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NUMERICAL SIMULATION ON MINING EFFECTS OF UPPER COAL SEAM ON LOWER COAL SEAM OF SPLITTING AREA OF SPLITTING AND MERGING COAL SEAM**

1. Face situation

The 7225 face is above the gob of 7118 face. The elevation of face ranges from –452.9 to –485.6 m, and ground elevation is +25.0 m. Strike length of the face varies from 417 to 527 m, 474 m, and the length of 121 m in width.72 coal seam in this face belongs to Lower Shihezi Formation of Lower Permian, thickness changes from 1.70 to 2.50 m, an average thickness of 2.50 m, occurrence is stable, spacing between 71 coal in the upper layers and 72 coal varies from 0.8 to 9.3 m, with an average 5.0 m, and the spacing of 82 coal in the lower part and 72 coal ranges from 14.35 m to 16.20 m, an average thickness of 15.15 m, coal seam dip angle vies from 8 to 16°, the average angle is 10°.

2. Establishment of model

2.1. Geometric model

The actual geological conditions are simplified appropriately. The length of the model is 260 m, and the strike length is 300 m. The total height of the model is 116.86 m. The width

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of face 7225 along the dip is120 m, face 7225 along the strike direction is 120 m. The part of the overburden is not shown in the model; it is replaced by the load. A geometric model of the numerical simulation of the 7225 face is shown in Figure 1.

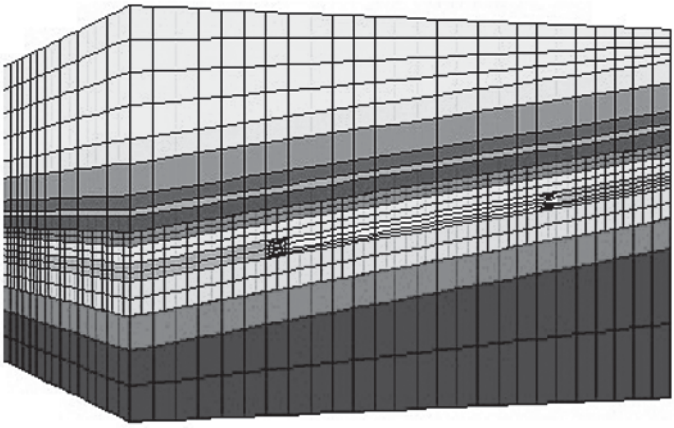


Fig. 1. Geometric model

2.2. Physical model and mechanical parameters

The rock mass failure is determined by applying Mohr-Coulomb yield criterion.

$$f_s = \sigma_1 - \sigma_3 \frac{1+\sin\varphi}{1-\sin\varphi} - 2c\sqrt{\frac{1+\sin\varphi}{1-\sin\varphi}} \tag{1}$$

where:

σ_1 and σ_3 — are the maximum and the minimum principal stress, respectively;

c and φ — are the cohesive force and the friction angle, respectively.

In Mohr-Coulomb plasticity model, physical mechanical parameters of rock and soil include the bulk modulus B, shear modulus S, cohesion force C ,angle of internal friction f, density D, and tensile strength P, in which B and S are determined by elastic modulus E and Poisson's ratio u of rock and soil.

$$S = \frac{E}{2(1+u)} \qquad B = \frac{E}{3(1-2u)} \tag{2}$$

The numerical simulation model of rock mechanics parameters are listed in Table 1.

TABLE 1

The mechanical parameters of rock

Lithology	Thickness, m	Density, kg/m^3	Modulus of elasticity, GPa	Poisson's ratio	Cohesion, MPa	Angle of internal friction, °	Tensile strength, MPa
Claystone	3.84	2530	4.19	0.26	1.70	32	1
51coal	1.24	1450	3.50	0.27	1.25	30	0.2
Claystone	46.9	2514	4.40	0.23	1.52	32	1.38
Fine sandstone	18.9	2600	33.4	0.23	5.20	42	4.38
Claystone	1.2	2504	3.92	0.21	1.16	29	0.7
71 coal	1.9	1400	3.50	0.27	1.25	30	0.2
Claystone	5.0	2510	4.42	0.15	1.92	28	1.1
72 coal	2.5	1400	3.80	0.21	1.46	30	0.2
Claystone	1.0	2260	4.65	0.20	1.85	32	1.1
Fine sandstone	14.2	2660	33.4	0.23	5.20	42	2.65
82 coal	2.74	1400	3.42	0.15	1.96	28	0.2
Fine sandstone	2.4	2520	4.19	0.23	1.70	32	2.75
Siltstone	9.2	2580	25.0	0.16	3.53	38	3.9
Claystone	4.4	2770	4.19	0.26	1.70	32	1.5
Siltstone	7.0	2580	28.0	0.21	3.27	35	2.1
Camel sandstone	3.2	2600	33.4	0.23	4.20	42	1.4

3. Simulation results

3.1. Stress distribution law of 7118 goaf bottom plate

3.1.1. Propagation along the coal seam abutment pressure in the bottom

Figures 2 illustrates the contours of abutment pressure concentration factor in front and rear of the face along the strike direction. The calculation results show the strata behaviors in the floor after mining can be divided into several different areas:

— stress increasing area: A region, which is larger than the original stress, is formed in front of face, and the closer to the seam stress concentration is, the greater is, and the maximum stress concentration factor is 2.3, the propagation depth in the floor is 85 m, the angle between peak transmission line and the seam vertical is 24°, the stress propagation angle is18°;

— stress decreasing area: Stress was significantly lower than the original stress in the floor strata under the goaf of neighboring coal body, stress and the coal body of the goaf edge shows certain angle, decreases gradually with the extent of the seam relief pressure;
— original rock stress area: the lower of the gob of coal body edge lies between stress decreasing area and stress increasing area , is impacted by the mining slightly.

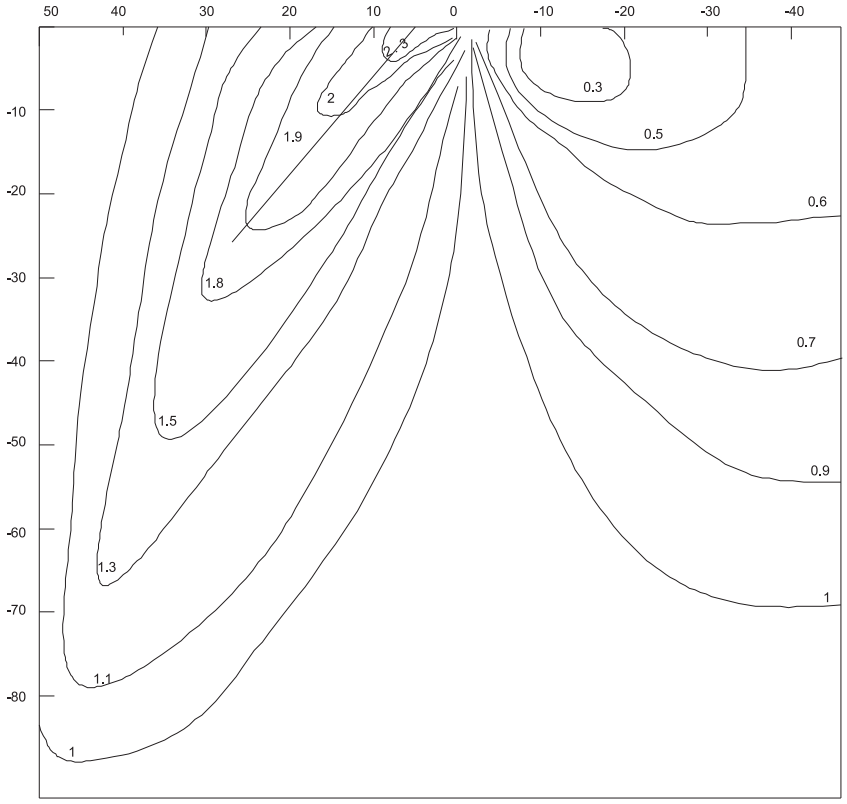


Fig. 2. The contour map of the stress concentration factor along the strike of the floor

3.1.2. Laws of abutment pressure propagation of the floor along the dip of the seam

Figure 3 shows the contour map of the stress concentration factor along the inclination of the floor, it can be included that stress increasing area is formed in the lower of the coal body, its maximum impacting depth is in the upper side 65 m, and the lower side of about 87 m, the upper of the angle between peak spread line and the seam is 23°, the lower angle is 32°, and stress decreasing area is produced below the goaf, in where about 90 m of the goaf is restored to the original rock stress state, the weak impacting area is formed at the junction of stress increasing area and stress decreasing area.

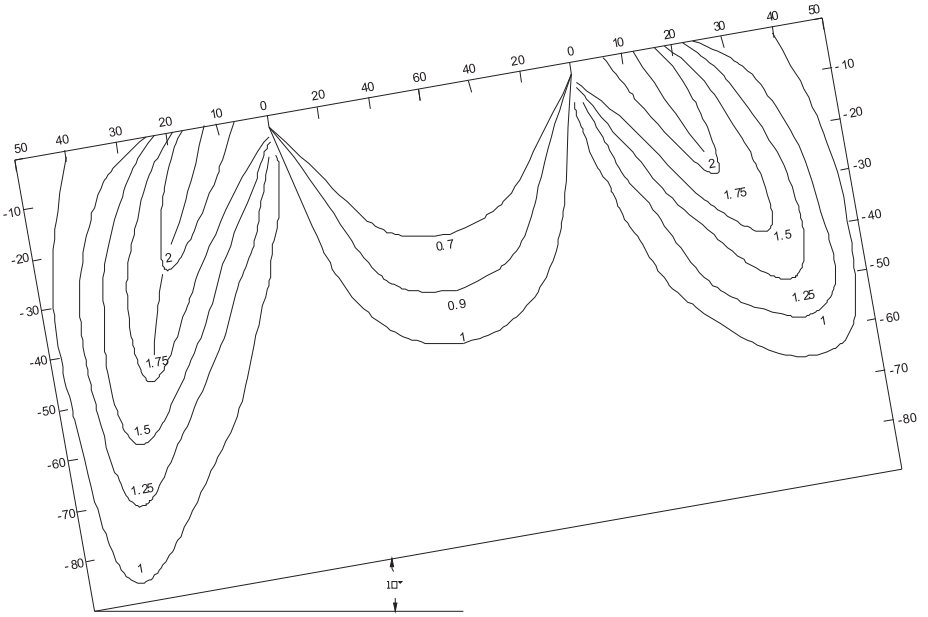


Fig. 3. Contour map of stress concentration factor along the floor dip

3.1.3. Failure laws of 7118 goaf floor

Figures 4 and 5 show plastic yield failure characteristics of the floor 20 m and 60 m behind the face, figure 6 illustrates the curve of floor failure depth behind the goaf changes with the distance away from the face. None shows that the cells do not produce tensile failure; shear-p is the unit of shear failure, shear-n stands for the unit is undergoing shear failure; tension-p cells represent tensile failure, tension-n means that the unit produces tensile failure. The simulation results show that with the advance of the face, caving rock in goaf 7118 was compacted, elasticity restored gradually, the floor also gradually returned to the elastic state, the failure depth decreased, and the failure range is about 5.04 m.

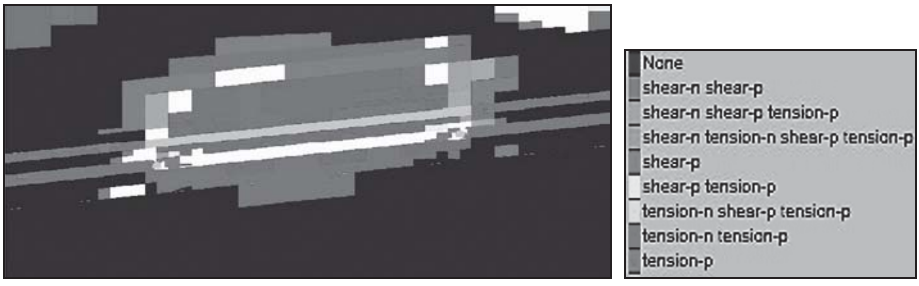


Fig. 4. Characteristics of plastic yield failure in rear of 20 m

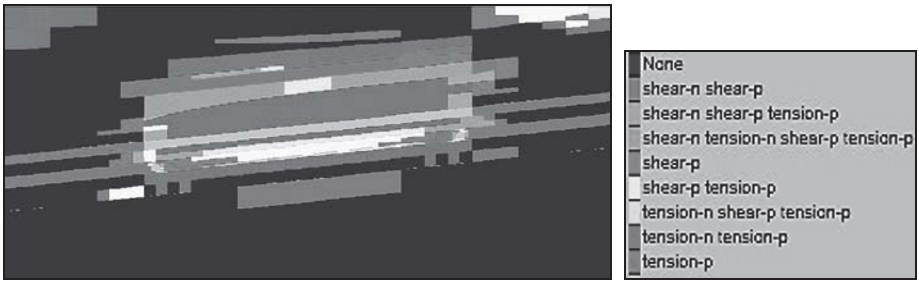


Fig. 5. Characteristics of plastic yield failure in rear of 50 m

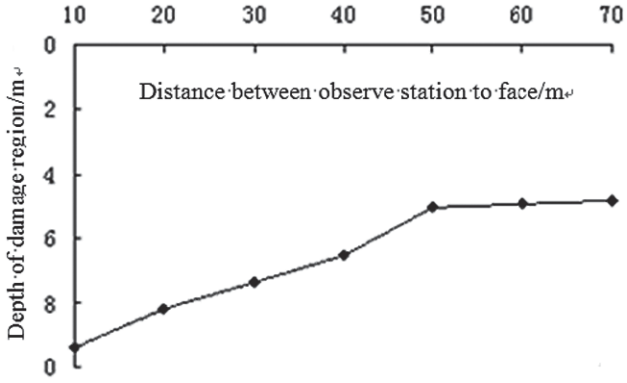


Fig. 6. The deep range of floor failure in rear of 7118 gob

4. Broken roof control technology

4.1. Selection of support type in the face

7225 face lies in the bifurcation of coal 71 and coal 72, because coal 71 mining has an influence on the floor failure, floor of 72 coal is extremely broken and fault structures are well — developed, this influences the mining of 72 coal seam strongly. Both immediate floor and immediate roof are mudstone ,and coal body is also loose, it belongs to coal face with typical broken roof „three soft". 7225 face is mined safety and efficiently, it had better choose four-pillar shield support. This support is helpful for leveling the roof beam under the condition of the broken loose roof, maintaining the roof, preventing rib spalling and caving in front of support. Type of f four-pillar shield support is ZZ7600/20/40, its nominal initial supports strength is 6970 KN, rated working resistance is 7600 kN, rated support intensity varies from 0.97 to 1.03 MPa, the height of bracket changes between 2.0 and 4.0 m, the width of support ranges from 1.43 to 1.6 m, the specific pressure of the floor varies from 1.8–3.2 MPa. The parameters are shown in Table 2.

TABLE 2

The main technical parameters of the hydraulic support ZZ7600/20/40 type

Type	ZZ7600/20/40
Height, m	2.0～4.0
Initial support strength, KN	6970
Working resistance, KN	7600
Width, m	1.43～1.6
Support strength, MPa	0.97～1.03
Floor specific pressure, MPa	1.8～3.2
Support strength, MPa	1.01

4.2. Roof pre-grouting reinforcement

On the basis of the numerical simulation results, the spacing of coal 71 and coal 72 is less than 5 m that of bifurcation area, control the broken roof by the use of pre-grouting reinforcement. Grouting materials is the mixture of cement-sodium silicate, and the amount of sodium silicate is about 3 to 5% of the cement. Grouting pressure is 2 MPa. The grouting arrangement is illustrated in Figure 7. Grouting design parameters are shown in Table 3 and 4.

TABLE 3

Parameters design of Grout hole in 1# drilling field

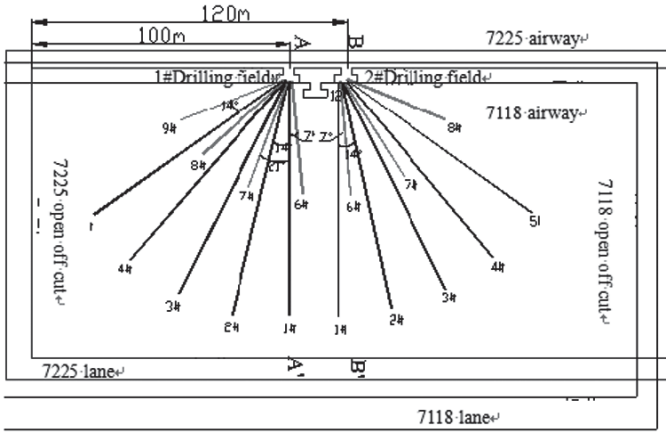
Borehole number	1#	2#	3#	4#	5#	6#	7#	8#	9#
Azimuth angle, °	90	104	118	132	146	83	111	139	160
Inclination angle, °	–11	–10	–8	–7	–6	–10	–8	–6	–5
Hole depth, m	80	80	80	80	80	40	40	40	40

TABLE 4

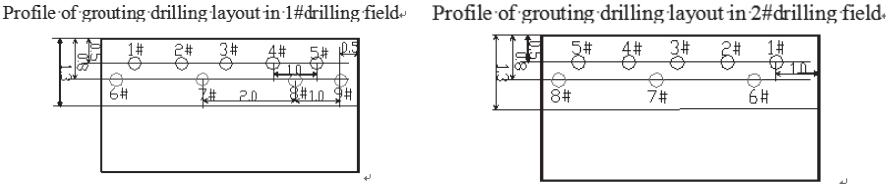
Parameters design of Grout hole in 2# drilling field

Borehole number	1#	2#	3#	4#	5#	6#	7#	8#
Azimuth angle, °	90	76	62	48	34	83	55	20
Inclination angle, °	–7	–6	–5	–4	–3	–3	0	3
Hole depth, m	80	80	80	80	80	40	40	40

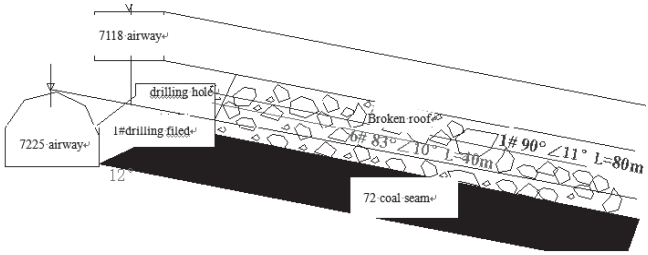
a)



b)



c)



d)

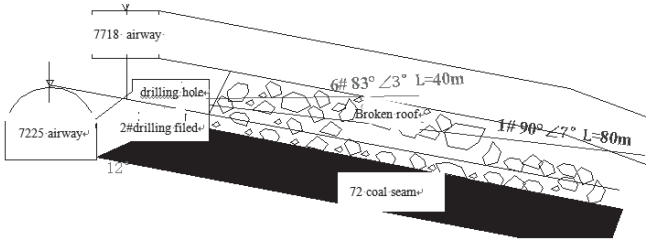


Fig. 7. Grout hole layout diagram:
a) plan of Grouting drilling layout; b) profile of grouting drilling layout;
c) A–A' profile of 1# drilling field; d) B–B' profile of 2# drilling field

Since the 7225 face has been mined, rib spalling and leakage gangue do not occur seriously, the recovery is very smooth, and the velocity of face recovery is 150 m per month, the maximum is nearly 100,000 t per month. Industrial applications shows that the mining method selection of the 7225 Face is reasonable, it is significant for reasonable selection of equipment and mining technology organization to obtain technical and economic benefits.

5. Conclusions

1) Floor stress distribution in the 7118 face were studied by numerical simulation, it provides a theoretical basis for the broken roof control technology.
2) On the basis of numerical simulation, ZZ7600/20/40 four-pillar shield support was developed and pre-grouting reinforcing drilling program and grouting parameters were designed, these provide for the safe and efficient exploitation of broken roof face protection.
3) Industrial applications show that the mining method selection for 7225 Face is correct, reasonable equipment selection and mining technology can obtain significant technical and economic benefits.

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