Numerical study of acceptable pillar size when mining against a steep fault

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Abstract: This paper used 3# coal seam mining of Mengzhuang Coal Mine as an example and the FLAC^{3D} software was used to analyze the reasonable fault coal pillar width leaving in high angle condition. The results show with the width reducing of coal pillar, the range of concentrate stress before the working face was getting larger meanwhile the phenomenon of stress concentration appeared in the fault zone and the stress concentration had an overlapping trend; the rock displacement of the fault two sides show significant difference. Finally, the coal pillar width was determined not less than 30m providing the theoretical basis for the fault coal pillar leaving.

Introduction

The fault zone rock which attracts the most attentions of underground mining is broken meanwhile it's also one of the main reasons causing the deformation of the roadways and water-inrush from coal floor (TANG et al, 2006; PENG, 2009). Coal mining near the fault zone may lead to the active of the fault zone and it is one of the main reasons leading to the water-inrush (WU et al, 2007; LI et al, 2002). The size of coal pillar near the fault zone was used to setting by the traditional method such as according to the accurate value in the relevant regulations. The stability of fault zone may change while mining caused by the mining stress. The displacement differences between two walls may lead to the activation of fault zone (LI et al, 1996; FENG and FU, 2004; UNVE and YASITLI, 2006). So, research on the mining characteristics near the fault zone and leaving reasonable size of coal pillar can improve the recovery rate of coal resources.

FLAC^{3D} software was used as the tool to research the change characteristics of stress and displacement of two walls while mining. Finally, the reasonable size of coal pillar was determined.

Mining area survey

Mengzhuang coal mine was located in Xiao xian of Suzhou city, Anhui province north from Xuzhou city of Jiangsu province 25km. Annual production capacity was 30 million tones and the service time was about 66 years. The coal mine was divided into four stages in different levels. The first level value was -200m and the second level was -300m. The third level was -450m and which of the fourth was -760m. The stratigraphic system belongs to North China stratum. The target coal was 3# coal and the average thickness was 2m.

The building of the model

The geological model was a steep angle model. The stratum angle of the working face was about 30°according to the data and which of F3 fault was nearly 70°with a drawdown between 20m to 40m. The elevation of coal floor was between -150m to -300m and the width of the working face was 150m.

The geometry of numerical model was as flows. The width of model was 210m and the length
of the model was 455m and the height was 304m. The numerical model was divided into 438816 grids. The dip angle was 30°.

The bottom boundary condition was fixed and the horizontal direction was limited around the model. The top of the model was free boundary and apply the equivalent stress above the model. The model reached the initial stress balance state after running about 2000 steps. The numerical model built was shown as Fig.1.

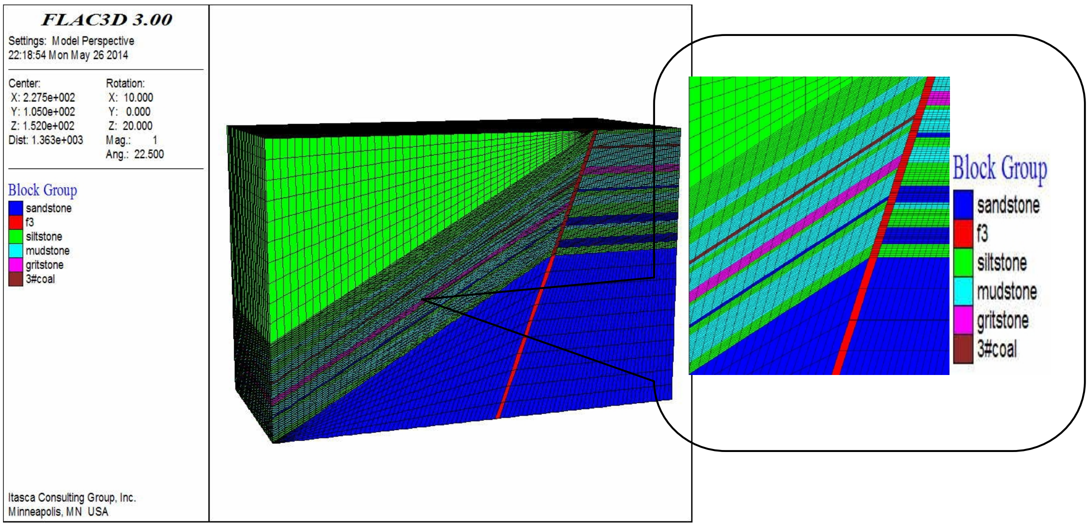


Fig.1 numerical model

The constitutive model and yield criterion was selected the Mohr-Coulomb plasticity model. The mechanical parameters of numerical model were achieved from the tests results of drill core and fault zone and the values were reformulated by RQD method. The bulk and shear modulus were calculated by the flow formulas. The results were shown as table 1.

$$K = \frac{E}{3(1-2m)} \quad G = \frac{E}{2(1+m)} \tag{1}$$

Where K was bulk modulus; G was shear modulus; E was elasticity modulus; m was Poisson's ratio

Table1 Mechanical parameters of numerical model

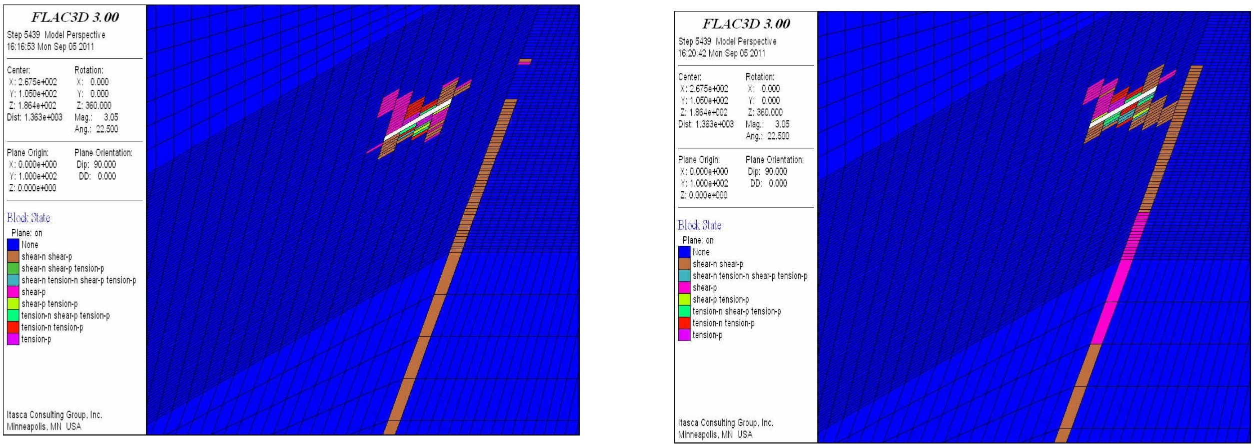
Rock name	Density (kg/cm^2)	Elasticity modulus (GPa)	Poisson's ratio	Cohesion (MPa)	Tensile strength (MPa)	internal friction angle (°)
Siltstone	2.56	14	0.25	2.4	2.2	32
Gritstone	2.82	16	0.23	7.5	6.2	40
Mudstone	2.65	12	0.22	2.2	1.6	30
Sandstone	2.65	13	0.21	6.2	4.5	36
3#coal	1.42	4	0.35	1	0.3	20
Fault zone	2.0	8	0.24	0.6	0.3	22

The results of numerical simulation

The characteristics of deformation and damage of coal floor and roof were calculated based on Mohr-Coulomb theory and iterative method. The influence of F3 fault zone caused by the mining stress was achieved while the reducing of the fault zone width. The characteristics of failure, stress and displacement were obtained. The hanging roof span and stress concentration degree were the maximum when the first weighting , so we choose the first weighting time for researching.

Analysis of plastic characteristics with different coal pillar width

The plastic damage appeared both in coal floor and roof and the shape was nearly saddle-shaped. This phenomenon was caused by the stress concentration. The influence degree of F3 fault zone caused by coal mining was getting larger with the reducing of coal pillar. The plastic damage was obvious while the coal pillar width was 20m. The plastic scope extended into the fault zone and the fault zone was almost broken. The plastic state of model was shown as Fig.2.

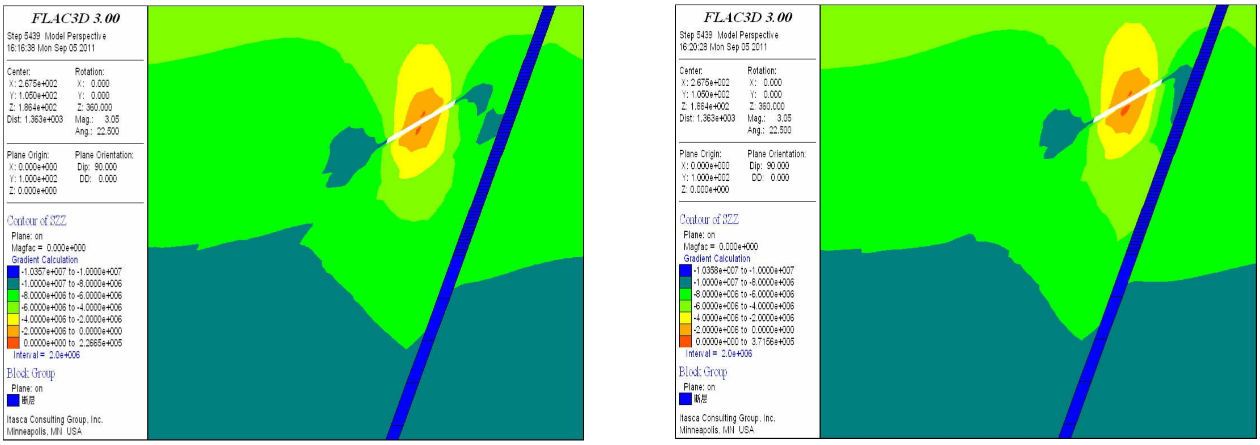


a plastic state while coal pillar width was 20m   b plastic state while coal pillar width was 10m

Fig.2 The plastic state of model in different coal pillar width

Analysis of stress characteristics with different coal pillar width

The stress concentration phenomenon was appeared near the fault zone and the range of scope was getting larger while the reducing of coal pillar. The stress concentration scope between support pressure of coal pillar and fault zone was underlying connection while the width of coal pillar was 20m. The stress concentration scope was fully connected together while the coal pillar width was 10m. The stress distribution was shown as Fig.3. The stress concentration on the fault zone can lead to the plastic damage of fault zone. If the fault zone was water conductive fault, the water from deep confined aquifer may inrush to the working face along the water flowing fractured zone.

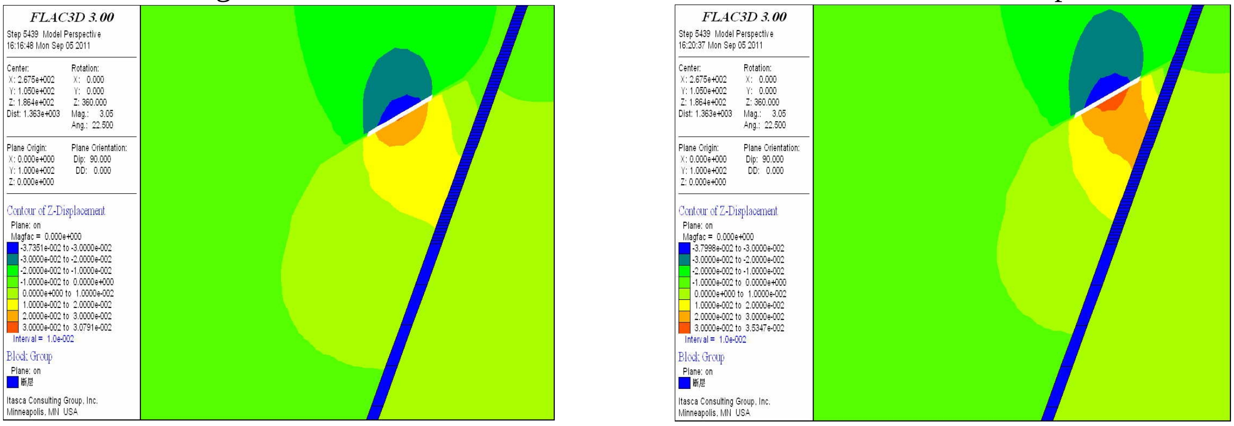


a stress distribution while coal pillar width was 20m   b stress distribution while coal pillar width was 10m

Fig.3 The stress distribution of model in different coal pillar width

Analysis of displacement characteristics with different coal pillar width

The vertical displacement of coal floor near the fault zone was getting larger while the width of coal pillar was reducing. Heaving floor appeared obviously when the width of coal pillar was 20m, the vertical displacement of coal floor can reached to 2~3 cm. The vertical displacement distribution was shown as Fig.4. This phenomenon leaded to the tensile failure of the coal floor and the fault zone. The rock mass of two walls of the fault zone may occur relative slip along the fault zone leading to the activation of fault zone. This was not conducive to water prevention.



a displacement distribution while coal pillar was 20m b displacement distribution while coal pillar was 10m

Fig.4 The vertical displacement distribution of model in different coal pillar width

The vertical displacement of rock mass near the two walls of fault zone was monitored to research the change of fault zone while reducing of coal pillar. The results were shown as Fig.5. When the state of the fault zone was compression state, in other words, the vertical displacement was negative; it was conducive to water prevention. On the contrary, while the direction of vertical displacement was up, the fault zone may be in tension state. Meanwhile, when the difference between two walls of fault zone was small, the fault zone was stable. When obvious difference of displacement appeared, the fault zone was active. It may lead to water inrush accident.

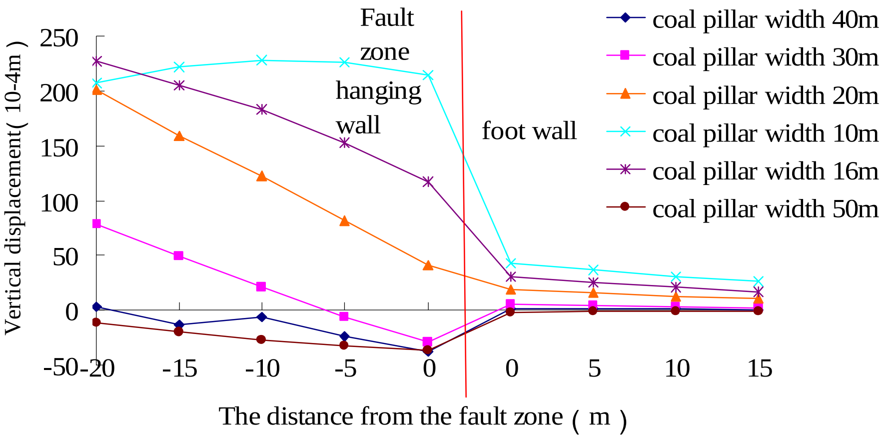


Fig.5 Displacement monitoring of the two walls of fault zone

While the width of coal pillar was 30m, the direction of vertical displacement of fault zone was down. The fault zone was in compression state meanwhile the rock mass of hanging wall was in compression state. There was small difference between two walls of fault zone. When the width of coal pillar was less than 30m, the direction of vertical displacement changed from up to down. The heaving of floor extended into fault zone. Meanwhile the displacement of the hanging wall increased suddenly and became larger while the reducing of coal pillar. Otherwise, the displacement of footwall did not change. The differences of displacement between two walls of fault zone may lead to water inrush from fault zone. So the critical width value of coal pillar was 30m.

Conclusions

The plastic state, stress and displacement of coal floor and fault zone were analyzed by numerical simulation. The results show that the scope of plastic area of coal floor and stress concentration was getting larger and finally extended into fault zone whiles the reducing of coal pillar. The direction of displacement changed from down to up appearing tension state while the width of coal pillar was 30m. Meanwhile the displacement differences appeared obviously. The reasonable width of coal pillar was not less than 30m. The results can provide theoretical basis for setting of coal pillar of F3 fault zone.

Acknowledgements

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