

Numerical Simulation Study on The Effect of Isolated Coal Pillar Width on The Subsidence Law of Deep Mining

Jianping Yao

Henan Polytechnic University, Jiaozuo, Henan, China

ABSTRACT

A large number of research results show that the reasonable determination of the width of the coal pillar is an important factor affecting the stability of the surrounding rock along the roadway along the fully mechanized discharge. In this paper, the mechanism of the specific condition of isolation of coal pillars in the deep roadway of Menkeqing coal mine area on the law of surface subsidence is analyzed. The FLAC3D numerical simulation technology was used to simulate the multi-level experimental scheme to analyze the influence of different remaining coal pillar widths on the stress and strain of overburden rock and surface subsidence, and to reveal the relationship between the width of isolated coal pillars and the surface subsidence law of deep mining.

KEYWORDS

Retention of coal pillars, FLAC3D, stress, subsidence law, Menkeqing coal mine.

1. INTRODUCTION

Coal mines need to set up coal pillars in the mining process, if the retention is too large, it will cause a waste of coal resources, and if the retention is too small, safety accidents may occur in the mining process. The retention of coal pillars greatly affects the advancement of the coal seam working face under the fault, therefore, it is particularly necessary to determine the height of the coal pillar and correctly retain the coal pillar under the premise of ensuring safe mining and effective resource conservation.

In view of the retention width, stress change characteristics and corresponding technologies of the coal pillars along the empty roadway, scholars at home and abroad have analyzed the structural mechanical model, non-uniform deformation mechanism, roof fracture mode, calculation model of the width of the coal pillar along the empty roadway, and asymmetric support technology [2-4] A lot of research has been done. Wang Xin [5] Taking the Kailuan mining area as the research object, the width of the fault waterproof coal pillar was calculated by using F-RFPA2D software and theoretical analysis method. Tu Min et al [6] Using the method of numerical analysis, the law of reasonable width of coal pillar is studied by single factor analysis method and function increase and decrease discriminant criterion, and a method of reducing the width of coal pillar will greatly improve the recovery rate is proposed, and finally the width of coal pillar is calculated. POULSEN ET AL [7] By analyzing the working face data, the size of the coal pillar is determined, and a method for calculating the load of the coal pillar is proposed, which is suitable for the coal pillar of arbitrary plane shape, and the spatial position of the pillar relative to other pillars, unmined coal and roadway network is considered. In order to ensure the safety of coal mining, it is usually necessary to reserve a small coal pillar when carrying out comprehensive discharge mining for the extra-thick coal seam, and how to determine the width of the coal pillar is a subject worthy of in-depth study [8]. If the width of the small coal pillar is too large, it will cause a waste of coal mine resources. On the contrary, if the

reserved width of the small coal pillar is too small, it will not be able to play its due role and threaten the safety of coal mine production [9].

In this paper, the mechanism of the specific condition of coal pillar isolation in the deep roadway of Menkeqing coal mine area on the surface subsidence law is analyzed and studied. The FLAC3D numerical simulation technology was used to simulate the multi-level experimental scheme to analyze the influence of different remaining coal pillar widths on the stress and strain of overburden rock and surface subsidence, and to reveal the relationship between the width of isolated coal pillars and the surface subsidence law of deep mining.

2. OVERVIEW OF THE MINING AREA

The name of the working face is 11-3105 working face. The strike length of the working face is about 4033m, the trend length is about 312m, the mining of 3-1 coal seams, the surface elevation of the working face is +1303.2~+1313.6m, the average elevation is +1308.4m, the average elevation of the main transportation lane of the working face is +585.27m, the average elevation of the return air lane is +582.86m, the average buried depth of the working face is about 724m, the average thickness of the coal seam is about 5m, and the average dip angle of the coal seam is about 1-3°, which is a near-horizontal coal seam. The working face adopts the comprehensive mechanized backward coal mining method, and the roof is managed by the natural collapse method. The lithology of the roof is mainly siltstone, followed by sandy mudstone and siltstone, and the lithology of the bottom plate is mostly sandy mudstone and siltstone. The 11-3105 working face is located at the western boundary of the Menkeqing coal mine field, and the 11-3103 working face is located on the east side of the 11-3105 working face, and a large coal pillar of 180 meters is retained between the two working faces. The position of the two working faces is shown in Figure 3

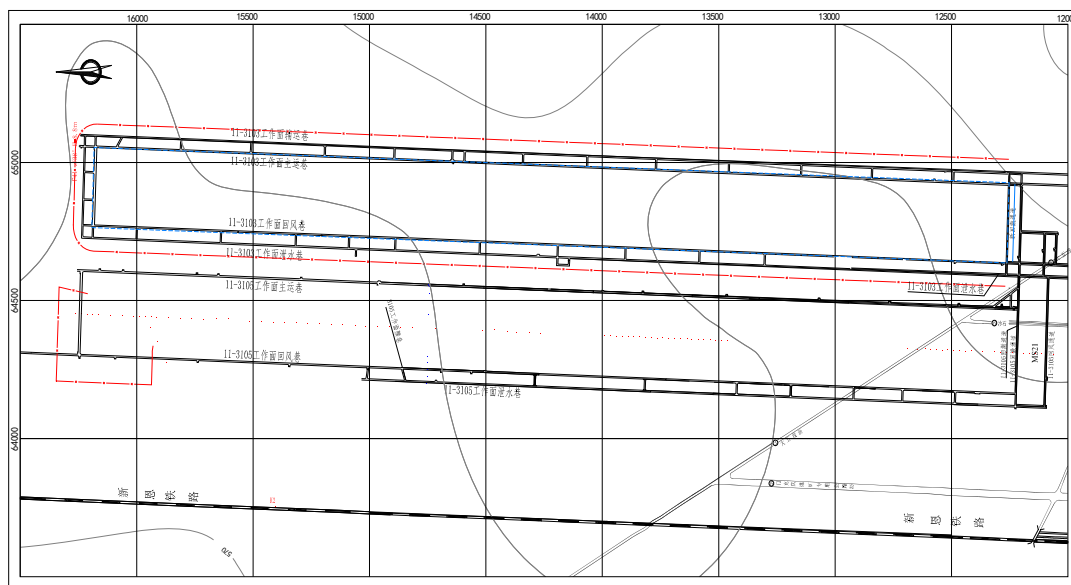


Figure 1. Schematic diagram of the location of the 3103 and 3105 working faces

3. ESTABLISH A NUMERICAL MODEL

3.1. Stratigraphic structure simplification

According to the calculation table of the comprehensive evaluation coefficient of overburden rock in MS08 borehole, the coal seam roof and floor of the 3105 working face have a variety of lithologies,

among which the sandy mudstone and fine and medium sandstone are the main ones, and the sand content at the bottom is large. The direct roof of the 2-1 coal seam is sandy mudstone with a thickness of 7.03m, and the direct bottom plate is sandy mudstone with a thickness of 12.45m. The comprehensive evaluation coefficient of borehole overburden is shown in Table 1 below

Because the spatial size of the study area is too large, the transverse and longitudinal spans of the stratum structure are large and the lithology is complex and diverse, and the strata in the study area contain many rock layers with different lithologies, if all the strata in the study area are modeled, this will bring a huge workload and calculation load, which is not very practical in practical engineering applications, so in practical engineering applications, it is necessary to compound the rock strata with similar physical and mechanical properties in the stratum structure, and simplify the study of stratum structure. According to the calculation table of the comprehensive evaluation coefficient of overburden rock in borehole MS08, the study of stratigraphic structure is simplified into 7 strata, that is, from the first layer at the top to the bottom, a total of 7 layers, and the 2-1 coal seam is located in the 2nd layer, which is also the stratum structure of this simulated excavation.

Table 2-1. Calculation table of comprehensive evaluation coefficient of overburden rock in borehole MS08

Rocky	thickness	Evaluation factor	mi·Qi	Rocky	thickness	Evaluation factor	mi·Qi
topsoil	21.2	1	21.2	Sandy mudstone	27.76	0.5	13.88
Medium-grained sandstone	34.74	0.7	24.318	Powdered sandstone	24.74	0.7	17.318
Fine-grained sandstone	45.22	0.6	27.132	Coarse-grained sandstone	26.04	0.8	20.832
Medium-grained sandstone	42.78	0.7	29.946	Sandy mudstone	7.03	0.5	3.515
Fine-grained sandstone	35.63	0.6	21.378	2-1 coal	4.9	1	4.9
Medium-grained sandstone	31.75	0.7	22.225	Sandy mudstone	12.45	0.5	6.225
Fine-grained sandstone	39.5	0.6	23.7	Powdered sandstone	12.05	0.7	8.435
Medium-grained sandstone	34.75	0.7	24.325	coal	0.4	1	0.4
Fine-grained sandstone	36.07	0.6	21.642	Sandy mudstone	1.6	0.5	0.8
Medium-grained sandstone	29.67	0.7	20.769	2-2	1	1	1
Powdered sandstone	11.69	0.7	8.183	Sandy mudstone	7.28	0.5	3.64
Medium-grained sandstone	34.58	0.7	24.206	coal	0.4	1	0.4
Fine-grained sandstone	33.29	0.6	19.974	Sandy mudstone	3.87	0.5	1.935
Sandy mudstone	30.31	0.5	15.155	Medium-grained sandstone	19.71	0.7	13.797
Powdered sandstone	38.67	0.7	27.069	Powdered sandstone	9.84	0.7	6.888
Sandy mudstone	37.97	0.5	18.985				
Powdered sandstone	32.71	0.7	22.897	total	729.6		477.069

3.2. Model creation and cell division

According to the on-site geological data and rock mechanical parameters obtained from the on-site geological data and rock mechanical properties of a coal mining face in Menkeqing mining area, it can be seen that the model is set at 2000m along strike, 2000m wide along trend, 715m in height, and 2000m×2000m×715m in size.

Griddle is a Rhino advanced mesh generation plugin that can be used to generate Rhino software surface meshes of exact size and type (triangular or quadrilateral regions) that can be used as boundaries for Gridde volume meshes to generate high-quality tetrahedral or hexahedral meshes that can be imported into most engineering analysis packages, including FLAC3D.

In this paper, the Griddle advanced mesh plug-in is used to mesh, and the generated mesh files are imported into FLAC3D by dividing them into a grid every 10 meters and 20 meters in the study area, and the model is divided into 71875 meshes, and the FLAC3D 3D model is shown in the figure.

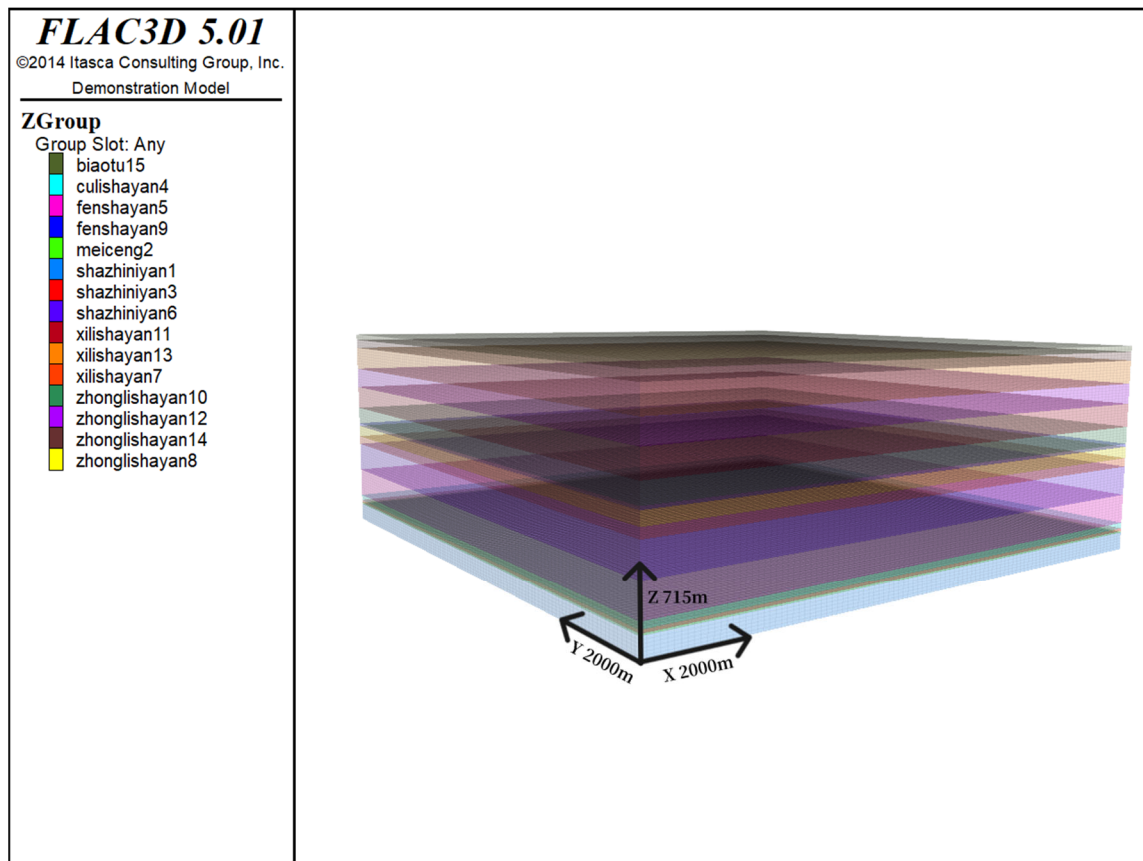


Figure 2-1. FLAC3D model

3.3. Model Parameters

The petrophysical and mechanical parameters used in this model are shown in Table 2

Table 2-2. Petrophysical and mechanical parameters

The name of the rock formation	Elastic modulus /GPa	Bulk modulus /GPa	Shear modulus /GPa	tensile strength /GPa	Tomarimatsuhi	angle of friction /°	cohesion /MPa	Bulk density kg/m3
Sandy mudstone	15.20	15.00	5.70	2.25	0.33	32.75	1.47	2410
coal	12.00	10.00	4.60	2.00	0.30	28.00	1.10	2300
Sandy mudstone	15.30	15.00	5.70	2.25	0.33	32.75	1.47	2410
Powdered sandstone	18.00	15.00	6.90	3.00	0.30	22.50	1.20	2430
Fine-grained sandstone	21.60	20.00	8.15	0.75	0.32	38.00	2.82	2550
Medium-grained sandstone	20.10	17.00	7.70	3.40	0.30	31.75	2.10	2540
topsoil	2.90	3.20	2.01	0.40	0.30	16.6	0.50	1870

3.4. Determination of boundary conditions

According to the actual situation of the 3105 and 3106 working surfaces, the boundary conditions of the model need to be set, the upper boundary of the model is the free boundary, the left and right boundaries are fixed with the displacement in the X direction, the front and rear boundaries are fixed with the displacement in the Y direction, and the bottom of the model is fixed with the displacement in the Z direction.

3.5. Monitoring point layout and excavation plan

The excavation of the working face, using the FISH language programming of FLAC3D, excavates 1000 meters along the x direction, that is, excavates from 500 to 1500 meters, and sets two working faces with a width of 400 meters in the y direction, and the position of the left working face is fixed, that is, excavates from 600 meters to 1000 meters along the y direction, and leaves 6m, 50m, 100m, 150m, 180m, 200m and other width coal pillars between the two working faces, and excavates. The observation line is arranged along the position of y=1000m, and the distance between the measuring points is 20m/piece.

4. ANALYSIS OF NUMERICAL SIMULATION RESULTS

4.1. Analysis of the displacement change law of excavated coal seam with different coal pillar widths

In order to study the mechanism of different coal pillar widths on surface subsidence, and to have a theoretical reference for the reasonable width of coal pillars, the widths of coal pillars left on the two working faces such as 3105 and 3106 were 6m, 50m, 100m, 150m and 180m. Five numerical simulations of 200m are used to analyze the change law of coal seam displacement and vertical stress at different widths of coal pillars, and the displacement and vertical stress contours of coal pillars with different widths are shown in the figure.

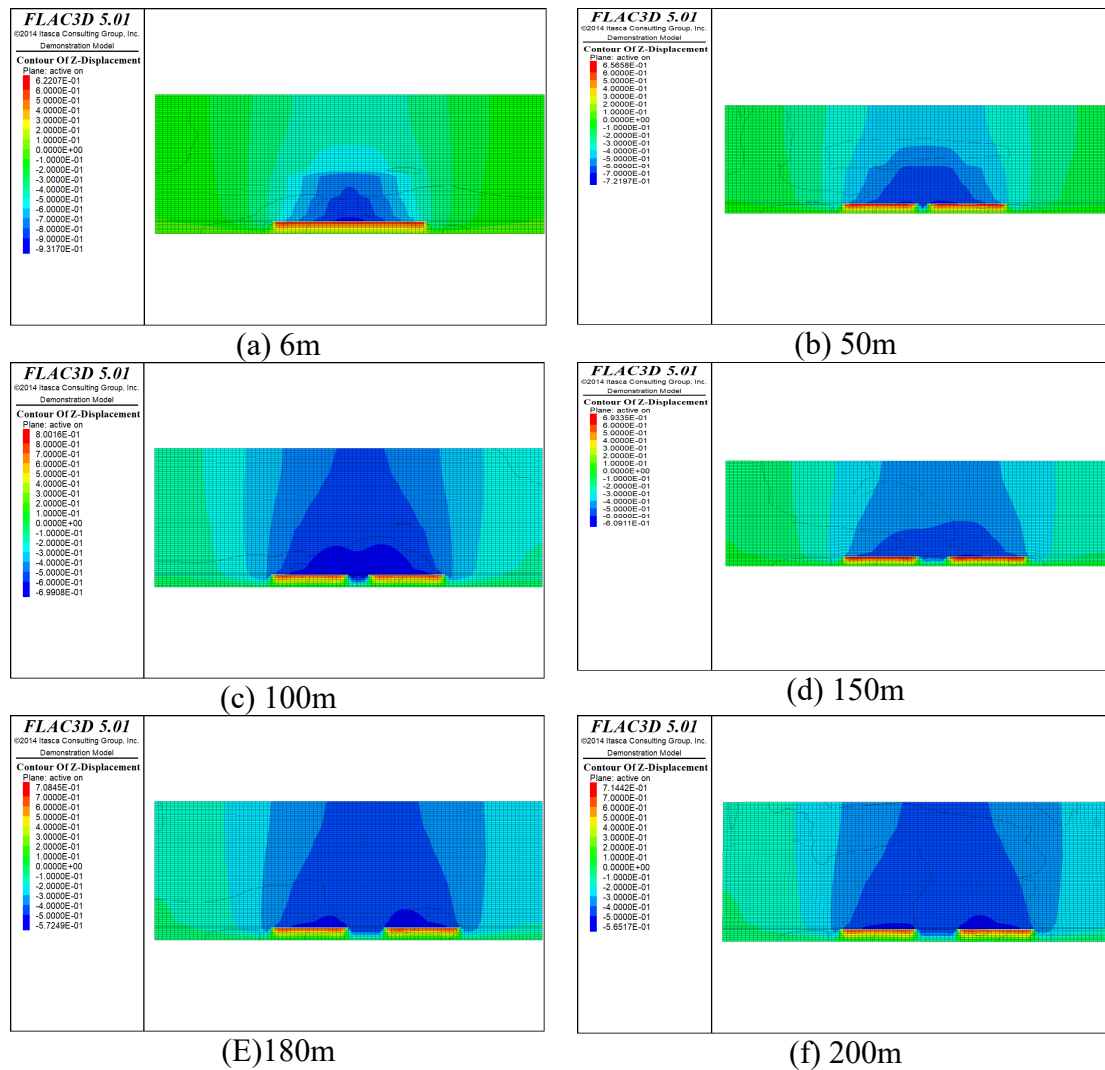


Figure 3-1. Vertical stress contour

The vertical displacement extracted from the above vertical displacement contour model is shown in the table

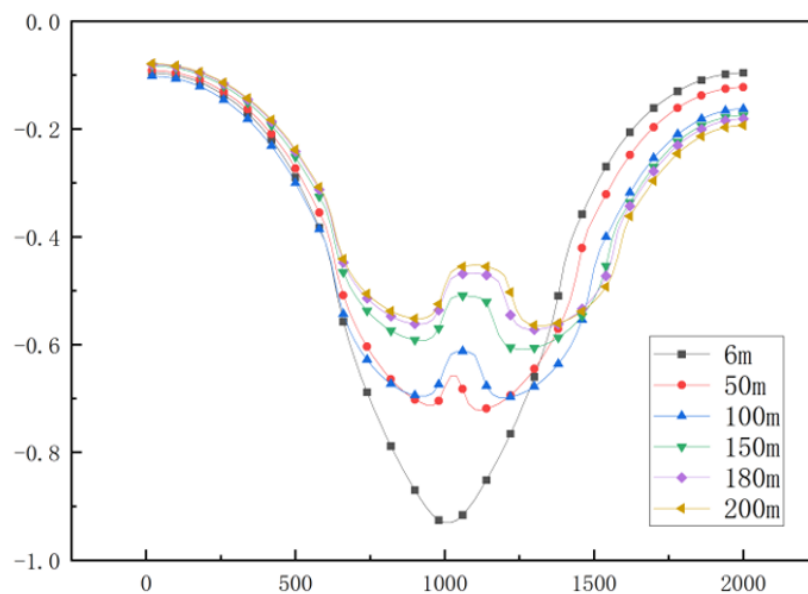


Figure 3-2. Vertical displacement curve

It can be seen from the surface subsidence values of each measuring point in the above table that when the width of the coal pillar between the two working faces is 6m, 50m, 100m, 150m, 180m and 200m, the basin formed gradually becomes shallower with the increasing width of the coal pillar, and the corresponding maximum surface subsidence values are 0.93m, 0.70m, 0.69m and 0.60m respectively, 0.57m, 0.56m. And it can be clearly seen that after the width of the coal pillar is set to 50m, the impact on the surface subsidence gradually weakens with each increase in the width of the coal pillar, and two basins are formed, the surface subsidence curve is gradually approaching and close to the same, and the corresponding change of the maximum surface subsidence value is becoming weaker and weaker.

Similarly, the horizontal displacement data is shown in the figure below:

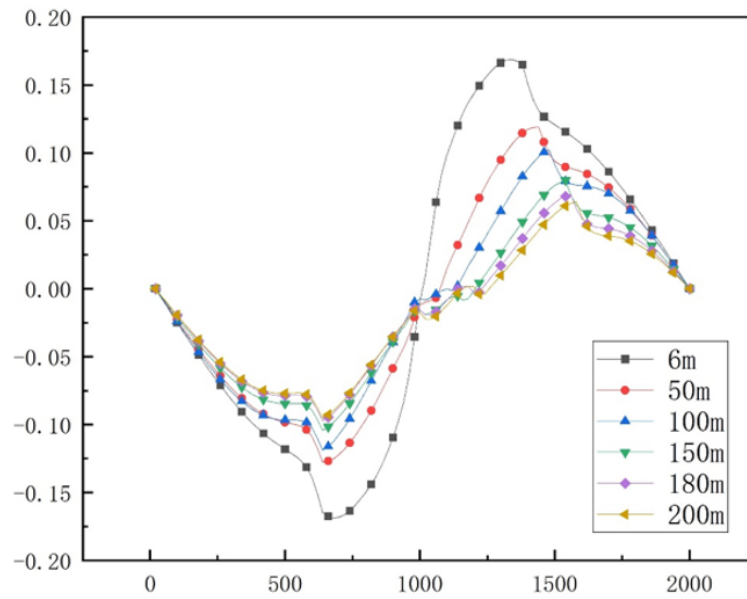


Figure 3-3. Horizontal displacement curve

The above figure shows the horizontal displacement distribution curve of coal pillar with different pillar widths. It is found that the horizontal displacement of the two sides of the remaining coal pillar shows the characteristics of central symmetry, and when the width of the remaining coal pillar gradually widens, the displacement of the coal pillar to the goaf shows a slow decreasing trend, and finally tends to a stable state. When the width of the small coal pillar increases from 6m to 200m, the horizontal displacement decreases gradually. When the width of the small pillar increases from 180 m to 200 m, the horizontal displacement decreases very little, and the two curves tend to coincide. It shows that when the width of the small coal pillar exceeds 180m, it has little effect on improving the horizontal displacement of the coal pillar.

It can be seen that the 11-3103 working face in the engineering example is located on the east side of the 11-3105 working face, and the reliability of the 180-meter large coal pillar retained between the two working faces, the laying of this coal pillar can not only reduce the impact on the surface subsidence, reduce the impact on the surface buildings and crops, but also can reasonably save coal resources.

4.2. Analysis of stress variation law of excavated coal seam with different coal pillar widths

The coal seam mining in the working face will lead to the fracture, fragmentation and collapse of the overlying rock layer in the goaf, so that the overburden damage will show a certain regular change. When the coal seam is mined, the stress in the coal seam will increase, decrease, concentrate and other changes, and the development range and characteristics of overburden failure can be judged according to its change characteristics. In order to more clearly reflect the stress distribution and evolution process of coal pillars of different widths in the simulation process, the maximum principal stress data with obvious stress changes were selected for analysis, and the stress evolution law and development form of overburden were judged to be judged.

The vertical stress contour diagram extracted from the vertical stress contour model is shown in the figure

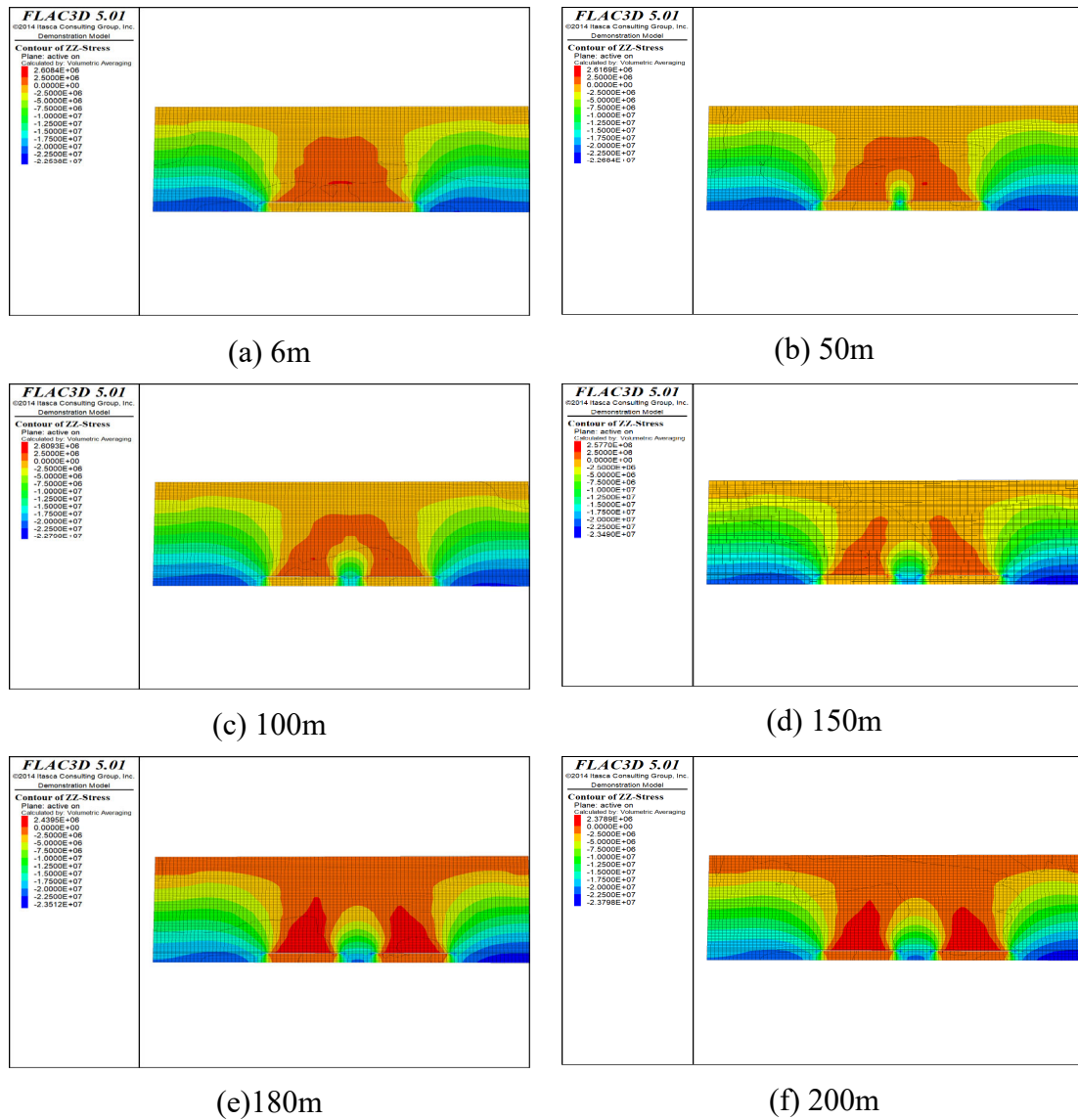


Figure 3-4. Vertical stress contour

In the process of coal seam mining, as the coal seam is gradually hollowed out. As a result, the roof loses its support and settles, and the bottom plate loses the pressure of the upper part, and the

phenomenon of uplift occurs. If the coal mine excavation in the goaf area is too deep and the coal pillar is too small, it will lead to the development of cracks or even the fragmentation of the upper overlying rock, and if it is connected to the aquifer or the rest of the water-rich areas, it will also lead to the occurrence of water inrush and flooding of wells. Therefore, numerical simulation research in the mining area can effectively avoid the occurrence of such accidents and take corresponding protective measures in advance. When the width of the coal pillar between the two working faces is 6m, 50m, 100m, 150m, 180m and 200m, the corresponding maximum vertical stresses are 22.53MPa, 22.68MPa, 22.79MPa, 23.49MPa, respectively 23.51MPa, 23.79MPa, It can be seen from the figure that in the process of face excavation, the compressive stress generated by the upper and lower ends is increasing, and at 6~150 m, the change amplitude of the compressive stress of the bottom plate is significantly faster than the stress of the roof, but at 150~200 m, the change amplitude of the compressive stress at both ends of the roof and the bottom plate is obviously smaller, indicating that the deformation of the top and bottom plate gradually tends to be stable. Therefore, during the mining process, the roof will bend and sink without breaking. And the stress is mainly concentrated at both ends of the roof, so in the mining process, the corresponding support treatment needs to be carried out at intervals, so that the occurrence of some unnecessary accidents can be prevented due to excessive mining.

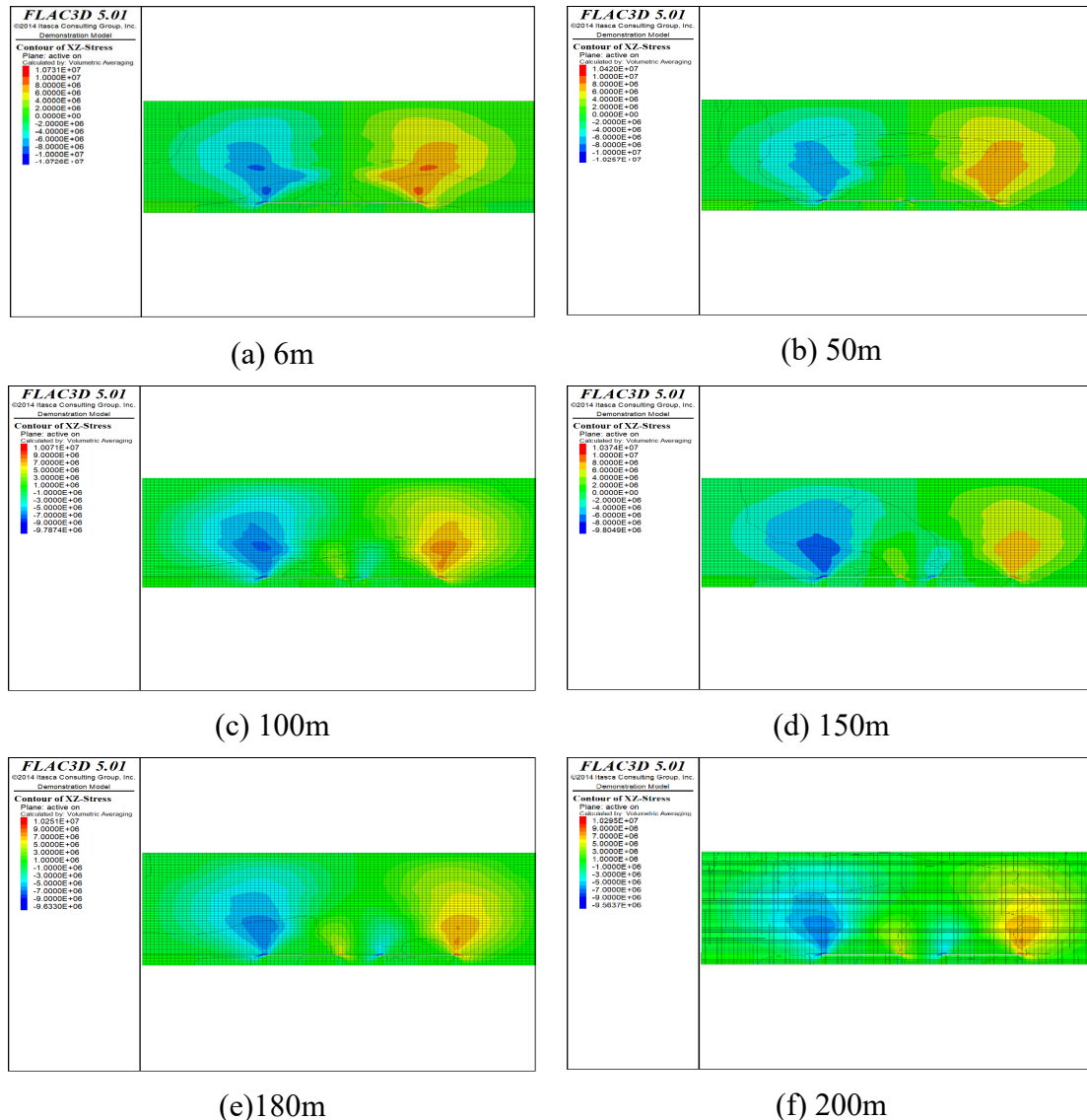


Figure 3-5. Shear stress contour

As can be seen from the above figure, in the process of mining and excavation, with the continuous increase of the goaf, the upper two ends of the overburden are affected by the vertical pressure, and the shear stress generated will also increase. When the width of the remaining pillar is 6m, 50 m, 100 m, 150m, 180m and 200m, the corresponding maximum shear stress is 10.72 MPa, 10.25 MPa, 9.98 MPa and 9.80 MPa, respectively, 9.63 MPa and 9.56 MPa. It can be seen from the figure that when the width of the coal pillar is from 6m~200m, the corresponding shear stress gradually decreases, indicating that with the increase of the width of the coal pillar, the degree of shear failure is constantly weakened, and the failure mainly occurs at both ends of the roof, which is in line with the principle of shear failure. It can be seen from the figure that with the increase of the width of the coal pillar, the corresponding shear stress curve gradually tends to coincide around the width of the 180m coal pillar, which illustrates the rationality of the design of the coal pillar width of the 3103 and 3105 working faces.

5. CONCLUSION

Referring to the actual stratigraphic survey data of Menkeqing Coal Mine, the displacement and stress after mining with different coal pillar widths were comprehensively analyzed through FLAC 3D numerical simulation, and the results showed that the vertical displacement, horizontal displacement, vertical stress and overburden shear stress of the excavation face were within the range of safe mining, and the conclusions were concluded

- (1) Based on FLAC3D software, numerical models of different coal pillar widths were established, in which the widths of the remaining coal pillars were set to 6m, 50m, 100m, 150m, 180m and 200 m, respectively, and the model parameters were set in strict accordance with the rock formation parameters of the borehole map to ensure the accuracy of the numerical simulation results.
- (2) When the width of the coal pillar is set from 6m to 180m, the vertical displacement and horizontal displacement gradually decrease, and the corresponding curves tend to coincide, and then the change is not obvious when the width is set to 200m. It can verify the reasonableness of setting 180m coal pillar width on the working faces of coal mines 3103 and 3105. The laying of this coal pillar can not only reduce the impact on the surface subsidence, reduce the impact on the surface buildings and crops, but also reasonably save coal resources.
- (3) When the width of the coal pillar increases, the corresponding compressive stress in the vertical direction gradually increases, while the corresponding shear stress decreases gradually, and the curve changes of vertical stress and shear stress become weaker and weaker and tend to coincide, indicating that with the increase of the width of the coal pillar, the damage degree to each rock layer after coal mining is gradually weakened.

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