The Research on Stability of Surrounding Rock in Gob-side Entry Driving in Deep and Thick Seam

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Abstract

The gob-side entry driving is driving in low pressure area, which bears less support pressure and is easy to maintain, so it is widely used. Taking the gob-side entry driving in thick coal seam of Dongtan Coal Mine as an example, the reasonable size of pillar and the section of roadway are numerically simulated by combining numerical with measurement, and the roadway support is designed. According to the distribution of lateral stress in working face, eight pillars of different sizes are designed. By simulating and comparing the stress distribution of surrounding rock and the development range and shape of plastic zone in different positions, the pillar size of gob-side entry driving is optimized to be 4.5m. According to the results of optimization of roadway section, the section of straight wall semi-circular arch roadway is adopted. According to the analysis, the roadway is supported by bolt + steel mesh + anchor cable. By observing the stability of roadway, it provides experience for the stability study of roadway the gob-side entry driving with small pillar in thick seam.

1 Introduction

The size of coal pillar in mining area has a great influence on the recovery rate of coal seam. The research shows that the coal loss of the gob-side entry driving with small coal pillar is smaller than that of the gob-side entry driving with large coal pillar, and the coal loss can be reduced as much as 6% ~ 9.5%. It is contradictory to improve the recovery rate of coal seam and control the deformation of surrounding rock of roadway. Therefore, it is necessary to take advanced theoretical analysis and optimization to find the balance point between them. (LI 2016; WANG 2015; ZHANG 2015; Yan 2013).

2 Geological Conditions

The maximum buried depth of tailentry in No.302 working face of Dongtan coal mine is 720m, which is arranged in the lower part of No.3 Coal Seam with a thickness of 5.8m. The tailentry of working face 302 is adjacent to the gob of the previous working face, and small coal pillars are reserved to gob-side entry driving. The immediate roof is argillaceous siltstone, the main roof is interbedded with siltstone and fine sandstone, and the upper is mudstone, medium sandstone and other rock layers in turn; the floor is argillaceous siltstone.

3 Optimization Analysis Of Coal Pillar Size

3.1 Model building

The physical and mechanical parameters of model is obtained through experiments. The finite difference program FLAC3D was used to construct the engineering geological model length × width × height = 200m×130m×120m. The model was discretized into 71840 zones with 77820 grid point nodes. The Mohr-Coulomb constitutive model is adopted in this work. The boundary conditions of the model are defined as follows: The model uses displacement constraints in addition to the upper surface. 80 m

above the coal seam as the upper boundary, 35 m below the coal seam as the lower boundary, 70 m from the upper trough to the gob as the left boundary, 20 m from the lower trough to the working direction as the right boundary, and the simulated length of the working face is 100 m. The simulated length of the strike of the model working face is 130m.

3.2 Lateral stress simulation

According to the simulation of the lateral stress distribution caused by the mining of working face 302, the range of stress reduction area is determined, and then the coal pillar design scheme is determined. As shown in Figure 1, through the simulation analysis, it can be seen that the peak value of the lateral stress caused by mining of working face 302 is about 8-10m.

3.3 Coal pillar size simulation

According to the lateral stress distribution of 302 working face, eight kinds of coal pillars with different sizes of 3M, 4m, 5m, 6m, 8m, 10m, 12m and 15m are designed according experience. The stress and deformation of the surrounding rock of the gob roadway with different sizes of coal pillars are compared and simulated. Based on the simulation and comparison of the stress distribution of surrounding rock and the development range and shape of plastic zone of roadway arranged in different positions along the gob, the reasonable pillar size of the gob-side entry driving was optimized in working face 302. In order to facilitate the construction of the model, the section along the working face is simulated as a rectangular section, which is 4.2m long and 3.0m high.

3.3.1 Vertical stress distribution of roadway surrounding rock

It can be seen from the vertical stress distribution figure 2 of the surrounding rock and the statistical table 1 of the stress distribution characteristics of the surrounding rock under the conditions of different sizes of coal pillars that the stress concentration degree and range of the surrounding rock vary with different sizes of coal pillars. When the pillar width is 3 m, the stress concentration area is at the solid coal side of the roadway. When the pillar size increases gradually, the stress concentration area gradually transfers from the solid coal to the pillar side, and the stress concentration degree increases gradually. When the pillar width increases to 8 m, the stress concentration area completely transfers to the pillar side (Fig. 2 (c)), and reaches the maximum value of 26.2 MPa, and the concentration coefficient $k = 2.0$. When the coal pillar is more than 8 m, with the increase of the width, the stress concentration degree of surrounding rock decreases gradually, but the range expands gradually, and the stress concentration areas on both sides of the roadway develop symmetrically.

Table 2

Stress distribution of roadway under different size pillar

characteristic value	Coal pillar width							
	3m	4m	5m	6m	8m	10m	12m	15m
$\text{Max}(\sigma_{zz})/\text{MPa}$	21.9	21.8	22.7	25.3	26.2	21.2	18.9	17.0
k	1.67	1.66	1.73	1.93	2.0	1.62	1.44	1.29

3.3.2 Distribution of plastic zone in surrounding rock of roadway

It can be seen from the distribution diagram 3 of the plastic zone of the surrounding rock of the roadway that the plastic zone of the coal pillar side of the roadway is larger than that of the solid coal side of the roadway, and the plastic zone of the roadway floor remains unchanged; when the coal pillar width is between 6-8m, the plastic zone reaches the maximum range of 5m (b); but when the coal pillar width exceeds 12M, the plastic zone of the surrounding rock on both sides of the roadway develops symmetrically, and the plastic zone is the same The enclosure is basically unchanged, which is consistent with the law of stress change of surrounding rock of the roadway. It shows that when the coal pillar is more than 15m, the influence of adjacent gob on the gob is less. (Yuan 2011;Peng 2013;Xie 2015;Ma 2015)

Based on the previous analysis and combined with the support theory research of deep soft rock roadway, an improved support scheme was designed including additional support form 45 angled bolt in the bottom corners of the roadway intended to control the roadway basal heave. This scheme included anchor net rope spraying in addition to the angled rock bolts. To verify the supporting effect, FLAC3D was used to simulate the revised support designs.

To sum up, based on the simulation results of surrounding rock stress distribution and plastic zone distribution under different coal pillars, in the principle of minimizing coal loss and combining with practice, it can be determined that the reasonable width of coal pillars for roadway protection is 4m ~ 5m, and the optimal width of coal pillars is 4.5m according compromise principle.

4 Shape Optimization Of Roadway Section

4.1 Model building

The large-scale numerical analysis software FINAL is used for optimization analysis. The roadway in the mining area is usually rectangular or trapezoidal. However, considering the particularity of deep gob-side entry driving, it is necessary to discuss the roadway shape, The commonly used and representative tunnel section, rectangular section and vertical wall semi-circular arch section are optimized and analyzed. The simulation scheme is designed as follows: after the excavation of the tunnel, the bolt net support is used to simulate the stress and deformation characteristics of surrounding rock around the tunnel. Vertical

wall semi-circular arch roadway: 4.0m wide and 3.0m high, including 1.0m high wall; rectangular roadway section: 4.0m wide and 3.0m high. The roadways are all supported by anchor mesh. The metal mesh is welded by $\phi 6.5$ mm steel bars. The bolt space is 800mm.

4.2 Stress simulation

It can be seen from the contour distribution map of σ_y and σ_x in the surrounding rock of roadway in Fig. 4 and Fig. 5 that:

(1) Under the specific conditions, the stress concentration in the four corners of the rectangular section roadway produces the stress concentration phenomenon, while the two sides, the top and the bottom of the roadway also produce a certain concentration, but relatively small; in the straight wall semi-circular arch section roadway, the stress concentration occurs in the two bottom corners of the roadway, the stress distribution around the roadway is relatively uniform, and the stress concentration exists in the arch shoulder and the top of the roadway. Generally speaking, the stress distribution of straight wall semi-circular arch roadway is better than that of rectangular roadway, and the concentration degree is small.

(2) The stress concentration degree of the surrounding rock of the roadway is related to the shape of the roadway section. From the contour distribution map of σ_y and σ_x , it can be seen that the stress concentration degree of the straight wall semi-circular arch roadway is significantly lower than that of the rectangular roadway under this specific condition.

5 Support Design

This design carried out in the roadways that have not yet been excavated. All the roadways are excavated by breaking the bottom, i.e. breaking the siltstone floor of coal seam 3. According to the results of numerical simulation and optimization of the tunnel section, the straight wall semi-circular arch tunnel section is adopted.

Through the analysis and research, combined with the above-mentioned numerical simulation results, it is determined that "bolt + steel mesh + anchor cable" support is adopted for the tailentry. The design support section is shown in Figure 6.

The tunnel section is straight wall and round arch, with the minimum design size of: $W \times H = 3800 \times 2800$ mm, and the excavation section size of: $W \times H = 4200 \times 3000$ mm, in which, the wall height is 1200mm, and the arch height is 1800mm; the bolt adopts the threaded steel bolt with the diameter of $\phi 22$ mm and the length of $L = 2500$ mm, arranged in three patterns, with the spacing of 800×500 mm; the anchor cable is arranged in five patterns, with the spacing of 2000mm, with the spacing of two 200 The minimum length of the anchor cable is 6800mm according to the condition of the roof of the tailentry on the 302 working face.

6 Roadway Pressure Monitoring

6.1 Deformation observation of surrounding rock

Figures 7 to 8 show the deformation observation results of the surrounding rock of the roadway during the influence period of mining, and the displacement rules and characteristics of the roadway can be obtained: during the mining, the advance influence range is about 70-80m, and the violent influence range is 30m; the deformation of the roadway roof and floor is 456MM, and the relative displacement of the two ribs is 518mm; the movement velocity of the two ribs of the roadway is greater than that of the roof and floor, and the maximum value is within 10m from the working face, which is 1 respectively 02mm / d and 84mm / d. When the deformation of surrounding rock is beyond the scope of violent influence in advance, the displacement of roof and floor is large, while when it is within the scope of violent influence, the deformation of two ribs is large.

6.2 Separation characteristics of roadway roof

The observation shows that the amount of roof separation is very small, and the roof separation rarely occurs. Figure 9 and figure 10 show the roof separation measured at observation station 3. It can be seen from the figure that there are separation layers inside and outside the anchorage zone, and the amount of separation layer inside the anchorage zone is slightly larger than that outside the anchorage zone, 8 mm and 6 mm respectively. It is consistent with the observation results of the displacement of the deep base point of the coal mine. Generally speaking, the overall stability of roadway roof is good.

7 Conclusions

- 1) According to the numerical simulation of stress distribution and plastic zone distribution of surrounding rock of different coal pillars, the reasonable width of coal pillar is optimized to be 4.5m.
- 2) According to the simulation results of the gob side roadway in no.302 working face, the displacement and plastic zone of the surrounding rock of the straight wall semi-circular arch roadway are smaller than the corresponding deformation value of the surrounding rock of the rectangular roadway, which is conducive to the stability of the surrounding rock of the gob side roadway and is the first choice for the support design.
- 3) Combined with the analysis results, the "bolt + steel mesh + anchor cable" support is adopted in the excavation of the broken siltstone floor of the roadway. According to the use, the stability of the roadway is good.□

Declarations

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Figures

Figure 1

Lateral stress distribution of workface

Figure 2

Vertical stress distribution of roadway

(a) 4m coal pillar

(b) 6m coal pillar

(c) 8m coal pillar

(d) 15m coal pillar

Figure 3

The plastic area of the roadway

Figure 4

Vertical stress contour map

Figure 5

Horizontal stress contour map

Figure 6

The design chart of roadway support

Figure 7

Deformation velocity of roadway during mining

Figure 8

Displacement of roadway during mining

Figure 9

Variation of roof separation velocity

Figure 10

Variation of roof separation