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Support technology for mine roadways in extreme weakly cemented strata and its application

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ABSTRACT

For the engineering geology conditions of bad mine roadway roof and floor lithology in extremely weak cemented strata, the best section shape of the roadway is determined from the study of tunnel surrounding rock displacement, plastic zone and stress distribution in rectangular, circle arch and arch wall sections, respectively. Based on the mining depth and thickness of the coal seam, roadway support technology solutions with different buried depth and thickness of coal seam are proposed. Support schemes are amended and optimized in time through monitoring data of the deformation of roadway, roof separation, I-beam bracket, bolt and anchor cable force to ensure the long-term stability and security of the roadway surrounding rock and support structure. The monitoring results show that mine roadway support schemes for different buried depth and section can be adapted to the characteristics of ground pressure and deformation of the surrounding rock in different depth well, effectively control the roadway surrounding rock deformation and the floor heave and guarantee the safety of construction and basic stability of surrounding rock and support structure.

1. Introduction

Weakly cemented soft rock strata with low strength, poor cementation and mudding and softening in water, are widely distributed in Inner Mongolia, Xinjiang, and Ningxia [1–3]. As a result, the coal seam roof and floor strata are weak and coal strength is relatively high. Bolting with wire mesh is difficult, especially in thin coal seam conditions. Following excavation of a rectangular cross-section mining roadway, the roof becomes unstable and is prone to collapse. Anchor bolts can only play a suspension role so the support provided is not effective. Many experts and scholars have studied the theory and engineering practice for selection of the most effective cross-sectional shape of mining roadways and resulting support difficulties [4–20]. Although research results have solved many types of engineering problems, it is still necessary to determine the most effective cross-sectional form and method of support in mining roadways in extremely weak cemented strata. This would provide a theoretical foundation for the safe and efficient exploitation of coal resources in western China.

The Xiyi mine is located in the southwest of the Wujianfang coalfield, west Ujimqin Flag, Inner Mongolia, and was developed by an inclined shaft. The main coal-bearing strata is the Cretaceous Bayan Hua Group and the coal-bearing strata are mainly soft rocks having a layered structure which is characteristic of developed horizontal and cross bedding, high clay content, poor cementation and few joint fissures. The compressive strength of the seam is about 2.9–20.1 MPa, with an average value of 8.77 MPa and is therefore classified as a soft-hard coal. The roof and floor of the seam are poorly-cemented mudstones, siltstones and sandstones, with an average compressive strength of 2.1–13.1 MPa. They can therefore be considered as weak rocks; physical and mechanical properties are very low with strength weathering, muddy and disintegration phenomena. The self-supporting capacity of the surrounding rock, whose strength dramatically decreases in water, has a saturated compressive strength of only 0–8.5 MPa. For this kind of extremely weakly-cemented soft rock in thin coal seams, there is no way to implement anchor, cable or other technical methods of active support. This is extremely detrimental to the support of mining roadways and roof control.

2. Testing and analysis of the failure zone in the surrounding rock of a mine roadway

The 1302 air return roadway is excavated within the 3–3 coal seam, which is stable with a thickness of 7.31–10.0 m; the coal seam roof is mudstone (11.04 m thick) and fine sandstone (15.58 m thick) whilst the coal seam floor is mudstone or siltstone (3.14–5.93 m thick). The roof and floor are vulnerable to weathering and water swelling. In order to study the failure zone in the

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surrounding rock of 1302 air return roadway after excavation and provide guidelines for selection of a method of support of the roadway, a non-destructive geological radar survey was carried out on the sides, roof and floor of the 1302 air return roadway in order to determine the failure zone in the surrounding rock after excavation. The geological radar survey results in 1302-return air roadway are shown in Fig. 1.

The test results for 1302 air return roadway are presented in Fig. 1, and show that the crack depth in the surrounding rock at the left side is 2.0–3.0 m, that of the roof is up to 3.0 m, that of the right side is about 2.5 m and that for the floor is about 1.5–2.0 m, which is a layered and relatively intact rock. Overall, the failure boundary range of 1302 air return roadway is extensive, basically within the range of 2.0–2.5 m and locally up to 3.0 m, which can be defined as a large failure circle. Because of low strength, low bearing capacity and poor stability of the roof and floor strata, a mine roadway has a large failure circle after excavation. The original design section shape of 1302 air return roadway is rectangular, which cannot form an effective combination of reinforcing arch effect following support by bolting and wire mesh. It is therefore difficult to control deformation and displacement of the roof, which may lead to further deterioration of the surrounding rock. Instability of the roof rock is not beneficial to the stability of the sides and floor. This leads to large deformations in 1302 air return roadway. Therefore, in order to ensure the long-term stability and security of the surrounding rock and support structure, it is necessary to optimize the roadway cross section shape by considering the cross section of the roadway and suitable support methods in extreme weakly cemented strata.

3. Determination of a suitable cross-section and shape for a mine roadway

According to the contour line, coal mine tunnel cross section shapes can be either straight or curved. In view of the pressure conditions, support difficulty and the extreme weakly cemented soft rock of 1302 air return roadway, in order to improve the self-stabilizing capacity, and to ensure adequate available space and to form an efficient combined arch structure in the tunnel vault after excavation, the 1302 air return gateway section shape is changed from rectangular to tangential arch. In order to determine the reasonableness of the tangential arch section in mine roadways, the FLAC^{3D} code is used to study the deformation characteristics, plastic zone evolution laws and features of stress distribution of rectangular, tangential arch and arch wall section roadway after excavation.

3.1. Numerical simulation model

The original design section shape of 1302 air return roadway in Xiyi mine is rectangular at 5200 × 3500 mm. The tangential arch and arch wall section are drawn up with a cross section of 5200 × 3700 mm as shown in Fig. 2. In this paper, a simulation area of length × width × height = 60 m × 50 m × 50 m is used. The element mesh model is shown in Fig. 3.

Both the bottom and lateral displacement are fixed in this model and gravity stress is applied on the surface according to the depth of the roadway. Numerical simulation parameters are chosen according to the Xiyi mine geological drilling data as listed in Table 1. Deformation of the surrounding rock, evolution laws of the plastic zone and stress distribution characteristics with section shape after excavation are studied based on Mohr–Coulomb failure criterion.

3.2. Numerical simulation results and analysis

3.2.1. Displacement and plastic region of surrounding rock

Table 2 shows the deformation of the roadway in which the floor heave is larger than the roof and side displacement, and the maximum displacement of the roof, floor and sides of the roadway. The values for the arch wall section are the least, whilst those for the tangential arch section are second and those for the rectangular

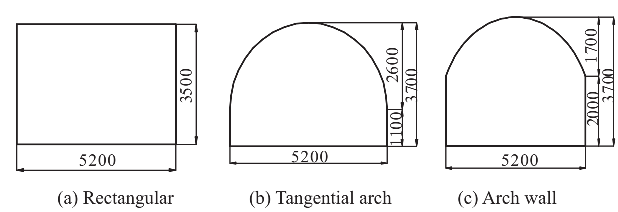

Fig. 2. Schematic diagram of roadway section size (mm).

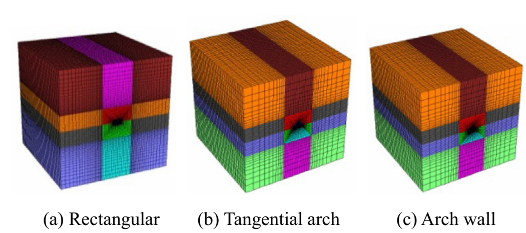

Fig. 3. Three-dimensional numerical simulation model.

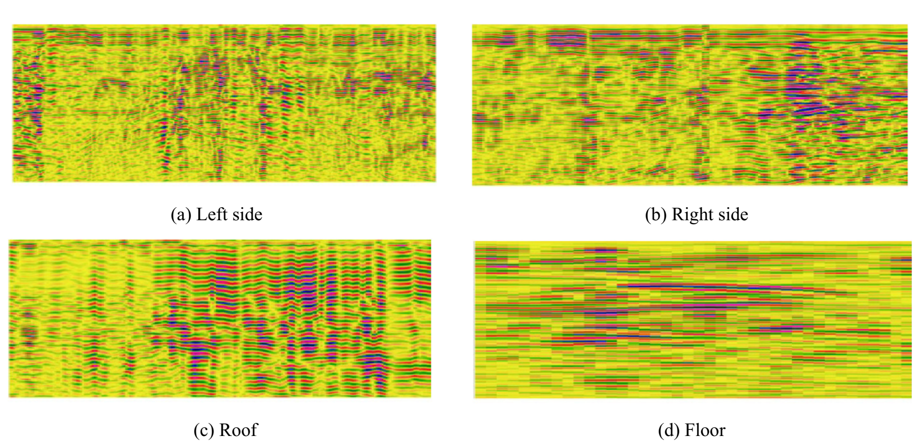

Fig. 1. Profile of geological radar survey in 1302 air return roadway.