

# Study on Movement Laws of Rockmass Structure and its Control in Gob-Side Roadway Retaining

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**Abstract.** According to the structural mechanics model of gob-side roadway retaining overlying strata, the paper analyzed the deformation characteristics of surrounding rock and the stress characteristics of filling body in the two stages and obtained the basic requirements for roadside filling body to keep the stability of gob-side roadway retaining as follows. The ultimate bearing capacity of filling body should enough to cutting off the key block B beside the goaf, and has a large deformation capacity during overlying strata movement and a high post-strength after stability of overlying strata movement. Based on above investigations and the geological conditions of W1305 panel in Gaohe coal mine, a new roadside support method named as pier column which is built with high-water material is innovatively proposed in this study. The site test showed that after the roof strata above the gob-side roadway retaining were stability, the surrounding rock of the roadway retaining and the pier column would be stabilized and the deformation value would be small. All these research results could have certain guidance to the practices of gob-side roadway retaining.

## 1. Introduction

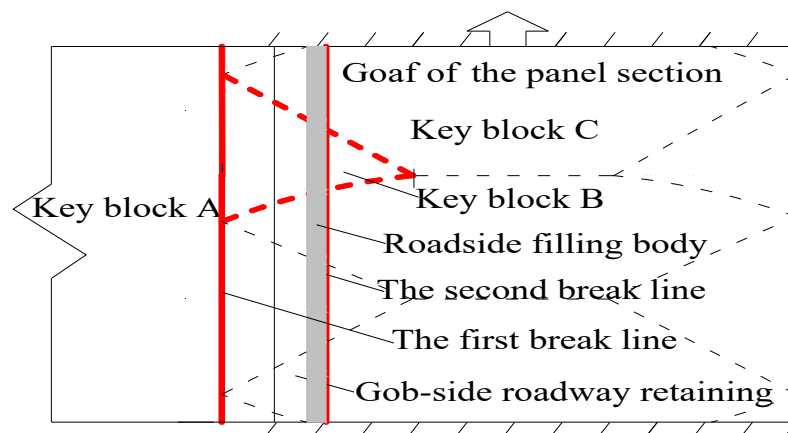
Gob-side roadway retaining is a process that retains the mining roadway which is in the back of working panel that has been mined-out [1], it is widely used in China for the last several decades. However, the roadside supporting resistance of gob-side roadway retaining is still under discussion, some mechanical models have been established to calculate it. Zhou [2] built a mechanical model with similar material, and hold that the hardest rock strata determined the supporting resistance of roadside filling body. Ma [3] construct an in-situ gob-side roadway retaining mechanical model, and deduced the calculation formulas of the supporting resistance. Based on the current research [4], few studies on movement laws of rock mass structure of gob-side roadway retaining and fewer studies about structure and material of filling body have been done. Our study considered the movement laws of gob-side roadway retaining overlying strata, and based on these theories, we designed a new type roadside filling body—pier column, which is built with high-water material. All the above research results are applied in controlling surrounding rock deformation of gob-side roadway retaining of W1305 panel mining roadway in Gaohe coal mine.



## 2. Instructions

### 2.1. Mechanism analysis of rock mass structure in gob-side roadway retaining

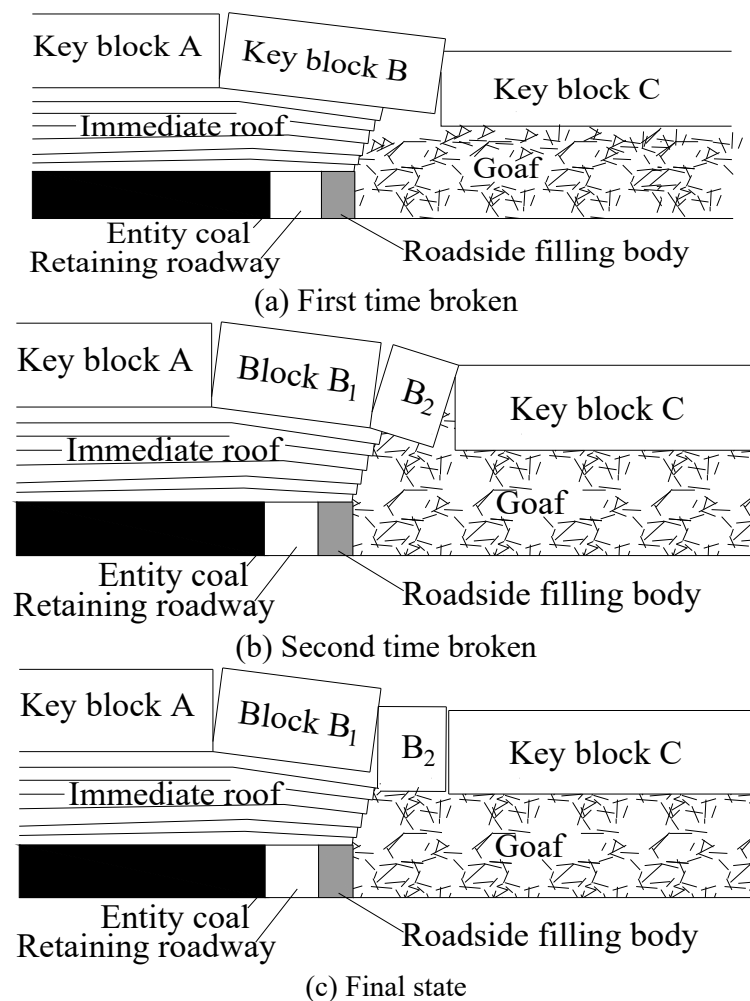
**2.1.1. The movement's laws of overlying strata.** During the mining of panel, the overlying strata above the goaf fractured, with the retaining entity coal side formed a status of 'four-terminal clamp supported' [5]. The first weighting causes the main roof to form an 'O-X' breaking; while the periodic weighting causes the panel end main roof to generate a triangular-patch [6], that is key block B (Fig. 1), above the gob-side roadway retaining. According to a large number of field observations and numerical simulation, the deformational rules of roof of gob-side roadway retaining are divided into two stages.



**Figure 1.** The structural model of main roof's fracture position

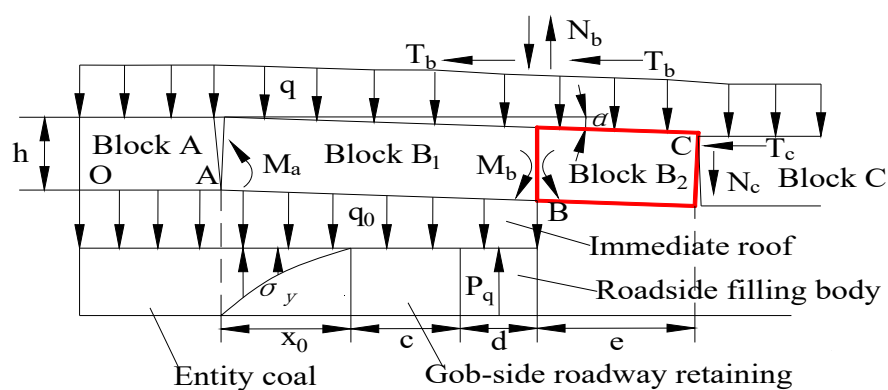
I —the first time broken of key block B. This stage usually locates within a periodic weighting length behind the working panel. One side of the gob-side roadway retaining is entity coal, while the other one is a filling body. In the rear of the working panel, the roadway is in the increasing stress environment during the process of key block B movement, the increased vertical stress mainly applied on the entity coal, causing the entity coal to be compressed, meanwhile, the same reacting force exerted on the key block B, which makes the key block B to be squeezed and induces cracking under the condition of high stress, and when the key block B reaches the limited span, it is broken for the first time beside the key block A, while the filling body beside goaf still didn't provide great support to the main roof.

II —the second time broken of key block B. As the distance from the working panel increasing, the key block B occurred rotary subsidence and deformation towards goaf with one end is supported by the entity coal and the other end is supported by the roadside filling body, and the bearing capacity acting on the roof by the filling body increased rapidly, which makes the tensile strength of key block B outside the filling body reaches its ultimate strength and result in the second time broken, formed the block B1 and block B2 (Fig.2). At the same time, the original plastic zone of surrounding rock enters the cracked state, the surrounding rock deformation is much larger in the cracked state than in the plastic state, and finally, the cracked rock strata above the goaf would contact gangue and stay stability, it would be relieved the violent influence of upper strata to the gob-side roadway retaining, and makes the gob-side roadway retaining remaining in a low stress environment.



**Figure 2.** The gob-side roadway retaining model of the different fracture position

**2.1.2. Building mechanical model.** Based on above analysis, in order to keep stability of gob-side roadway retaining, the cutting-off resistance of filling body should strong enough to make the tensile strength of key block B outside the filling body reaches its ultimate strength and broken for the second time. The mechanical model of gob-side roadway retaining is shown in Fig.3.



**Figure 3.** Mechanical model of gob-side roadway retaining

The cutting-off resistance of filling body  $P_q$  is:

$$P_q = [M_b + (N_c + q \cos \alpha e)(x_0 + c + d + e) + \frac{1}{2}(q \cos \alpha + q_0)(x_0 + c + d)^2 - \int_0^{x_0} \sigma_y(x_0 - x)dx - (T_c + q \sin \alpha e)(h - \Delta S_B) - M_a - q \sin \alpha (x_0 + c + d) \left( \frac{h}{2} - \Delta S_B \right)] / \left( x_0 + c + \frac{d}{2} \right) \quad (1)$$

In above equation,  $c$  is the width of gob-side roadway retaining, m;  $d$  is the width of filling body, m;  $N_c$  is the shear stress of key block B beside goaf, KN;  $N_{ab}$  is the shear stress of key block B where the second broken happened, KN;  $m_y$  is the abutment pressure of entity coal, MP;  $b$  is the periodic weighting length of main roof, m;  $L_m$  is the length of working panel, m;  $\Delta S_B$ ,  $\Delta S_C$  is the sink age of key block B for the first time broken on B and C side respectively, m. The length of block B2,  $e$  is:

$$e = \frac{2b}{17} \frac{b}{L_m} \sqrt{100 + 102 \left( \frac{L_m}{b} \right)^2} - x_0 - c - d \quad (2)$$

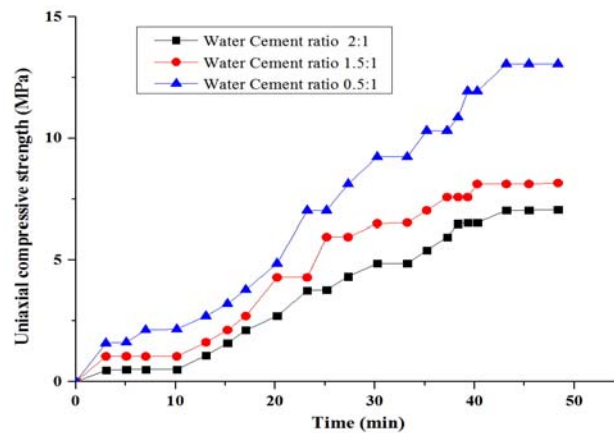
For security, defined the safety coefficient  $K_1$  is the ratio of the ultimate bearing capacity and cutting-off resistance of filling body:

$$K_1 = \frac{N}{P_q} \quad (3)$$

In above equation,  $N$  is the ultimate bearing capacity of filling body, KN;  $K_1$  is 1.3~1.5 generally.

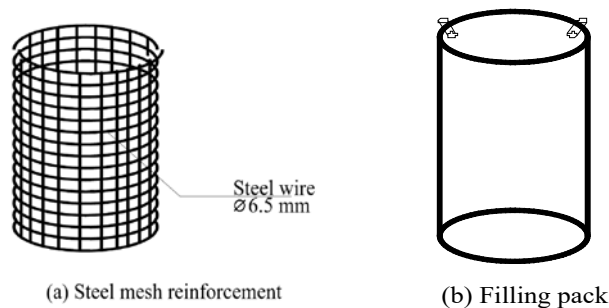
## 2.2. Design of roadside filling body

The traditional support material of roadside filling body, include wood crib, gangue and concrete, have some deficiencies in stability, increment speed of support resistance and capacity of compression [7~8]. In contrast, high-water material have some advantages [9~10], such as: (1) Rapid consolidation and high strength. (2) Strong compressibility. (3) High post strength. The compressive strength of high-water material with different water cement ratio is shown in Fig.4.



**Figure 4.** Compressive strength of high-water material with different water cement ratio

The filling body beside goaf should keep the stability of gob-side roadway retaining to meet the requirement of ventilation, meanwhile, the costs of filling body should reduce as much as possible. So, we designed a new type filling body--pier column by filling high-water material into a cylindrical pack, and the outside surface of cylindrical pack is enwrapped with steel mesh reinforcement. The structure of steel mesh reinforcement and pack is shown in Fig.5.



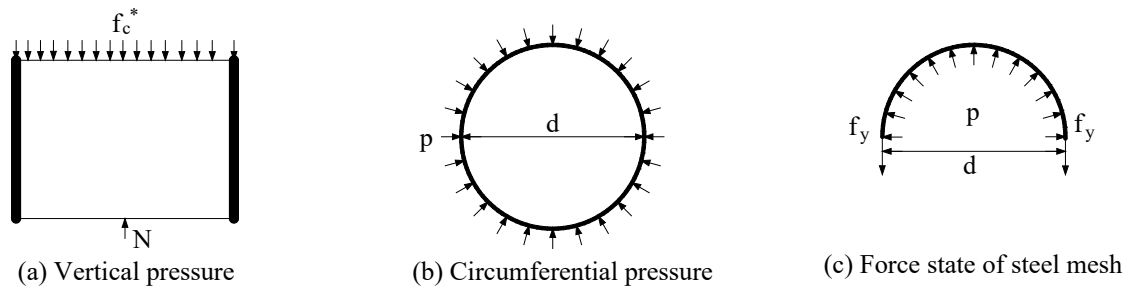
**Figure 5.** Structure of roadside filling body

To satisfy the operating requirements of gob-side roadway retaining, the pier column should have adequate capacity to bearing the high stress generated from the fracture of immediate roof and main roof.

**2.2.1. Bearing capacity of pier column.** The force state of pier column is shown in Fig.6. The compressive strength of pier column  $f_c^*$  is:

$$f_c^* = f_c + k \cdot p \quad (4)$$

In above equation,  $f_c$  is the compressive strength of pier column without lateral pressure, MP;  $k$  is the lateral pressure coefficient of pier column, generally 3~5;  $p$  is the equivalent lateral pressure, MP.



**Figure 6.** Force diagram of pier column

According to the analysis of static equilibrium, then:

$$2f_y \cdot t = p \cdot d \quad (5)$$

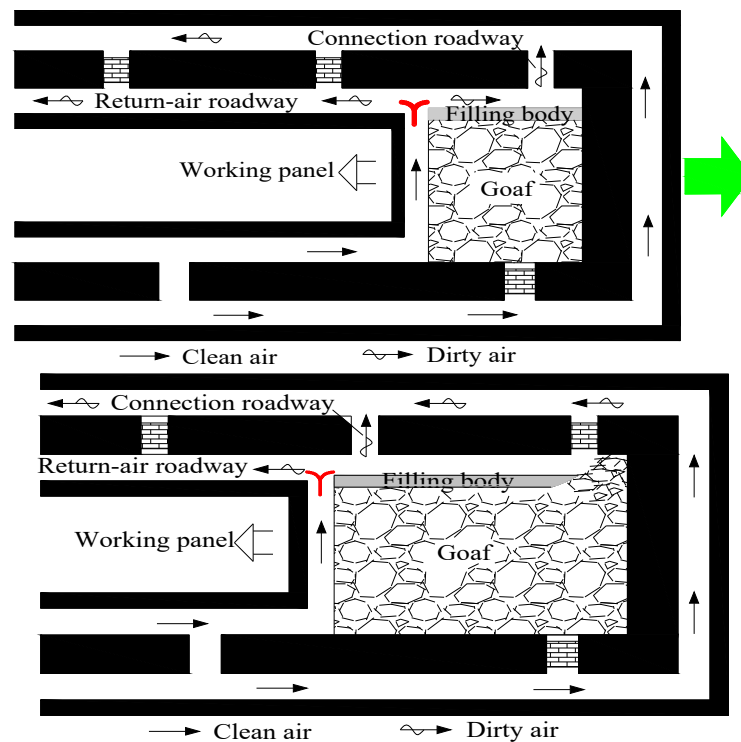
The ultimate bearing capacity of pier column N is:

$$N = S \cdot f_c^* = S \left( f_c + k \frac{2f_y \cdot t}{d} \right) \quad (6)$$

In above equation,  $f_y$  is the yield strength of steel mesh reinforcement, MP;  $d$ ,  $t$  are the diameter and thickness of the steel mesh reinforcement respectively, m;  $S$  is the cross sectional area of pier column, m<sup>2</sup>.

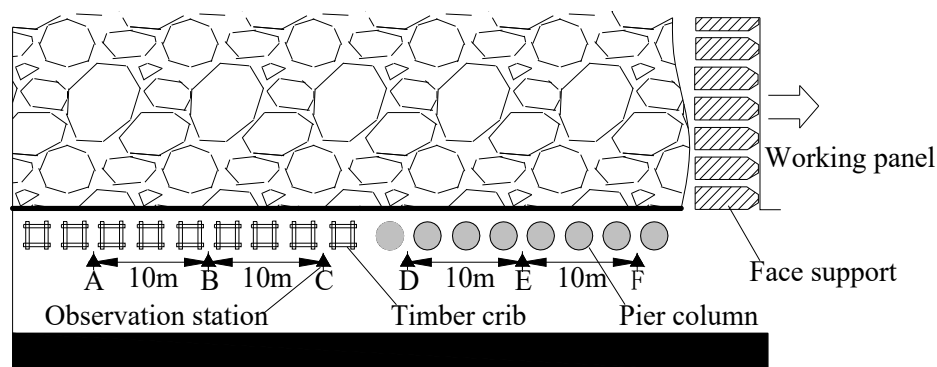
### 2.3. Mineral pressure observation

Gauche coal mine is a high gassy mine, in order to reduce the gas density in return-air roadway, the mining roadway in W1305 panel is designed into double "U" type. The gob-side 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 gob-side roadway retaining that is useful is the distance between two connection roadways, about 80m. Fig.7 shows the process of gob-side roadway retaining.



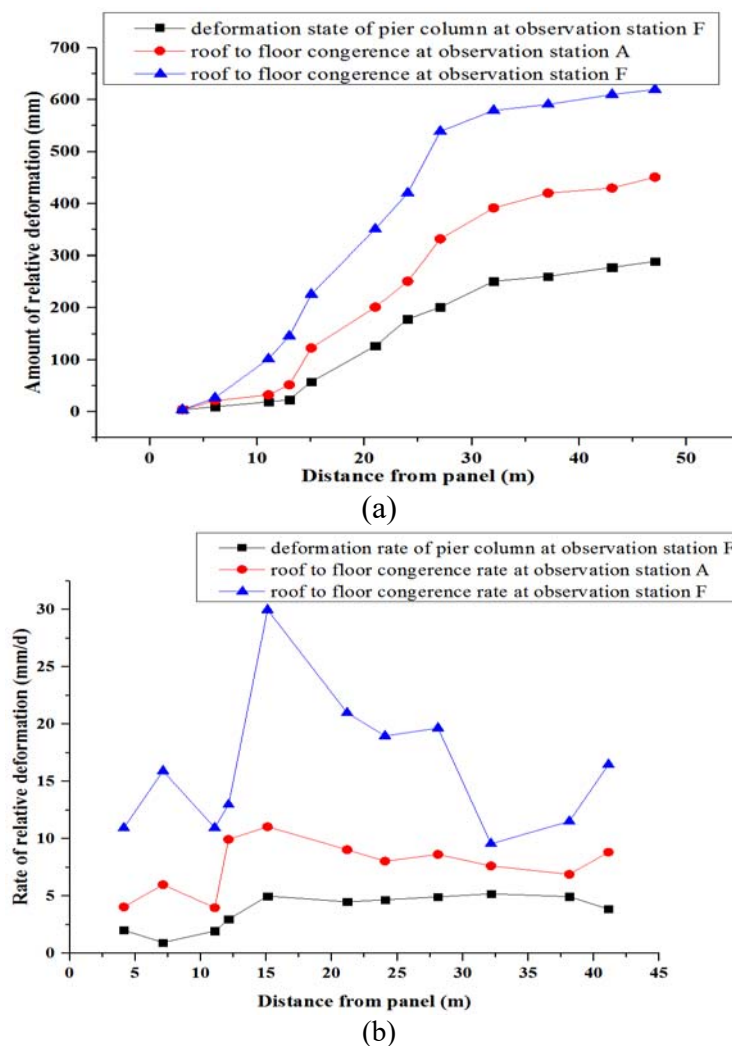
**Figure 7.** The gob-side roadway retaining process

Before using pier column, the timber crib have been used to support the roof of gob-side roadway retaining in W1305 panel. In order to observe the deformation conditions of surrounding rock, three observation stations were set in the location of timber cribs (marked as A, B and C) and pier columns (marked as D, E and F) respectively, and the interval between two stations is 10 m (Fig.8).



**Figure 8.** Layout of observation station in gob-side roadway retaining

The roof to floor convergence can reflect not only the stress and deformation state of the filling body, but the deformation rules of surrounding rock. The main content of mineral pressure observation includes: 1) the relationship between the roof to floor convergence, convergence rate and the distance from observation station to working panel at observation station A and F respectively; 2) the self-deformation condition of pier column at observation station F. Measuring guns and poles were used to measure the deformation of the surrounding rock of the roadway and the specific data are shown in Fig. 9, the observation data at other stations just used as auxiliary material.



**Figure 9.** Relationship between roof to floor convergence and the distance from observation station to panel

As shown in Fig.9 (a), the maximum value of roof to floor convergence is 613 mm at observation station A, and 456 mm at observation station F, meanwhile, the maximum deformation of pier column at observation station F is 268 mm.

As shown in Fig.9 (b), the roof to floor convergence rate of the section support with wooden crib is about 6-31mm/d, 15.4 mm/d on average. In comparison, the roof to floor convergence rate of the section support with pier column is about 4-11 mm/d, 7.2 mm/d on average, and the maximum deformation rate of pier column is 5 mm/d. All the above three maximum values are obtained in the rear of the panel about 20 m, which is caused by the periodic weighting of the main roof, at the same time, the rate of rotary subsidence of key block B increased rapidly, and the mining activities have great influence on the stability of gob-side roadway retaining also. When the distance from observation station to panel over 50 m--about two times periodic weighting pace, the deformation rate of surrounding rock and pier columns decreased gradually, and finally trends to be stabilized.

### 3. Conclusion

(1) Based on the mechanical model of gob-side roadway retaining, the activities of surrounding rock is divided into two phases. Meanwhile, we analyzed the deformation characteristics of surrounding rock and the stress characteristics of filling body in these two phases, and obtained the computational



formula of cutting-off resistance of filling body. For security, the safety coefficient is defined as the ratio of the ultimate bearing capacity and cutting-off resistance of filling body.

(2) We designed a new type filling body-pier column, which is built with high-water material. The pier column has some merits: 1) Rapid consolidation and high strength. 2) Strong compressibility. 3) High post strength. Besides, we also deduced the formula of bearing capacity and bending deflection of the pier column.

(3) Engineering practice shows that the maintenance condition of roadway supporting with pier column is significantly better than that the roadway support with wooden crib, namely, roof to floor convergence reduced by 30%, and the self-deformation of pier column is smaller too.

### Acknowledgments

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