ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

Research on the settlement and deformation law of overlying rock under the influence of mining

Longhui Guo*

School of Civil Engineering and Architecture, Anhui University of Science and Technology, Huainan 232001, China
**Corresponding Author: 1363501559@qq.com.*

ABSTRACT. *Taking the mining of a certain coal seam as the research background, in order to study the settlement deformation law of the overlying rock under mining disturbance, combined with the physical and mechanical parameters of the actual rock layer, the mechanical model is established, and the flac3D numerical simulation is designed to determine the settlement deformation and horizontal displacement of the overlying rock under mining disturbance. And the vertical stress distribution law, the research results show that the settlement cloud map of the overburden rock under the influence of mining takes an "arch" shape, and the settlement value decreases with the increase of the arch height. The maximum settlement occurs in the center of the goaf, which is 3.51. m, which is 87.85% of the mining height; the horizontal displacement cloud map of the overburden rock under the influence of mining is distributed in a symmetrical "dipper" shape immediately above the goaf and in the middle of the overburden rock, and the maximum displacements are 50.2cm and 54.3cm respectively; Under the influence of mining, the vertical stress distribution area of overlying strata is divided into stress relief zone, concentrated zone and constant stress zone. The maximum stress value in the concentrated zone is 37.3MPa, and the maximum stress in the stress relief zone is 8.78 MPa; the research results can be similar rock formations the settlement problem provides a useful reference.*

KEYWORDS: *settlement deformation, echanical model, flac3D, umerical simulation*

1 Introduction

Due to coal seam mining, the overburden collapse of the mined-out area has caused delays in mining and the lives of workers are not uncommon. China's coal fields are widely distributed and incomplete statistics. Every year, nearly 100 million cubic meters of the surface are due to the loss of the mined-out areas. The collapse pit is formed due to stable failure, so it is very important to study the collapse failure mode of the overburden rock in the goaf and its sinking characteristics. In recent years, many scholars [1] have also devoted themselves to

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

the study of the overburden in the goaf. Huang et al[2] used similar material simulation tests to divide the collapsed area of the overburden into unstable areas and basically stable areas. And the stable area, and found that the rock mass in the collapsed area has a closed phenomenon; Fang et al[3] used various methods such as experiment, theoretical analysis, numerical simulation and field measurement to study the movement law of the overlying rock in the mined-out area and found The stability of the "masonry beam" structure overlying the goaf mainly depends on the thickness of the bedrock and the physical and mechanical properties of the rock layer; this paper establishes a physical model, designs similar material simulation tests and flac3D numerical simulations, and analyzes the overlying rock Describe the failure characteristics and summarize the subsidence and deformation laws of the overlying rock, so as to study the subsidence and deformation of the overlying rock in the goaf.

2 Project overview

The surface of the mine is located in the plain, there is no perennial water on the surface, the surface is farmland, there are no buildings, the mining face is located at 570-630m underground, the coal seam height is uneven, the average is 4m, the mining method is one-time mining of full height and phased mining, with a long tendency 400m, the strike length is 800m, the coal mining face advances along the strike direction, and the bedrock above the coal seam is mostly siltstone and mudstone with low strength.

3 Model building

3.1 Introduction to flac3D

Flac (Fast Lagrangian Analysis of Continua) is the abbreviation of fast Lagrangian difference analysis. Flac3D is a powerful three-dimensional finite difference program. It uses the display Lagrangian algorithm and hybrid-discrete partitioning technology, which can analyze soil, rock and other The three-dimensional structure of the material is subjected to force simulation and plastic flow analysis, which can accurately simulate the yield, plastic flow, softening and even large deformation of the material. Due to the impact of mining, the overburden of the goaf will experience large deformations such as collapse and settlement. And the rock formations are discontinuous, so the three-dimensional discrete unit program Flac3D is used to study the settlement and deformation laws of the overlying rock in the thick loose layer and thin bedrock mining.

3.2 Numerical simulation design and process

The design process of numerical simulation mainly includes determining the simulation scope, dividing unit grids, setting boundary conditions, selecting material

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

parameters and selecting model criteria, etc. The specific numerical simulation process is as follows:

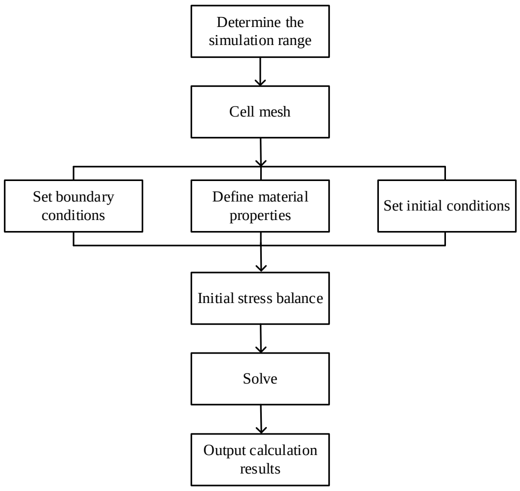


Fig. 1 Modeling flowchart

3.2.1 Numerical simulation design and process

Considering the actual working conditions of the site comprehensively, a numerical model with a length of 500m, a height of 177m and a width of 200m was established, and the excavation size was determined to be 360m×80m×3m (length×width×height). The simulated excavation was carried out in 36 times, each excavation 10m, a total of 360m excavated.

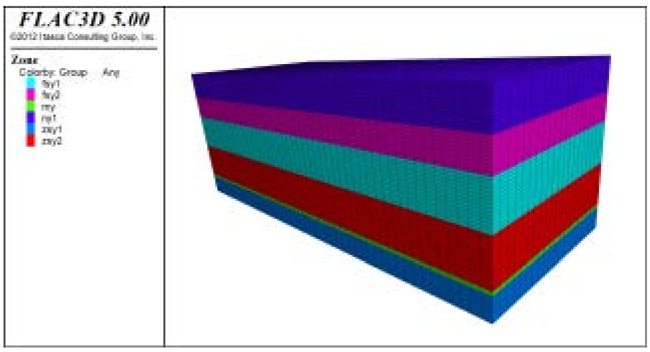


Fig. 2 Numerical model and meshing

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

3.2.2 Boundary conditions

(1) Displacement boundary

The upper part of the model is a free boundary without constraints.

The lower part of the model is fully fixed in the horizontal and vertical directions, that is, the displacement in the horizontal and vertical directions is zero, which is a fully constrained boundary, which can be expressed as follows with the flac3D command:

fix x y z range z -0.9 0.1

The front and back, left and right boundaries around the model adopt the horizontal displacement single constraint condition to limit the movement of the model in the horizontal direction. The command to restrict the front and back boundaries is expressed as:

fix y range y -99.9 -100.1

fix y range y 99.9 100.1

The command to constrain the left and right boundaries is expressed as:

fix x range x -249.9 -250.1

fix x range x 249.9 250.1

The displacement boundary diagram of the numerical model is as follows:

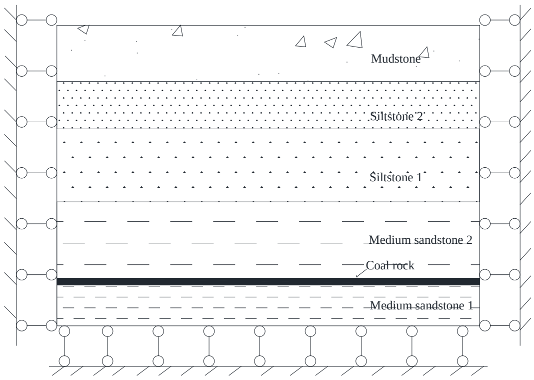


Fig. 3 Displacement boundary map

(2) Stress boundary

In order to simulate the force state of the numerical model to be similar to the actual force state of each deep-buried rock layer, it is necessary to impose stress boundary conditions on the model. Academician Kang et al collected and sorted out the in-situ stress data of major coal mines across the country, and obtained the

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

underground underground stress distribution law [4], and perform linear regression on the stress data, and obtain the linear regression equations of the maximum and minimum horizontal principal stress and vertical stress with the buried depth:

$$\begin{cases} \sigma_H = 0.0215H + 3.267 \\ \sigma_h = 0.0113H + 1.954 \\ \sigma_v = 0.0245H \end{cases} \quad (1)$$

Where σ_H is maximum horizontal principal stress; σ_h is minimum horizontal principal stress; σ_v is vertical stress; H is embedding depth.

According to the above formula, combined with the actual working conditions, a vertical stress of 11.0985 MPa is applied to the upper part of the numerical model, and a horizontal stress of 13.0065 MPa is applied to the periphery of the model.

3.2.3 Model guidelines

The numerical simulation should start from the simplest material model. In most cases, the isotropic elastic model should be selected. Due to the diversity of the overlying rock and soil materials in the stope and the complexity of the mechanical relationship between the materials, comprehensive Considering that the overlying rock and soil in the goaf are all elastoplastic materials, the Mohr-Coulomb criterion is selected to simulate the settlement and deformation of the overlying rock in the stope.

3.2.4 Determination of model parameters

Choose different model criteria to correspond to different material parameters. This model adopts the Mohr-Coulomb criterion. The corresponding material parameters include bulk modulus, shear modulus, cohesion, internal friction angle, tensile strength, elastic modulus, bulk density, Poisson's ratio, etc., where the bulk modulus and shear modulus need to be obtained from the elastic modulus and Poisson's ratio, as follows:

$$K = \frac{E}{3(1-2\mu)}$$

$$G = \frac{E}{2(1+\mu)}$$

Where: K is bulk modulus; G is shear modulus; E is modulus of Elasticity; μ is poisson's ratio

The material parameters of each rock formation are shown in the following table:

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

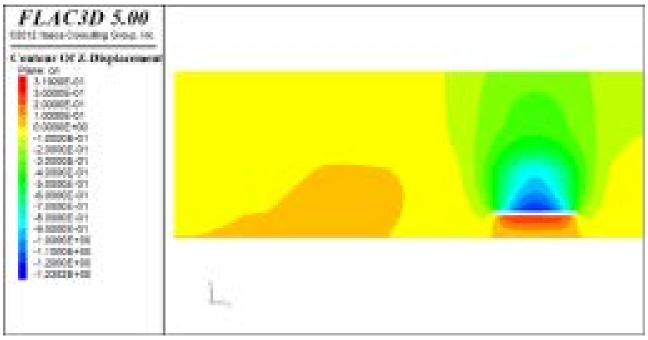
Table 1 Modeling material parameter table

Lithology	Thickness m	Elastic Modulus GPa-	Poisson's ratio -	Friction °	Cohesion MPa	Tension MPa	Bulk density KN/m^3	Bulk GPa	Shear GPa
Mudstone	33	2	0.25	39.21	1.1	0.68	26.37	1.33	0.80
Siltstone2	28	16	0.22	32.37	7.7	0.82	26.65	9.52	6.56
Siltstone1	43	8	0.2	31.19	4.4	1	26.97	4.44	3.33
Medium sandstone2	45	14	0.17	32.67	7.5	4.2	27.04	7.07	5.98
Coal	4	15	0.15	29	2.28	1.43	14	7.14	6.52
Medium sandstone1	24	14	0.17	32.67	7.5	4.2	27.04	7.07	5.98

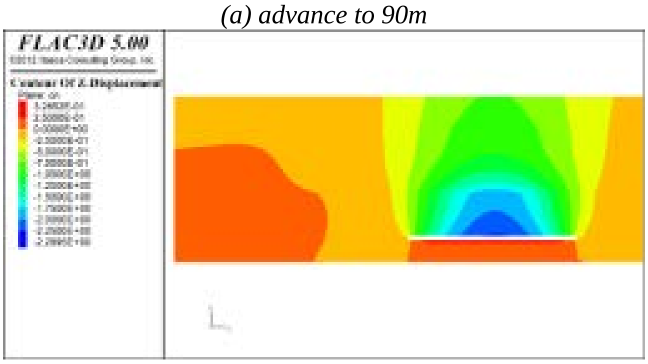
4 Numerical simulation results

4.1 Model settlement cloud image analysis

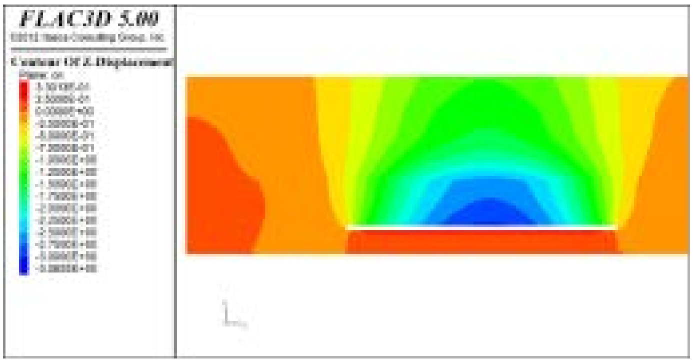
In order to study the settlement of the overlying rock under mining disturbance, the settlement cloud map of the overlying rock at 90m, 180m, 270m and 360m is selected for analysis.



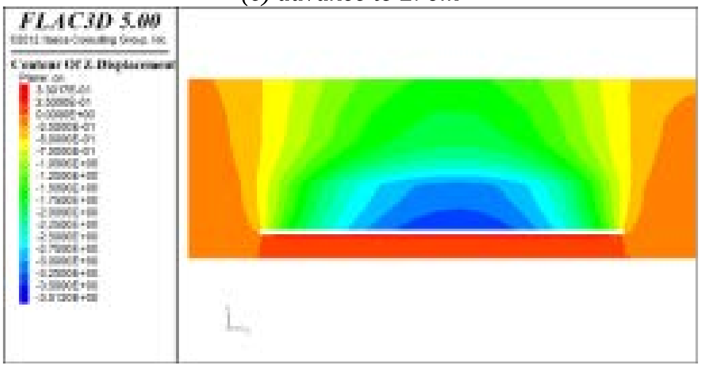
(a) advance to 90m



(b) advance to 180m



(c) advance to 270m



(d) advance to 360m

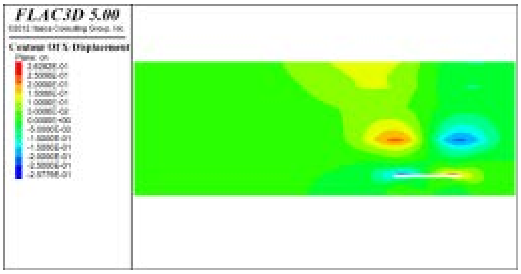
Fig. 4 Cloud map of overburden settlement

According to the cloud map of overlying rock settlement, it can be found that under the influence of mining, the cloud map of overlying rock takes a symmetrical "arch" shape, and the higher the arch height, the greater the settlement and the greater the impact range. As the mining advances, the "arch" moves forward. Move, the settlement expands forward and upward; the maximum settlement is in the center of the goaf, the maximum settlement of the roof is about 3.51m, which is 87.85% of the mining height.

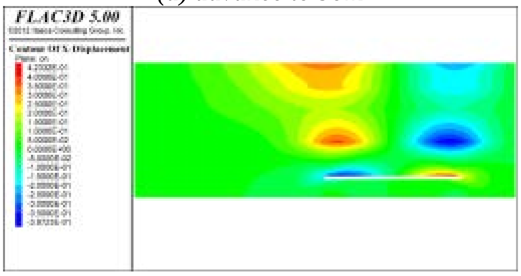
4.2 Model settlement cloud image analysis

In order to study the horizontal displacement of the overburden under the mining disturbance, the settlement cloud map of the overburden at 90m, 180m, 270m and 360m is selected for analysis.

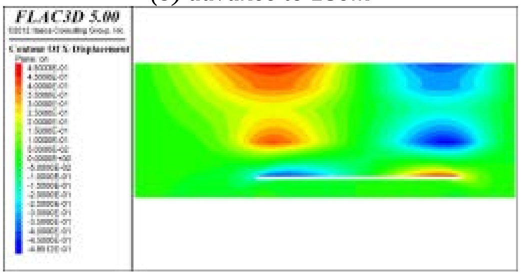
ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517



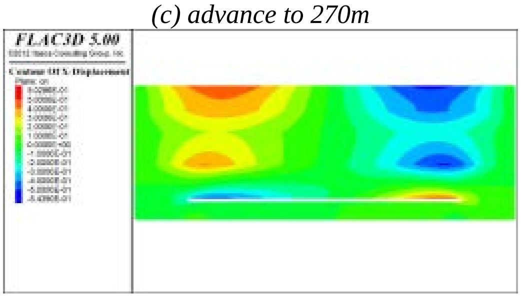
(a) advance to 90m



(b) advance to 180m



(c) advance to 270m



(d) advance to 360m

Fig. 5 Overlying rock horizontal displacement cloud map

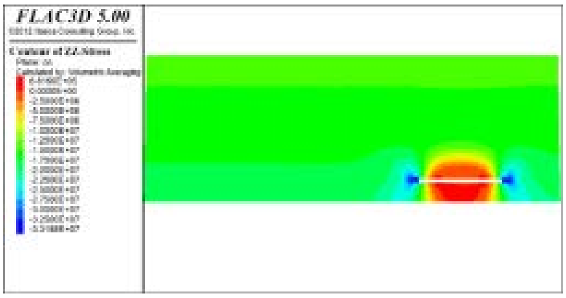
From Figure 5, it can be found that under the influence of mining, the overlying rock settlement cloud picture is in a left-right symmetrical "dipper" shape. Just above the mined-out area, with the mined-out area as the center of symmetry, there are two large displacements of the overlying rock. Areas, one is located above the

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

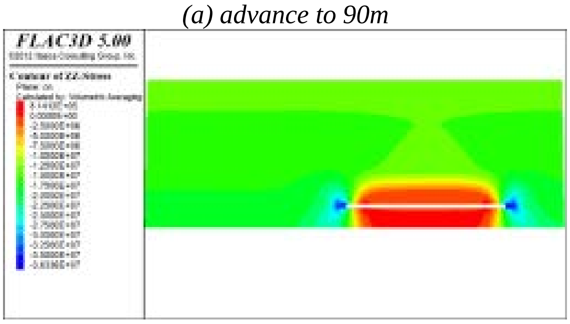
open cut and one is located above the working face, and the two displacement directions are opposite; the middle of the overburden also has two symmetrical areas with larger and opposite displacements, due to the open cut direction and the working face direction The different ways of collapse lead to the opposite direction of movement. The maximum displacements are 50.2cm and 54.3cm, which are almost equal.

4.3 Distribution law of model vertical stress field

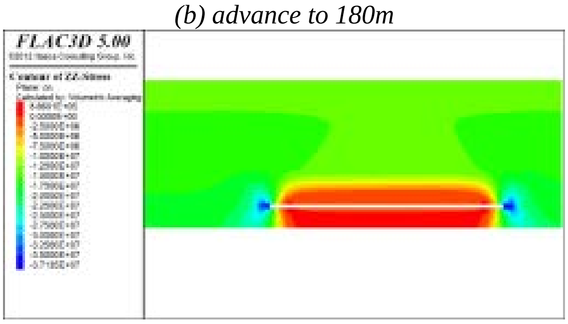
In order to study the distribution of vertical stress under mining disturbance, the settlement cloud diagram of overlying strata at 90m, 180m, 270m and 360m is selected for analysis.



(a) advance to 90m

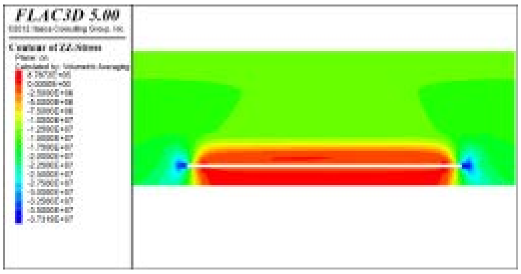


(b) advance to 180m



(c) advance to 270m

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517



(d) advance to 360m

Fig. 5 Vertical stress distribution cloud chart

After the coal seam is mined, the overburden stress is divided into stress concentration area, stress relief area and stress invariant area; The stress concentration area is located about 15-20m in front of the open cut and the coal wall in front of the working face, and the maximum stress value is 37.3MPa; The stress relief zone is located above the goaf and the bottom plate. The stress relief zone is in an "arch" shape. The inside of the arch is the pressure relief zone, and the outside of the arch is the constant pressure zone. The maximum pressure of the relief zone is 8.78 MPa.

5 Conclusion

(1) The settlement cloud map under the influence of mining takes an “arch” shape. The greater the “arch” height, the smaller the settlement; the greater the buried depth, the smaller the “arch” height and the smaller the settlement range. The maximum settlement occurs in the mined-out area. In the center, the maximum settlement is 3.51m when mining is stopped, which is 87.85% of the mining height.

(2) Under the influence of mining, the cloud map of the horizontal displacement of the overburden is in a symmetrical "dipper" shape, distributed immediately above the mined-out area and in the middle of the overburden, and the maximum displacement values are 50.2cm and 54.3cm, respectively.

(3) The vertical pressure of the overlying rock under the influence of mining is divided into stress relief zone, stress concentration zone and stress constant zone. The maximum stress value of the stress concentration zone is 37.3MPa, and the maximum stress value of the stress relief zone is 8.78MPa.

References

[1] Y.P. Wu, J.Y.HuangFu, et al (2020). Overlying strata migration and roof failure characteristics in high-dip coal seam mining at close distances[J]. Journal of Xi'an University of Science and Technology, vol.40, no.1, p. 1-10.

ISSN 2616-5767 Vol.3, Issue 5: 131-141, DOI: 10.25236/AJETS.2020.030517

[2] H.F. Huang(2007),Research on the overburden movement law of thick surface soil and thin bedrock mining in Sima Mine[J]. Coal, no.S2, p. 48-50+68..
[3] X.Q. Fang, H.F. Huang and T. Jin (2008). Movement of overlying strata in coal seams with thick topsoil and thin bedrock[J]. Chinese Journal of Rock Mechanics and Engineering, vol.27, no.S1, p. 0-6.
[4] H.P. Kang, B.D. Yi and F.Q. Gao(2019), Lv Huawen. The in-situ stress database and the distribution of in-situ stress in Chinese coal mines[J]. Journal of China Coal Society, vol.44, no. 1, p. 23-33.