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Research on Surrounding Rock Control Technology of Advanced Section of Mining Roadway in High Stress and Large Mining Length Working Face based on FLAC^{3D}

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Abstract: In order to solve the serious problem of roadway deformation and failure in the advance section of large mining face under deep high stress conditions, taking the mining roadway of 2112 working face as the research background, the stress distribution law of surrounding rock in the mining roadway of high stress and large mining face is analyzed by numerical simulation, and different sections in advance are divided. The control scheme of roadway surrounding rock is put forward and applied in the field. The results show that the deformation of roadway surrounding rock is controllable and the supporting effect of surrounding rock is good after adopting the new supporting scheme, which provides a case reference for the control of surrounding rock of the same type of roadway.

Keywords: High Stress; Soft Rock Roadway; Mining Roadway; Surrounding Rock Control.

1. Introduction

With the depletion of shallow coal resources, coal mining is gradually turning to deep mining. The complex stress environment and difficult control of surrounding rock in deep mining have become the key problems restricting the safe and efficient mining of underground. For the advance section of the mining roadway in the working face, under the influence of advance support pressure and mining stress, the surrounding rock of the roadway shows serious deformation characteristics. The traditional support design method based on empirical formula has been difficult to meet the construction requirements.

In recent years, FLAC^{3D} numerical simulation technology has shown great advantages in analyzing the stress distribution of surrounding rock of roadway with its explicit solution difference algorithm, which provides a new technical means for the study of mechanical behavior of surrounding rock of deep high stress roadway. Li Zhuang et al. [1-2] analyzed the large deformation characteristics and failure process of high stress soft rock tunnel by numerical simulation. Nie Taoyi et al. [3] studied the splitting failure phenomenon of high stress roadway through numerical simulation, and obtained the influence law of buried depth, lateral pressure coefficient, bulk modulus and shear modulus on the splitting failure of roadway. Ma Chunde et al. [3] analyzed the pressure relief scheme of roadway surrounding rock under high stress environment by numerical simulation. Fan Renzhong [5] determined the influence range of advance support pressure in high stress and large mining height working face by means of numerical simulation, and mastered the deformation law of surrounding rock in advance support section. Lu Shengliang [6] studied the distribution characteristics of advance support pressure through numerical simulation for high pumping roadway. Hui et al. [7] analyzed the relationship between the advance support pressure of the working face and the mining distance, and further analyzed the stability of the surrounding rock of the roadway under the influence of the lateral-advance support pressure. Aiming at the problem of surrounding rock control of large deformation roadway in deep high stress soft rock, Xu Lei et al. [8-11] proposed the coordinated control technology of ' bolt + anchor cable + grouting '.

Many scholars have applied FLAC^{3D} to the study of roadway surrounding rock control, but the research on the surrounding rock control of the advance section of the mining roadway in the high stress and large mining face needs to be further studied. Based on the predecessors, this paper uses FLAC^{3D} numerical simulation to analyze the distribution of the advance support pressure in the advance section of the soft rock mining roadway in the high stress and large mining face, and divides the different sections in advance. The control scheme of roadway surrounding rock is put forward, and it provides a case reference for mines with similar conditions.

2. Engineering Background

The coal seam exposed during the excavation of the mining roadway in the 2112 working face is a nearly horizontal coal seam, and the dip angle of the coal (rock) layer is 1° to 5°, with an average of 3°. The thickness of the coal seam is 1.6~6.7m, the average coal thickness is 3.5m, the coal seam structure is simple, the local gangue is contained, the thickness is between 0.1m~0.4m, the coal seam is affected by the sliding structure, the organization is loose, the strength is low, the coal seam is mainly powdered, the block is crossed, and the Platts hardness coefficient is less than 0.3. The mining area is a 'three soft' coal seam, so the hardness of the roof and floor of the coal seam is small, and the ground pressure is relatively large. The coal seam situation is shown in Table 1.

The roof lithology of the coal seam is mainly mudstone and sandy mudstone. Among them, the mechanical samples of mudstone, sandy mudstone, carbonaceous mudstone and siltstone roof have low compressive strength and tensile strength. The compressive strength is 15.6~54.8MPa, the tensile strength is 0.4~2.39MPa, and the previous drilling RQD statistical value is 16.2~47.9%. Most of them are unstable rock strata, which are easy to soften in water. The roof rock mass belongs to the moderately complete (grade III) and poor quality (grade IV) roof.

The lithology of the direct floor of the coal seam is mainly siltstone and mudstone. The compressive strength is 25.0~35.6MPa, and the tensile strength is 1.06~1.95MPa, which is also an unstable rock stratum. There is a local false bottom, and the lithology is mudstone. It is easy to soften, expand and deform in water, and it is not easy to manage. The floor rock mass belongs to the medium complete (grade III) and poor quality (grade IV) floor.

Table 1. Coal seam characteristics table

Index	Parameter	Remark
Coal seam thickness (minimum~maximum/ average) / m	1.61-6.77/3.78	
Coal seam dip angle (minimum ~ maximum / average) / (°)	1-5/3	
Coal seam hardness f	<0.3	
Coal seam bedding (development degree)	aplasia	
Coal seam joints (development degree)	development	
Spontaneous combustion tendency grade of coal seam	class III	It is not easy to spontaneous combustion coal seam

3. Bread Board Design

The model is designed with the 2112 working face as the background. The length×width×height of the model is 350m ×100m×45m. The design width of the roadway in the model is 4m. The model is a horizontal model to simulate the site along the strike. During excavation, 50 m protective coal pillars are left on both sides of the model. The excavation size of the roadway section is 4m×4m, and the excavation length of the roadway is 70 m. The roadway is arranged in the coal seam along the floor. The length of the working face is 250 m, and the goaf behind the working face is 30 m (Fig.1). In the calculation, the Mohr-Coulomb model is used for the main rock layer of the model. The numerical simulation parameters are shown in Table 2.

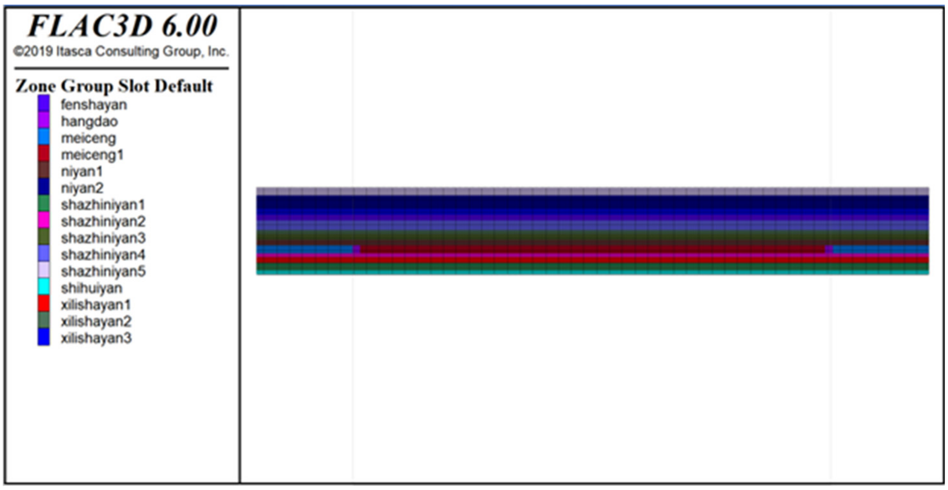

Figure 1. Numerical simulation model diagram

Table 2. Numerical model of rock mass physical and mechanical parameters table

lithologic characters	Density (kg/m^3)	Poisson 's ratio /μ	Elastic modulus (/GPa)	Internal friction angle/°	Cohesion (/MPa)
sandy mudstone	2381	0.21	2.1	30.5	2.73
mudstone	2301	0.17	1.2	33.2	3.37
post office box stone	2600	0.26	2.3	33.6	3.24
coal	1450	0.13	0.6	26	2.51
limestone	2550	0.31	4.76	41.2	5.76

Firstly, the model is grouped according to different rock strata, and a total of five surfaces of the left and right sides of the model and the bottom are fixed to limit the movement of the X and Y directions of the model, and the pressure of the overlying strata is applied at the top of the model. The unsimulated depth of overlying strata is 550 m. According to the field measurement data, the vertical stress of 13.5MPa is applied above the model.

In the goaf behind the working face, a non-slip contact surface is established along the floor to prevent the roof subsidence of the goaf from being too large and invading the floor, resulting in hourglass damage to the model during the operation and system collapse.

4. Simulation Procedure

1.Establish a geological model, the model is grouped, and the goaf generates a contact surface;

2.The different rock groups are assigned; the contact surface is assigned;

3.Fixed boundary conditions, applied internal force (stress field) and external force (overlying weight) to the model;

4.Operation balance, clearing the displacement and velocity, producing the initial original rock stress;

5.The rectangular roadway is excavated at one time, and the bolt / cable support is carried out in time, and the different support materials are assigned;

6.The influence range of roadway stress state and advance stress under the influence of mining (roadway excavation and working face mining) is studied.

7.Record the roadway surrounding rock state data or cloud image, operation balance;

8.Export part of the data for origin drawing.

5. Modeling Results

5.1. Simulation Process Analysis

In the roadway at 0m from the working face (Fig.2), the upper side of the roadway is the coal wall of the working face. Due to the decrease of the stress of the coal wall of the working face, the stress of the two sides of the roadway is mainly concentrated in the lower side, and the concentrated stress is 29.7MPa.

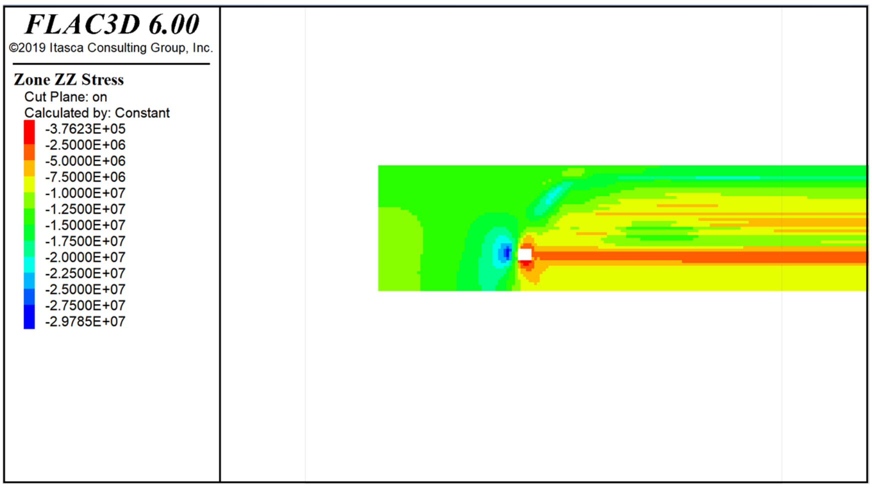

Figure 2. The stress cloud diagram of surrounding rock of 0 m ahead roadway

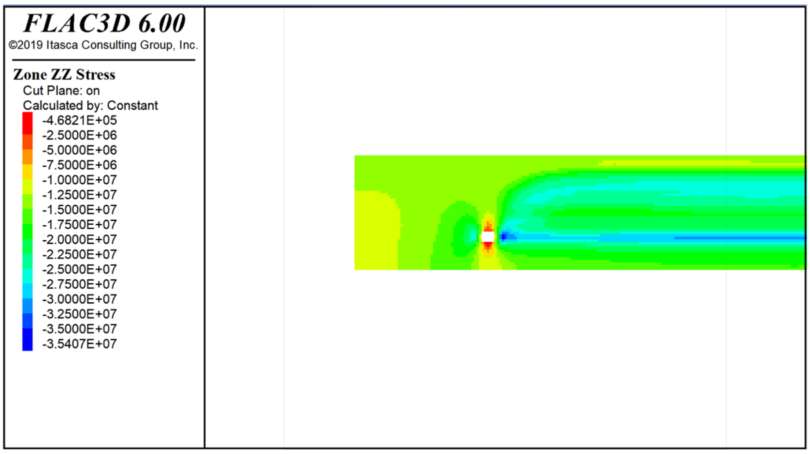

Figure 3. The stress cloud diagram of surrounding rock of 5 m ahead roadway

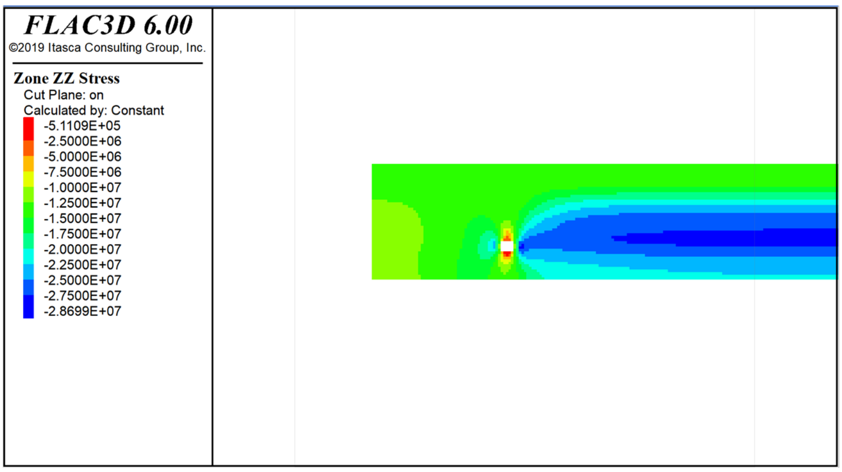

Figure 4. The stress cloud diagram of surrounding rock of 10 m ahead roadway

In the roadway 5m away from the working face (Fig.3), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 35.4MPa, and the concentrated stress of the lower side is 20MPa.

In the roadway 10 m away from the working face (Fig.4), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 28.69MPa, and the concentrated stress of the lower side is 22.5MPa.

In the roadway 15 m away from the working face (Fig.5), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 25.45MPa, and the concentrated stress of the lower side is 22MPa.

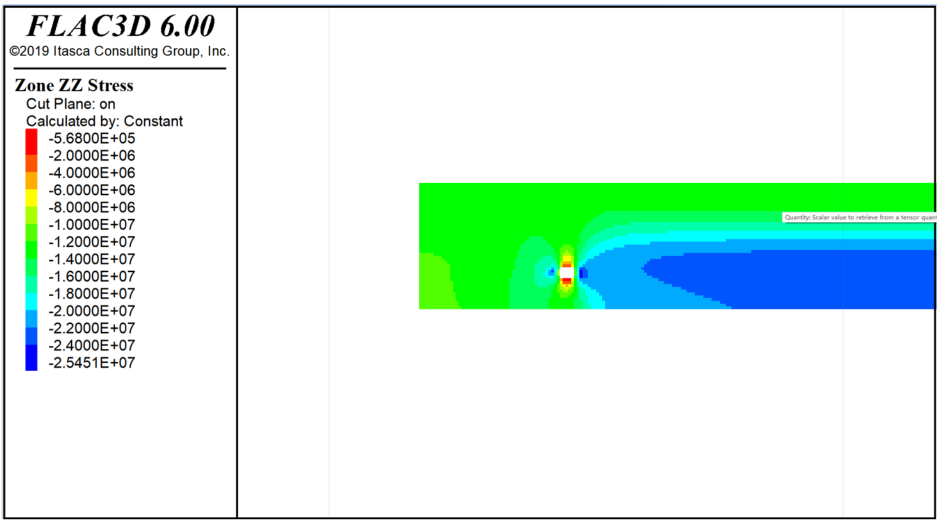

Figure 5. The stress cloud diagram of surrounding rock of 15 m ahead roadway

In the roadway 20 m away from the working face(Fig.6), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 22.2MPa, and the concentrated stress of the lower side is 20MPa.

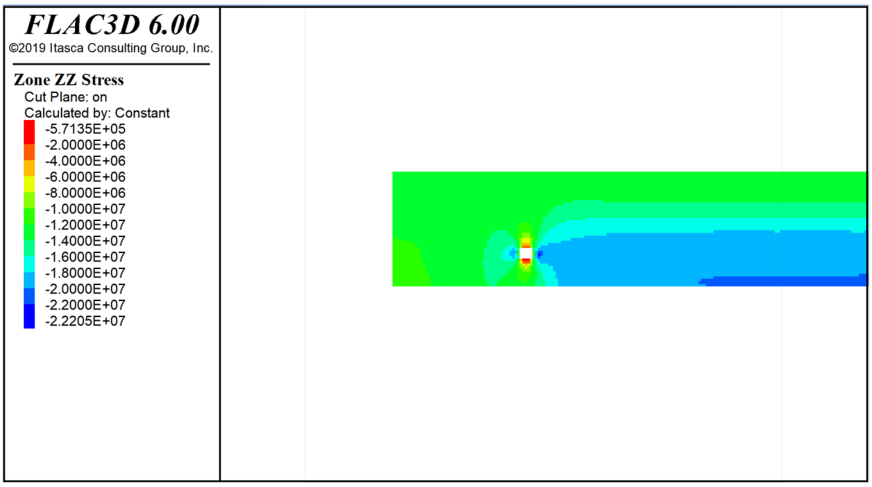

Figure 6. The stress cloud diagram of surrounding rock of 20 m ahead roadway

In the roadway 25 m away from the working face(Fig.7), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 19.77MPa, and the concentrated stress of the lower side is 19MPa.

In the roadway 30 m away from the working face(Fig.8), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 18.1MPa, and the concentrated stress of the lower side is 18MPa.

In the roadway 35 m away from the working face (Fig.9), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 25.45MPa, and the concentrated stress of the lower side is 22MPa.

In the roadway 40 m away from the working face (Fig.10), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 16.84MPa, and the concentrated stress of the lower side is 16MPa.

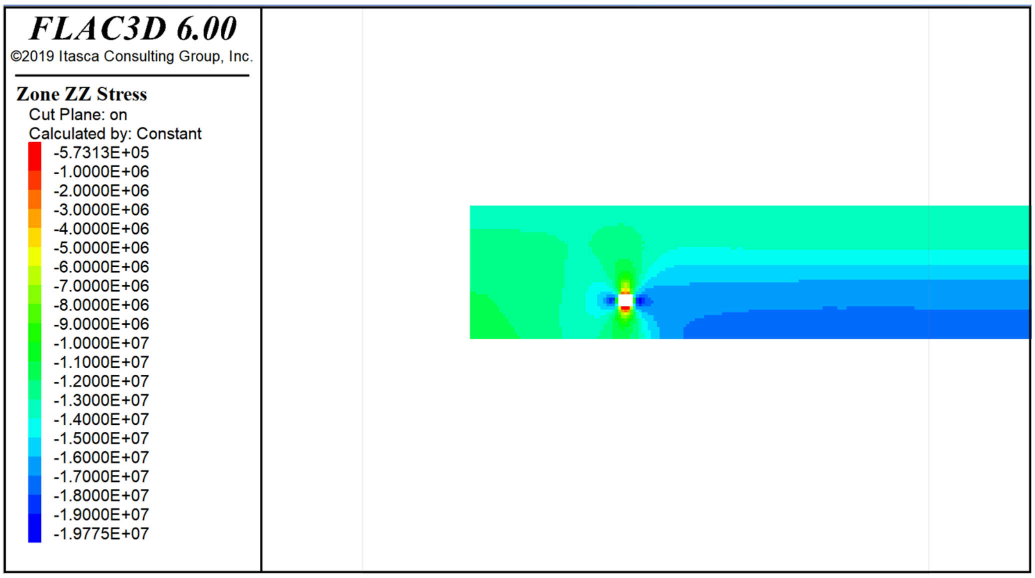

Figure 7. The stress cloud diagram of surrounding rock of 25 m ahead roadway

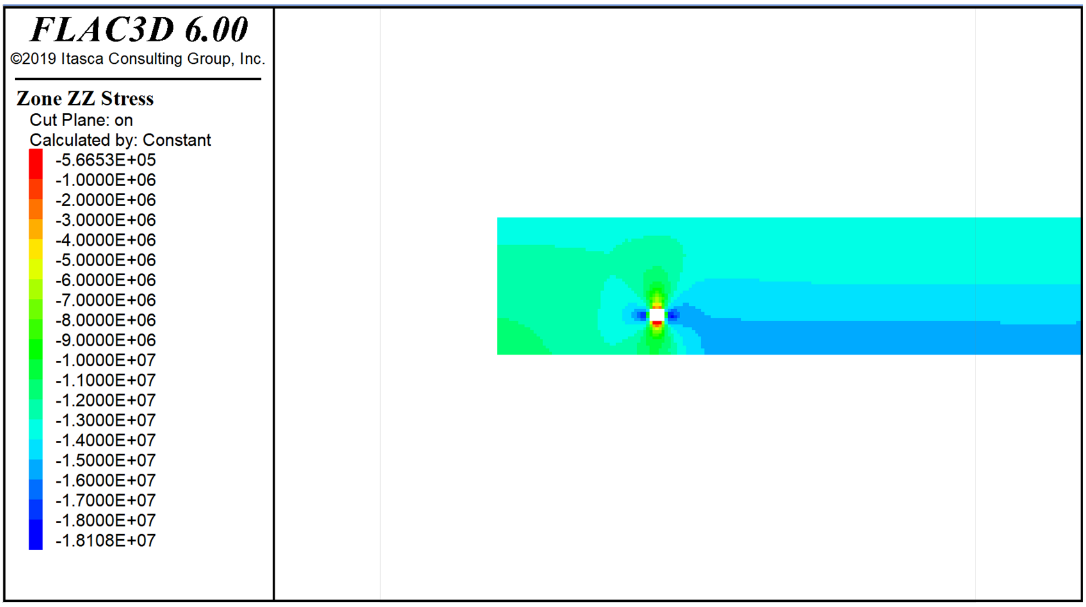

Figure 8. The stress cloud diagram of surrounding rock of 30 m ahead roadway

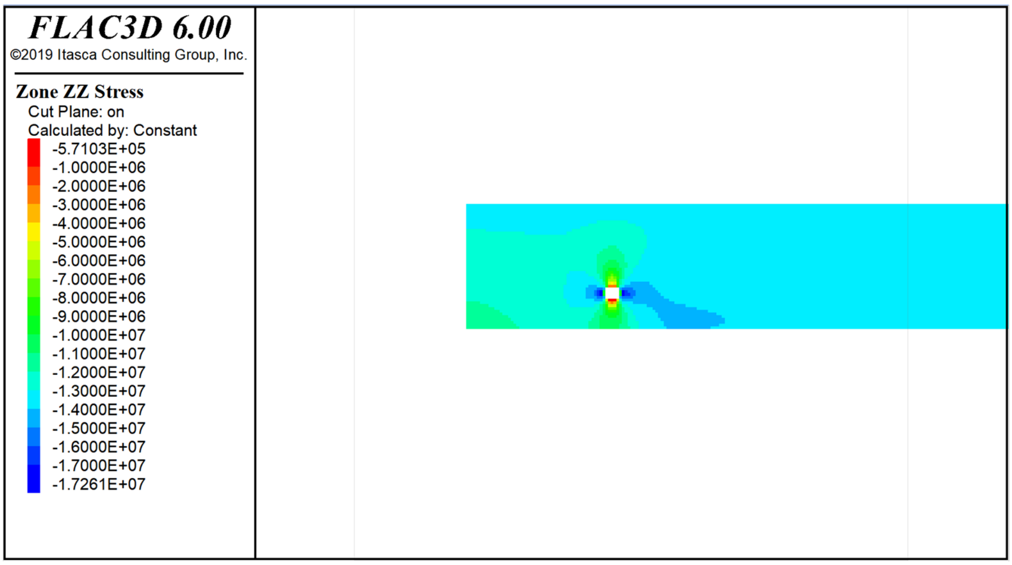

Figure 9. The stress cloud diagram of surrounding rock of 35 m ahead roadway

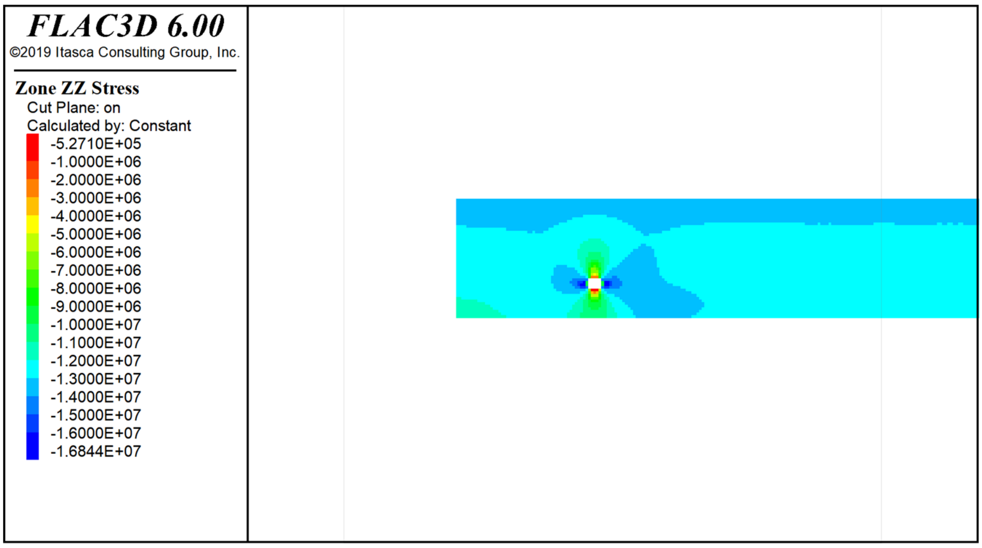

Figure 10. The stress cloud diagram of surrounding rock of 40 m ahead roadway

In the roadway 45 m away from the working face(Fig.11), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 16.64MPa, and the concentrated stress of the lower side is 16MPa.

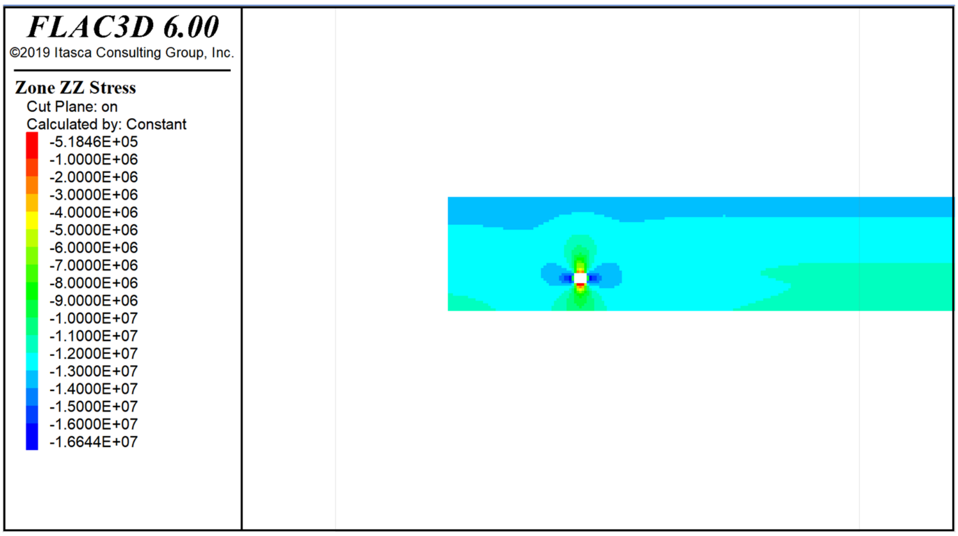

Figure 11. The stress cloud diagram of surrounding rock of 45 m ahead roadway

In the roadway 50 m away from the working face(Fig.12), the stress of the roadway is mainly concentrated in the upper and lower sides. The stress concentration of the upper side is greater than that of the lower side. The concentrated stress of the upper side is 16.51MPa, and the concentrated stress of the lower side is 16MPa.

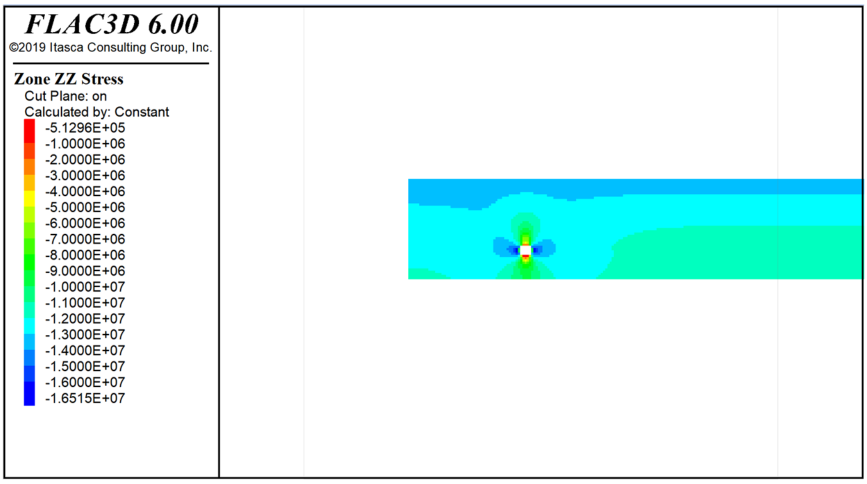

Figure 12. The stress cloud diagram of surrounding rock of 50 m ahead roadway

5.2. Advanced Stress Analysis of Roadway

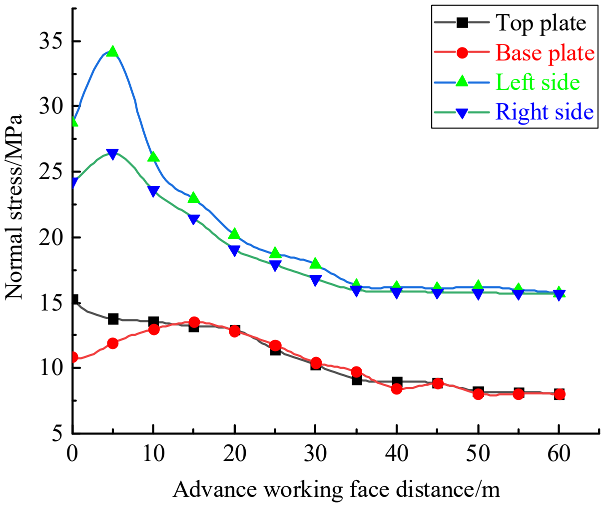

Figure 13. Surrounding rock stress diagram of advanced roadway

After the mining of the 2112 working face (Fig.13), the stress redistribution of the surrounding rock of the stope is caused, which leads to the change of the stress of the surrounding rock of the roadway due to the overlying and floor strata and the large-scale strata migration.

For the 2112 working face mining roadway, the stress of the upper side gradually rises within the range of 7m in advance, and the stress of the upper side of the roadway reaches the peak at 7m in advance, and the peak stress is 34.13MPa. The stress of the upper side of the roadway in the range of 7~35m in advance gradually decreases, and the stress of the upper side of the roadway beyond 35m in advance is no longer affected by the mining of the working face, and the stress reaches stability.

The stress of the lower side increases gradually in the range of 6m ahead, and the stress of the lower side of the roadway reaches the peak value when the advance is 6m, and the peak stress is 26.43MPa. The stress of the lower side of the roadway decreases gradually in the range of 6~35m ahead, and the stress of the lower side of the roadway beyond 35m ahead is no longer affected by the mining of the working face, and the stress reaches stability.

The stress of roadway roof decreases gradually in the range of 35m ahead, and the stress of roof reaches the peak value when it is 0m ahead, and the peak stress is 15.26MPa. The stress of roadway roof beyond 35m ahead is no longer affected by the mining of working face, and the stress reaches stability. The stress of roadway floor gradually rises in the range of 15m in advance, and the stress of roadway floor reaches the peak value at 15m in advance, and the peak stress is 13.54MPa. The stress of roadway floor decreases gradually in the range of 15~40m in advance, and the stress of roadway floor outside 40 m in advance is no longer affected by the mining of working face, and the stress reaches stability.

5.3. Advance Stress Zoning

The advanced section of the roadway is divided according to the rise and fall of stress. The stress rise area is within 10m in advance of the roadway. The stress of the roadway in this area is gradually increased by the mining influence of the working face. The range of 10m~40m ahead is the stress reduction area. The roadway in this area is gradually reduced by the mining influence of the working face, and the stress of the surrounding rock of the roadway is gradually reduced. The roadway beyond 40m ahead is no longer affected by the mining of the working face, and the stress is stable.

6. Support Scheme Design

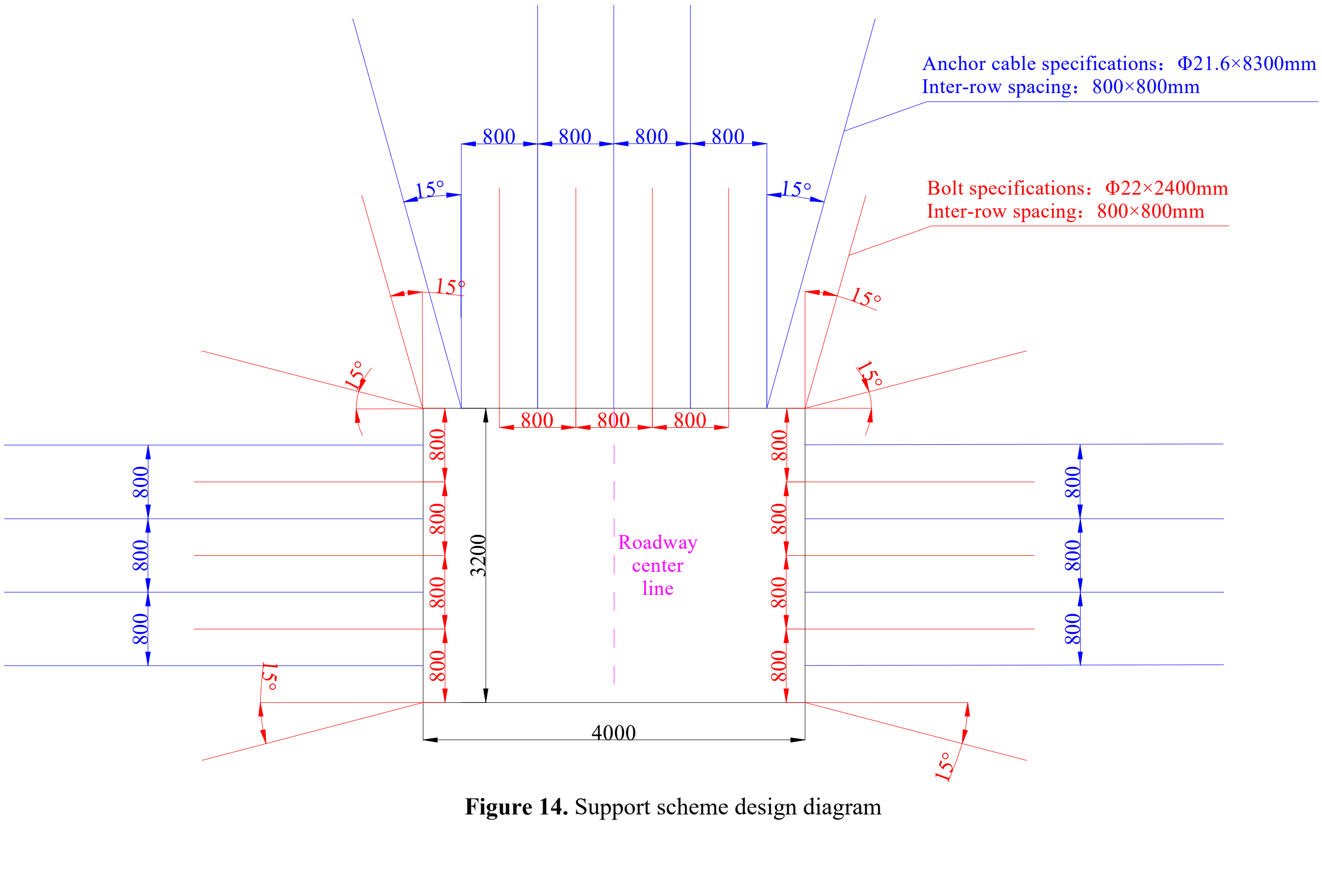

Figure 14. Support scheme design diagram

The whole section of the roadway is supported by bolt (Fig.14), and the anchor cable is set up between the bolts for reinforcement support.

The roof of the roadway is constructed with 6 bolts, the specifications of the bolts are φ22×2400 mm, the row spacing between the bolts is 800×800 mm, the left and right sides of the roof are perpendicular to the roof and inclined outward by 15 °, other vertical to the roof, the anchoring force is not less than 100KN, 5 bolts are constructed on both sides of the roadway, the specifications of the bolts are φ22×2400 mm, the row spacing between the bolts is 800×800 mm, the upper (lower) corner of the two sides is perpendicular to the two sides. Inclined upward (downward) arrangement, other vertical to the roof arrangement, anchoring force is not less than 100KN.

The roof of the roadway is constructed with 5 anchor cables, the specification of the anchor cable is φ21.6×8300 mm, the row spacing between the anchor cables is 800 × 800 mm, the intermediate anchor cable is located on the central line of the roof, and the outermost anchor cable is perpendicular to the roof. The outermost anchor cable is inclined outward by 15°, and the other is perpendicular to the roof layout, and the anchoring force is not less than 150KN. Four anchor cables are constructed on both sides of the roadway, the specification of the anchor cable is φ21.6×8300 mm, the row spacing between the anchor cables is 800×800 mm, and the anchor cables are perpendicular to the side layout, and the anchoring force is not less than 150KN.

7. Conclusion

(1) The range of 10m in advance of the roadway is the stress increase area, and the stress of the roadway in this area is gradually increased by the mining influence of the working face. The range of 10m~40m ahead is the stress reduction area. The roadway in this area is gradually reduced by the mining influence of the working face, and the stress of the surrounding rock of the roadway is gradually reduced. The roadway beyond 40 m ahead is no longer affected by the mining of the working face, and the stress is stable.

(2) For the roadway in the stress increase area and the stress decrease area, the roadway is affected by the mining of the working face, and the support needs to be strengthened.

(3) The numerical simulation results show that the control effect of roadway surrounding rock is good after using the support scheme designed in this paper.

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