractures at a large angle is selected as the line measuring orientation according to the principle of maximizing information. The data of intersection position, occurrence, filling and roughness of each fracture and surveying line are obtained. Then on this basis, rock mass structure division is carried out[6]. The process of partitioning is as follows:

- Taking 2m as the length of the basic evaluation unit of the line, the number of structural planes in each basic unit of the line is counted, and the total number of joints and volume joints of each basic evaluation unit are obtained.
- According to the stereographic projection of the occurrence of all fractures on the survey line, the fractures on the survey line are displayed in groups, and the representative fractures in the bandwidth range are selected for the statistical analysis of the spacing of fractures. As shown in Figure 1.
- The structural planes in the bandwidth range are divided into groups to obtain the average spacing of dominant cracks in each basic evaluation unit on the survey line.
- The average spacing of cracks in each unit is obtained, and the rock mass structure types are classified and checked according to the integrity of the rock mass.
- On the basis of the division of rock mass structure of basic units of each survey line, the comprehensive division of rock mass structure is carried out according to the development of rock mass fractures and so on.

![Figure 1 Fracture distribution and group shows of CX13 in study area](image)

Based on the above methods, 62 surveying lines in the study area are divided into rock mass structures, and then rock mass structure zoning is studied on the basis of the above results, and then the overall development and distribution of rock mass structures in the study area are obtained.

Because the line measuring method is based on the classification and evaluation of rock mass structure with 2 m length as the basic rock mass unit, the line measuring unit in the zoning is a "large rock mass structure unit" composed of several small units, and the value of its comprehensive average spacing will directly affect the final zoning evaluation results. For this reason, the weighted average method is used to obtain the comprehensive average spacing of the "large line unit". That is, the "geometric average spacing" of the corresponding rock mass structure types is weighted by the proportion of the rock mass structure types in the length range of the line. The comprehensive average spacing is calculated according to the following formula:

$$D = \sum_{i=1}^{n} \omega_i D_i, \quad n=1,2,3,4,5$$

In the above formula, $\omega_i$ is the weight of the i-th rock mass structure type, taking the percentage of the length of the corresponding unit of the rock mass structure type as a percentage of the total length of the survey line; $D_i$ is the geometric mean spacing of the i-th rock mass structure type. According to formula, the weighted average spacing of rock mass structures of each line in the study area is shown in Table 1. According to the proportion of different rock mass structure types on
each line, the average fracture spacing is weighted, and the rock mass structure distribution in the study area is obtained as shown in Figure 2.

Table 1. Weighted average spacing of rock structure in study area

| Line number | Item       | Overall | Blocky | Sub-block | Mosaic structure | Fragmented | Weighted spacing (m) |
|-------------|------------|---------|--------|-----------|------------------|------------|---------------------|
| CX01        | Average spacing(m) | 0       | 0      | 0.365     | 0.27             | 0          | 0.333               |
|             | weight (%)            | 0       | 0      | 66.67     | 33.33            | 0          |                     |
| CX02        | Average spacing(m) | 0.533   | 0.38   | 0         | 0                | 0          | 0.495               |
|             | weight (%)            | 75      | 25     | 0         | 0                | 0          |                     |
| CX03        | Average spacing(m) | 0.515   | 0.41   | 0         | 0                | 0          | 0.480               |
|             | weight (%)            | 66.67   | 33.33  | 0         | 0                | 0          |                     |
| CX04        | Average spacing(m) | 0.51    | 0.397  | 0         | 0                | 0          | 0.442               |
|             | weight (%)            | 40      | 60     | 0         | 0                | 0          |                     |

Figure 2. Rock mass structure division in the study area

It can be seen that there are three types of rock mass structure in the study area: sub-block, block and mosaic. The main rock mass structure type is sub-block. According to the statistics of the distribution area of various structural rock masses, the sub-massive rock mass accounts for 84% of the total area, the massive rock mass accounts for 15.74% and the mosaic rock mass is about 0.26%.

3. Homogeneity evaluation of rock mass structure

The essence of homogeneity evaluation of rock mass structure is the division of statistical homogeneous zones[7]. Statistical homogeneous zones of rock mass are the basis of classification and analysis of fractured rock mass and simulation of three-dimensional fracture network. Generally, the uniformity of fractures development in rock mass can be analyzed by the statistical parameters of joint occurrence, joint density and joint trace length[8]. Among them, the occurrence and joint density are often used in the classification of statistical homogeneous zones.
Indicators reflecting the characteristics of joint density include a number of indicators such as joint average spacing, line density, areal density and bulk density. The fracture spacing index reflects the size of the rock mass unit formed by the cutting of the rock mass. The linear density, areal density and bulk density reflect the number of fractures included in the statistical range, where the areal density and bulk density are The scale of the structural surface itself is not easy to determine, and the operability is low. It has certain limitations in practical application. Therefore, it is more appropriate to study the development density of rock mass fracture by linear density. It is roughly determined primarily by the ratio of the number of statistical joints within the line range to the length of the line. The frequency analysis of the line structure areal density of each line shows that the average line joint density of the line in the study area is 4.68 lines/m and the standard deviation is 2.47.

In order to eliminate the problem of large difference in absolute linear density and inconvenient comparison, the normalization is first performed according to the maximum value in the drawing, and then the contour map is drawn according to the relative density of the normalized processing. Based on this, the relative joint density contour maps in the study area are obtained as shown.

The relative joint density contours in the figure are all in a soothing state, but there are dense areas in the area, which indicates that the linear density of the joints of the rock mass in the study area is roughly uniform, and only the local anomaly area exists, mainly located in the southeast corner of the study area.

According to the distribution characteristics of the survey lines in the study area, most of the survey lines in the study area have higher occurrence correlation and more uniform joint density, and the study area belongs to the homogeneous structure of rock mass structure with higher similarity.

Figure 3 Contour map of line joint density in study area

4. Conclusion
Joint occurrence, joint density and joint trace length are often taken as the key elements in the division of homogeneous zone of rock mass structure. However, in practical work, appropriate division methods should be selected according to specific projects. Collecting the occurrence data of fractures
in surface rock mass survey is difficult, but it is more appropriate to use linear density to study the density of fractures in rock mass.

The weighted average spacing used in the calculation of rock mass structure has a certain weakening effect on the rock mass with less proportion and less integrity, which leads to the general preference of rock mass structure classification. But as a whole, the general trend and the main distribution range of the rock mass structure types in the outcrop of each rock in the study area are basically consistent with the actual situation.

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