The method of prediction of roof collapse hidden trouble in the roadway of No.2 in Anjialing

Sang Pengde
Taiyuan Research Institute, China Coal Technology and Engineering Group Corporation, Taiyuan, Shanxi, 030006, China
*Corresponding author’s e-mail: sangpengde2008@126.com

Abstract: The thickness and strength of strata composing roof stratum will change a lot because of the change of coal forming environments and long time geological evolution. Only knowing these changes exactly, we can get the right design and prevent roof collapse. We can get the thickness, relative position and location of cracks and roof separation of strata with the changing of length of roadway at any time, and design the roof of roadway dynamically according to the lithology and combination changes of roof. In accordance with these, we can ensure not only the economic, but also safety in production.

1. Introduction
The structure and mechanical properties of the surrounding rock are the most important basic data for the design of roadway support parameters. However, the abuse of these two basic data is common in China's coal mines. In the process of supporting design of mining roadway with a length of several thousand meters, regardless the great changes in the stratification thickness and strength of the rocks of the roof, the design was carried out on the basis of the rock structure of a comprehensive bar chart of coal seam geology, and the results were applied to the whole roadway. The abuse of such basic data directly leads to the excessive supporting strength of the most of roadway supported by bolt, while some of the roadways supported are seriously insufficient [1], leaving hidden safety hazards and even causing roof caving accidents. Roof caving accident occurred during the tunneling of No. 11 coal roadway in No.2 mine of Anjialing shaft, including the influence of composite roof and unreasonable support parameters.

Therefore, according to the changes in the properties and combinations of roof strata, we use the roof rock peeping instrument to observe the bolt and cable drilling, dynamically design the mining roadway roof, timely obtain the lithology, thickness and relative position of various strata that are constantly changing with the length of roadway, and discover the location and range of separation layer and fracture in time.

2. Observation method of lithologic combination of roof
Local and limited geological data are used for the overall support design (the whole roadway and even the whole mining area), and the significant difference of geological conditions in different regions of the roadway is completely ignored, so a so-called design suitable for the whole roadway is made [5]. In order to meet the safety requirements under local harsh geological conditions, we have to sacrifice the economic principle and make a more conservative design, so that a large number of supporting materials are wasted. As it is difficult to investigate clearly the changes of geological conditions,
which is impossible to correctly judge the areas of deterioration of strata combination and major caving hidden danger areas, caving in local roadway becomes inevitable \([1, 3]\). TYGD10 roof peepers are used to identify lithological combination, separation and fracture location and development of roof together with borehole data \([4]\). According to the analysis results of borehole data near the observation area and the comprehensive analysis of the peeping borehole in the mining area, the following conclusions can be drawn: all kinds of information other than mechanical properties of rock strata can be obtained through observation, including lithology, thickness of rock strata, degree of cleavage fracture development, type of rock strata combination, cementation between different strata, etc. The information can be obtained from the color of the rock (coal) layer in the video of peeping through the drill hole and the drilling marks left by the drill tool in the hole wall during drilling. The integrity of rock layers and separation cracks can be directly observed by naked eyes, and the thickness of the formation can be read directly from the tape (FIG. 1).

![FIG. 1 Examples of peeping results from different lithologies](image)

3. Observation of 21104 heading face roof
21104 gateway roof is a composite roof with multiple layers and low strength, which belongs to the general stability roof. In the initial stage of roadway construction, the amount of roof and floor moving is generally not large. However, after a certain period of time, the amount of roadway deformation starts to increase, and it tends to be stable after several weeks or months. The reason is that it is impossible to anchor the direct roof in the upper stable rock layer, and under this circumstance, the direct roof will go down as a whole, resulting in straight span and fall. Therefore, observation on the roadway roof can guide the improvement of support form.

3.1 Lithological observation results
Examples of interface, separation, fracture and inter-layer positions of various strata are shown in FIG. 2. It is easy to identify, because of the color difference between coal-seam and rock-layer interface. Mud-stone and sand-stone interface can be comprehensively distinguished by color and drilling marks. The interface between siltstone and fine sandstone is difficult to distinguish \([5]\), but it can still be recognized by different drilling trace, at the same time, as the roadway adopts bolt support, sandstone is of great strength and can be treated as a stable rock layer when designed. Therefore, as long as the interface of siltstone and fine sandstone has no cracks and other weak interlayers, it can be treated as a complete rock layer. Other factors such as the degree of fracture, the location, the extent and the inter-layer can be directly observed. The fissures that are not easy to find are those with large included Angle with the free surface of roadway roof and longitudinal fissures. The discovery of such cracks is closely related to the location of boreholes, and only one longitudinal crack was found in nearly 1,000 peep-hole videos.
Coal-rock interface  Interface of mud-stone and sand-stone  Interface of silt-stone and fine sand-stone
The broken area  Separation layer, crack location  Coal line or soft flat bed

**FIG. 2.** Peeping results of interfaces and fissures and inter-layers of different strata

### 3.2 Drawing of rock column along roadway strike

Based on the analysis results of the peeping video of the drilling, and in accordance with the original drilling data on the site, the borehole columnar shape of roadway roof along the strike can be drawn. The distance of observation borehole can be determined according to specific field conditions. Taking the actual observation results of a mine as an example, only 10 observation holes in a roadway are selected to illustrate, and the spacing of boreholes is 20m, as shown in **FIG. 3**.

(a) The peep hole is numbered along the roadway

| Description       | Column thickness | Converted rock | Remark (column) |
|-------------------|------------------|----------------|-----------------|
| Coal-rock         | 3.60             | 8.33           |                 |
| Fine sandstone    | 2.10             | 4.73           |                 |
| Coal-rock         | 0.90             | 2.63           |                 |
| Fine sandstone    | 1.20             | 1.73           |                 |
| Top coal          | 0.83             | 0.83           |                 |

(b) **FIG. 3** column diagram of roof strata structure
Figure 3 (a) is the column diagram of the rock strata along the roadway in the tunneling section; Figure 3 (b) shows the lithology description map of a single borehole after analyzing the peeping video of a borehole. Due to the small range of fractures and crushing zones, the proportion is too small, so it is not marked on the map, only text descriptions are made. According to the strike bar graph, the following conclusions can be drawn:

1. The lithological combination of the roadway roof is relatively simple. It is mainly composed of top coal and sandstone, with relatively stable thickness and relatively good integrity of sandstone;
2. The top coal thickness is about 3m, and most of the upper part is sandstone within the observation range;
3. In borehole No.1, there is a layer of mudstone with a thickness of more than 1.8m at a depth of 4.5m, with relatively developed bedding.
4. The thickness of top coal at borehole No.4 is relatively thin, 1.8m thick.

4. Evaluation of support parameters and regional analysis of potential roof caving hazards

Due to the previous work, no special support parameter design was made to follow the tunneling head to peep into the roof structure, so only the support parameters used in the field were evaluated. Because of the thick top coal and the weak nature of coal seam, part of the coal roof caved like a pot in the tunneling process. The original supporting method adopts bolt + anchor cable + metal mesh, the length of bolt is 2.2m and the length of anchor cable is 6m. The main role of metal mesh is to prevent local caving from injuring people.

Combined with the analysis of strike rock column diagram, the existing supporting parameters can be improved as follows:

1. In addition to No.1 observation hole and No.4 observation hole, the surrounding area of other observation holes can still adopt the original application support parameters. There is a risk of roof collapse when the original supporting method is adopted near hole No.1, and there is a surplus of supporting strength when the original supporting parameters are adopted near hole No.4.
2. The area around hole No. 4 is characterized by excessive support strength and 1.8m thick top coal. The length of bolt in the original supporting mode is 2.2m with round steel end. Most of the anchorage ends are anchored in stable fine sandstone. After checking the strength of bolt, the single bolt support can meet the requirements, so that at least 2 ~ 3 anchor cables can be saved in one supporting section.
3. The area around hole No.1 is characterized by inadequate support strength or improper support mode. The thickness of top coal is 2.9m, the thickness of upper fine sandstone is 1.6m, and the deepest part is mudstone with a thickness of more than 1.8m. The mudstone bedding in this layer is relatively developed, softened in water, and the mechanical properties rapidly deteriorate. The original use of 6m long anchor cable anchorage end most of the anchorage in this layer of mud-stone, greatly affecting the anchoring effect, there is a hidden danger of local roof caused by failure of the anchorage end.

For roof rock formation combination and roadway range similar to hole No.1, the length of anchor cable can be changed so that the anchor end of the anchor cable can be anchored in the stable rock formation to ensure the supporting effect. At the same time, the type of bolt support can be changed, and the end-anchored bolt can be changed into full-length anchor or length-anchored anchor, so as to ensure the integrity of roof support structure and prevent roof caving accidents.

5. Conclusion

Timely observation of roof structure by means of peeping instrument of rock stratum is not required to consume other working hours. Observation during drilling construction process of anchor rod or anchor cable drill is enough. However, it cannot observe the mechanical strength of rock strata, it is better to detect the rock strata with roof structure detector. This method has the following characteristics:

1. We follow the heading closely to detect the deterioration of roof structure, so that we can take
timely measures to adjust supporting parameters;

(2) To detect the tunneling roadway, the supporting effect of existing supporting parameters can be evaluated. Areas with excessive supporting strength can be found, and areas with insufficient supporting strength also can be detected, providing guidance and reference for roof support of adjacent roadway.

(3) According to the detection results, roof structure can be dynamically classified after analysis, so that the roof support parameters can be "adapted to the symptoms", which not only meets the economic requirements, but also ensures safe production.

Acknowledgment
Fund project: China Coal Science and Industry Group Taiyuan Research Institute Co., LTD. (Shanxi Tiandi Coal Machinery Equipment Co., LTD.) self-support project (M2018-19)

Author profile:
Sang Pengde (1985-), male, from liaocheng in shandong province, mining engineer, master, graduated from China University of Mining and Technology (Beijing) in 2011, majoring in mining engineering. Now in China coal science and industry group Taiyuan Research Institute Co., LTD., has been engaged in the technical and management work of mining engineering.

References
[1] Ma Nianjie etc. (2006) New Bolting Technology for Coal Roadway [M], China University of Mining and Technology Press, Xuzhou.
[2] Qian Minggao, Liu cheng, (1992) Mine Pressure and Control [M], Coal Industry Press, Beijing.
[3] Gou Panfeng, (1998) Study on Improvement of Surrounding Rock Strength and Stability by Roadway Bolt Support [D], China University of Mining and Technology, Xuzhou.
[4] Xie Feihong; Sun Wei, Liu Jingxue, (2009-03), Journal of Lanzhou Jiaotong University, Stability Analysis of Layered Composite Roof Roadway [J], Lanzhou.
[5] Guo Deyong, Zhou Xinquan, Han Xiyun, (2002-06), Acta Coal Sinica, Research and Application of Structural Analytical Method for Roof Stability Prediction of Coal Seam [J], Beijing.