

# Research on the Relief Effect of Coal and Rock in The Protected Layer Under the Mining Action of The Upper Protective Layer

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**Abstract:** In order to investigate the pressure relief effect of coal and rock in the protected layer during long-distance upper protective layer mining, the FLAC3D numerical simulation software was used to simulate and analyze the deformation and stress changes of the coal and rock layers after upper protective layer mining, and the pressure relief range was verified through on-site drilling. The research results show that: (1) After the mining of the protective layer of the 7 # coal seam, the maximum upward deformation of the roof of the 12 # coal seam can reach 40mm, and the maximum upward deformation of the floor of the 13 # coal seam can reach 35mm. (2) At the middle position of the 13 # coal seam floor, the vertical stress decreased to 2.5MPa, which is 15MPa lower than the original stress. (3) The on-site pressure measurement drilling proved that the mining of the protective layer of the 7 # coal seam had a certain pressure relief effect on the overlying 12 # and 13 # coal seams.

**Keywords:** Protective layer, Pressure relief, Numerical simulation, Deformation, Stress.

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## 1. Introduction

In recent years, with the increasing depth and intensity of coal mining, coal and gas outburst has become increasingly serious, posing a serious threat to the safety of coal production [1-2]. The protective layer mining technology has become an effective technical means for preventing coal and gas outburst [3-4]. Both the "Coal Mine Safety Regulations" and the "Regulations on the Prevention and Control of Coal and Gas Outbursts" regard the mining of protective layers as the main measure to prevent and control coal and gas outburst. It is stipulated that outburst mines must first mine protective layers, and regional outburst prevention measures should prioritize the use of protective layers [5]. Numerous scholars have conducted extensive research on issues such as pressure relief gas extraction and effectiveness evaluation for protruding protected layers. Ren Weiguang et al. [6] found that the stress of the protected layer under the mining method of the protective layer was obtained through similar material simulation tests. During the mining of the upper protective layer, the coal seam pressure first increased and then decreased, and after the mined out area was re compacted and stabilized, the stress state was approximately restored to the original rock stress state. By analyzing the stress state of the protected coal seam after the mining of the protective layer, the stress state of the coal seam after deformation is obtained. After the mining of the upper protective layer, the coal seam of the protected layer undergoes deformation, and the upper part of the coal seam expands and deforms, with a stress lower than the original rock stress. The lower part of the coal seam is compressed, and the stress is greater than the original rock stress. Chai Jing et al. [7] used the mining of the upper protective layer in Hulusu Coal Mine in the Hujilt Mining Area as the research background. Through theoretical analysis and on-site measurement with optical fiber sensing, they analyzed the depth of the bottom plate failure after the upper protective layer was mined, obtained the stress distribution law of the underlying coal and rock body after the

upper protective layer was mined, the stress release rate and its change characteristics of the protected layer, and obtained parameters such as the pressure relief angle of the protected layer and the depth of the bottom plate failure. Zhang Lei [8] used ANSYS software to simulate protective layer mining and explore the stress and deformation patterns of the protected coal seam perpendicular to the coal seam bedding plane as the protective coal seam working face advances. Sa Zhanyou et al. [9] constructed a coal rock creep dynamic model based on the Poyting Thomson model, taking the No.16-17 coal seam of Pingdingshan No. 4 Mine in Henan Province as the object. Using Comsol Multiphysics5.2 software, simulation and engineering verification were conducted on the expansion deformation and pressure relief distribution patterns of the underlying coal seam. Qin Ruxiang et al. [5] took the 18125 working face of Pan'er Coal Mine of Huainan Mining Group Co., Ltd. as the research object, and used numerical simulation calculation and on-site inspection analysis methods to study the stress distribution of the protected layer after mining, the expansion deformation rate of the coal seam roof and floor, and the variation characteristics of the coal seam gas pressure. Gao Zeshuai et al. [10] used PFC2D to study the fracture and collapse of overlying coal layers, crack development, and changes in coal seam porosity during the mining process of the lower protective layer. They also conducted on-site research on the effectiveness of pressure relief gas extraction and coal seam permeability. Liu Jun et al. [11] used FLAC3D numerical simulation software to study the stress distribution and evolution law of surrounding rock after mining the upper and lower protective layers. Based on the distribution of pressure relief range, they achieved precise layout of pressure relief gas extraction drilling holes. Therefore, the author adopts a combination of numerical simulation and on-site investigation to study the pressure relief effect of the upper protective layer in the coal seam group under actual mining conditions, in order to guide the safe and efficient mining of the protected layer.

## 2. Background of Coal Mining Engineering

The Third Mine is located in Shenyang City, Liaoning Province. There are 5 minable coal seams in the mine, including 3 #, 7 #, 12-1 #, 12-2 #, and 13 #. Currently, the 7 # coal seam is the main mining seam. The average distance between 7 coal seams and 12 coal seams is 65m, and the average distance between 12 coal seams and 13 coal seams is 1.8m. At the same time, the relative gas emission from the mine is 7.56m<sup>3</sup>/t, and the absolute gas emission is 39.32m<sup>3</sup>/min, which belongs to a gas mine. Therefore, the pressure relief effect on the 12 # and 13 # coal seams after the mining of the 7 # coal seam is of great significance for the subsequent safe mining of the 12 # and 13 # coal seams. The 703 fully mechanized mining face is located south of the 2 # return air contact road in the West Third Upper Mining Area, adjacent to the 701 goaf in the West Third Upper Mining Area to the east, and the west and south sides are undeveloped areas. The upper and lower coal seams are also undeveloped. The elevation of the working face is -1063~-1095m, the ground elevation is +20.1~+21.8m, the burial depth is 1083.1~1116.8m, the strike length of the working face is 1258m, the dip length is 216m, the average thickness of the pure coal is 2.10m, the dip angle of the coal seam is 3 °~8 °, and the average is 5 °. The strike long arm mining method has a mining height of 3m, and the roof is managed by the full collapse method.

The maximum protection vertical distance when mining the 7 # coal seam as the upper protective layer is calculated according to Appendix E of the "Outburst Prevention Rules". Through calculation, it was found that the theoretical maximum protection vertical distance after mining in the 703 working face of the experimental area is 42m, which is less

than the average distance of 65m between the 7 # and 12 # coal seams.

## 3. Establishment of Numerical Simulation Model

A numerical model was established based on the coal strata and layout of the 703 fully mechanized mining face to simulate the changes in stress field, displacement, and other factors after the mining of the 7 # coal seam, as shown in Figure 1. The specific strength parameters of the geological model in the experimental area are shown in Table 1. The lower part of the model has a fixed boundary, meaning that the displacement in the z-direction at the bottom of the model is zero. The left, right, and front and rear boundaries of the model adopt lateral constraints, and the direction of the coal seam strike is in the x direction. The original rock stress at the upper boundary of the model is 28.6MPa.

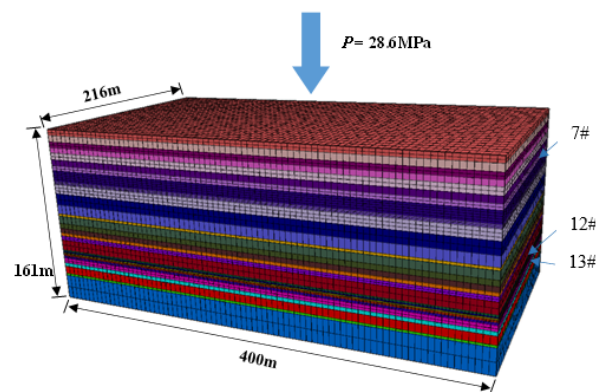


Figure 1. Numerical model

Table 1. Strength parameters of the geological model in the experimental area

Type	Bulk modulus /GPa	Shear modulus /GPa	Density /kg/m <sup>3</sup>	Internal friction angle /°	Cohesion /MPa	Tensile strength /MPa
Siltstone	4.890	6.148	2650	27	3.1	2.4
Fine sandstone	6.667	6.140	2730	33	5.0	1.1
Medium sandstone	4.230	3.000	2720	26	8.43	3.3
Limestone	4.230	2.900	2690	26	6.32	2.5
Coal seam	6.825	6.085	1360	30	3.50	1.8
Clay rock	6.667	6.045	2500	33	9.00	2.50
Mudstone	3.930	3.000	2630	28	6.26	2.4

## 4. Numerical Simulation Results and Analysis

### 4.1. Changes in displacement field after mining of protective layer

During the mining process of the upper protective layer working face, the distribution pattern of top and bottom plate displacement at different advancing distances is shown in Figure 2. From Figure 2, as the working face continues to advance, the top and bottom pressure relief area of the goaf continuously moves towards the middle, and the collapse range behind the goaf gradually increases, resulting in an increase in stress values. The subsidence of the top plate of the upper protective layer working face is significantly greater than the expansion of the bottom plate, and the displacement

change of the working face bottom plate is distributed in an "arch" shape, that is, the displacement change in the middle of the goaf bottom plate is the largest, and the displacement change gradually decreases with the increase of depth from the middle of the goaf bottom plate, indicating that the mining of the upper protective layer has a significant impact on the pressure relief of the underlying coal and rock mass.

When the working face is pushed to 25m, plastic damage begins to occur on the overlying rock of the goaf roof and floor. After the upper protective layer is mined, the overlying coal rock layer on the goaf roof loses its support. Under the action of gravity, the coal rock layer begins to move, deform, bend, sink, detach, and eventually cause damage, forming a falling zone, a fracture zone, and a bending subsidence zone from bottom to top. Overall, the cracks in the coal seam floor of the protective layer working face gradually expand from

top to bottom, and the fracture depth first increases with the increase of mining distance. After the mining of the working

face is completed, the damage depth is basically stable.

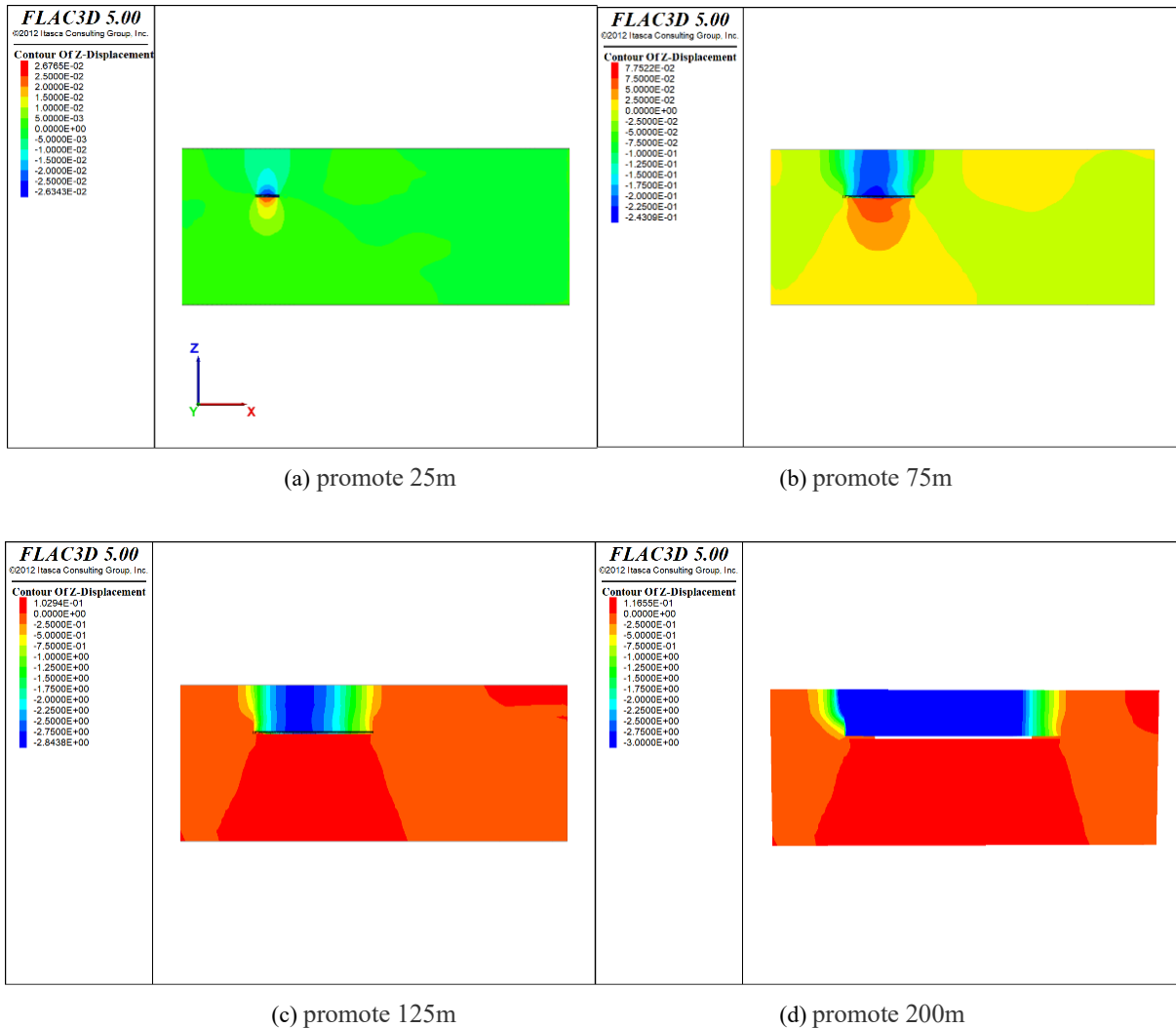


Figure 2. Vertical displacement distribution of top and bottom plates at different propulsion distances

#### 4.2. Changes in stress field after mining of protective layer

The stress changes of the overlying coal rock mass at different driving distances during the mining process of the upper protective layer are shown in Figure 3. From Figure 3, it can be seen that as the working face continues to advance, the farther it is from the working face bottom, the smaller the effective pressure relief range. The stress change below the middle area of the goaf bottom is the greatest, and the stress change of the protected layer is symmetrically distributed in a "V" shape in the vertical direction. That is, the stress change in the middle area of the goaf bottom is the greatest, and the pressure relief influence range of the bottom area is smaller than that of the top plate. And there was a phenomenon of stress concentration near the coal pillars at both ends of the cutting hole and the working face. From the direction of direction, as the working face continues to advance, the stress near the working face increases and the position of the stress concentration area continues to move forward. The longer the advance distance, the larger the range of pressure relief in the

lower part of the goaf. The longer the goaf range, the greater the effective degree and range of pressure relief.

After the mining of the working face is completed, the vertical stress changes of the goaf floor and coal seams 12 and 13 show the trend shown in Figure 4. From Figure 4, it can be seen that when the opening is formed, the vertical stress at the bottom of the working face rapidly increases from the original rock stress to the peak, and then rapidly decreases from near the peak to the minimum value, indicating that before the upper protective layer is mined, a large amount of strain energy is stored in the coal pillar on both sides of the working face. As the working face continues to advance, the overhanging length of the overlying coal rock layer increases, leading to an increase in the self weight of the coal rock mass. At the bottom plate of the protective layer working face, the vertical stress decreases to a minimum of below 1MPa. As the depth of the goaf bottom plate increases, the bottom plate stress gradually increases, showing a symmetrical distribution phenomenon. At the middle position of the 13 # coal seam bottom plate, the vertical stress decreases to 2.5MPa, which is 15MPa lower than the original stress.

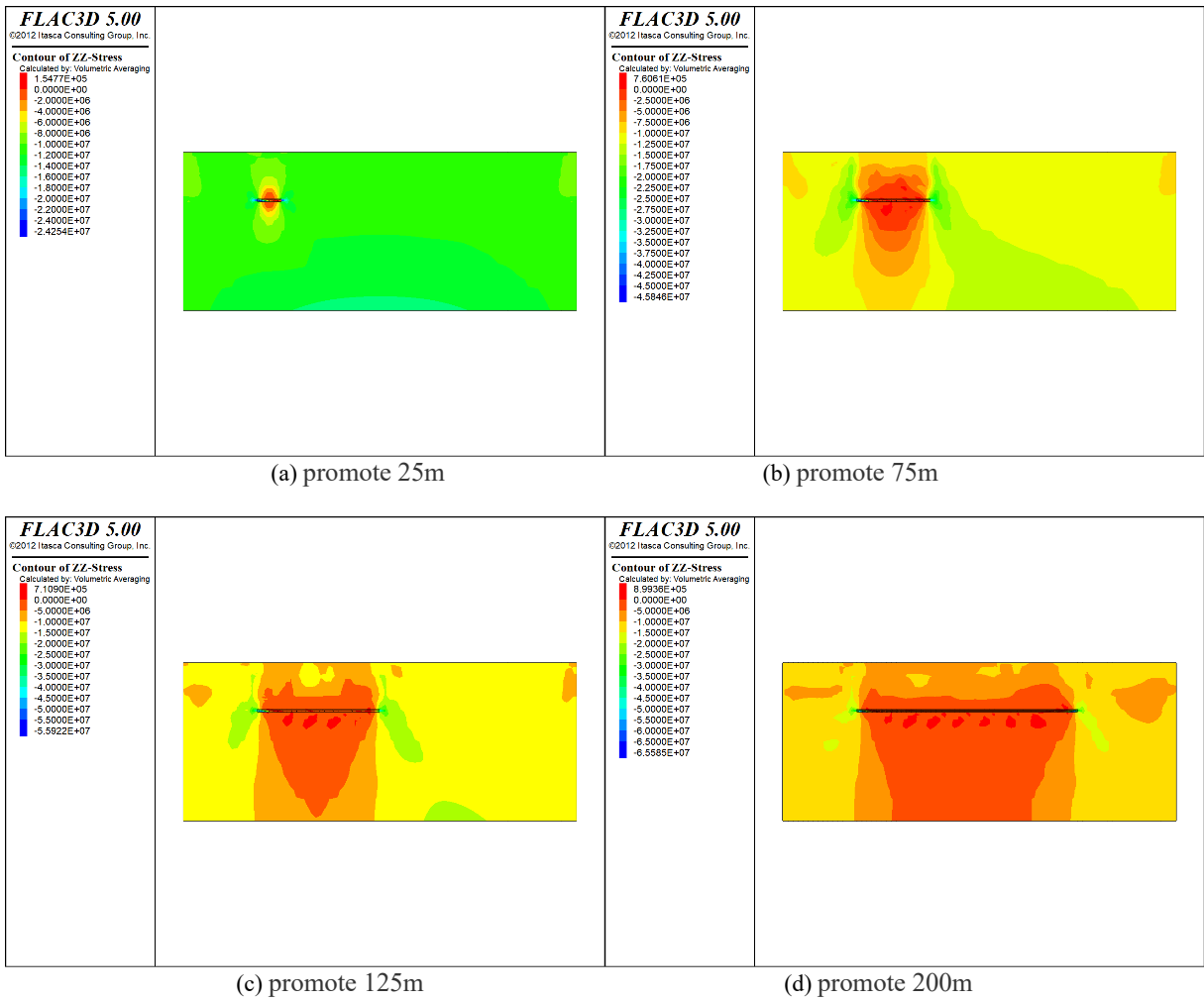


Figure 3. Vertical displacement distribution of top and bottom plates at different propulsion distances

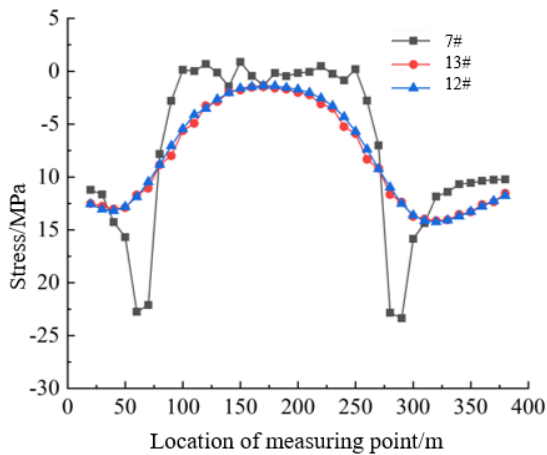


Figure 4. Stress distribution at different burial depth measurement points

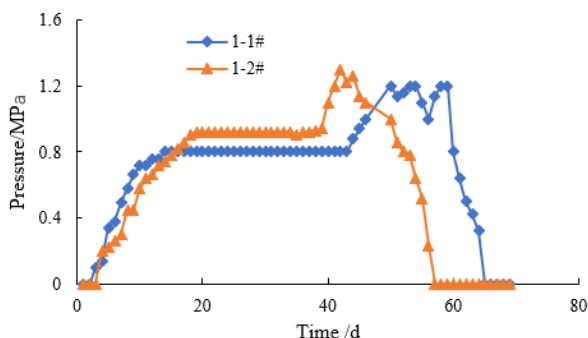
Overall, through numerical simulation of the pressure relief range of the working face in the experimental area, it can be concluded that after the mining of the 7 # coal protective layer, the maximum deformation of the lower 12 # coal roof can reach 40mm, and the maximum deformation of the 13 # coal floor can reach 35mm. Moreover, the vertical stress of the 12 # coal and 13 # coal has been reduced to a certain extent compared to the original stress. At the middle position of the 13 # coal floor, the vertical stress decreases to 2.5MPa, which is 15MPa lower than the original stress. Therefore, the

analysis suggests that the mining of coal seam 7 has played a certain role in relieving pressure on the underlying 12 # and 13 # coal seams, and the reliability of numerical simulation of the pressure relief range of the working face needs to be verified on-site.

## 5. On-site Verification

To verify the accuracy of the numerical simulation results in the experimental area, two downward boreholes were arranged at the intersection of the 703 transportation channel and the 705 working face cut hole based on the on-site roadway layout to measure the comprehensive gas pressure of 12 # and 13 # coal. The designed borehole inclination angle is  $70^\circ$ , which is less than the mining pressure relief angle of the upper protective layer ( $75^\circ$ ), so that the borehole is completely within the pressure relief angle along the inclined direction of the upper protective layer. The borehole numbers are 1-1 # and 1-2 #. After completing the sealing of the pressure measuring borehole and collecting gas samples, a pressure gauge was installed to observe the comprehensive gas pressure of 12 coal and 13 coal. The pressure reading changes are shown in Figure 5. After installing the pressure gauge, the gas pressure from 1 to 1 # gradually increased, reaching a maximum value of 0.8MPa after 15 days. After maintaining stability for 30 days, the gauge pressure began to rise and fluctuated between 1~1.2MPa, and finally decreased in a straight line until it dropped to 0MPa. After installing the pressure gauge 1-2, the gas pressure gradually increases, reaching a maximum value of 0.92MPa after 18 days. After

maintaining stability for 17 days, the gauge pressure starts to rise and fluctuates between 1~1.3MPa, and finally decreases in a straight line until it drops to 0MPa. The results indicate that the 703 working face has played a certain role in relieving pressure on the underlying 12 # coal and 13 # coal after mining.



**Figure 5.** Pressure observation changes in pressure measurement boreholes 1-1 # and 1-2 #

## 6. Conclusion

(1) Through numerical simulation of the pressure relief range of the working face in the experimental area, it can be concluded that after the mining of the protective layer of 7 # coal, the maximum upward deformation of the top plate of 12 # coal can reach 40mm, and the maximum upward deformation of the bottom plate of 13 # coal can reach 35mm. Moreover, the vertical stress of 12 # coal and 13 # coal has decreased to a certain extent compared to the original stress. At the middle position of the bottom plate of 13 # coal, the vertical stress decreases to 2.5MPa, which is 15MPa lower than the original stress.

(2) Based on the analysis of the layout of pressure measuring boreholes, changes in gas pressure, and the impact of mining on the working face, it is believed that the mining of the protective layer of coal seam 7 in the experimental area has played a certain role in relieving pressure on the underlying 12 # and 13 # coal seams.

## Acknowledgment

The study was supported by Tiandi Technology Co., Ltd. Technology Innovation and Entrepreneurship Fund Special Project (2022-2-TD-ZD010) and Key R&D Project of middling coal Science and Engineering Group Chongqing

Research Institute Co., Ltd. (2022ZDXM09).

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