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Research Article

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Study on the Movement and Damage Law of Close Coal Seam Overburden

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Abstract In order to study the overburden damage law of the close coal seam, the overburden movement after mining at the working face was analyzed by using numerical simulation method and verified based on the actual measured data at the site; the dynamic movement law of the overburden of the upper and lower coal seam mining in the close coal seam of Tuanbai coal mine was summarized. The research results show that: within a certain range of the coal column in the section between working faces, the maximum vertical stress can reach 27MPa, and the stress concentration coefficient reaches 3.6; the upper coal seam back mining makes the pressure on the roof of the lower coal seam greater, which leads to the fragmentation of the rock between coal seams and greatly reduces the bearing capacity. The field data shows that the average working face cycle coming pressure step is 9.81m, the average working face dynamic load factor is 1.32, and the average end resistance value of working face bracket is 3686.72kN, which is about 76.8% of the rated working resistance of the bracket, which is consistent with the simulation results.

Keywords proximity coal seam, overburden transport, incoming pressure distribution, stress distribution

1. Introduction

In close coal seam mining, as the distance between coal seams decreases, the mutual influence of mining between upper and lower coal seams will gradually increase, when the coal seam spacing is small, the top plate of the lower coal seam is damaged by the upper coal seam mining, resulting in stress concentration in the roadway [1]. This will reduce the stability of the roadway and lead to difficulties in support [2]. The top plate accident even occurs, which seriously affects the normal production of the mine [3-5]. The normal production of the mine is seriously affected.

In recent years, some scholars have conducted relevant studies on proximate coal seams. Zhang Guojun [6] Using FLAC^{3D} simulation software and combining with field conditions, the mine pressure law of overburden rock in very shallow buried coal seam mining in close proximity was studied; Pan Zhongde [7] used FLAC^{3D} to analyze the reasonable layout of the roadway; Chen Changyi [8] used similar simulation and numerical simulation to investigate the stability time of the overburden layer and the law of roof bubble fall; Cheng Wei [9] constructed a structural mechanics model of the surrounding rock of the close coal seam roadway, analyzed the stress distribution characteristics under the leftover coal column of the upper coal seam, and obtained a reasonable arrangement method of the roadway. However, there is less research on the overburden damage law of close coal seam mining. Therefore, the study of overburden movement and damage law of close coal seam mining can guide the safe mining of coal mines, further improve the safety production level in the area, and produce good social and economic benefits.

2 Project Overview

Tuanbai coal mine is currently mining 11# coal seam, 11# coal seam is located in the lower part of the lower section of Taiyuan Group, and the average spacing between the upper and 10# coal seams is 4.3m, which is a close coal seam. The integrity of the roof plate before mining of the lower coal seam has been affected by the mining damage of the upper coal seam, and the mine pressure of the back mining roadway is very obvious, with special pressure transfer law, large amount of roadway surrounding rock shift, and difficult roadway support.

11101 working face is the first mining face under the 10# and 11# close coal seams of Tuanbai coal mine, with a strike length of 840 m and a tendency length of 135 m. 11101 working face is mainly located below the 111 working face of the overlying 10# coal seam, and the working face roadway arrangement adopts the outward staggered arrangement.

The thickness of 10# coal seam within the mining area of 11101 working face is 2.13m on average, the thickness of 11# coal seam is 1.20-6.13m, 3.49m on average, the dip angle of coal seam is 1°~9°, 4° on average; the old top is K2 tuff, 9.7m thick, with 0. 4m mudstone in the middle; the direct top is siltstone, 5.4m thick; the direct bottom is aluminous mudstone, 1.5m thick. Mud structure.

3. Numerical simulation study of the movement law of the coal bed overburden at close range

In order to investigate the overburden movement law of upper coal seam mining, this paper uses UDEC (Universal Distinct Element Code) discrete unit method numerical analysis software to investigate the overburden movement law and the state of each stage after mining at the working face.

3.1 Modeling

According to the lithology, hardness and thickness of the overlying coal seam, each layer of overlying rock is divided into several blocks, as shown in Figure 1, and each block can form a deformation body by generating a finite unit, and the unit division of the block is shown in Figure 2.

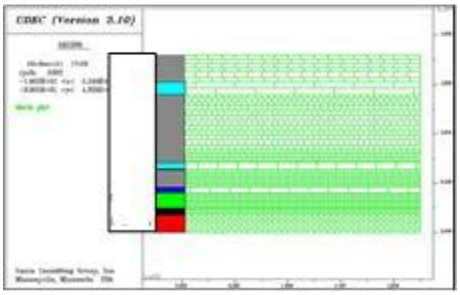

Figure 1: UDEC numerical simulation model

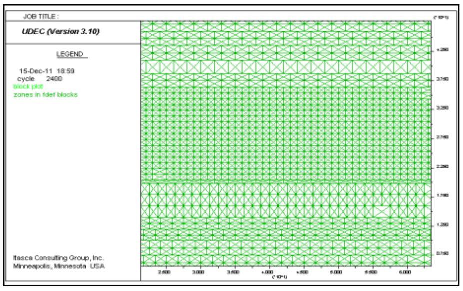

Figure 2: Block cell division (partial enlargement)

3.2 Measurement line and measurement point arrangement

Measurement points and lines were arranged on the model to track the stress distribution within this marker layer and its coal rock seam subsidence and deformation pattern during the mining process, as shown in Figure 3.

Seven measurement lines L1, L2, L3, L4, L5, L6, L7 are arranged in the coal seam and in the coal rock layers of different levels to track the evolution of vertical stresses in the coal seam floor, roof, old roof, sub-critical layer, main critical layer and special rock layers under the action of mining of No.3 coal seam, and to observe the vertical displacement of each layer overlying the coal seam. Measurement points A, B, C, D and E are used to record the vertical displacement of each special layer at different distances from the working face, and can be used to explore the law of internal vertical stress change.

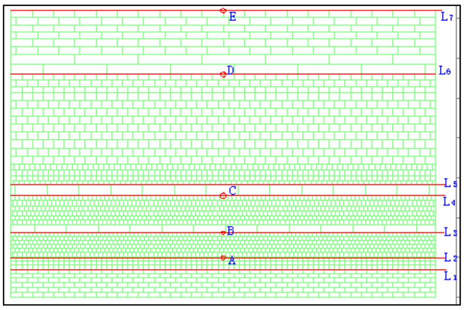

Figure 3: Layout of model laterals and measurement points

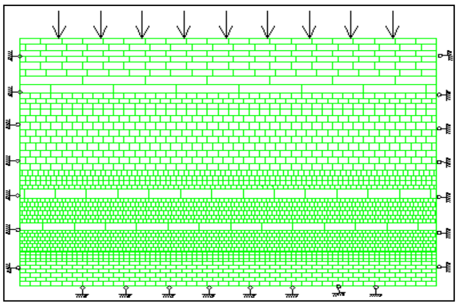

Figure 4: Schematic diagram of boundary conditions of the model

3.3 Boundary conditions

The computational model boundary conditions are shown in Figure 4:

(1) The left, right, front and rear sides of the model are single constraint boundaries with horizontal constraints imposed, i.e., the horizontal displacement of the boundary is zero and the boundary nodes are allowed to move along the vertical direction.

(2) The bottom of the model is a fully constrained boundary, i.e., the horizontal displacement and vertical displacement of the bottom boundary node are zero.

(3) The load boundary conditions of the model, according to the burial depth of the model, the self-weight stress of the original rock acts on the upper boundary.

3.4 Mechanical parameters

For materials such as rocks, which have significant volume deformation during plastic deformation, the effect of volume stress must be taken into account, so the Moore-Coulomb yield criterion in rock mechanics is chosen to express it.

Tensile stress closure zone:

$$I_1^t = T \tag{1-1}$$

Yield surface:

$$f = aI_1 + J_2^{1/2} - k = 0 \tag{1-2}$$

Compressive stress closure zone:

$$I_1^t = I_1^0 \tag{1-3}$$

The principal structure relationship (stress-strain relationship), which is the relationship between plastic stress and strain established by the law of elastic flow, is as follows:

$$d\varepsilon_{ij} = c_{ep} d\sigma_{ij} \tag{1-4}$$

Where, Cep is the elastic-plastic matrix associated with the yield criterion; α ,k yield function, α dimensionless, k , MPa. α ,k is determined experimentally and is usually used to express the rock strength in terms of cohesion with C and the angle of internal friction φ:

$$\alpha = \frac{\sin\varphi}{(9+3\sin^2\varphi)^{1/2}} \tag{1-5}$$

$$k = \frac{3C\cos\varphi}{(9+3\sin^2\varphi)^{1/2}} \tag{1-6}$$

T, I_1^0 - the initial position of the tensile stress zone. The yield surface of the Moore-Coulomb criterion is its damage surface.

The Moore-Coulomb model is used in the calculation, so the main rock mechanics parameters involved include: bulk modulus B, shear modulus G, cohesion C, and internal friction angle φ .

3.5 Simulation results

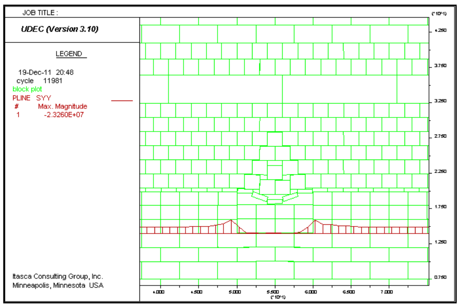

Figure 5: working face advances 10m

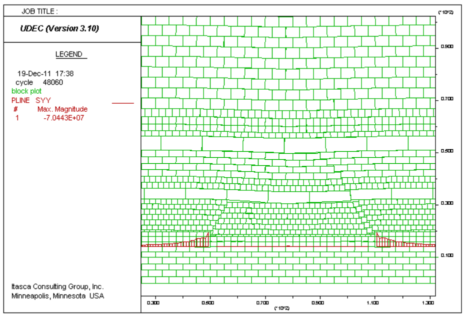

Figure 6. working face advances 60m

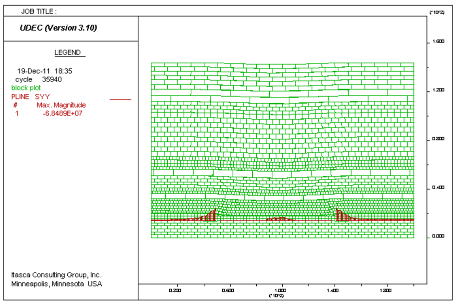

Figure 7: working face advances 90m

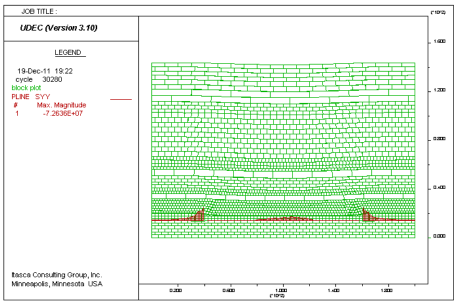

Figure 8: working face advances 120m

As in Figure 5~Figure 8, when the working face advances 10m, the direct top begins to fall off the layer, in the shape of "arch"; when the working face advances 60m, the overhanging area of the old top reaches the limit span and the first fracture touches the gangue, the height of the fall zone reaches the maximum and no longer develops upward; when the working face advances 120m, the working face is fully mined.

4. Coal seam working face roof pressure monitoring statistics

Analyze the mineral pressure manifestation during the recovery of the first mining face of 11# coal seam, summarize and analyze the law of mineral pressure manifestation in the recovery stage of coal seam, and provide actual measurement basis for the study of overburden movement law of mining coal seam.

4.1 Cycle to pressure

Monitoring the mine pressure data during the recovery process of the 11# coal seam retrieval face 11101 retrieval face in Tuanbai coal mine. The pressure monitoring substation sends the recorded data regularly, and the online monitoring data is analyzed by the hydraulic bracket working resistance monitoring system software in the computer, and the statistical results of the working face cycle coming pressure step are shown in Figure 9.

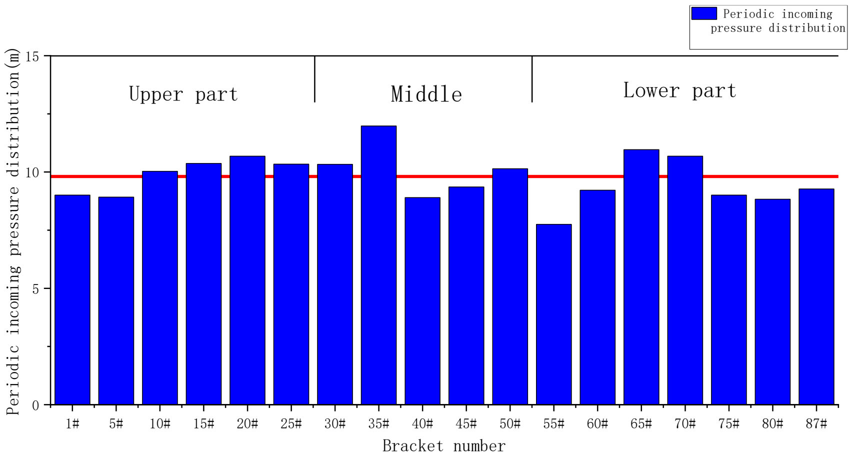

Figure 9: Periodic incoming pressure distribution at the working face

As shown in Figure 9, the average incoming pressure step of working face 11101 is 9.81 m. From the perspective of working face position, the incoming pressure step is the largest in the middle, followed by the head, and the smallest in the tail.

4.2 Analysis of resistance at the end of the bracket

The evaluation of the working performance of the bracket and the degree of roof impact is mainly determined by the percentage of the working resistance of the bracket in different intervals. The specific method of this division is to divide several intervals according to each interval width of 5MPa, and then count the percentage of the working resistance of the stent in each interval section. The statistical results are shown in Figure 10.

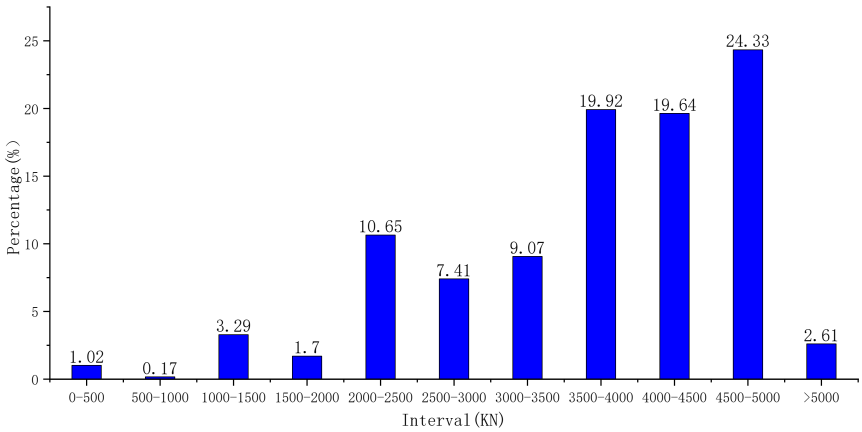

Figure 10: Histogram of frequency statistics of resistance distribution at the end of the support at the working face

As can be seen in the figure10, the average end resistance value of the working face bracket is 3686.72kN, which is about 76.8% of the rated working resistance of the bracket, the end resistance of the working face bracket is mainly distributed above 3500kN, the maximum working resistance of the hydraulic bracket of the working face can reach 5056KN, and the frequency of the end resistance over 3500KN reaches 66.5%. It can be seen that the pressure on the roof plate of the working face of the lower coal seam is very obvious when close back mining in this area.

5. Analysis of overburden damage law of coal seam mining above and below the close coal seam

5.1 Upper coal seam mining overburden rock movement damage law

The upper basic top is far away from the working face, and the thickness and strength are large, the sinking amount is small and will not break, the main role of the pressure on the working face is the lower basic top near the working face, as the working face advances, the lower basic top gradually breaks into neatly arranged blocks along the direction of advancement, forming the periodic pressure on the working face.

According to the theory of "masonry beam", the mining range of the coal seam and the deformation, breakage and movement of the roof rock layer, the coal rock layer above the mining area will form a fall zone Ⅰ, a regular moving zone Ⅱ and a bending sinking zone Ⅲ from bottom to top. After back mining for a period of time, the overburden rock above the mining area can appear three representative parts with time destruction and movement, which are called bubble fall belt, fracture belt and bending belt from bottom to top.

5.2 Lower coal seam mining overburden rock movement damage law

According to the interlayer structure of the upper and lower coal seams in Tuanbai coal mine, the overlying rock layer structure distribution characteristics on the working surface of the coal seam, the overlying rock structure between the coal seams under the near coal mining void area is divided into two categories: no basic top structure between the coal seams and a basic top structure between the coal seams.

1、No basic top structure between coal seams

When there is no basic top structure between coal seams, the lithology of the top plate is weak, and the drilling of the cuthole causes stress concentration in the nearby surrounding rock, which causes plastic deformation in the cuthole and keeps stable under the support of anchor rods, and when the anchor rods are removed in the initial mining, there is no support on the coal wall side of the cuthole at this time, which may cause the top plate of the upper part of the coal wall to fall. situation.

2、There is basic top structure between coal seams

When the coal seam spacing is large, the destruction of the rock between coal seams is not sufficient, and because the direct top of 11# coal seam is siltstone, the content of Al_2O_3 cement in the top plate of each stratum is slightly higher than the content of Al_2O_3 in the loess, so it is easy to form a regenerated top plate after encountering water. Therefore, when the overlying rocks of the lower coal seam are affected by mining, they will not collapse immediately, but will form a "masonry beam" structure to prevent further downward sliding of the upper mining area.

Its breakage and destabilization characteristics depend on whether the "masonry beam" structure is destabilized after the breakage of the main key layer of the overburden after the mining of the upper coal seam, and the S-R stability criterion of the "masonry beam" structure is used to determine:

$$h + h_1 \geq \frac{\sigma_c}{30\rho g}\left(\tan\varphi + \frac{3}{4}\sin\theta_1\right)^2 \qquad \text{(S Judgment)}$$

$$h + h_1 \geq \frac{0.15\sigma_c}{40\rho g}\left(i^2 - \frac{3}{2}i\sin\theta_1 + \frac{1}{2}\sin^2\theta_1\right) \qquad \text{(R Judgment)}$$

Where: h - thickness of the critical layer, m;

h_1 - thickness of the rock layer loaded by the key layer, m;

σ_c - compressive strength of the critical layer, MPa;

ρg - the bulk force of the rock mass;

θ_1 - angle of reversal of the overhanging rock mass in the masonry beam after fracture, °;

tanφ - the friction factor between the rock masses;

i - the thickness to length ratio of the rock mass, i.e. i = h/l (l is the length of the rock mass).

If the key layer structure of the roof of the upper coal seam has been destabilized before the mining of the lower coal seam, all the rock loads will act on a single key layer between two coal seams, at this time, the h1 in the S criterion is too large so that the "masonry beam" structure after the key layer of the upper coal seam is broken cannot meet the "masonry beam The "masonry beam" structure after the breakage of the key seam of the upper coal seam cannot meet the conditions of the "masonry beam" structure of the slip destabilization, which leads to the occurrence of dynamic mine pressure during the mining of the lower coal seam.

6. Conclusion

In this paper, the following results were obtained by using field measured data, numerical simulation and similar simulation to study the movement and dynamic damage law of coal seam mining overburden above and below the close coal seam:

(1) The numerical simulation results show that the upper coal seam retraction makes the pressure on the roof of the lower coal seam greater, resulting in the fragmentation of the rock layer between the coal seams and the reduction of the bearing capacity.

(2) Field data show that the average working face cycle pressure step is 9.81m, the average working face dynamic load factor is 1.32, the average end resistance value of the working face bracket is 3686.72kN, which is about 76.8% of the rated working resistance of the bracket, and the pressure on the roof of the working face of the lower coal seam is very obvious when close back mining.

(3) Through analysis of field measurement data and numerical simulation, the dynamic movement law of overburden rock of upper and lower coal seam mining in Tuanbai coalfield close to the coal seam is summarized: the movement law of overburden rock after mining in upper coal seam is similar to the movement law of overburden rock after mining in single coal seam; the movement law of overburden rock after mining in lower coal seam depends on the inter-seam structure, when the basic top structure exists in the inter-seam structure, the "masonry beam The S-R stability criterion of the "masonry beam" structure can be used to determine the overburden damage mode.

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