

# Based on Flac3D Research and Analysis of the Mining Pressure Development Law in the Top Coal Section of the Roadway Support of the Working Face Transport

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**Abstract:** Top coal supporting roadway is widely used in the transportation roadway of thick coal seam face, which can not only increase the coal extraction rate but also reduce the driving cost. Based on the engineering geological conditions of the transportation lane of the working face of Zhongma Cun mine, the law of mine pressure development in the roadway of the top coal section is studied and analyzed based on Flac3D and field monitoring methods. The numerical simulation analysis shows that when the working face is pushed to 55m for the first time, the displacement of the area affected by the leading abutment pressure and the surrounding rock on the mining side of the roadway reaches the peak value, and the step distance of the first time is 55m. According to the analysis of stress monitoring data of single pillar and roof anchor cable on site, the first pressure occurs when the working face advances to 51m, which is consistent with the numerical simulation conclusion.

**Keywords:** Roadway for Top Coal Section; Numerical Simulation; Ore Pressure Distribution.

## 1. Introduction

The With the development of mining technology, the arrangement of top coal transport roadway in thick coal seam coal mine can not only improve the recovery rate but also reduce the driving cost [1-3]. However, in actual coal mine production and mining, due to the influence of stress concentration and rock burst pressure, the support of top coal transport roadway is more complicated [4-5]. Many researchers have conducted research on the top-coal supporting roadway. Chen Xiaoxiang et al. [6] studied the deformation and failure of the roof of the top-coal supporting roadway in the area prone to flake loading in thick coal seam, and proposed the joint control technology of advance pipe pre-grouting and wall-top of the top-coal supporting roadway, which successfully controlled the top-coal supporting roadway. Jiang Fuling et al. [7] studied the deformation and failure of large-span cutout of thick top coal in soft crushing, proposed the surrounding rock control strategy and support scheme, and the cutout surrounding rock was effectively controlled. Chen Chuan et al. [8] studied the deformation characteristics and control technology of the roadway supporting top coal in goaf excavation of soft coal seam, and proposed a comprehensive roof cooperative control technology, which includes high-strength anchor net to ensure the integrity of surrounding rock, long anchor cable to control roof stability, and arrangement of bolting at side angles to strengthen the roof. A large number of researchers have done a lot of research on the roadway support and surrounding rock stability, but there is little research on the law of rock pressure development in the coal supporting section. Based on the engineering background of the top coal section in the transport channel of Zhongma Cun Mine, this paper studies the ore pressure law of the top coal section by Flac3D and field monitoring.

## 2. Engineering Background

The buried depth of the working face of Zhongma Cun mine is 344.0m~ 417.5m. The thickness of coal seam in the working face varies greatly, and the average thickness of coal is 6.5m. Coal averages  $12^{\circ}$ . The design length of the transport lane is 804m, and the length of the coal supporting section is 316m. The thickness of the top coal is 5~3m in the range of 173m outward from the opening of the top coal section, and 3~1m in the range of 173-316m outward from the opening. The roadway in the top coal section of the transportation roadway is a rectangular section with a width of 5m and a height of 3.5m. The supporting section of the roadway is shown in FIG. 1. The Angle between the two shoulder angles of the anchor cable and the roof normal is  $10^{\circ}$ , and the preload of each anchor cable is not less than 300kN; Four anchor cables are arranged on each side of the side, the specifications are  $\Phi 21.6 \times 3200\text{mm}$ , the top and bottom normal lines are  $10^{\circ}$  Angle, and the preloading force is not less than 150kN.

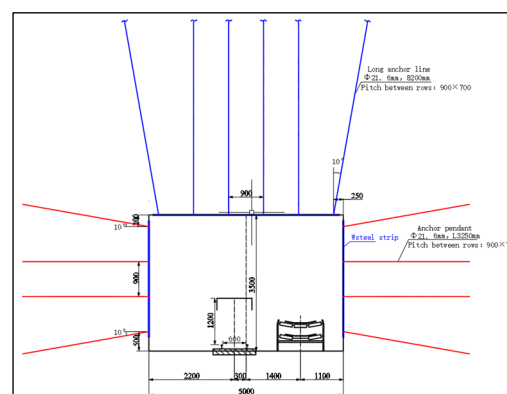


Figure 1. Transport roadway support profile

### 3. Mechanical Model Analysis of Top Coal

In the process of continuous advancement of the working face of the thick coal seam and the roadway supporting top coal, due to the large mining void, large mining size and fast advancement, the stope pressure is intense and the influence range is large, so the mining influence of the working face has a greater impact on the stability of the roadway supporting top coal. Therefore, the roof breaking characteristics in the advancing direction of the working face of the thick coal seam and the influence range of advance pressure are studied. It is of great significance to the control of the surrounding rock of the tunnel supporting top coal.

With the continuous advance of the working face and the recovery of top coal, the scope of the gob increases, and the direct roof collapses along with the advance of the working face. Due to the thick coal seam, the rocks falling from the direct roof are not enough to fill the gob, and the basic roof cannot contact the caved rocks, forming a cantilever structure. In the continuous advance of the working face, the length of the overhanging basic roof increases, and when the length reaches the limit span, the basic roof breaks, resulting in the initial pressure of the working face. During the whole advancing process of the working face, the basic roof breaks periodically, resulting in the working face forming periodic pressure. The whole process repeats the masonry beam structure of "one end is fixed and the other end is simply supported", and the periodic fracture characteristics are shown in FIG. 2.

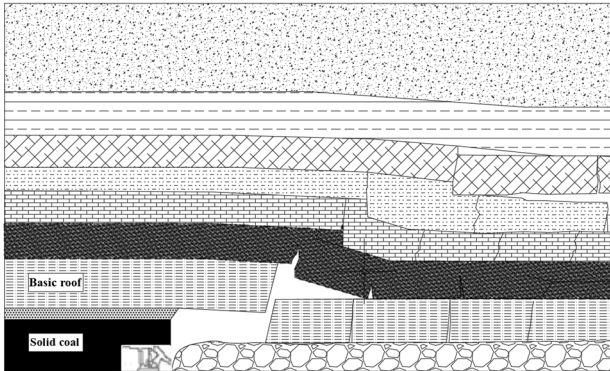


Figure 2. Basic top cycle fracture characteristics

Different from ordinary roadway, the roof and two sides of the roadway supporting top coal are both coal bodies and can be regarded as complete structures. Therefore, the stress analysis of the coal roof is carried out with fixed beams, and the research and analysis of the coal roof and side coal is carried out with "roof and side in one [9]". The rock stability analysis model of the roadway supporting top coal is shown in Figure 3. The roof and two sides of a rectangular roadway are considered as homogeneous elastic bodies, and the bending moment produced by the equivalent wall is only affected by the horizontal stress. According to the Moore-Coulomb criterion, the Angle between shear plane and maximum principal stress is  $\pm(\pi/4 - \varphi/2)$ . According to the theory of limit equilibrium condition, the conditions for shear failure of roof can be calculated as follows:

$$F \leq \frac{Q}{2 \sin\left(\frac{\pi - \varphi}{2}\right) \left(\tan \varphi_0 - \cot\left(\frac{\pi - \varphi}{2}\right)\right)} \tan \varphi_0 \quad (1)$$

Where: F—friction force, N;

N—shear force, N;

$\Phi$ —rock internal friction Angle, ( $^\circ$ );

Q—rock body weight, N;

$\varphi_0$ —friction Angle in shear plane, ( $^\circ$ );

With the top coal and both sides of the coal wall as the boundary to form an equivalent coal wall fixed beam structure, ignoring the effect of vertical stress, if there is a horizontal uniform load  $q_0$  on the roadway wall. According to the calculation of the mechanical formula, the bending moment generated by the fixed beam structure is:

$$M_1 = \frac{q_0 h^2}{12} \quad (2)$$

Formula:

$M_1$ —Bending moment generated by fixed beam structure, KN·m;

$q_0$ —horizontal uniform load, KN/m;

h—roadway height, m;

According to formula (2), the bending moment of the fixed constrained end of the fixed supported beam is obtained. The bending moment diagram of the roadway side is shown in Figure 4.

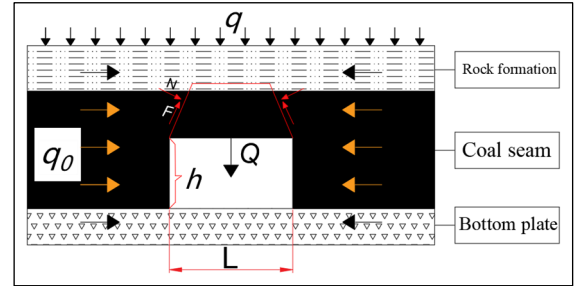


Figure 3. Stability analysis model of top coal tunnel

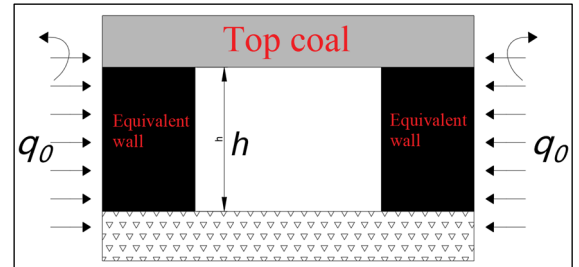


Figure 4. Tunnel side bending moment diagram

In the model, the equivalent coal wall is taken as the fulcrum, and the top coal is taken as the simple supported beam for force analysis. The simple supported beam is subject to the joint action of uniform load  $q$  and equivalent coal wall support, and the bending moment  $M_2$  of reverse action is generated at both ends. The total load on the coal beam is  $ql$ , and  $l$  is the length of the coal beam (m). According to the symmetry, the constraint reaction at each end is  $ql/2$ . The bending moment  $M_2$  of the coal beam is  $M_2 = ql/2$ . It can be seen from the symmetry that the maximum deflection value of the coal beam appears at the midpoint.

When the bending moment of coal beam and coal beam side is superimposed on each other, the superimposed bending moment  $M$  is:

$$M = M_2 - M_1$$

The maximum deflection value of the structure under the action of superimposed bending moment  $M$  is analyzed by mechanics

Formula:

$$W_{max} = \frac{2Ml^2}{9\sqrt{3}E_m I_m} = \frac{6ql^3 - q_0 h^2 l^2}{54\sqrt{3}E_m I_m} \quad (3)$$

M—superimposed bending moment of the coal beam under uniform load in the vertical direction, KN·m

$E_m$ —elastic modulus of coal beam, MPa;

$I_m$ —section moment of inertia of coal beam,  $m^4$ ;

$M_2$ —reverse bending moment at both ends of the beam, KN·m;

q—Vertical uniform load, KN·m;

The roof of the roadway supporting top coal is affected by the bending moment of the coal beam and the superimposed bending moment of the coal beam side. Because the lithology of the overlying strata is different from that of the top coal, the downward movement rate of the overlying strata in the roadway is lower than that in the middle of the roof, resulting in the coal rock in the middle of the roof being prone to separation. The reaction bending moment of the coal beam side can slow down the subsidence rate of the top rock beam, but it may cause the coal body at the corner of the top wall to break, resulting in shear failure at the top corner of the roof.

## 4. The Law of Mine Pressure Development in Supporting Top Coal Roadway

### 4.1. Top Coal Tunnel Simulation Model

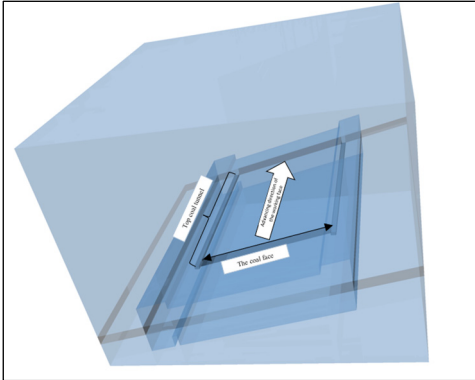


Figure 5. Working face numerical simulation model diagram

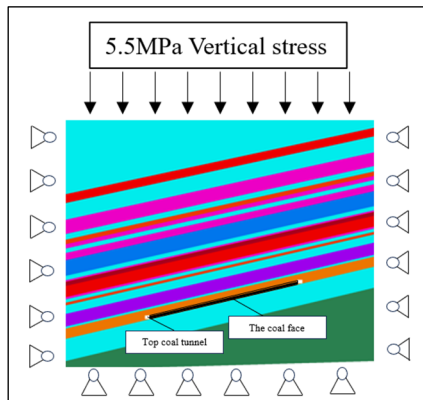


Figure 6. Schematic diagram of boundary constraints for numerical simulation

The model is established with the working face of Zhongma Cun mine as the background. The roadway size is: width × height = 5.0m × 3.5m, and the model size is: length × width × height = 300m × 300m × 235m, as shown in Figure 7. Constraint conditions are applied to the boundary of the model, the top of the model is the stress boundary, and the other three are fixed boundaries to limit the displacement. The

buried depth of coal in the working face is about 380m, and the vertical stress caused by the dead weight is about 9.6MPa. The average height of coal in the working face is 160m from the top of the model. The ground stress exerted on the upper boundary of the model is mainly the vertical stress caused by the dead weight, which is about 5.5MPa.

### 4.2. Lead Abutment Pressure Distribution Characteristics

In the early stage of disturbance of roadway excavation and working face mining, stress concentration cannot be formed due to the failure of the top coal structure. In order to effectively analyze the phenomenon of stress concentration in front of working face, survey lines are arranged at 2m in the coal body of the mining side of transportation lane, with the same height as the height of the roadway, and the starting and ending positions are from the coal wall of working face to 100m in front. A measuring line is arranged along the strike at an interval of 10m between 15m and 75m of the working face to monitor the advance abutment pressure of the working face of the transportation lane. The relevant parameters are shown in Table 1 after sorting out the survey line data.

Table 1. Lead abutment pressure characteristic table

| Advance distance /m | Peak value /MPa | Stress concentration factor | Sphere of influence/m |
|---------------------|-----------------|-----------------------------|-----------------------|
| 15                  | 15.6            | 1.61                        | 22.2                  |
| 25                  | 13.4            | 1.41                        | 23                    |
| 35                  | 13.5            | 1.42                        | 24.3                  |
| 45                  | 14.2            | 1.42                        | 29.1                  |
| 55                  | 14.4            | 1.48                        | 27.1                  |
| 65                  | 14.3            | 1.55                        | 27.4                  |
| 75                  | 15.2            | 1.55                        | 27.6                  |

As can be seen from Table 1: The peak area of advance abutment pressure decreases from 6.0~9.8 when advancing 55m to 8.2~9.4 when advancing 65m. Meanwhile, the influence range of advance abutment pressure decreases from 29.1m when advancing 55m to 28.1m. The comprehensive analysis shows that the initial pressure is triggered by the basic roof break of the cantilever structure during the working face advancing to 45m~55m.

### 4.3. Deformation Characteristics of Roadway Surrounding Rock

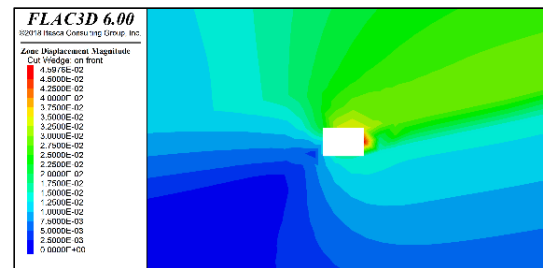


Figure 7. Displacement cloud map at the working face

It can be seen from FIG.5 and 6 that during the initial mining period of 15m, the maximum displacement of the transportation lane occurred in the mining side of the roadway with a displacement of 4.59cm. However, in the advanced working face 9m, there was no displacement area in the deep mining side of the transportation lane. According to the displacement, the area under the advanced influence of the

working face during the initial mining period was less than 9m.

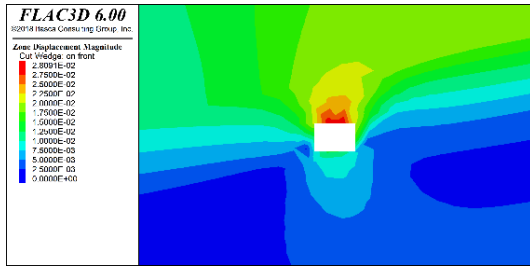


Figure 8. 9m displacement cloud image in front of work

According to the displacement of surrounding rock of the initial 15m mining roadway and the displacement of 2m in the coal pillar at the mining side of the roadway, two measuring lines are set respectively for the advancing working face of 25m~75m, and the displacement of surrounding rock of the roadway and 2m in the coal pillar at the mining side are measured. The displacement data of the surrounding rock of the roadway are obtained as shown in Table 2.

Table 2. Displacement characteristic table of roadway surrounding rock

| Advance distance /m | Maximum displacement of transport trough /cm | Sphere of influence/m |
|---------------------|----------------------------------------------|-----------------------|
| 15                  | 4.59                                         | 9                     |
| 25                  | 3.87                                         | 11                    |
| 35                  | 4.30                                         | 11                    |
| 45                  | 4.83                                         | 11                    |
| 55                  | 5.37                                         | 9                     |
| 65                  | 5.74                                         | 9                     |
| 75                  | 6.15                                         | 9                     |

As can be seen from Table 2, after the initial mining, the top coal discharge began, and the maximum displacement of the transport lane gradually increased from 3.87cm after mining 25m to 6.15cm after mining 75m with the increase of the advancing length. The leading influence area of the working face increased to 11m when the mining was 25m, and changed back to 9m when the mining was 55m, which is speculated to be caused by the initial pressure of the fully mechanized caving face during the period of 45-55m, which is also consistent with the characteristics of the leading abutment pressure analyzed in the previous analysis.

#### 4.4. Development Law of Advance Abutment Pressure in Coal Supporting Tunnel

In order to more intuitively study and analyze the law of mine pressure development in the roadway supporting top coal, the stress monitoring of the single support pillar and the stress monitoring of the roadway roof anchor cable are respectively monitored. Monitoring the stress on the single pillar 100m away from the cutting eye; At the same time, the stress of the roof anchor cable is monitored at a 2m interval. The monitoring data are summarized in the following graph.

As can be seen from FIG. 7, the stress on the working face reaches the peak value when the working face is pushed to about 51m, and the stress on the working face decreases sharply after the working face continues to push. As can be seen from Figure 8, when the working face is pushed 15m~45m, the influence range of the leading abutment

pressure on the roof increases from 20m to 26m, while when the working face is pushed to 55m, the influence range on the roof drops to 25.9m. According to the analysis of two monitoring data, it can be seen that the basic top of the working face breaks and collapses when it is pushed to about 51m, and the initial pressure occurs.

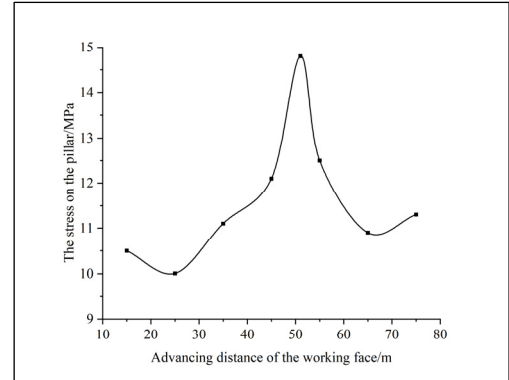


Figure 9. Stress curve of single pillar

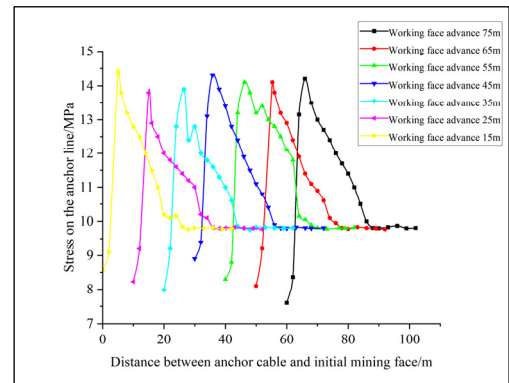


Figure 10. Stress curve of anchor cable on coal side of roof

## 5. Conclusion

According to the geological conditions of the working face of Zhongma Mine, the law of mine pressure development in the working face supporting coal roadway is analyzed theoretically and simulated, and the following conclusions are drawn:

(1) Through theoretical analysis, it is concluded that in the process of fully mechanized caving mining, the direct roof falls with the advance of the working face, while the basic roof with the cantilever beam structure continues to advance with the working face, and the overhanging basic roof accumulates to a certain length and breaks, resulting in the initial pressure.

(2) The peak range and influence range of advance abutment pressure of the top-coal supporting roadway and the influence range of surrounding rock displacement of the top-coal supporting roadway change significantly between 45m and 55m during the advancing of the working face. It can be inferred that the initial pressure is caused by the breaking and turning of the basic roof during the advancing of the working face to 45m and 55m, and the initial pressure step is 45m to 55m.

(3) According to the stress monitoring of the single pillar of the roadway supporting top coal and the stress monitoring of the roof anchor cable during the advancing of the working face, the pillar pressure reaches its peak when the advancing of the working face reaches 51m, and the influence range of

the advance abutment pressure between 45m and 55m of the working face decreases from 28m to 25.9m, which indicates that the initial pressure occurs when the advancing of the working face reaches 51m. The initial compression step is 51m, which is consistent with the initial compression conclusion obtained from the numerical simulation of abutment pressure and the analysis of displacement data of roadway surrounding rock.

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