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Adaptation assessment of gob-side entry retaining based on geological factors

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ABSTRACT

The technique of gob-side entry retaining has been widely used in underground coal seam mining, where the headgate of current panel is retained and reused for adjacent next panel mining. To evaluate the adaptation of this technique, six geological factors, including coal seam dip angle, mining height, cover depth, thickness influence coefficient of immediate roof (TICIR), lithology of immediate roof and roof integrity, were determined, and their distribution characteristics in practice and weight analysis using 1–9 scale method of analytic hierarchy process (AHP) were used to apportion weight of indicators. It is found that, among all indicators, the dip angle had the highest weight while the buried depth had the lowest weight, indicating that the coal seam dip angle is the most important factor. Moreover, five adaptive grades were classified and gob side support strategy for entry of each grade was provided according to technical standards, statistical information and field experience. Finally, fuzzy comprehensive evaluation was used to weight the gateway adaptive grade index. The adaptation assessment grades may be evaluated as reasonable and scientific by six validated cases. Therefore the proposed method and framework can be considered as a supplementary tool in design of gob-side entry retaining.

1. Introduction

In gob-side entry retaining of underground coal seam mining, the headgate of current mining panel is retained and serviced as the tailgate of subsequent adjacent panel. Due to high coal recovery rate, low roadway development rate, this technique has been prevailed in some countries, such as China. Furthermore, no pillar is left in the retained entry and, as a result, the outburst risk during the subsequent panel mining is significantly mitigated. However, an artificial filling wall is required on the gob side to isolate the gob of previous panel and specific support scheme are needed so that the cross section of retained entry can still satisfy the service requirement after deformation.

Since 1950s, pillarless gateways have been widely used in underground coal mining industry, mainly in the UK, Germany, Poland, Russia and China, and extensive studies have been carried out with regards to different geological conditions. It is known that many factors impact the quality of gob-side entry retaining, including geological conditions and detailed retaining technique. Geological factors include the cover depth, mining height, coal seam dip angle, etc., while the detailed retaining technique involves the support method, the cross section size and shape, etc. In mining, the former is objective and beyond the control of mining practitioners and the latter is subjective and determined by the mining practitioners. Further study has shown that the detailed retaining technique is basically controlled by natural factors. For example, the gateway shape mainly depends on the size and dip angle of coal seam, and the support method is dependent on lithology of surrounding rock mass. Therefore, the study on geological factors is significant in gob-side entry retaining.

Usually, the geological conditions of coal seam are complex, such as in China. So far, With different geological conditions, a large number of coal mines have used the technique of gob-side entry retaining, such as cover depths (Tang et al., 2010; Chen et al., 2012a; Zhang et al., 2015), different mining heights (Zheng et al., 2012; Xue and Han, 2012), different roof lithologies (Cao et al., 2012; Ning et al., 2013; Cheng et al., 2012; Tan et al., 2016) and different coal seam dip angles (Hua et al., 2005) (Zang and Zhang, 2015). Such cases have provided good experience for future gob-side entry retaining design. However, many impact factors are often described as uncertain variables and there is a lack of system that can weigh the relative importance of these impact factors. What is more, the adaptation of gob-side entry retaining is fuzzy and a grade system has not been developed. This leads to the inconvenience when utilizing this roadway technique in practice.

In rock mechanics and rock engineering, some rock mass classification systems have been developed and successfully used in tunnelling, underground mining based on practical experience, such as Rock Quality Designation (RQD), Rock Mass Rating scheme (RMR), Rock Mass Quality Index (Q-system), China Technical Standard for Bolt Shotcrete

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Support (GBJ 86–85) and coal mine deep rock roadway support design classification (Liu et al., 2010). This help the engineer to qualitatively understand the potential behavior of surrounding rock mass during engineering and further provide guidance for support design. Recently, classification of the surrounding rock mass for the purpose of gateway support design has been widely studied (Chen et al., 2012b; Zhang et al., 2009).

To promote the application of gob-side entry retaining in underground coal seam mining and reduce the support cost due to inappropriate decision, this study presents a statistical analysis of retained gateways in China mining industry and distribution characteristics of geological factors are summarized. Then, analytic hierarchy process (AHP) was applied to weighting these factors (Saaty, 1980). Another step is to invite experienced field practitioners, i.e., senior engineers in China, to mark with the 1–9 scale method (Wang et al., 2012). Subsequently, the adaptive grades and scope of each grade are investigated and the support method for each grade is provided according to relative regulations, statistical data and practical experience. Finally, a decision-making method is proposed to determine the adaptation grade for a gateway and take the appropriate support method based on fuzzy comprehensive evaluation.

2. Determination of impact factors

2.1. Determination principles

The factors that influence the gob-side entry retaining are various due to site-specific geological conditions. To make it representative, some principles should be followed when selecting these factors:

1) Materiality principle. The selected factors should have a significant effect on the stability of gateway, excluding the secondary factors that have relatively small effect on stability.
2) Independence principle. One factor can reflect an aspect of the respective attributes, and the correlation among other factors should be as low as possible.
3) Separability principle. Obvious difference exists in sample data among different factors (Lei et al., 2012).
4) Easy acquisition principle. Factors can be easily measured or acquired in the coal mine and quantitative data can be provided for the design.
5) Fundamental principle. The selected factors should be fundamental to facilitate comparative analysis for practitioners using monitoring data in the process of construction or after construction, even from the support system unfavourably selected.
6) Universal principle. Selected factors should be universal in mining area.

2.2. Factors selection

Based on the determination principles mentioned above and combining mining geological conditions, mining technology, and relevant practical experience, six geological factors were selected to evaluate the adaptation of gob-side entry retaining: coal seam dip angle (α), mining height (m), cover depth (H), thickness influence coefficient of immediate roof (TICIR) (N), lithology of the immediate roof and roof integrity, as shown in Fig. 1 and Fig. 2.

For the dip angle of coal seam (α), it mainly influences the stress distribution in the surrounding rock. With the change of coal seam dip angle, the stress in two side walls and roof of the gateway changes greatly, leading to the difference in failure mode and size of failure zone of surrounding rock. Moreover, if the dip angle is greater than the natural repose angle of gangue in the gob, specific measures should be taken to prevent gangue fleeing.

Here, mining height (m) denotes the thickness of coal seam. Generally speaking, the cave-in scope of immediate roof and main roof increases with the coal seam thickness. This could lead to the difficulty

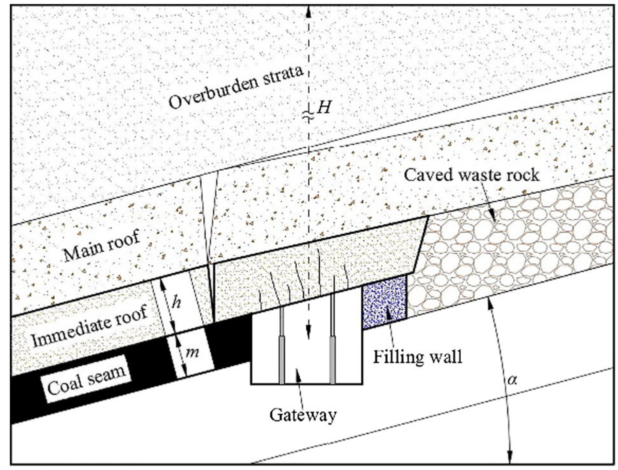

Fig. 1. Schematic diagram of gob-side entry retaining.

in maintaining the retained gateway as the height increase in collapsed roof strata intensifies the degree of periodic weighting. Moreover, the height of the constructed filling wall should be based on the thickness of the coal seam and higher filling wall is needed for larger mining height. This not only requires extra filling materials but also increases the difficulty for filling process and reduces the stability of the developed filling wall.

The in-situ stress generally increases with the cover depth, indicating more energy is stored in surrounding rock mass before mining. The mining excavation leads to energy release from surrounding rock mass and tends to transfer to the unmined coal block. Therefore, the cover depth increase can make the failure zone larger and the retained gateway difficult to maintain.

The lithology of immediate roof determines its strength. The higher the strength of the immediate roof, the greater the roof-cut resistance needed on the gob side. This requires complex technology to cut the hard immediate roof, otherwise the deadweight of roof overhang in the gob area would transfer the roof of the retained gate, leading the roof damage. On the other hand, if the immediate roof has very lower strength, it can be broken easily and also hard to support.

The thickness influence coefficient of the immediate roof (N) mainly impacts the stability of main roof after the immediate roof cave-in. It can represent the stability degree of the immediate roof to the retained gateway for a certain mining height (m) and can be expressed as follows:

$$N = h/m \tag{1}$$

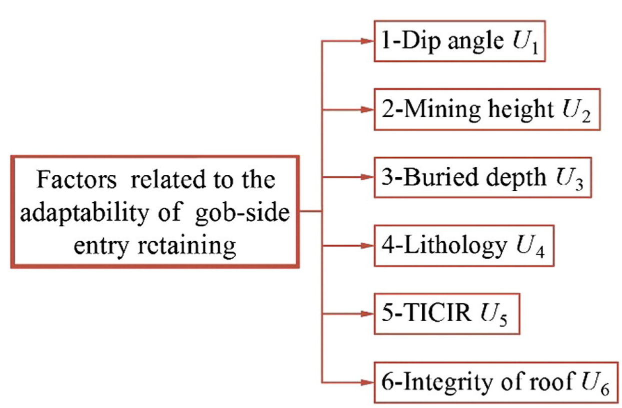

Fig. 2. Factors selected and used in assessing the adaptability of gob-side retaining technique.