Mechanisms of Roadside Support and Application of Pier Column in Gob-Side Roadway Retaining

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Abstract. The stability control of roadside filling body is the key to keep the gob-side roadway retaining. According to the mechanical model of gob-side roadway retaining overlying strata, the paper analyzed the movement laws of main roof, especially the deformation process of key block B in the two stages. Based on this, we proposed and used the pier column supporting body as roadside support in the gob-side roadway retaining. We built a numerical model by using FLAC3D to analysis the supporting effect of pier column. All the above research results are applied in the tailway of W1305 working panel in Gaohe coal mine and have certain guidance to the practice of gob-side roadway retaining in other coal mine.

Keywords: gob-side roadway retaining; roadside support; pier column; FLAC3D.

1. Introduction

Gob-side roadway retaining is a process that retains the mining roadway which is in the back of working panel that has been mined-out [1] , it is widely used in China for the last several decades. When gob-side roadway retaining is implemented in coal mine, it is inevitably impacted by the roof movement during mining [2]. Chen [3] built a structural mechanics model of the gob-side roadway retaining overlying strata to analysis the load and deformation characteristics of roadside support in the three stages. Kan [4] held that the thickness of immediate roof has great influence on strata-pressure behavior and roadside supporting resistance.

Therefore, we built a mechanical model of gob-side roadway retaining overlying strata to analyze the movement laws of main roof, especially the deformation and fracture process of key block B. Based on this, we proposed and used the pier column supporting body as roadside support, and analyzed the supporting effect by using numerical simulation. Finally, the above researches were applied in the tailway of W1305 working panel in Gaohe coal mine of Lu'an Ming Group.

2. Movement laws of overlying strata in roadway retaining

During the mining of working panel, the overlying strata above the goaf fractured, with the retaining entity coal side formed a status of 'four-terminal clamp supported' [5]. The first weighing causes the main roof to form an 'O-X' breaking, while the periodic weighting causes the panel end main roof to generate a triangular-patch [6] (Fig.1).

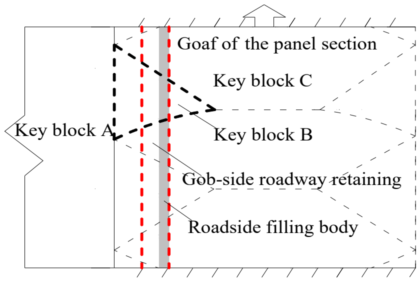


Fig.1. The top view of structural model of main roof

As shown in Fig.1, the main roof strata above the gob-side roadway retaining breaks into regular blocks that extrude and integrate mutually to form the "hinged beam" structure and develop A, B and C key blocks in the gob side. According to a large number of field observations and numerical simulation, the deformation and fracture process of key block B above the roadway retaining are divided into two stages.

Ⅰ—The first time broken of key block B. This stage usually locates within a periodic weighting length behind the working panel. One side of the gob-side roadway retaining is entity coal, while the other one is a filling body. When key block B reaches the limited span, it is broken for the first time beside the key block A. Then, the key block B occurs rotation and subsidence deformation towards goaf and constantly imposes pressures to the entity coal and roadside filling body. While the entity coal and roadside filling body are impossible to control the movement of key block B, thus keeping roof in the state of "given deformation" ultimately.

Ⅱ—The second time broken of key block B. As the distance from the working panel increased, the movement of key block B is reached stability gradually. As the distance from the working panel increased, the movement of key block B is reached stability gradually. At this time, the bearing capacity acting on the roof by the filling body increases rapidly, which makes the tensile strength of key block B outside the filling body reaches its ultimate strength and results in the second time broken, formed the block B1 and block B2 (Fig.2).Finally, the cracked roof strata above the goaf would contact gangue and the surrounding rock of roadway retaining is tending to stability.

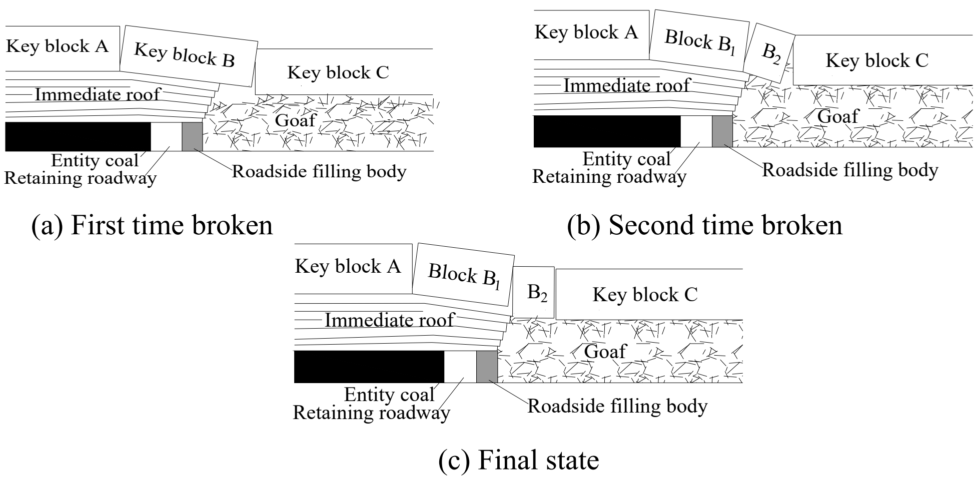


Fig.2 The fracture process of key block B

3. Support mechanism of pier column

When pier column supporting body is used as roadside support for gob-side roadway retaining, it is constructed by filling high-water material into a cylindrical filling pack, and enwrapped with steel bar mesh on the outside surface of filling pack. The structure of pier column is shown in Fig.3.

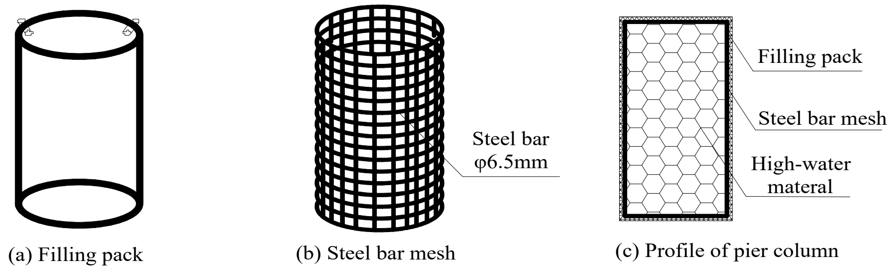


Fig.3 Structure of pier column

In comparison with traditional roadside supporting body [7], the pier column supporting body have some advantages as follows: Strong compressibility and high post strength. When water cement ratio reaches 1.5:1 (Fig.4), in the early stage, the support resistance of pier column supporting body increases slowly with the increase of the amount of compression. So the pier column have strong compressibility to adapt the heavy rotation and subsidence deformation of key block B. And in the later stage, when the compression reaches 18 percent, the residual support resistance is still 50 percent of the peak value. The high post strength of pier column can cut off the key block B for the second time. It will relieve the violence influence of upper strata to the go-side roadway retaining.

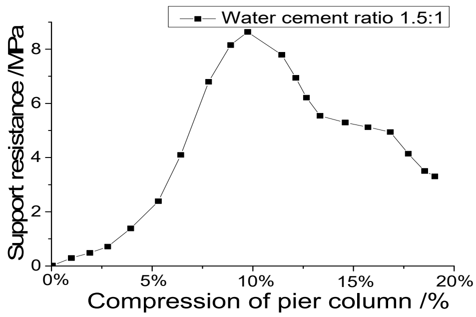


Fig.4 Stiffness curve of pier column

During the movement of key block B, the pier column supporting body not only bear the high vertical stress generated by the fracture of main roof, but undertake the lateral thrust due to the rotation deformation of key block B. The theoretical model of pier column in roadway retaining is shown in Fig.5.

Fig.5 Theoretical model of pier column

4. Numerical simulation of roadside support

4.1. Numerical model establishment

Gaohe coal mine of Lu'an Ming Group is a high gassy mine, in order to reduce the gas density in tailway, the mining roadway in W1305 panel is designed into double "U" shape. The roadway retaining just need to keep stability to satisfy the demand of ventilation before working panel advanced to the next connection roadway, and the maximum length of roadway retaining that is useful is the distance between two connection roadways, about 60m. Fig.6 shows the process of gob-side roadway retaining.

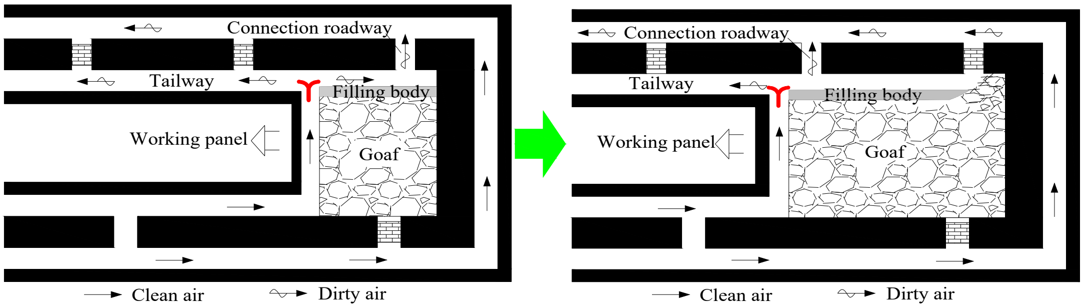


Fig.6 The process of gob-side roadway retaining in Gaohe coal mine

According to the geological and mining condition of W1305 working panel, a basic numerical model is built by using FLAC3D. W1305 working panel uses strike longwall sub-level caving mining technology. It is about 620 m in depth, 1100 m in strike length, and 200 m in trend length. The immediate roof is grey black thick-bedded sandy mudstone, 7.3 m thick at average, above which is 11.7 m dark grey fine sandstone. The immediate floor is dark grey siltstone, with an average thickness of 1.5 m, under which is average 10.2 m thick sandy mudstone. The average thickness of coal seam is 6.5 m, extraction-caving ratio is 1:1.17, with inclination of 6-10°, 8° on average. The periodic weighting length of main roof is 25 m. The Protodikonov's Hardness Coefficient of coal is 1.0, and the mechanical parameters of rock mass and coal are shown in table.1.

The tailway is the rectangular cross-section with 5.2 m wide and 3.5 m height. For the support patterns of the roof, φ22*2400 mm high-strength threaded steel bolt is employed with the tensile strength of 200 KN, and the spacing and row of bolts is 800*800 mm. Besides, three additional cables, φ18.96*8300 mm are installed at every two rows bolt intervals, and the tensile strength of cable is 368 KN. For the reinforcement of both sides, φ22*2400 mm high-strength bolt with row spacing of 800 mm are applied, each row including five bolts in each side, and the supporting sketch is shown in fig.7. In addition, within the scope of 40 m ahead of the panel in tailway, single hydraulic prop is employed in the panel side, and the spacing and row of prop is 1500*900 mm.

The numerical model is generated in three dimensions and its size is 120 m×65 m×80 m, corresponding to X, Y, Z direction respectively, and mining of working panel along the minus Y direction. The location of tailway in numerical model is: x= (40, 45.2), z= (27, 30.5). The in-situ stress is reproduced by setting initial conditions. The top of the model applies a vertical stress which is equal to the gravity of the overlying stratum, the horizontal stress coefficient on the lateral sides is set as 1.2. The constitutive relation is Mohr-Coulomb model.

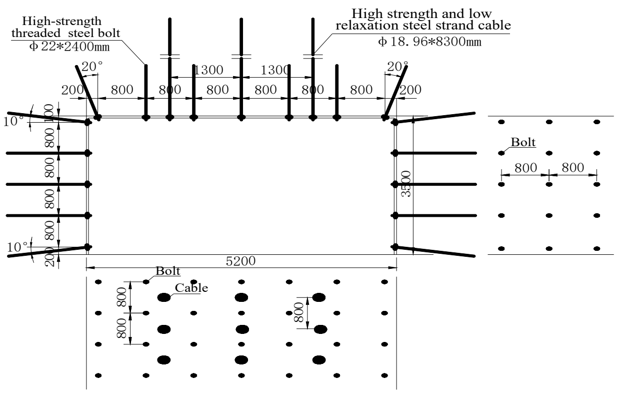


Fig. 7 supporting schemes of tailway in W1305 panel

Table 1. Mechanical parameters of rock and coal

Rock type	Density /Kg·m^{-3}	Bulk modulus /GPa	Thickness/m	Friction angle/°	Cohesion/MPa	Tensile strength /MPa
Fine sandstone	2600	13.62	11.7	38.0	3.32	3.0
sandy mudstone	2400	10.24	7.3	34.0	2.86	2.0
Coal	2400	4.22	6.5	32.0	1.75	1.2
Siltstone	2500	11.35	1.5	36.0	3.07	2.6
Sandy mudstone	2400	12.65	10.2	38.0	3.28	2.0

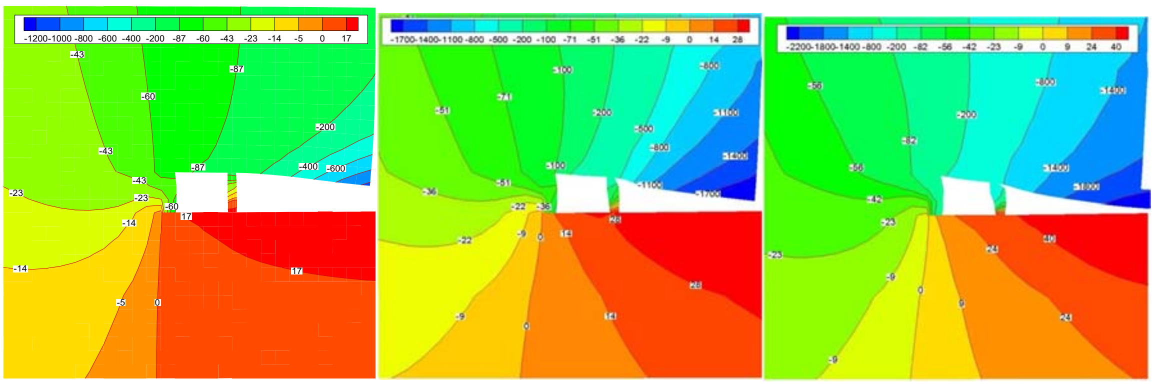
Table 2. Mechanical parameters of pier column in numerical model of FLAC3D

Support scheme	Density/Kg·m^{-3}	Bulk modulus /GPa	Shear modulus /GPa	Friction angle/°	Cohesion/MPa
Pier column	2500	7.5	5.8	35.0	4.3
Support scheme	Compressive strength /MPa	Kelvin shear modulus /GPa	Kelvin viscosity /GPa	Maxwell shear modulus /GPa	Maxwell viscosity /GPa
Pier column	8.4	6.0	15.0	7.1	12.0

With the advance of the working panel, the pier column roadside support scheme is designed beside goaf, and the water cement ratio of high-water material is 1.5:1. The mechanical parameters of pier column are shown in table. 2. The diameter and the center-to-center distance of pier column are 0.85 m and 1.25 m respectively, locate at: x= (43.8, 44.7), z= (27, 30.5). In the numerical model, the pier column uses viscoelastic-plastic model (Cvisc), which takes Mohr-Coulomb model as failure criterion, while the coal and rock use Mohr plastic model. The goaf is seen as a null unit in the numerical simulation. According to the field monitoring, the lateral length of key block B is approximately equal to the periodic weighting length of main roof, about 25 m.

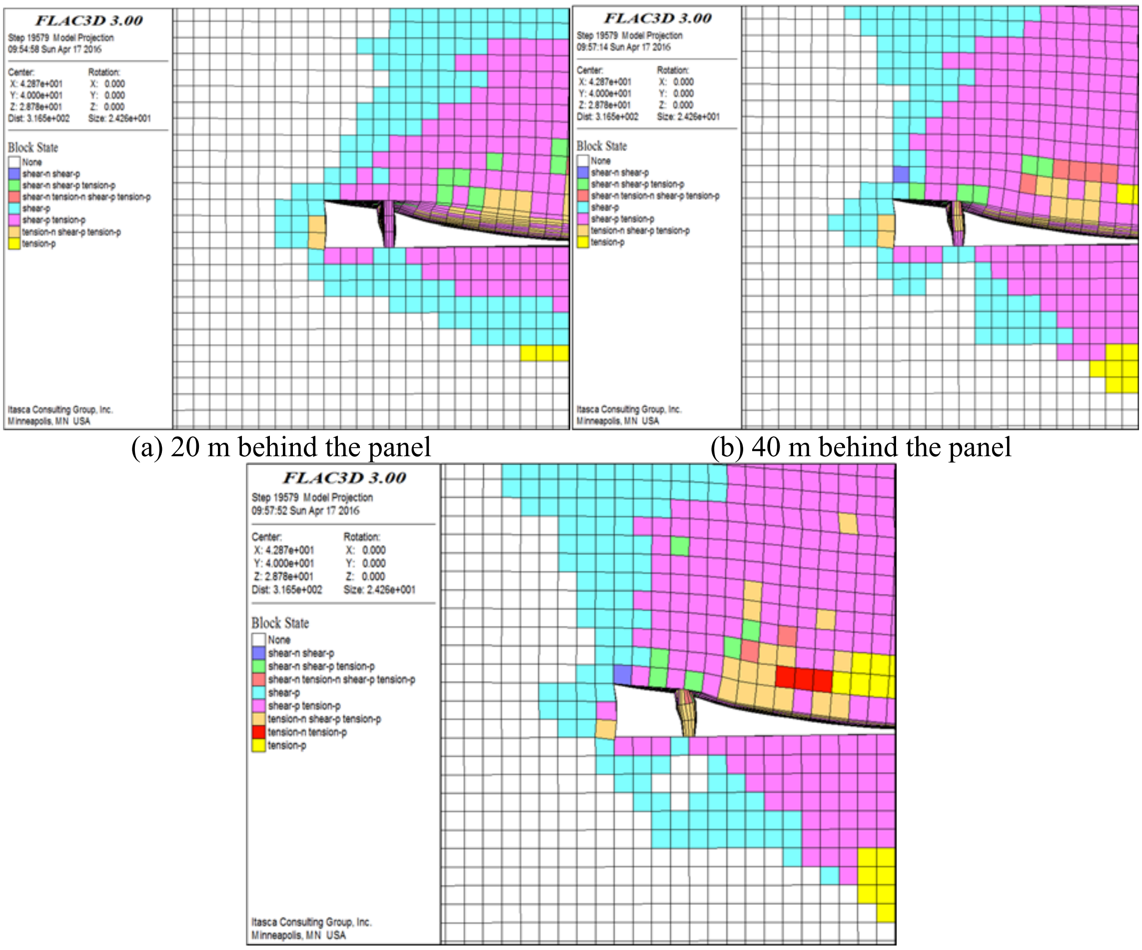
4.2. Simulation results of roadside support

With the advance of the working panel, the pier column supporting body is used as roadside support in roadway retaining, and the evolution laws of vertical displacement and plastic zone of surrounding rock within the scope of 60 m behind the panel are shown in fig.8 and fig.9 respectively.



(a) 20 m behind the panel (b) 40 m behind the panel (c) 60 m behind the panel

Fig.8 Nephogram of vertical displacement in roadway retaining



(a) 20 m behind the panel (b) 40 m behind the panel

(c) 60 m behind the panel

Fig.9 Nephogram of plastic zone in roadway retaining

According to Fig.8 (a) and Fig.9 (a), the vertical displacement of entity coal and pier column are 40 mm and 90 mm respectively, and the main range of plastic zone are locate in the upside of goaf and roadway retaining. When advancing distance of working panel is up to 40 m, the main roof of roadway retaining is in the state of "given deformation" due to the first weighting. Also, the plastic zone in roof strata is expanded to the entity coal gradually. However, since pier column has great compressibility that allows the roof to sink in this period and release some roof pressure, only small part of pier column is into plastic zone. When the advancing is 60 m, the deformation of surrounding rock is tending to stability, and the final vertical displacement of pier column is more than 300 mm. While the range of plastic zone in entity coal side is only expanded 3--4 m. At the same time, a large proportion of pier column is into plastic zone and presents tensile failure on the external surface, but it still has high post strength that is large enough to support the roof, which will realize the stability of roadway retaining.

5. Conclusions

(1) Based on the mechanical model of gob-side roadway retaining overlying strata, we analyzed the movement laws of key block B in the two stages. In the early stage, the main roof of roadway retaining is in the state of "given deformation", and heavy deformation will take place in surrounding rock. In the later stage, the bearing capacity acting on the roof by the filling body increases rapidly, which makes the key block B appears second time broken. After this, the cracked roof strata above the goaf would contact gangue and the surrounding rock of roadway retaining is tending to stability.

(2) The supporting scheme of pier column supporting body, which is constructed by high-water material, is proposed as roadside support for the gob-side roadway retaining. On the one hand, the strength of pier column increase rapidly and high after constructed, which can guaranteed the promptly support to the roof of pier column. On the other hand, the pier column have strong compressibility and high post strength. The strong compressibility can adapt the heavy rotation and subsidence deformation of key block B in the early stage. And the high post strength can cut off the key block B for the second time in the later stage, it will relieve the violence influence of upper strata to the go-side roadway retaining and makes the roadway retaining in the low stress environment.

(3) The numerical simulation show that using the pier column as roadside support could be suitable for the laws of roof movement, and the supporting effect is good. The gob-side roadway retaining can meet the basic requirements of pedestrian and ventilation.

Acknowledgments
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