International Journal of Natural Resources and Environmental Studies
ISSN: 3006-2012 (Print), ISSN: 3006-0834 (Online) | Volume 7, Number 3, Year 2025
DOI: https://doi.org/10.62051/ijnres.v7n3.10
Journal homepage: https://wepub.org/index.php/IJNRES/index

Simulation of the Development Height of the Two Zones in the 23041 Working Face of Gaocheng Coal Mine

Huaiyang Shi[1, 2, *]

[1]Department of Physics, Colorado State University, Fort Collins, CO 80523, USA
[2]Electrical Engineering Department, University of Colorado, Boulder, CO 80309, USA
[*]Corresponding Author: Huaiyang Shi

ABSTRACT

Sliding structure refers to the rock deformation process and result where the upper plate rock layers continuously slide and erode downward under the action of gravity. During the downward sliding process, after two major slides, the strata on the upper and lower sliding surfaces are both inclined in the opposite direction to the strata of the sliding body, forming an overlying strata reverse dip zone. This paper takes the 23041 working face of Gaocheng Coal Mine as the research object and develops a device for similar simulation experiments, which has applied for a national invention patent. Similar material simulation experiments and UDEC software were used to simulate the influence of different dip angles of the overlying strata reverse dip on mining fractures and surface subsidence. Based on the results of numerical simulation, the development law of mining fractures under the overlying strata reverse dip can be obtained. The research shows that the larger the dip angle of the overlying strata reverse dip, the lower the development height of the water-conducting fracture zone and the lower the height of overlying strata damage.

KEYWORDS

Keywords: Sliding structure; Antioverturning rock; Surface subsidence; Separate layer grouting.

1. INTRODUCTION

Within the range of mining influence in the Gaocheng mining area, there is the world's oldest existing astronomical observatory - the Observatory Site, which is a key national cultural relic protection unit. In addition, there are several key cultural relic protection units in Henan Province within the mining area, such as the Yangcheng Site, Wangchenggang Site, Shuangmiaogou Site, Bafang Site, and the Stone Inscription on the Cliff of Shizong River. The currently replacing 23041 working face corresponds to the ground of the key national cultural relic protection unit, the Yangcheng Site (verified to be the ancient city from the Eastern Zhou to the Han Dynasty). The ancient city wall of the Yangcheng Site runs from west to east through the working face. If traditional coal mining methods are adopted without taking measures, it will inevitably cause damage to the Yangcheng Site. Therefore, how to effectively increase the coal recovery rate of the 23041 working face while effectively protecting the cultural relics is a key issue faced by the production of this working face. Studying the development height and law of the water-conducting fracture zone during mining has guiding significance for the selection of the injection layer in the overlying strata separation injection mining of this working face.

To modify the header, double-click in the Header section at the top of this page. Fill in the author and article titles.

To insert images in Word, position the cursor at the insertion point and either use Insert | Picture | From File or copy the image to the Windows clipboard.

2. WORKING FACE OVERVIEW

The 23041 working face is located at the bottom of the 23 mining area (upper part). It is adjacent to three downhills of the 23 mining area to the south, the 25 mining area to the north, the unexcavated 23031 working face to the east, and the unexcavated 23051 working face to the west. The ground position of the working face: the northern, southern, and western parts of the Yangcheng Site are all inhabited by residents of Beigou Village, Gaocheng Town. This working face is arranged in a longwall along the strike, with full-height caving and complete roof caving for roof management. The strike length is 912m, the cutting length is 150m, the average coal thickness is 5.4m, the coal bulk density is 1.35t/m³, and the recoverable reserves are 981,300t. The bottom elevation of the coal seam within the working face is -256.8m to -357.5m, and the vertical ground elevation corresponding to the working face is +283.5m to +298.4m. The burial depth is 510 to 698m.

层号	厚度 /m	埋深 /m	岩层岩性	关键层位置	岩层图例
16	6.1	334.50	中砂岩		
15	18.6	353.10	细砂岩		
14	25.1	378.20	中砂岩	主关键层	
13	16.1	394.30	细砂岩	亚关键层	
12	16.3	410.60	泥岩		
11	15.4	426.00	粉砂岩		
10	16.5	442.50	细砂岩	亚关键层	
9	9.5	452.00	砂质泥岩		
8	7.0	459.00	泥岩		
7	6.8	465.80	砂质泥岩		
6	3.4	469.20	细砂岩		
5	4.9	474.10	泥岩		
4	11.4	485.50	细砂岩		
3	6.8	492.30	泥岩		
2	3.2	495.50	砂质泥岩		
1	18.5	514.00	砂砾岩		
0	5.4	519.40	煤层		

Figure 2-1 Columnar Diagram of Key Layer Discrimination for Drilling Hole 12602

3. ESTABLISHMENT OF NUMERICAL SIMULATION MODELS

Based on the drilling columnar diagram of drilling hole 12602 in the 23041 working face of Gaocheng Coal Mine, this study constructs four groups of numerical simulation models to systematically investigate the influence of the overburden dip angle on the mining-induced rock movement under the geological mining conditions of reverse-dipping strata. The coal seam thickness in the model is 5.4m, with a dip angle of 10°, and the dip angles of the overburden strata are 10°, 20°, 30°, and 40° respectively. According to the actual overburden strata conditions of the 23041 working face in Gaocheng Coal Mine, a UDEC simulation calculation model was established. The model's strike length is set to 300m, and the vertical height is 200m. The rock strata are divided into eighteen layers, each corresponding to the columnar diagram.

The constitutive relationship adopted in the simulation is Mohr-Coulomb. The boundary conditions of the calculation model are as follows:

Since the simulation does not directly reach the surface, additional loads need to be applied. Therefore, the gravity gradient and the gravity conditions of the overburden strata need to be considered to match the actual geological stress environment.

Bottom boundary conditions: The bottom boundary of the test model can be simplified as a displacement boundary condition: free movement is allowed in the x direction, and a fixed hinge support is set in the y direction, that is, the displacement constraint condition v=0.

Side boundary conditions: The side boundaries of the test model correspond to the solid coal and rock mass, and can also be simplified as displacement boundary conditions: free movement is allowed in the y direction, and a fixed hinge support is set in the x direction, that is, the displacement constraint condition u=0.

After comparing the literature and laboratory measured data, the final determined mechanical parameters of the rock strata are shown in Table 3-1, while the mesoscopic mechanical parameters of the overburden structural planes are determined through a combination of joint shear test data and discrete element contact model parameters. The specific parameter values are detailed in Table 3-2.

Table 3-1 Rock Mechanics Parameter Table

Lithology	Young's modulusE(GPa)	Poisson's ratio μ	Cohesion C(MPa)	Internal friction angle ϕ (°)	Uniaxial tensile strength(MPa)	Bulk density (Kg/m³)
Sandy mudstone	10.2	0.25	6.53	28	2.92	2560
Medium-grained sandstone	16.4	0.24	10.2	31	5.88	2760
Fine-grained sandstone	8.0	0.22	6.35	33	3.17	2700
Siltstone	11.9	0.30	2.56	29	2.39	2720
Shale	13.0	0.28	1.5	26	1.92	2730
Coal	3.3	0.33	1.0	25	0.1	1400

Table 3-2 Parameters for the rock-covering joint surfaces

Lithology	Normal stiffness ×109/Pa	Tangential stiffness×109/Pa	Joint cohesion ×106/Pa	Joint friction angle/(°)	Tensile strength× 106/Pa
Shale	3.1	1.82	1.68	13	2.32
Siltstone	4.2	1.76	2.08	13	3.2
Fine-grained sandstone	4.4	1.81	1.62	14	3.16
Sandy mudston	3.8	1.61	1.31	11	3.42
Medium-grained sandstone	3.1	2.6	1.68	13	5.05
Coal	1.65	0.62	1.12	14	0.12

In order to analyze the migration and evolution characteristics of the overlying strata, two survey lines were set up in the numerical model for this experiment. The positions of the survey lines are shown in Figure 3-1. Each survey line has an interval of 10 meters, and each line has 30 measurement points. The length of each survey line is 300 meters. The vertical displacement of these two survey lines is used to monitor the migration of the overlying strata. The schematic diagram of the model boundary conditions is shown in Figure 3-1.

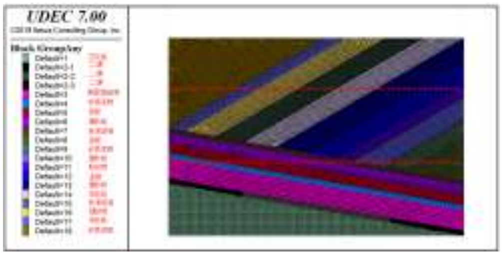

Figure 3-1 Schematic diagram of the model with an inclination angle of 30°

4. NUMERICAL SIMULATION RESULT ANALYSIS

4.1. Analysis of the Height of the Collapse Zone Shape

A total of four models were designed in this experiment. The coal seam inclination angle for each model was set at 10°. By changing the inclination angle of the rock strata, experimental models with overlying strata inclination angles of 10°, 20°, 30°, and 40° were constructed. After the working face completed excavation and reached a stable state, the sliding structural zone above the models basically collapsed completely. The specific descriptions of the height of the collapse zones for the four models are shown in Table 4-1, and the collapse morphology diagrams are shown in Figures 4-1 to 4-4.

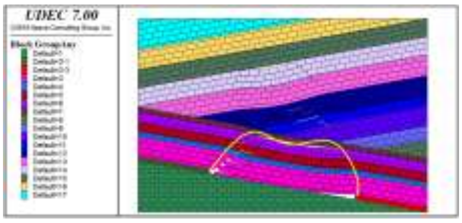

Figure 4-1 The morphology of the collapse zone with a rock cover inclination of 10°

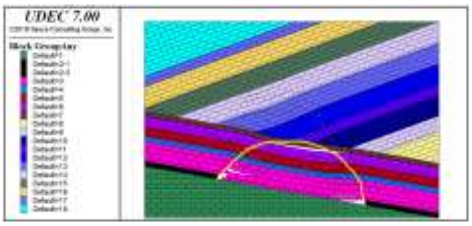

Figure 4-2 The morphology of the collapse zone with a rock cover inclination of 20°

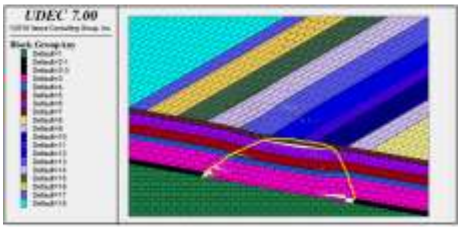

Figure 4-3 The morphology of the collapse zone with a rock cover inclination of 30°

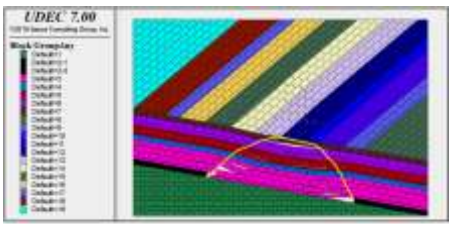

Figure 4-4 The morphology of the collapse zone with a rock cover inclination of 40°

Table 4-1 The shape and height of the collapse zone

Inclination angle of overlying strata / °	The morphology of the collapse zone	Height of the collapse zone/m
10	The shape of the collapse zone is similar to an inverted saddle, but it is asymmetrical. The highest point is located in the downhill direction of the working face.	58
20	The shape of the collapse zone is parabolic, with the highest point located exactly in the center of the working face.	55
30	The shape of the collapse zone is similar to a parabolic curve, with the highest point leaning towards the uphill direction of the working surface.	52
40	The shape of the collapse zone is parabolic, with the highest point trending towards the uphill direction of the working surface.	50

4.2. Distribution Pattern of Fractures in Mining

After coal mining, the overlying strata will form two types of fractures; one is the interlayer gap, which occurs due to the different sequential subsidence of the overlying strata according to the movement mechanism of the strata. The interlayer gap appears between different strata; the other is the vertical fracture, which is formed by the fracture and breakage as the rock layers sink. According to the results of numerical simulation, as shown in the figure, to facilitate observation, a part of the rock layer has been enlarged and the enlarged part has been processed into black.

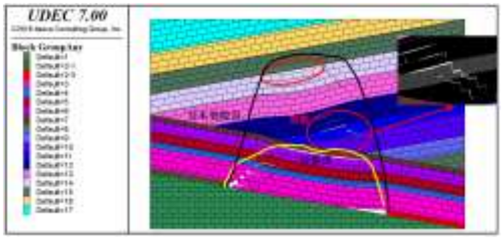

Figure 4-5 Two-layer structure with a rock cover inclination of 10°

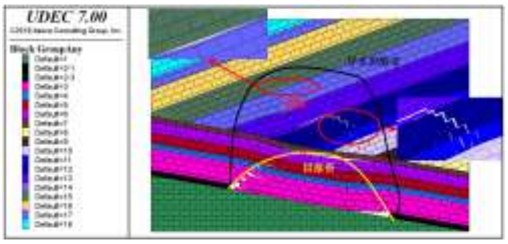

Figure 4-6 Two-layer structure with a rock cover inclination of 20°

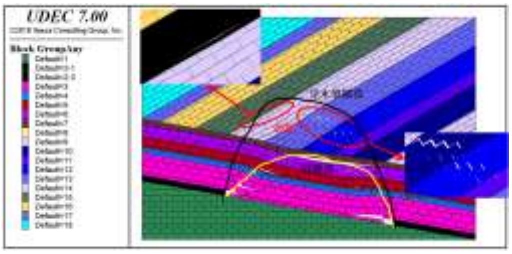

Figure 4-7 Two-layer structure with a rock cover inclination of 30°

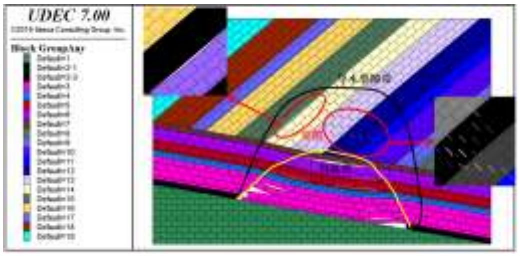

Figure 4-8 Two-layer structure with a rock cover inclination of 40°

As can be seen from the figure, after mining in the anti-inclination rock area, dislocation and vertical fractures appeared above the mined-out area. Among the four models, the dislocation occurred in the middle of the 14th and 15th layers of the model, with the position biased towards the uphill direction of the working face. The height of the dislocation decreased as the angle of the anti-inclination rock increased. According to the borehole profile diagram, the corresponding stratum of the 15th layer is the medium-grained sandstone layer, which is the main key layer. This indicates that the key layer theory is still applicable under the special geological conditions of anti-inclination rock.

According to the results of numerical simulation, the development height of the water-conducting fracture zone decreases as the inclination angle of the overlying rock layer increases. When the overlying rock layer inclination angle is 10°, the maximum height of the water-conducting fracture zone is approximately 132m; when the overlying rock layer inclination angle is 20°, the maximum height of the water-conducting fracture zone is approximately 126m; when the overlying rock layer inclination angle is 30°, the maximum height of the water-conducting fracture zone is approximately 121m; when the overlying rock layer inclination angle is 40°, the height of the water-conducting fracture zone is approximately 116m.

4.3. Subsidence height analysis

After coal seam mining is completed, the movement of the overlying rock will cause the rock layer above the mined-out area to sink. The UDEC displacement gradient diagram can directly present the displacement values of the rock layer. Different colors correspond to different displacement values; among them, the deep red color represents the maximum displacement value, and the dark blue color represents the minimum displacement value. From dark blue to deep red, the displacement value shows a gradually increasing trend.

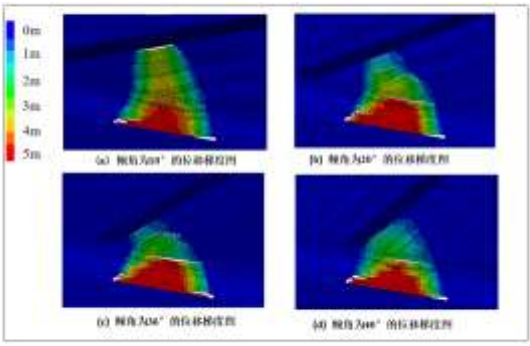

Figure 4-9 Vertical displacement map of overlying strata

In order to further analyze the changing pattern of vertical displacement with the variation of overlying rock inclination, observation lines were set up at the same height in all four models.

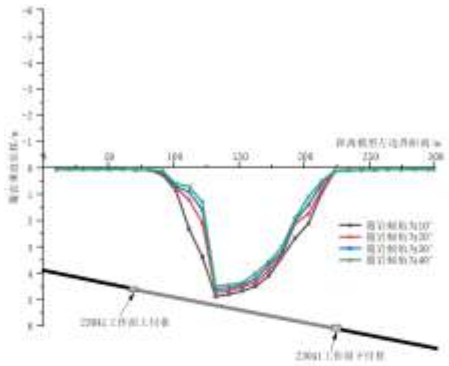

Figure 4-10 Delineation curve of the underground subsidence at a distance of 50 meters from the seam

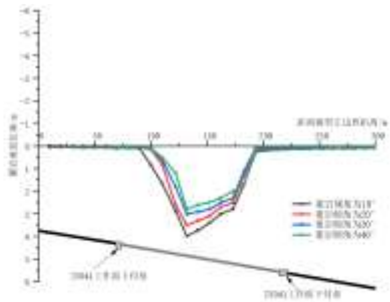

Figure 4-11 Delineation curve of the underground subsidence at a distance of 150 meters from the coal seam

Based on the analysis of the displacement gradient diagram and the subsidence curve diagram, it can be seen that the rock layer above the center of the mined-out area has the largest subsidence amount, and the subsidence amount gradually decreases as it moves towards both sides. The maximum subsidence point is biased towards the uphill direction of the working face. The subsidence amount of the overlying strata at the same layer decreases as the dip angle of the overlying strata increases.

REFERENCES

[1] Guo Wenbing, Tan Zhixiang, Chai Huabin, et al. Coal Mine Mining Damage and Protection (Third Edition) [M]. Beijing: Emergency Management Press, 2019.

[2] Qian Minggao, Xu Jialin, Wang Jiachen. On the Scientific Mining of Coal Again [J]. Journal of China Coal Society, 2018, 43(01): 1-13.

[3] Xie Renhai, Qu Tianxiang, Qian Guangmo. Structural Geology [M]. Xuzhou: China University of Mining and Technology Press. 2007.

[4] Guo Wenbing (ed.). Special Mining Techniques for Mines [M]. Xuzhou: China University of Mining and Technology Press, 2021.

[5] Guo Wenbing, Bai Erhu, Zhao Gaobo. Current Status and Progress of Surface Damage and Control Technology of Overlying Rock during High-Intensity Mining [J]. Journal of Coal Science, 2020, 45(02): 509-523.