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Study on Surrounding Rock Stability of Long-Span Coal Roadway under Influence of Mining and Support Technology Optimization

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Abstract: Taking stoping safety of large-span working face in a coal mine in Shanxi as the background, the damage and movement law of overlying strata structure in coal roadways under the influence of mining are studied. Combined with the actual production of the mine, the mining pressure characteristics of the working face and the influence range of mining in the working face are mastered. Main research contents and conclusions are that: (1) Numerical simulation of roadway stability is carried out using UDEC software, stimulating the stress and strain variation of surrounding rock under unsupported state. Based on this, the roadway support parameters are simulated and optimized, which provides valuable reference for practical engineering. (2) Study the simplified design process of bolt support parameters, improve the accuracy of bolt support parameters and reduce the cost of coal mine support to increase the incidence of coal mine roof accidents, providing a basis for coal mine safety production.

1. Introduction

In recent years, with the improvement of mechanized level of fully mechanized top coal caving, the mining strength and output of fully mechanized caving face have been greatly improved, with more and more coal roadways of large section[1]. Due to the low strength of the surrounding rock of the roadway, the significant large section makes the deformation of the roadway increase and the damage of the high roof separation layer and the support body is prominent[2]. Besides, the adjacent working face and the own working face are affected by the drastic mining, so the horizontal crushing damage of the poof often occurs in the roadway, and the roof collapse frequently happens[3]. Because there is no mature roof control theory of the fully-mechanized and long span coal roadway, the excavation of such coal roadway under the severe influence mining is delayed, seriously hindering the normal production of the enterprise[4].

Based on the actual production situation of a coal mine in China Coal Mine, this paper studies the surrounding rock deformation of stoping roadways and the support system, reveals the mechanical mechanism and basic laws of the surrounding rock deformation of coal seam roadways in fully mechanized caving mining, which provides a scientific basis for solving the problems of stoping roadway support and the control of surrounding rock and roof.

2. Numerical simulation of overlying rock movement law and stability of stoping roadways in the working face of no.9 coal seam

2.1 Numerical simulation content

(1) Movement law of overlying strata in No. 9 coal seam
The No. 9 coal seam is divided into three working faces of 912, 913 and 914. The working face 914 is taken as the research object to simulate the law of rock movement during the stoping process.

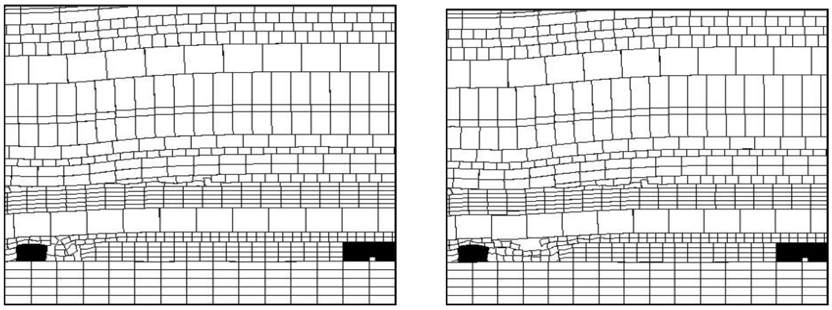
(2) Stability of stoping roadway of No.9 coal seam in mining liberated seam
The influence of stoping in the working face 914 on the roadway along the gob-side entry is simulated; The influence of stoping in the working face 914 on the solid coal roadway is simulated.

2.2 Simulation method

Stoping sequence in the working face: The working face 914 is excavated from left to right and right to left respectively, by excavating 30m each time.

2.3 Analysis of simulation results

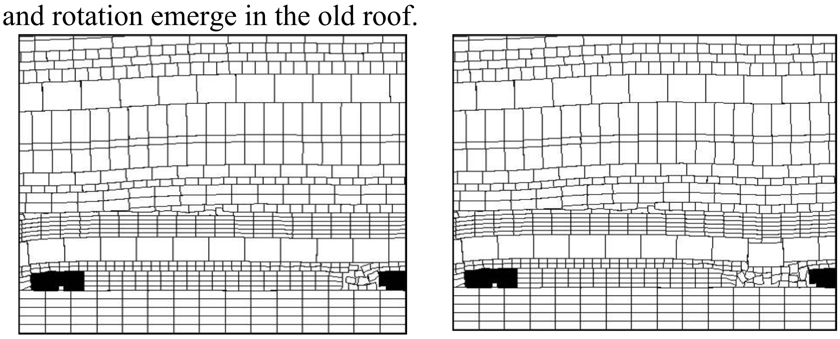
(1) Movement law of the rock in the roof of the working face
Movement Law of the roof rock during the stoping in the working face 914
Figure 1 displays the movement effect sketches of the rock stratum during the stoping in the working face 914 from left to right. It can be seen from the figure that when the working surface is propelled by 30m, the direct roof falls, and the old roof is bent to sedimentation. When the working surface is propelled by 60m, the direct roof totally collapses, and the direct roof and the old roof are separated, with the formation of rock skeleton structure in the old roof.



(a) Propelled by 30m (b) Propelled by 60m

Figure 1 Movement effect sketches of the rock stratum in the working face 914 (from left to right)

Figure 1 displays the movement effect sketch of the rock stratum during the stoping in the working face 914 from right to left. As can be seen from the figure, when the working surface is propelled by 30m, the direct roof will locally fall, with an appearance of separation layer between the old roof and the direct roof, and the old roof is bent to sedimentation. When the working surface is propelled by 60m, fracture and rotation emerge in the old roof.



(a) Propelled by 30m (b) Propelled by 60m

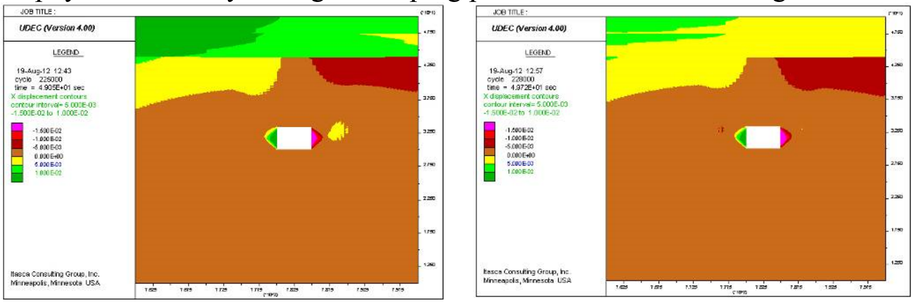
Figure 2 Movement effect sketch of the rock stratum in the working face 914 (from right to left)

It can be seen from the above simulation results that the movement laws of the roof rock stratum during the mining process in the No.9 working face are similar. When the working face is propelled by 30 m, the direct roof is completely collapsed. When it is propelled by 60 m, the old roof fractures and rotates. With the progress of the working face, periodic fractures occur in the old roof.

(2) Influence of mining in the working face on the stability of stoping roadway

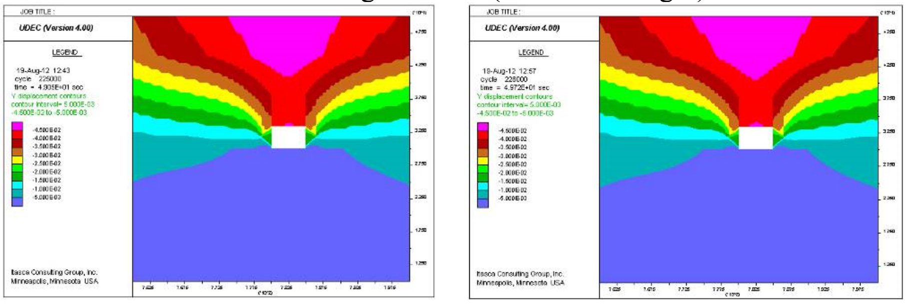
Influence of the stoping in working face 914 on the stability of physical roadway

Figure 3 and Figure 4 present the horizontal displacement cloud map and vertical displacement cloud map of the physical roadway during the stoping process in the 914 working face.



(a) Propelled by 30m (b) Propelled by 60m

Figure 3 Horizontal displacement cloud map of the physical roadway during the stoping process in the working face 914 (from left to right)



(a) Propelled by 30m (b) Propelled by 60m

Figure 4 Vertical displacement cloud map of the physical roadway during the stoping process in the working face 914 (from left to right)

As can be seen from Figures 3 and 4, when the distance from the working surface to the physical roadway is greater than 40m, the variations of the sides and the roof-to-floor convergence are small. When the distance from the working surface to the physical roadway is less than 40m, the surrounding rock deformation of the roadway increased sharply. When the distance from the working surface to the physical roadway is 10m, the convergence of the roadway sides and the roof-to-floor convergence both reach 1000mm. Therefore, the influence distance and influence degree of the mining physical roadway in the working face are small.

3. Deformation mechanism and control technology of surrounding rock in long-span roadway of dynamic pressure

3.1 Deformation mechanism of surrounding rock in long-span roadway of dynamic pressure

The deformation process of surrounding rock in long-span roadway of dynamic pressure is shown in Figure 5. It can be seen from the figure that the surrounding rock deformation of this type of roadway can be divided into the following stages:

1) The roof rock stratum is subjected to vertical loads. Due to the influence in advance of the mining in the working face and the lateral bearing pressure, the roof rock stratum of the working face will be subjected to a large vertical stress.

2) Both sides of the roof are subjected to a large horizontal stress, which causes deflection and separation of the roadway roof. Under the horizontal stress and the deadweight of the roof, the roadway roof subsides, and if the support is unreasonable, a roof falling accident extremely likely to occurred.

3) Under the large vertical stress and horizontal stress, the shear stress that the shoulder angle of the roadway suffered will cause the dilatancy and expansion of the rock mass and promote the subsidence of the roof.

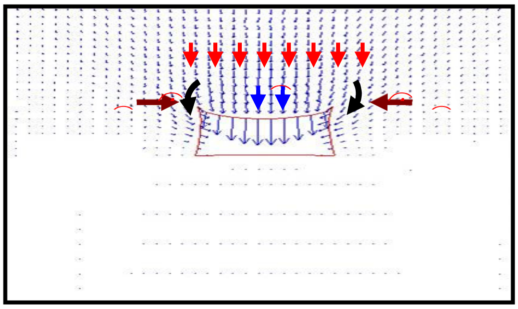
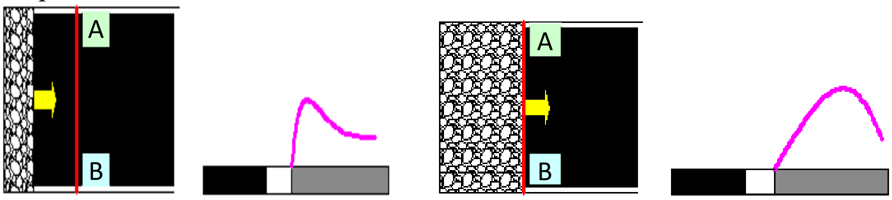


Figure 5 Schematic diagram of deformation mechanism of surrounding rock in long-span roadway of dynamic pressure

For the gate entry of the working face, it will certainly experience the advanced impact of the working face, as shown in Figure 6, and there must be the above-mentioned surrounding rock deformation process.



(a) (b)

Figure 6 Evolution process of lateral bearing pressure in the working face

Based on the above analysis, an effective way to control the deformation of the surrounding rock of the working face is to strengthen the roof control of the roadway.

3.2 The control technology of the surrounding rock of the gate entry in the working face 914

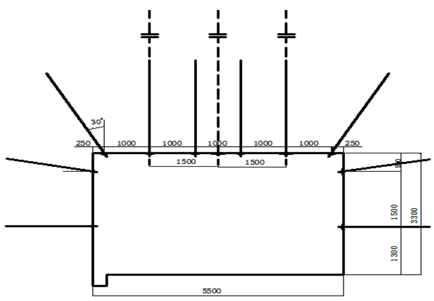
According to the site survey and the results from the geological data review, the headentry and tailentry of the working face 914 are both caved along the coal seam floor. The coal seam floor is quite hard, and under the current mining conditions, generally no obvious floor heave occur. Therefore, the deformation of the gate entry in the working face 914 is mainly concentrated on the two sides and the roof.

Because the roof and the two sides are relatively soft coal bodies, under the concentrated stresses, it is easy for the two sides to move closer and the roof to subside. The top coal and the roof rock stratum will be combined to the composite rock stratum. If the control is weak, the top coal and the roof rock stratum will fall off, and a roof collapse occurs. Therefore, under the mining and geological conditions of the face 914, the gate entry roof is the focus to control. Due to the shallow burial depth of the gate entry and the hard coal body, the current and relatively mature anchor bolt-cable support technology can effectively control the roof of the roadway, and the cost saving is the key to design the support for the gate entry.

3.3 Control Scheme

In general, the row spacing of the side bolts is the same as that of the roof bolts. The role of the anchor bolts is to inhibit the loosening and extrusion of the coal bodies in the roadway sides due to shear failure. Therefore, the sum of the shearing forces of the anchor bolts should be greater than the weight of the coal body within the damage range of the sides, and the two supporting schemes for determining the gate entry in the working face 914 are shown in Figures 7 and 8, respectively.

Scheme 1: the sides use 2 FRP anchor bolts, while Scheme 2: the sides use 1 metal anchor bolt.



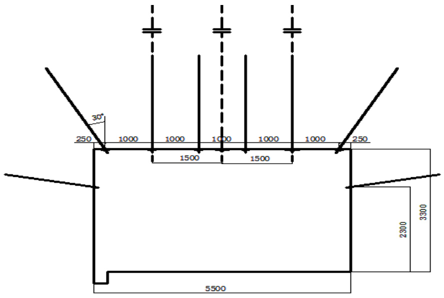
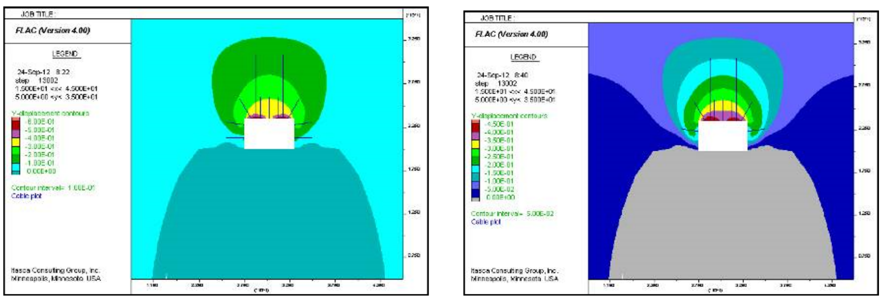


Figure 7 Support effect diagram of Scheme 1 Figure 8 Support effect diagram of Scheme 2

In order to compare the advantages and disadvantages of these two schemes, the numerical simulation method is still used to compare the support effects. It can be seen from the existing analysis results that these two schemes can meet the requirements of roadway control when they are not affected in advance by the working face. Consequently, here only the stability of the roadway affected in advance by the working face is simulated analyzed.

1) Comparison of the roof subsidence

Figure 9 displays the vertical displacement cloud of the surrounding rock of the roadway. As can be seen from the figure, under the condition of the Scheme 1 implemented, the maximum subsidence amount of the roadway roof is 600mm, and the average subsidence amount is about 350mm; under the condition of the Scheme 2 implemented, the maximum subsidence amount of the roadway roof is 450mm, and the average subsidence amount is about 350m. Visibly, the support effects of the two schemes are little different. In addition, the pre-tightening force exerted by the metal anchor bolt is larger than that by the FRP bolt, and its supporting strength is relatively larger. The comparison shows that the reinforcement of the two sides is advantageous for controlling the subsidence of the roof.

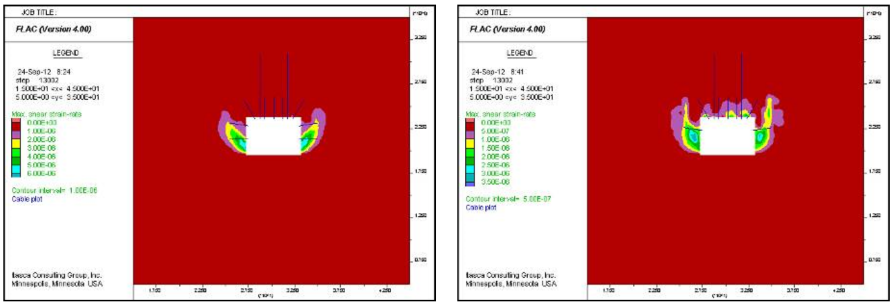


(a) Scheme 1 (b) Scheme 2

Figure 9 Vertical displacement cloud map of the roadway surrounding rock

2) Comparison of the shear strain of the roadway surrounding rock

Figure 10 shows the shear strain distribution of the surrounding rock of the roadway. It can be seen from the figure that the shear strain of the roadway surrounding rock mainly occurs in the two sides, and the maximum shear strain occurs at 1.5m away from the side. Visibly, the anchor bolt with a length of 2.0 m can basically pass through the maximum shear strain zone; under the condition of the Scheme 1 implemented, the shear strain of the roadway sides is larger. From the perspective of shear strain distribution, the effect of Scheme 2 is better than that of Scheme 1.

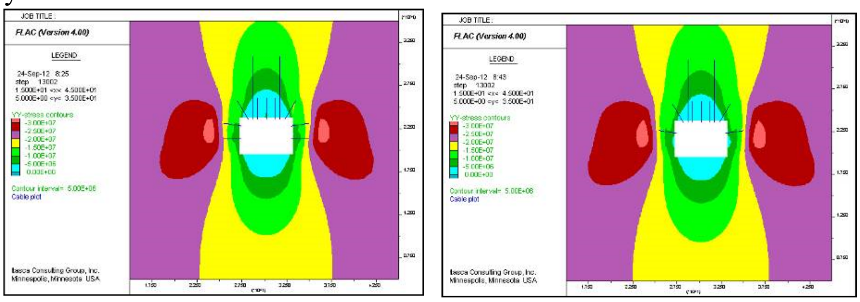


(a) Scheme 1 (b) Scheme 2

Figure 10 Horizontal displacement cloud map of the roadway surrounding rock

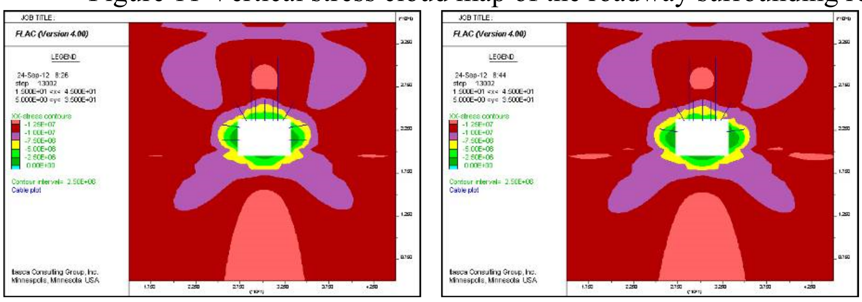
3) Comparison of stress distribution of surrounding rock of roadway

Figures 11 and 12 show the vertical stress distribution cloud map and horizontal stress distribution cloud map of the surrounding rock of the roadway. As can been seen from the figure, under the conditions of Scheme 1 adopted and Scheme 2 adopted, the stress distributions of the roadway surrounding rock are completely consistent.



(a) Scheme 1 (b) Scheme 2

Figure 11 Vertical stress cloud map of the roadway surrounding rock



(a) Scheme 1 (b) Scheme 2

Figure 12 Horizontal displacement cloud map of the roadway surrounding rock

By comparing the subsidence amount of the roadway roof, the strain variations and stresses of the surrounding rock when two schemes are adopted, it can be concluded that: (1) from the perspective of surrounding rock control effect, the effects of the two schemes are basically the same and meet the engineering requirements. (2) From the perspective of the shear strain distribution of the sides, the Scheme 2 is superior to the Scheme 1.

4. Conclusion

(1) The support method and support strength of the gate entry in the working face 914 can meet the engineering requirements. After the influence of mining in the working face, the deformation of the roadway surrounding rock and the stress subjected to the anchor bolts are small. The root causes are the larger strength of the roadway surrounding rock and good conditions of the surrounding rock.

(2) The numerical simulation results show that as the influence of mining on the roadways extends, the subsidence of the roadway roof increases gradually, and the distribution range of the plastic zone of the surrounding rock expands gradually. The roof subsidence of the roadway is the main deformation

feature of the surrounding rock of the large-span roadway, and the roof is the focus of the surrounding rock control of the gate entry in the working face 914.

(3) According to the geological conditions of the gate entry surrounding rock, and aiming at the support of the sides, two schemes are put forward: one is to use two FRP bolts for the sides, and the other is to use one metal anchor bolt for the sides.

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