Investigation on the Overburden Deformation and Failure under the Influence of Thrust Faults: A case study in the Yima Mining Area

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Abstract

This paper presents an experimental and numerical simulation of the overburden deformation and failure due to coal mining under the influence of a regional thrust fault, namely F16, in the Yima mining area, Henan province, China. The failure heights of caving zones and water flowing fractured zones after mining each coal seam were gained in the condition with and without setting up fault coal-pillars, respectively. The results show that the fault has the "barrier" effect on overburden failure and deformation, the caving zone, water flow fractured zone developed in the footwall would hardly extend to hanging wall. The heights of overburden failure were finally determined by considering the results from scale simulations, numerical simulations and calculations according to the code. The results put forth an engineering geological basis for safety assessment of coalmining in the area influenced by thrust faults.

Keywords: thrust fault, overburden failure, caving zone, water flow fractured zone, ground movement.

1. Introduction

As important discontinuities in rock mass, faults damage the integrity of the rock mass seriously, and also dramatically change its mechanical strengths (Kurlenya and Seryakov, 1996). Faults are prone to be activated by mining activities and then influence the roof stability of coal seams. In the panels with faults, the overburden failure will be affected obviously and should be taken into consideration.

The hard roof and thick gravel stone strata are the main geological characteristics of the Yima mining area, Henan, China, the influence on the overburden failure of the complex shape of the fault are safety geological problems during coal mining.

The F16 thrust fault is located in the southern part of the Yima mining area, it is a group of compressive shear thrust faults with a strike of nearly east-west. The fault and its influenced zone have a complex geological conditions, with a thick overlying gravel stone strata and an obvious stress accumulation. Therefore, in order to evaluate coal mine safety production near the fault, the investigation on the overburden deformation and failure during coal mining under the influence of thrust faults should be studied systematically.

2. Geological Conditions

The Yima mining area is located in the west of Henan province, China. It is the only huge thick Mesozoic coal field in Henan province. The northern and western boundaries of the Yima mining area are the outcrops of coal Seam 2-3; its eastern boundary is the Jurassic strata, and its southern boundary is the F16 thrust fault. The main body of mining area is geologically located in the northern wing of a syncline, and its whole shape is a southward monocline, generally striking in East-West with a dip in the middle of the coal field of less than 16°, and a larger one about 35° in the eastern part of the mining area. Figure 1 shows the geological structure outline of the Yima mining area.

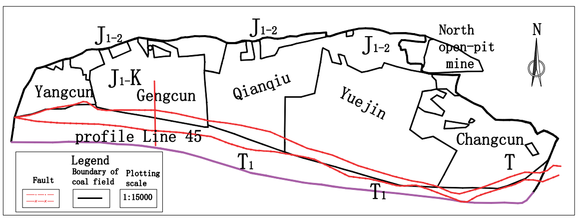


Fig. 1 Geological structure outline of the Yima mining area

The regional major geological tectonic unit is the Mianchi-Yima syncline, which presents a asymmetric syncline with a length of 50 km and a width of 20 km, approximately. Its axial direction is near the northeast, dipping to the southwest. The faults in the Yima mining area are mainly divided into two types; tensile shear faults and compressive shear ones. The compressive shear faults are step thrust fault. They were mainly formed in late Yanshanian Period.

3. Methodology

3.1 Scale Model

Scale model simulation is a model experiment technology based on the similarity theory (Bai et al., 2001; Cui, 1990). The experiment in this paper is mainly based on geological conditions of F16 thrust fault and its affected zone in Yima mining area, from the coal geological drilling data and seismic exploration results. The section at profile Line 45 across the F16 thrust fault was selected to be prototype for scale modeling. Two mining situations were simulated: one is with setting up fault coal-pillar (a coal-pillar left for safety purpose when mining adjacent to a fault), another without. The overburden deformation and failure during mining, relevant overburden movement, mining influencing scope, and influence on F16 thrust fault when mining in the footwall. Figure 1 also shows the location of the profile Line 45.

The geometric similarity scale for the model b=1/200, time scale $a = \sqrt{b}$ =0.07, weight scale *C*r is determined 1. Then, the strength scale C_R=1/200. The geometric size of the model is 3 m × 1.6 m × 0.33 m (Length × wide × height). Two coal seams would be extracted in the model; the upper is coal Seam 1-2 (a productive coal seam with a thickness of 2.4 m) with a thickness of 1.2cm in model, the lower is coal Seam 2-3 (a productive coal seam with a thickness of 14.2 m) with a thickness of is 7.1cm in model. Figure 2 shows the engineering geological model of profile Line 45.

Rock physical and mechanical parameters of profile Line 45 were measured and satiated according to experimental results and geological data. The proportion of each material to simulate rocks in the profile Line 45 was determined by trial and error method.

Grid calibration points were used to monitor the overburden deformation and failure during mining.

Table 1 Types of rocks and its material ratios of profile Line 45

No.	Chronostratigraphy	Lithology	Thickness (m)	UCS (MPa)	Density (g/cm^3)	Weight proportion (%)		
						Sand	Calcium carbonate	Gypsum
1	J_{2m}	sandy mudstone	22.04	21.75	2.51	87.5	6.25	6.25
2	J_{2m}	fine sandstone	159.56	47.2	2.52	80	6	14
3	J_{2m}	conglomerate	3.15	29.76	2.50	85.7	4.3	10
4	J_{2y}	mudstone	15.44	11.57	2.451	85.7	4.3	10
5	J_{2y}	1-2 coal seam	2.35	8.45	1.36	90.9	6.4	2.7
6	J_{2y}	mudstone	24.03	30.1	2.45	85.7	4.3	10
7	J_{2y}	2-3coal seam	14.24	8.65	1.36	90.9	6.4	2.7
8	J_{2y}	interbedded mudstone and fine sandstone	12.01	17.3	2.39	83.3	11.6	5.1
9	T_3	mudstone	16.18	30.1	2.45	90.9	5.5	3.6
10	T_3	medium sandstone intercalated by mudstone	50.9	19.3	2.50	87.5	6.25	6.25
11	T_3	interbedded medium sandstone and mudstone	63.3	15.9	2.52	85.7	10	4.3
12		Fault zone		0.58	1.90	87.5	6.25	6.25

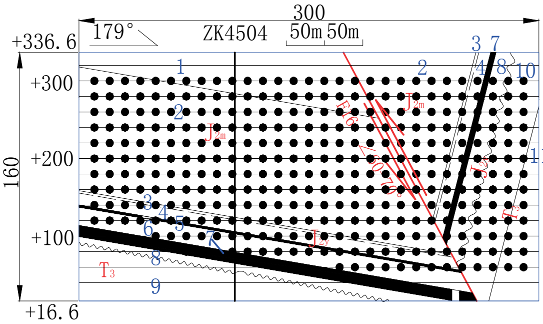


Fig. 2 Engineering geological model of profile Line.45

3.2 Numerical Simulation

UDEC has been widely used in mining, tunneling and other geotechnical engineering (Zhang and Yu 2004).

Numerical simulation model in this paper is established by using UDEC 4.0 to simulate overburden deformation and failure situation in the process of mining, which is under the influence of F16 thrust fault. The main purpose is: by analyzing the failure structure diagram, we can get the overburden deformation and failure process while coal seam mining.

Comparing to the scale model, a two-dimensional calculation model with a length of 600m and a height of 320 m was established by using UDEC 4.0. The elevation of the top of +336.6 m and the bottom is +16.6 m. The ground elevation is +620 m, then, the overburden above the model thickness is about 280m. According to the calculation, A vertical load of 7.0MPa was applied on the top of model to simulate the overburden weight. Figure 3 shows the distinct element calculation model.

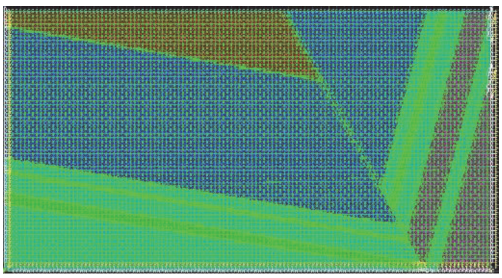


Fig. 3 A distinct element calculation model for profile Line 45

4. Results and Analysis

4.1 With Setting up Fault Coal-pillars

A 100 cm wide coal pillar on the left side of model was set up. On the right side of the model, a 45 cm wide fault coal pillar in Seam 1-2 was set up, and a 60cm wide fault coal-pillar in Seam 2-3was set up. Coal seam was extracted from left to right with a speed of 5cm per hour mine. The total mining length for Seam 1-2 is 150 cm, and for Seam 2-3 is 150 cm.

Figure 4 shows the overburden deformation and failure situations at each stage during the mining process of the model. Along with the mining of Seam 1-2, separation began and then roof caved. The caving zone and water flow fractured zone developed continuously. Throughout the mining process, the immediate roof periodically caved and the main roof remained stable. After mining Seam 1-2, 24 hours was needed to make sure the complete subsidence. Along with the mining of Seam 2-3, at early stage the main roof remained stable, but after Seam 2-3 mining 60 cm, the caving zones of the Seam 2-3 and Seam 1-2 superimposed together, the caving zone and water flowing fractured zone grow quickly.

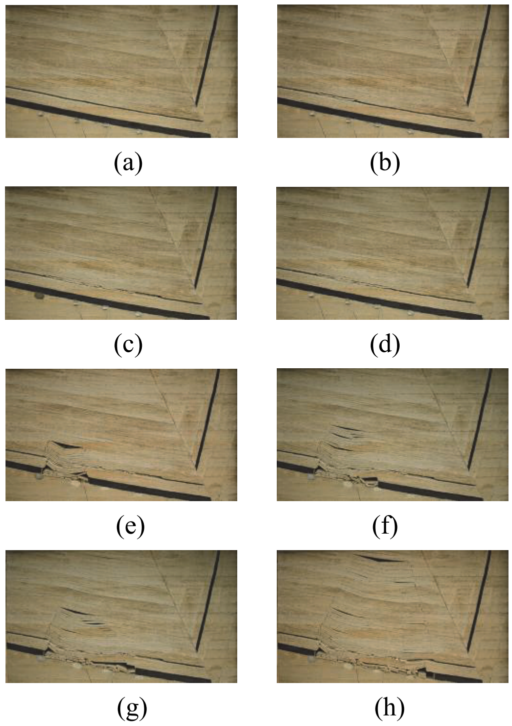


Fig. 4 Overburden deformation and failure at different stages

(a) before mining; (b) Seam 1-2 mining 60cm; (c) Seam 1-2 mining 100cm; (d) Seam 1-2 mining 150cm; (e) Seam 2-3 mining 60cm; (f) Seam 2-3 mining 80cm; (g) Seam 2-3 mining 115cm, (h) Seam 2-3 mining 150cm.

Figure 5 shows the roof subsidence contour map after mining the Seams 1-2 and 2-3. After mining Seam 1-2, the overburden deformation and failure is not obvious, the whole overburden displacement value is smaller, mining has no impact on the fault virtually, hanging wall has no overburden displacement. After mining Seam 2-3, the overburden deformation and failure extend to the top of model, the whole overburden displacement value is large. However, the hanging wall has no overburden displacement still. Setting up fault coal-pillars can prevent caving zone and water flow fractured zone extend to hanging wall, F16 thrust fault has a barrier effect, thus guarantee coal mine safety production.

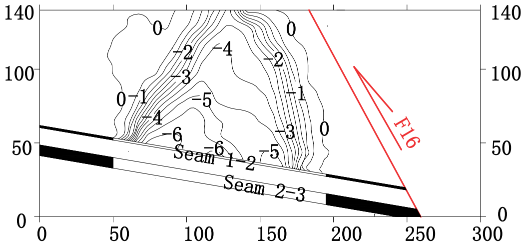


Fig. 5 Contour map of roof subsidence after mining when setting up fault coal-pillar

4.2 Without Setting up Fault Coal-pillars

Figure 6 shows the process of mining the fault coal-pillar. Along with the mining of Seam 1-2, when the fault coal-pillar Seam 1-2 mining lest 30 cm, F16 thrust fault started to move. When Seam 1-2 mining into fault, F16 thrust fault completely separated along the fault plane. Along with mining the fault coal-pillar of Seam 2-3, the caving zone and water flow fractured zone developed quickly, reached to the top of model at last. Therefore, setting up 30 cm wide fault coal-pillar is reasonable by scale simulation.


(a)


(b)


(c)


(d)


(e)


(f)

Fig. 6 Overburden deformation and failure situations at each stage
(a) Seam 1-2 mining with 30 cm fault coal-pillar left; (b) Seam 1-2 mining to fault; (c) Seam 2-3 mining with 45 cm fault coal-pillar left; (d) Seam 2-3 mining with 25 cm fault coal-pillar left; (e) Seam 2-3 mining with 10 cm fault coal-pillar left; (f) Seam 2-3 mining into the fault.

Figure 7 shows the roof subsidence contour map after mining the fault coal-pillars of Seams 1-2 and 2-3. It is found that the maximum overburden displacement value is located in the footwall, and the footwall overburden displacement value is larger than hanging wall. It shows that without setting up fault coal-pillar, the fault barrier effect reduced, coal mining may lead to the fault plane cracking and activation.

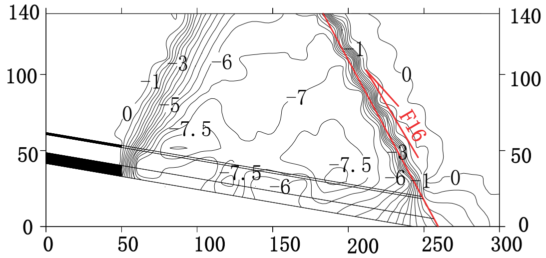
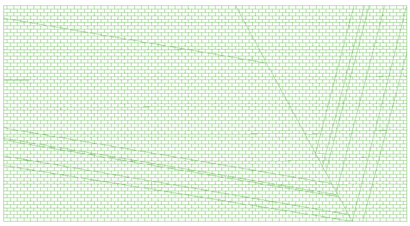
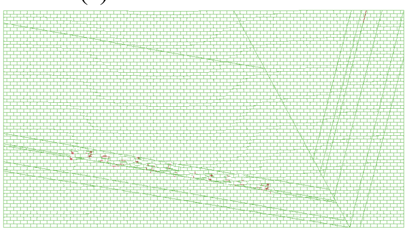


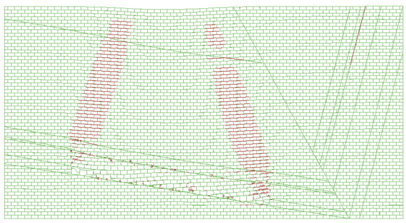
Fig. 7 Contour map of roof subsidence after mining without setting up fault coal-pillars

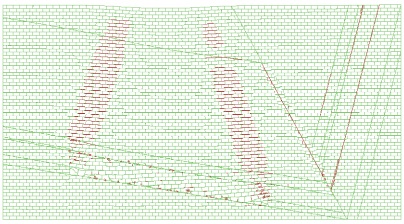
4.3 Numerical Results and Analysis

Figure 8 shows the failure pattern of overlying strata after mining seams in profile Line 45. From the perspective of overburden deformation and failure process, when Seam 1-2 was extracted to 300m, caving rock filling mined-out area, the fractures appeared in both sides above the mined-out area. The height of caving zone is 15.35m and height of water flow fracture zone is 63.13m. When Seam 2-3 was mined to 300m, both sides above the mined-out area formed shorter cantilever. The rock stratum between Seams 2-3and 1-2 caved completely. The water flow fractured zone expanded and displacement value of curve subsidence zone increased. The height of caving zone is 57.5 m, and water flow fracture zone 150.7 m.

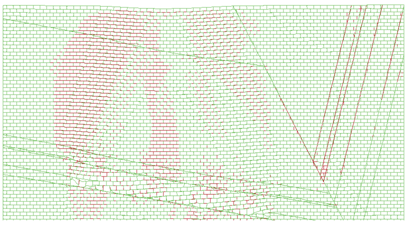

(a) Model initialization


(b) Seam 1-2 mining 300 m


(c) Seam 2-3 mining 300 m



(d) Seam 1-2 mining to the fault



(e) Seam 2-3 mining to the fault

Fig. 8 Failure pattern of overlying strata after mining along profile Line 45

The mining of the fault coal-pillar of Seam 1-2 shows that F16 thrust fault appeared its activity when the mining distance to the fault reached 65m. Along with the mining of Seam 2-3, in the footwall, caving rocks filled the mined-out area and the water flow fractured zone expanded to reach the top of model at last. In the hanging wall, rock stratum slide along the stratum's surface. Thus setting up 70m wide fault coal-pillar is reasonable according to the results.

4.4 Comparison Analysis for Failure of Overburden

According to the Code "Buildings, water bodies, railways and the main shaft's coal pillar setting and press coal seam mining regulations (National Coal Industry Department, 2000)", the heights of caving zone and water flow fractured zone can be calculated, and then compared with the results from scale model simulations and numerical simulations. Results are shown in table 2.

Table 2 Results and comparisons

Methods	caving zone height (m)		water flowing fractured zone height (m)	
	Seam 1-2	Seam 2-3	Seam 1-2	Seam 2-3
Calculations	13.91	24.80	58.00	87.80
Scale simulations	4.10	55.50	22.20	146.00
Numerical simulations	15.35	57.50	63.13	150.70

5. Conclusions

When setting up fault coal-pillar, the thrust fault has a "barrier" effect on overburden deformation. As a natural discontinuous structural plane, fault has an obvious barrier effect, the fault zone, water flow fractured zone and subsidence developed in the footwall would hardly extend to the hanging wall. However, when there is no fault coal-pillar, barrier effect of the fault reduced, coal mining may lead to the fault plane cracking and activation.

With setting up fault coal-pillar, mining in the footwall will not leading to fault slide along the fault plane, hanging wall has no obvious overburden displacement. Without setting up fault coal-pillar, due to the existence of fault zone, the rock mass broken seriously in the fault zone and its influence scope, specific performance for caving zone is high and roof stability is poor. As the distance to the fault plane decreased, the fault influence on overburden increased, the footwall overburden near fault plane was most likely to cave.

Through comparative analysis of the calculations, scale model simulations and numerical simulations results, the heights of overburden failure were finally determined.

Acknowledgements

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