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Research Article

Analysis on Spatial Disturbance Influence of Surrounding Rock Stress in the Staggered Roadways and Its Control Countermeasures

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Combined with specific engineering examples, the spatial disturbance influence characteristics and laws of the surrounding rock stress in the staggered roadways are analyzed by numerical simulation. This paper concludes that (1) compared with the surrounding rock pressure behavior of the general roadway, the surrounding rock stability of the staggered roadway is relatively poor, showing the characteristics of the local serious roadway rock pressure behavior, such as the intensified destruction of the roadway side, the failure and fracture penetration of the surrounding rock between the roadways, and the relatively serious deformation of the surrounding rock. The reason is that the stress of the surrounding rock at the staggered roadway position is obviously superimposed and disturbed by each other; (2) the influencing factors of the failure and instability of the surrounding rock between interlaced roadways are as follows: the greater the buried depth and the smaller the distance between roadways, the more intense the superposition disturbance of the surrounding rock stress between roadways; the smaller the horizontal azimuth, the greater the influence range of superposition disturbance of surrounding rock stress between roadways; the more unbalanced the original rock stress field, the worse the stability of the surrounding rock between roadways, resulting in the more serious failure and instability of the surrounding rock between roadways; (3) for the staggered roadway layout, increasing the distance between roadways, the closer to the orthogonal layout and selecting the arch section of the lower roadway is conducive to the bearing stability of the surrounding rock between roadways; (4) constrained by the space conditions of staggered roadway, the role of bolt and cable support is limited. Passive support is the key to realize the safety and stability of surrounding rock of staggered roadway, so the control technical scheme of active and passive combined support in staggered roadway position is put forward, the combined support of the upper roadway "bolt + cable + shotcrete + concrete cushion of floor" and lower roadway "bolt + cable + U-shaped steel support passive reinforcement + shotcrete" within the spatial disturbance influence the range of surrounding rock stress in the staggered roadways, and the technical scheme can achieve satisfactory supporting effect.

1. Introduction

In mining engineering, underground geotechnical engineering, hydropower engineering, and other fields, it is common to meet the engineering situation of roadways (tunnels) with spatial staggered layout. In the position and nearby of staggered roadways, the local surrounding rock stress superposition and mutual interference are formed, which not only aggravates the failure and instability of surrounding rock but also is relatively more sensitive to the mechanical response of many influencing factors, which leads to serious engineering problems such as roof caving and instability of roadway sides in the staggered position, and once the bearing surrounding rock of the staggered roadways is unstable, the whole safety production system of the coal mine will be seriously damage. Studying the instability of complex space roadway such as staggered roadway is very important to ensure the safety and stability of underground engineering.

The instability of complex space roadway such as staggered roadway has attracted much attention. Some scholars take the close distance parallel tunnel as the engineering object, analyze the failure of parallel tunnels stress disturbance through numerical simulation, and reveal that the bearing capacity of surrounding rock between parallel tunnels is weakened and the failure of surrounding rock stress disturbance [1–7]. Several scholars analyzed the surrounding rock stability of the parallel roadways in the underground mine site and then revealed the stress disturbance distribution of "double peak" superposition in the surrounding rock of the close parallel roadways [8–11]. Many scholars analyzed the distribution characteristics of surrounding rock stress caused by the spatial staggered layout of underground multiple roadways and then proposed targeted technical measures such as surrounding rock grouting repair, the combined support of bolt + mesh + shotcreting, the strong support of steel reinforced concrete, and so on so as to optimize the bearing stability of surrounding rock between multiple roadways [12–16]. Other scholars have carried out numerical simulation and engineering practice research on spatial staggered roadways, through optimizing the spatial layout of roadways, designing the optimal excavation process and selecting reasonable support technology scheme, the surrounding rock disturbance influence degree of the staggered roadways is improved, and the surrounding rock stability control of deep mine caverns is realized [17–20]. Bu Qingwei, Xin Yajun, and Ye Meng analyzed the failure and instability characteristics of the surrounding rock of the staggered roadways in coal mine, established the mechanical analysis equation of the surrounding rock failure of the staggered roadways, and provided a theoretical discrimination method for the break through and instability of surrounding rock mass between roadways [21, 22].

At present, there are many technical achievements on the stability support of staggered roadways, but most of the technical schemes are only put forward based on experience and lack of reliable scientific basis. There is still little scientific analysis on the stress disturbance influence and instability of the surrounding rock in staggered roadways, and the existing results cannot meet the needs of the surrounding rock stability control. Therefore, in this paper, combined with specific engineering examples, through numerical simulation, the spatial disturbance influence of the surrounding rock stress in the staggered roadways is analyzed, and the characteristic laws of the main control factors on the spatial disturbance influence of the surrounding rock stress are revealed, so as to provide a valuable research basis and reference for the stability control of the staggered roadways.

2. Analysis of Engineering Situation

During the main mining period of No.9 coal seam (buried depth 520 m, average thickness 2.67 m) in Linnancang Coal Mine, a group of special transportation uphill and return air uphill were arranged to serve the production of mining area. However, the transportation roadway of 2294 working face must be driven across the special return air uphill to complete the layout of the mining roadway. According to the engineering situation of the coal mine, it is known that there is a spatial staggered layout relationship between the 2294 transport roadway (the upper roadway) and the special return air uphill (the lower roadway), the roadway spacing distance in the staggered position is only 3.0 m, and the horizontal azimuth angle is 57°. The spatial staggered roadways layout is shown in Figure 1.

During the roadway construction, there are safety concerns about the staggered roadways layout with short distance. The excavation of 2294 transport roadway causes secondary disturbance to the lower special return air uphill, once the bearing capacity of the lower special return air uphill exceeds limit and which will lead to the breakthrough and instability of surrounding rock in the staggered roadways. Due to the different uses of the lower roadway and upper roadway, the staggered roadways instability will lead to the production stoppage and the safety system failure in the mining area. Therefore, it is necessary to carry out the analysis of the spatial disturbance influence of the staggered roadways and study the surrounding rock stability control to guide the support technical design of the staggered roadways.

3. Spatial Disturbance Influence Characteristics of Surrounding Rock Stress in Staggered Roadways

Considering the spatial characteristics and complex analysis of surrounding rock failure and instability of staggered roadway, in this paper, the numerical simulation method is used to analyze the spatial disturbance characteristics of the surrounding rock stress and the influence law of the main factors from three aspects of the surrounding rock stress field, displacement field, and surrounding rock failure distribution.

3.1. Modeling and Simulation Parameter. Taking the staggered roadways with the 2294 transport gateway and special return air uphill as the research objects, the upper 2294 transportation roadway is a rectangular roadway (4400 mm × 3500 mm), and the lower special return air uphill is a semicircular straight wall arch roadway (4400 mm × 3800 mm), the two roadways are spatially staggered layout with 3 m spatial distance and 57° horizontal azimuth angle, the model size is 80 m (X) × 80 m (Y) × 40 m (Z) and is divided into 118 360 units, the numerical modeling is shown in Figure 2.

The lateral boundary and bottom boundary of the numerical model are constrained by displacement; the top boundary is the stress boundary and the original rock stress environment is 13.5 MPa (the buried depth is 520 m). The widely used Mohr-Coulomb constitutive model is used for the simulation. The simulation parameters are shown in Table 1. The simulation scheme settings of main influencing factors are shown in Table 2.

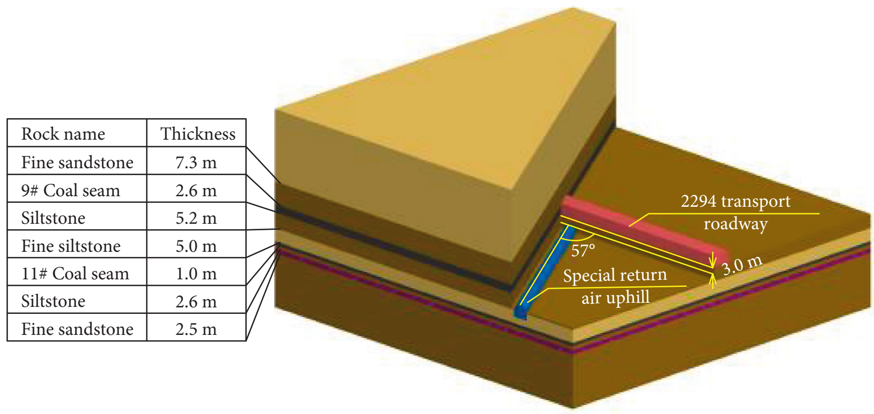
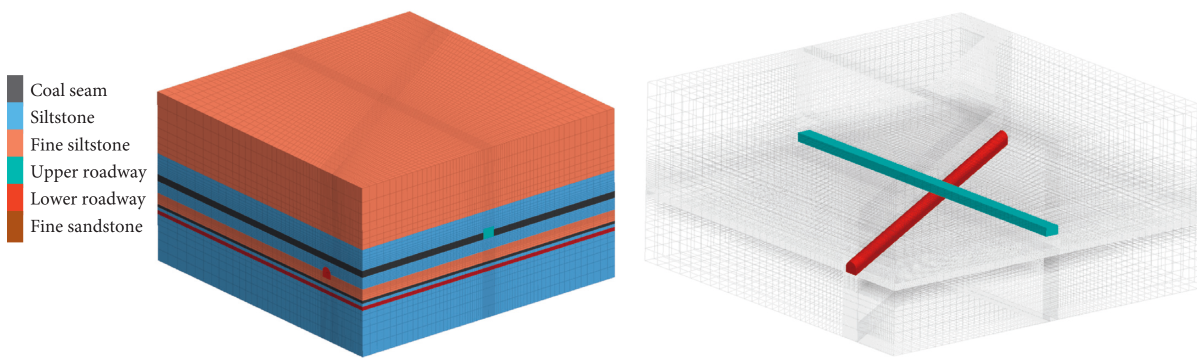


Figure 1: Schematic diagram of roadway spatial staggered layout.



(a) (b)

Figure 2: Calculation model (a) 3D model and (b) staggered roadways layout.

The numerical simulation process of staggered roadways is (1) according to the actual roadway layout, the model construction and simulation parameters are completed; (2) the given or limited boundary mechanical conditions and displacement conditions are set in the calculation model, and the initial equilibrium calculation is completed; (3) the lower special return air uphill is firstly excavated; (4) after the balance calculation of the lower special return air uphill, the upper 2294 transportation roadway is excavated; and (5) after the balance calculation of the upper 2294 transportation roadway, the simulation results were collected and analyzed.

3.2. Analysis of Numerical Simulation Results. As shown in Figure 3, the vertical stress of the staggered roadway transfers from the upper roadway to the lower roadway and acts near the staggered position, when the roadway spacing is reduced from 12m to 2m, the vertical stress of surrounding rock increases from 13 MPa to 20 MPa, the smaller the distance between roadways, and the more serious the bearing load of surrounding rock near staggered roadways. As shown in Figure 4, when the surrounding rock between staggered roadways is not broken through, the horizontal stress of the surrounding rock between staggered roadways is higher than that at other locations; when the distance between lanes is too small, the surrounding rock between staggered roadways is broken through, the horizontal stress of the surrounding rock is released, and the reason is that the surrounding rock of the staggered roadway loses its bearing capacity due to serious damage.

As shown in Figure 5, with the decrease of the distance between roadways, the surrounding rock in the staggered position first presents “the disturbance failure is relatively close to the breakthrough evolution,” and the surrounding rock deformation of the lower roadway roof and side in the staggered position is obviously more serious. The above analysis reveals that the smaller the distance between roadways is, the more serious the superimposed disturbance influence of surrounding rock stress is; when the distance between roadways is too small, it will even lead to a large range of surrounding rock failure and break through, which will cause serious deformation and overall bearing instability of roadway surrounding rock in staggered position.

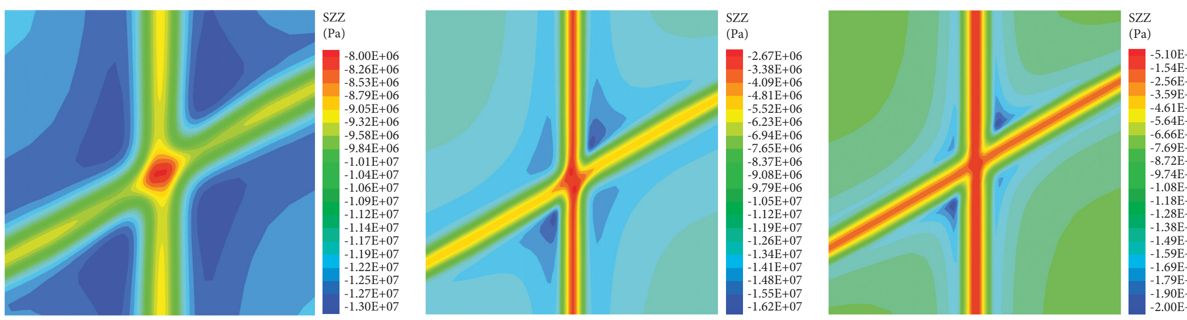
As shown in Figure 6 and 7, the smaller the horizontal angle of staggered roadways is, the more serious the vertical stress transmission effect of surrounding rock in small angle position will be, which will lead to serious pressure manifestation of roadway surrounding rock; at this time, the unloading range of surrounding rock horizontal stress between roadways is gradually expanded, which shows that when the horizontal azimuth angle decreases, the spatial

Table 1: Mechanical parameters of coal and rock.

Rock name	Density (kg/m^3)	Bulk modulus (GPa)	Shear modulus (GPa)	Friction angle (°)	Cohesion (MPa)	Tensile strength (MPa)
Fine sandstone	2600	1.42	0.87	29.00	1.10	1.66
Siltstone	2400	0.55	0.34	25.00	1.04	1.15
Coal seam	1400	0.37	0.29	23.00	0.80	0.80
Fine siltstone	2450	0.58	0.36	25.00	1.04	1.06

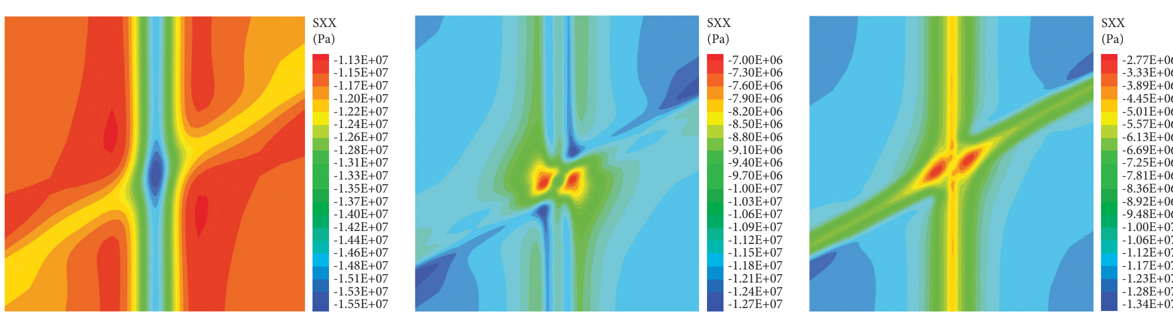
Table 2: Simulation scheme setting table.

	a	*b*	*c*
Spatial distance	12 m	6 m	2 m
Horizontal azimuth angle	90°	60°	30°
Buried depth of roadway	100 m	200 m	400 m
Ratio coefficient of horizontal stress to vertical stress	0.5	1.0	1.5



(a) (b) (c)

Figure 3: Disturbance influence of distance between roadways on surrounding rock vertical stress of staggered roadway. (a) Distance between roadways 12 m, (b) distance between roadways 6 m, and (c) distance between roadways 2 m.



(a) (b) (c)

Figure 4: Disturbance influence of distance between roadways on surrounding rock horizontal stress of staggered roadway. (a) Distance between roadways 12 m, (b) distance between roadways 6 m, and (c) distance between roadways 2 m.

disturbance of surrounding rock stress in staggered roadway changes into the aggravating influence on the sides of roadway with small angle and the surrounding rock between the upper and lower roadway.

As shown in Figure 8, with the decrease of the azimuth angle of the staggered roadways, the disturbance failure and deformation degree of the surrounding rock in the small angle position are obviously serious, while the failure and deformation degree of the surrounding rock in the large angle position are relatively weak, and when the roadways are arranged in parallel, the failure and deformation degree of surrounding rock is the most serious. Therefore, in practical engineering, the support strength of surrounding rock in small angle position should be increased reasonably to ensure the safety and stability of staggered roadways.

As shown in Figure 9 and 10, the greater the roadway layout depth is, the greater the original rock stress is, which leads to the spatial disturbance of surrounding rock stress of staggered roadways gradually aggravates; the vertical stress of surrounding rock around the staggered position always

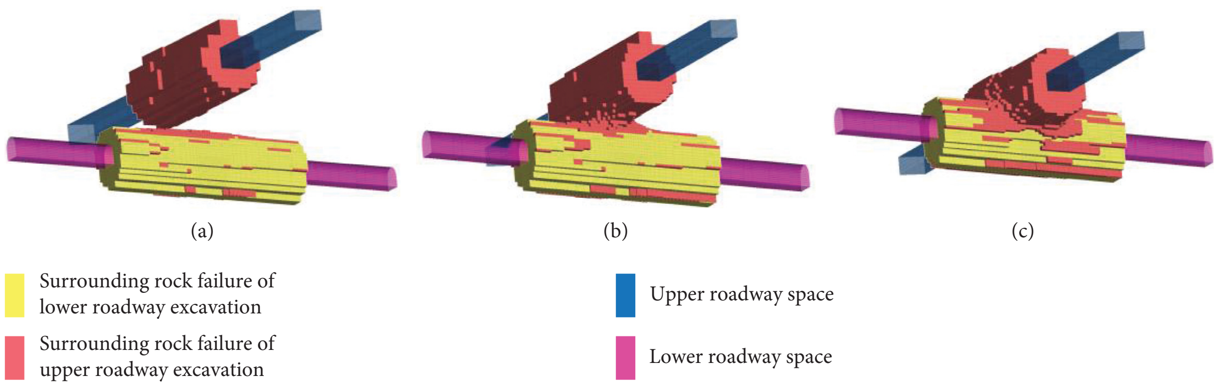


FIGURE 5: Disturbance influence of distance between roadways on surrounding rock failure of staggered roadway. (a) Distance between roadways 12 m, (b) distance between roadways 6 m, and (c) distance between roadways 2 m.

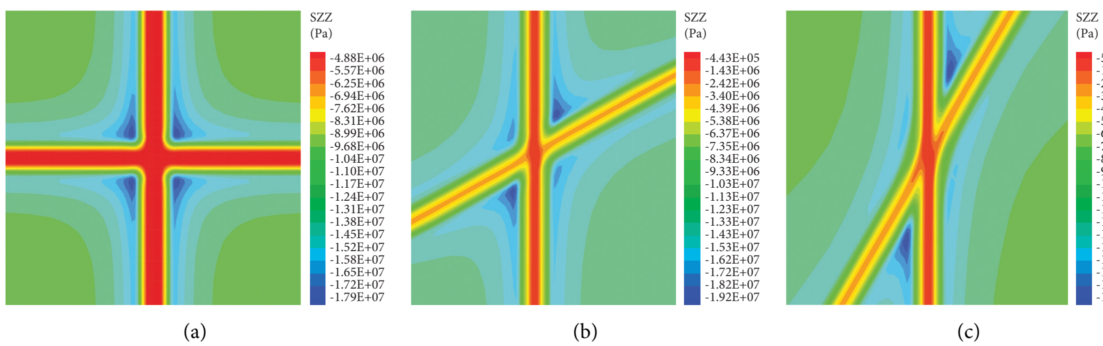


FIGURE 6: Disturbance influence of horizontal azimuth angle on surrounding rock vertical stress of staggered roadways. (a) 90° horizontal azimuth angle of staggered roadways, (b) 60° horizontal azimuth angle of staggered roadways, and (c) 30° horizontal azimuth angle of staggered roadways.

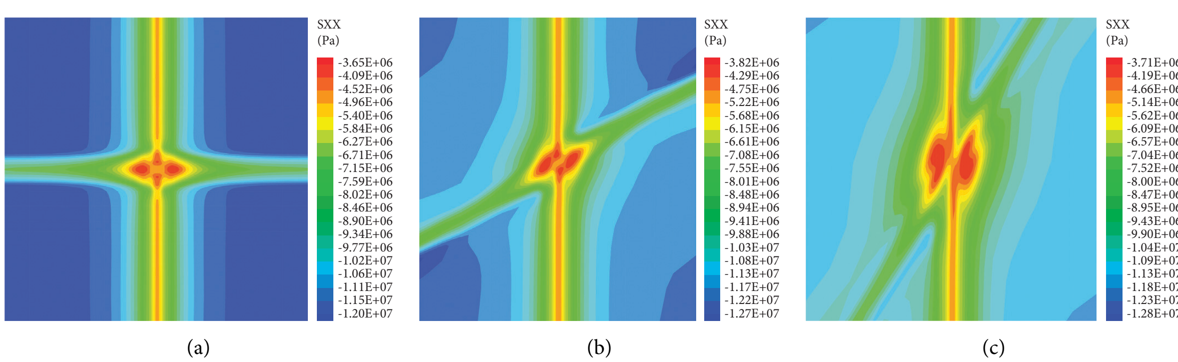


FIGURE 7: Disturbance influence of horizontal azimuth angle on surrounding rock horizontal stress of staggered roadways. (a) 90° horizontal azimuth angle of staggered roadways, (b) 60° horizontal azimuth angle of staggered roadways, and (c) 30° horizontal azimuth angle of staggered roadways.

shows an increasing trend, the horizontal stress of surrounding rock gradually intensifies when the surrounding rock between staggered roadways is not broken through, but it is obviously reduced when the surrounding rock body between roadways is broken through.

As shown in Figure 11, the greater the original rock stress is, the more serious the failure degree of the surrounding rock between the staggered roadways is, and the surrounding rock failure and deformation of the lower roadway in the staggered position are more and more serious. The analysis shows that when the staggered roadways are arranged in a large in situ stress environment, the strata pressure manifestation of the surrounding rock is serious, and the control of the surrounding rock in the staggered roadways is more difficult, and what was more, the vertical staggered layout should be emphasized, the distance between the staggered roadways should be increased, and the cross-section design of the staggered

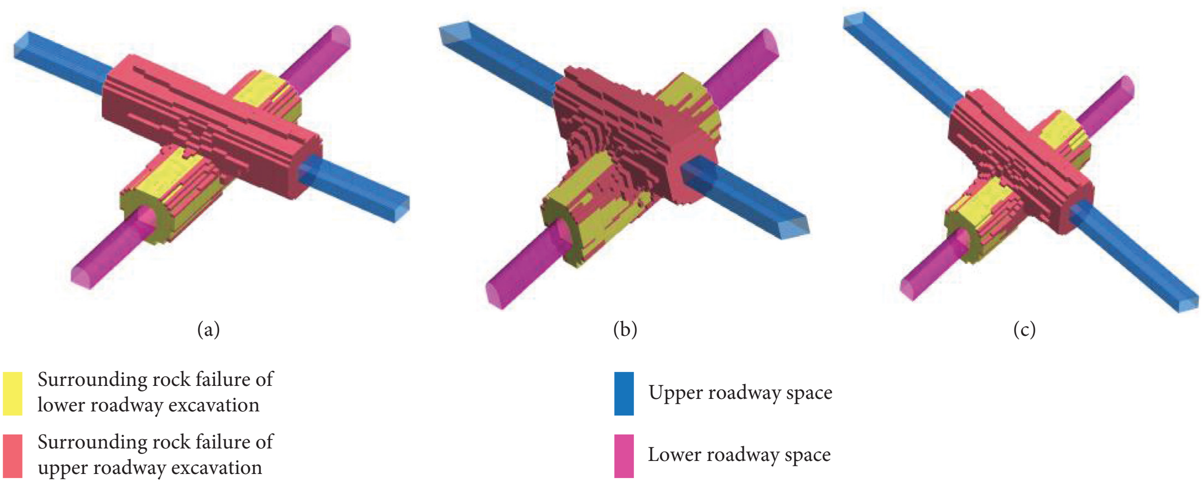


Figure 8: Disturbance influence of distance between roadways on surrounding rock failure of staggered roadways. (a) 90° horizontal azimuth angle of staggered roadways, (b) 60° horizontal azimuth angle of staggered roadways, and (c) 30° horizontal azimuth angle of staggered roadways.

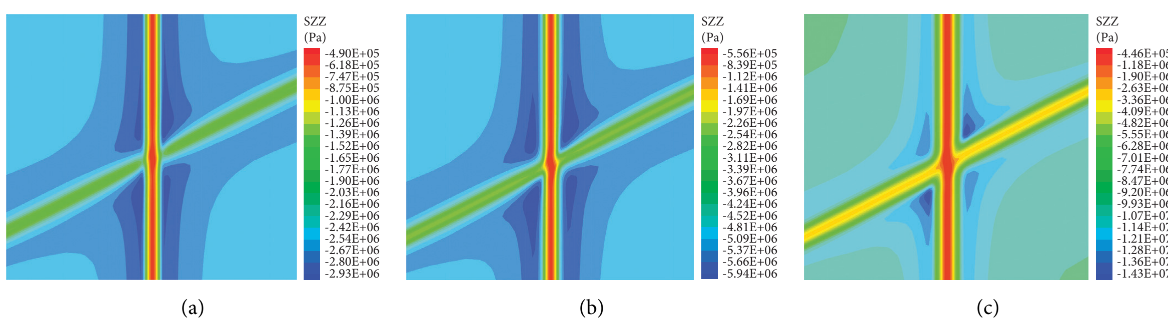


Figure 9: Disturbance influence of buried depth on surrounding rock vertical stress of staggered roadways. (a) 100 m roadway buried depth, (b) 200 m roadway buried depth, and (c) 400 m roadway buried depth.

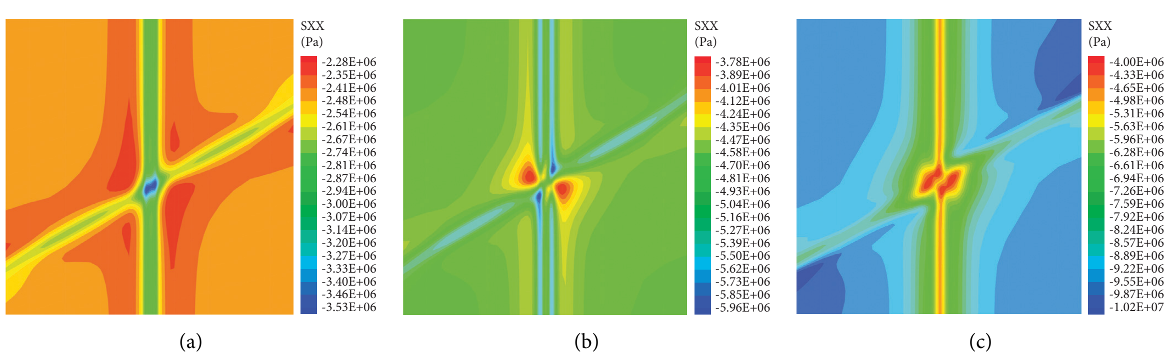


Figure 10: Disturbance influence of buried depth on surrounding rock horizontal stress of staggered roadways. (a) 100 m roadway buried depth, (b) 200 m roadway buried depth, and (c) 400 m roadway buried depth.

roadways should be optimized, these measures are conducive to the surrounding rock stability control of the staggered roadways.

As shown in Figure 12–14, when the ratio of horizontal stress to vertical stress in the original rock stress field is less than 1.0, the disturbance influence of vertical stress on surrounding rock near the staggered position is relatively obvious, the hidden danger of the surrounding rock bearing instability in the staggered roadways mainly comes from the failure and instability of the surrounding rock near the staggered position and the serious deformation of the lower roadway sides. However, when the ratio of

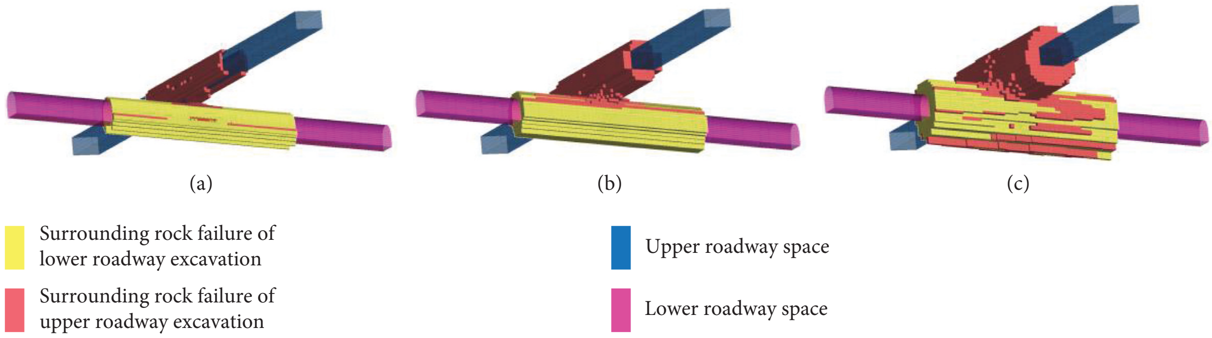


Figure 11: Disturbance influence of buried depth on surrounding rock failure of staggered roadways. (a) 100 m roadway buried depth, (b) 200 m roadway buried depth, and (c) 400 m roadway buried depth.

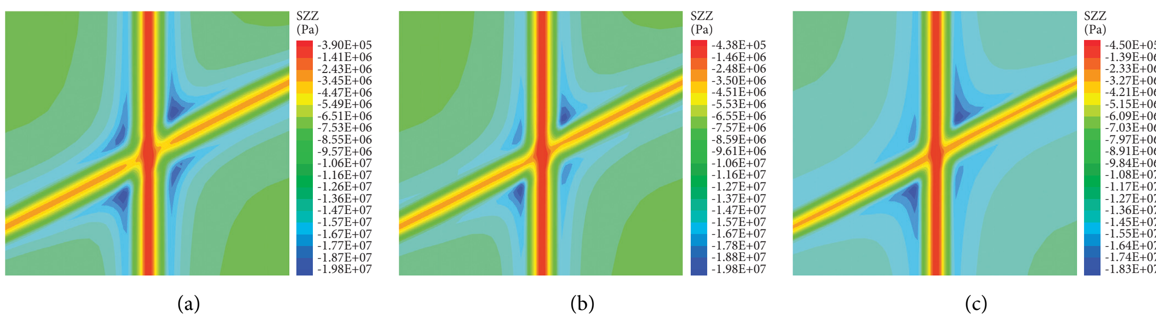


Figure 12: Disturbance influence of stress ratio on surrounding rock vertical stress of staggered roadways. (a) 0.5 ratio of horizontal stress to vertical stress, (b) 1.0 ratio of horizontal stress to vertical stress, and (c) 1.5 ratio of horizontal stress to vertical stress.

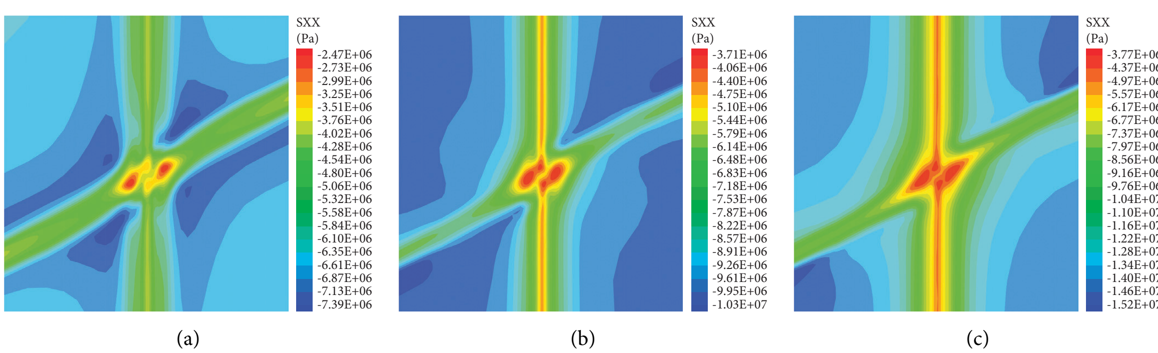


Figure 13: Disturbance influence of stress ratio on surrounding rock horizontal stress of staggered roadways. (a) 0.5 ratio of horizontal stress to vertical stress, (b) 1.0 ratio of horizontal stress to vertical stress, and (c) 1.5 ratio of horizontal stress to vertical stress.

horizontal stress to vertical stress in the original rock stress field is greater than 1.0, the disturbance influence of horizontal stress on the surrounding rock in the staggered position is relatively obvious, the hidden danger of bearing instability of the surrounding rock in the staggered roadways mainly comes from the failure of the surrounding rock between the staggered roadways and the serious deformation of the roof in the lower roadway. From this point of view, the more unbalanced the stress of the original rock is, the more obvious the more serious the stress disturbance influence of surrounding rock is, so the surrounding rock control of the staggered roadways needs to carry out specific support design according to the original rock stress situation.

4. Analysis on the Stability Control Measures of Staggered Roadways Surrounding Rock

Based on the analysis of the spatial disturbance influence of the surrounding rock stress in staggered roadways, in view of the safety problems of staggered roadways instability, the following control measures are proposed for the surrounding rock stability of staggered roadways:

(1) The shorter the distance between the staggered roadways is, the more serious the surrounding rock stress failure of the staggered roadways; so the roadway surrounding rock is in the staggered position and its nearby area is the key support area, and

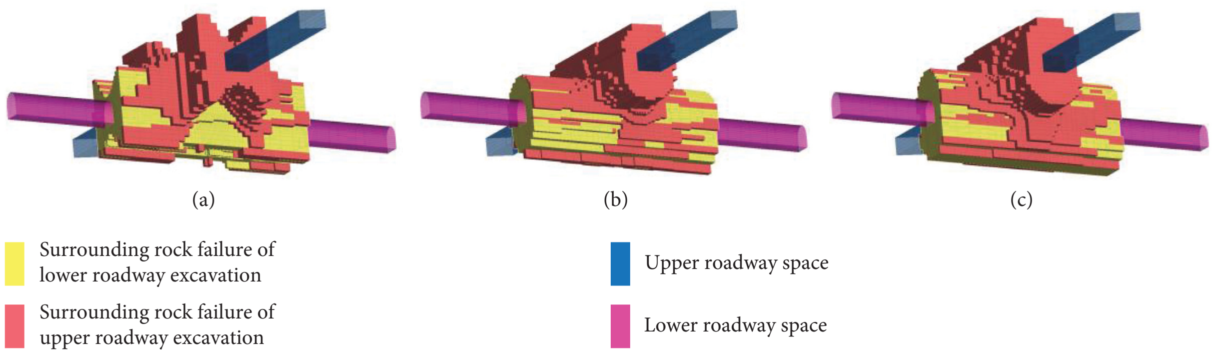


Figure 14: Disturbance influence of stress ratio on surrounding rock failure of staggered roadways. (a) 0.5 ratio of horizontal stress to vertical stress, (b) 1.0 ratio of horizontal stress to vertical stress, and (c) 1.5 ratio of horizontal stress to vertical stress.

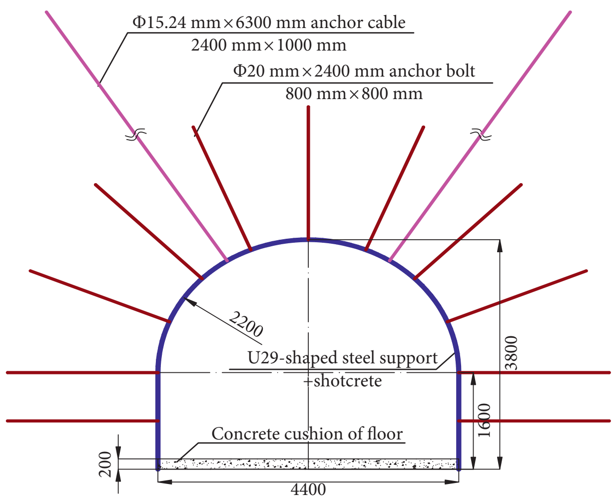


Figure 15: The combined support of the lower roadway "bolt + cable + U-shaped steel support passive reinforcement + shotcrete".

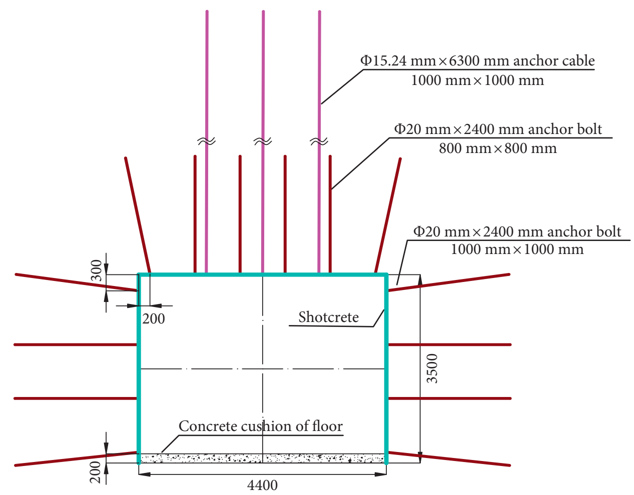


Figure 16: The combined support of the upper roadway "bolt + cable + shotcrete + concrete cushion of floor".

the technical schemes such as high-density bolt + mesh support, bolt + mesh + shotcrete support, active and passive combined support can be adopted, so as to improve the support strength of the roadway surrounding rock in the staggered position, which is conducive to the staggered roadways bearing stability.

(2) The smaller the horizontal azimuth angle of staggered roadways is, the larger the failure degree of surrounding rock in staggered position is, and the more serious the bearing load of surrounding rock in small angle position of lower roadway is. In the design of staggered roadway support layout, we should try our best to avoid the small included angle in the horizontal direction, resulting in the serious damage and instability of the surrounding rock at the small angle roadway side. For the inevitable working conditions, we need to strengthen the roadway side at the small angle roadway side (such as bolt shotcrete support, bolt grouting support, etc).

(3) According to the above analysis on the surrounding rock disturbance instability of staggered roadways, due to the superimposed disturbance influence of the surrounding rock horizontal stress between the staggered roadways, and the excavation of the upper and lower roadways leads to the limited size of the surrounding rock, the safety hidden danger of surrounding rock breakthrough and disturbance instability is particularly serious. Therefore, it is suggested to adopt passive support to realize the surrounding rock stability of the staggered roadways.

(4) Through the artificial reconstruction of the surrounding rock between the staggered roadways, the bearing stability of the short distance staggered roadways is realized. In view of the engineering situation of the short distance staggered roadways, it is necessary to predict whether the surrounding rock between staggered roadways occur breakthrough instability in advance, and the breakthrough surrounding rock is timely adopted such as surrounding rock grouting, concrete construction, and other technical means.

(5) In design of roadway layout, on the premise of ensuring the normal production and use of staggered roadways, roadways layout design should focus on

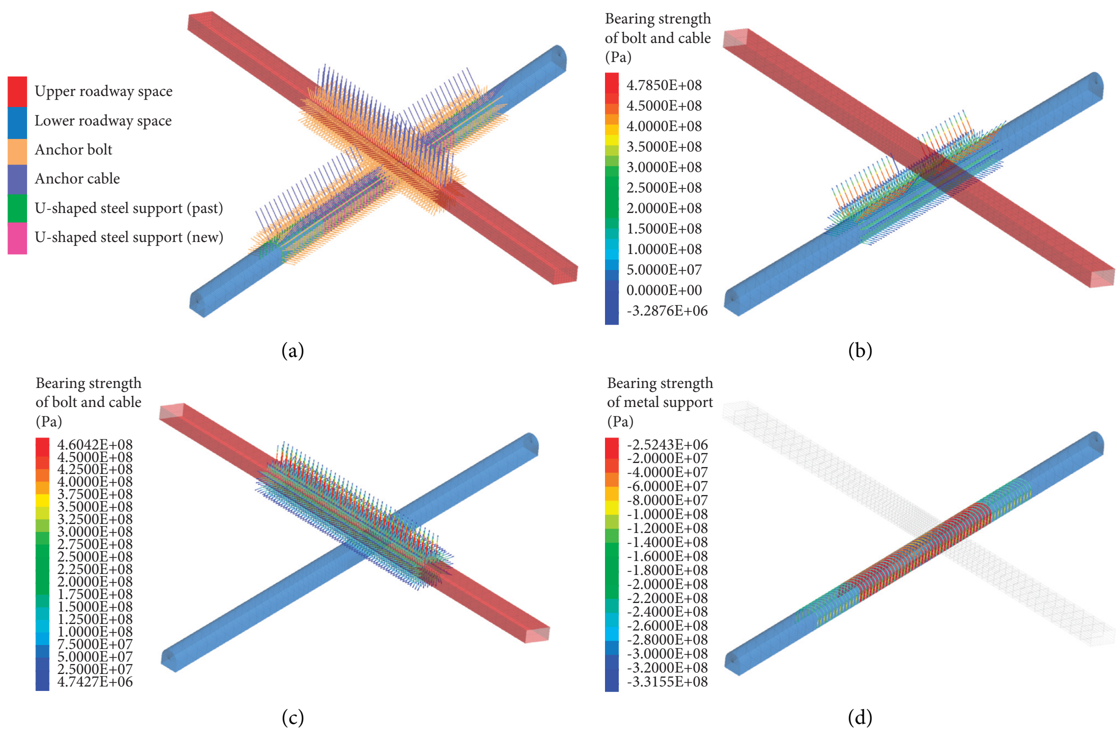


Figure 17: Stress characteristics of supporting structures in the staggered roadways position. (a) Roadway support layout model, (b) bearing condition of bolt and anchor cable active support structures in lower roadway, (c) bearing condition of bolt and anchor cable active support structure in upper roadway, and (d) bearing condition of U-shaped steel support in lower roadway.

horizontal orthogonal layout to reduce the disturbance influence range and increase the distance between staggered roadways to weaken the disturbance influence degree.

(6) Considering the mechanical properties of surrounding rock "compressive and nontensile," the arch or arc-shaped cross section should be selected to design the lower roadway, in order to improve the bearing state of the lower roadway surrounding rock.

(7) Combined with the safe use of the mine roadway, the bearing stability of the staggered position should be evaluated by considering the influence of the self-weight load of the upper roadway floor through the equipment. The safety margin coefficient of surrounding rock support control between roadways can be set as 1.2–1.5 to ensure the stability of surrounding rock of staggered roadways and the normal operation of production system.

5. Analysis on the Combined Support of Staggered Roadways

5.1. Design of the Combined Support Scheme for Staggered Roadways. In view of the fact that the 2294 transportation roadway and the special return air uphill in Linnancang Coal Mine are staggered roadways, combined with the above analysis of the staggered roadways stability control countermeasures, the paper puts forward the technical scheme of active and passive combined support for staggered roadways, that is, the combined support of the upper roadway "bolt + cable + shotcrete + concrete cushion of floor" and lower roadway "bolt + cable + U-shaped steel support passive reinforcement + shotcrete" within the spatial disturbance influence range of surrounding rock stress in the staggered roadways. As shown in Figure 15 and 16, the detailed design scheme for the active and passive combined support of staggered roadways is as follows:

As shown in Figure 15, the design of the combined support for the special return air uphill, the section is arched section with semicircular straight wall, Φ20 mm × 2400 mm screw thread steel bolts are selected at the roof and side of roadway, and the row spacing between bolts is 800 mm × 800 mm; the roof anchor cable is made of Φ15.24 mm × 6300 mm steel strand, and the row spacing is 2400 mm × 1000 mm; the U29 type steel support is added in the staggered position and its vicinity, and the spacing between supports is 500 mm; the thickness of shotcrete is 40 mm on the roadway surface, and the concrete cushion is 200 mm on the floor. The combined support design of the upper transport roadway is shown in Figure 16, the cross section is rectangular section, the bolt specification is Φ20 mm × 2400 mm screw steel bolt, the row spacing on the roadway roof and floor is 800 mm × 800 mm, the row spacing on the roadway sides is 1000 mm × 1000 mm; the anchor cable is Φ17.8 mm × 6.0 m steel wire anchor cable with spacing of 1000 mm × 1000 mm; 5500 mm × 1100 mm steel mesh and 4800 mm × 100 mm steel ladder are used to reinforce the top plate with anchor bolt and cable, and the bottom plate is reinforced with 200 mm concrete cushion.

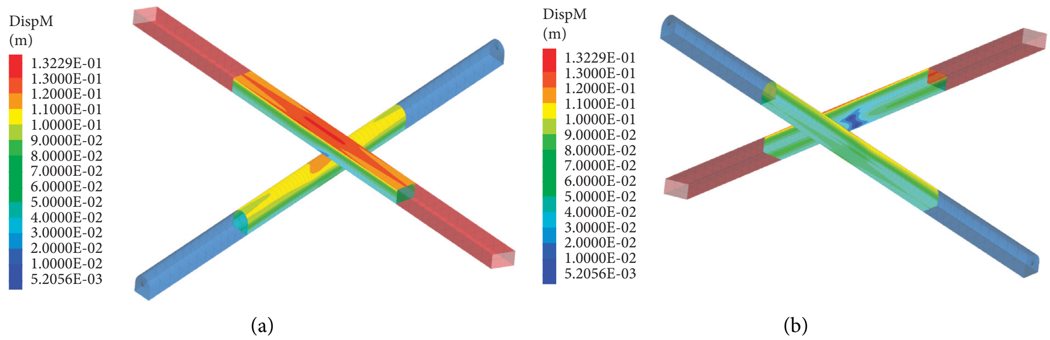


FIGURE 18: Deformation characteristics of surrounding rock in the staggered roadways position. (a) Vertical view and (b) bottom view.

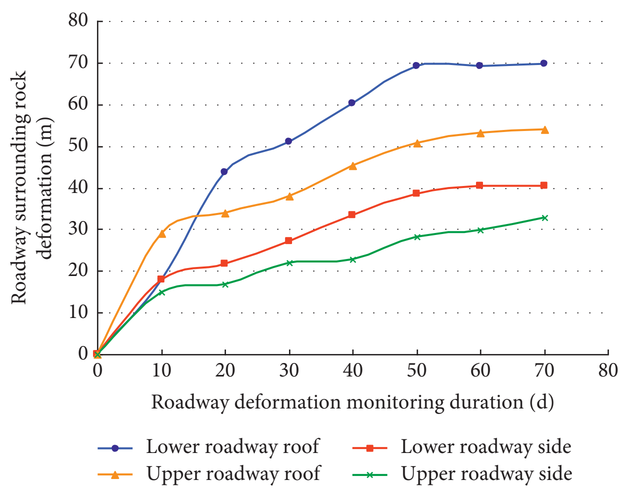


FIGURE 19: Surrounding rock deformation monitoring of staggered roadway.

5.2. Simulation Analysis of Combined Support Effect. As shown in Figure 17, the bearing condition of supporting structures is simulated, the numerical simulation results show that the maximum pull-out strength of anchor bolts in the upper and lower roadways is 250 MPa, which does not exceed the yield strength of 335 MPa; the maximum pull-out strength of anchor cables in the upper and lower roadways is 460 MPa, which does not exceed the ultimate load of 1200 MPa; the maximum stress of U-shaped steel support in staggered position and nearby is about 480 MPa, which is less than the yield strength of 800 MPa. Except that the anchor cable of roadway roof in staggered position is damaged (due to the excavation of upper roadway), the other supporting structures are in safe and stable working state.

As shown in Figure 18, under the combined support scheme, the spatial disturbance effect of surrounding rock stress of staggered roadways can be effectively alleviated. The maximum deformation of surrounding rock of staggered roadways is 132 mm and mainly distributed in the roof of lower roadway; the deformation of surrounding rock in other parts is 70–80 mm and relatively weak. Due to the combined support scheme of staggered roadways, the bearing capacity of surrounding rock of lower roadway is improved, and it has an effective bearing effect on the upper roadway surrounding rock stability control.

However, in the actual engineering construction and the process of roadway use, it is still necessary to pay attention to the monitoring of the failure and deformation in the lower roadway roof of the staggered position and increase the passive reinforcement support strength of the U-shaped steel support if necessary, so as to improve the stability of the common bearing structure of the "surrounding rock and support" in the lower roadway of the staggered position.

5.3. Feedback Evaluation of Field Support. At the scene of Linnancang Coal Mine, before driving 2294 transport roadway through the staggered position of special return air uphill roof, the special return air uphill is reinforced and supported according to the proposed combined support scheme, and then the 2294 transport roadway is driven through the staggered position safely and smoothly. The surrounding rock deformation monitoring results after staggered roadway construction are shown in Figure 19.

The monitoring results of surrounding rock deformation after staggered roadway construction show that the roof deformation of the lower roadway is 70 mm, the side deformation of the lower roadway is 40 mm, the roof deformation of the upper roadway is 54 mm, and the side deformation of the upper roadway is 33 mm, the roadway section at the staggered position is complete without obvious deformation and damage. In general, the combined support scheme proposed has good control effect on the surrounding rock of the upper transport roadway and the lower special return air uphill, which meets the coal safe mining requirements.

6. Conclusions

(1) Compared with the surrounding rock pressure behavior of the general roadway, the surrounding rock stability of the staggered roadway is relatively poor, showing the characteristics of the local serious roadway rock pressure behavior, such as the intensified destruction of the roadway side, the failure and fracture penetration of the surrounding rock between the roadways, and the relatively serious deformation of the surrounding rock. The reason is that the stress of the surrounding rock at the staggered roadway position is obviously superimposed and disturbed by each other.

(2) The influencing factors of the failure and instability of the surrounding rock between interlaced roadways are as follows: the greater the buried depth and the smaller the distance between roadways, the more intense the superposition disturbance of the surrounding rock stress between roadways; the smaller the horizontal azimuth, the greater the influence range of superposition disturbance of surrounding rock stress between roadways; the more unbalanced the original rock stress field, the worse the stability of the surrounding rock between roadways, resulting in the more serious failure and instability of the surrounding rock between roadways.

(3) For the staggered roadway layout, increasing the distance between roadways, the closer to the orthogonal layout and selecting the arch section of the lower roadway is conducive to the bearing stability of the surrounding rock between roadways.

(4) Constrained by the space conditions of staggered roadway, the role of bolt and cable support is limited. Passive support is the key to realize the safety and stability of surrounding rock of staggered roadway; so the control technical scheme of active and passive combined support in staggered roadway position is put forward, the combined support of the upper roadway "bolt + cable + shotcrete + concrete cushion of floor" and lower roadway "bolt + cable + U-shaped steel support passive reinforcement + shotcrete" within the spatial disturbance influence range of surrounding rock stress in the staggered roadways, the technical scheme can achieve satisfactory supporting effect.

Data Availability

The data in this study come from the actual situation of the project site, and the data results analyzed in this paper are true and reliable.

Conflicts of Interest

The authors state that the study was conducted without any commercial or financial relationships that may be interpreted as potential conflicts of interest.

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