Study on Surface Deformation Caused by Comprehensive Mining in a Coal Mine in Northwest China

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Abstract. The exploitation of underground coal can cause many problems such as the ground surface subsidence, ground crack, surface damage of the road, and it would affect people travelling, living and life safety seriously. Based on this situation, this paper will point at a typical coal exploitation (including a large-scale coal exploitation and private coal mine exploitation), study the change mechanisms of the surface deformation and the law of the rock movement of underground coal mining conditions, surface stability and safety are verified by the ground surface settlement and horizontal displacement, The result shows that: The mining subsidence caused by the large coal mining has some influences to the highway operation, the surface deformation is stacked by the exploitation of two coal mining, the damage of road surface is mainly caused by the private coal mine exploitation, the long term deformation caused by the large coal mine is not the main influence of the damage of the road and village. The influence of the coal mining is small and the deformation is small, the building does not need maintenance, and can be used normally.

Keywords: Coal mine · Vertical subsidence · Horizontal displacement
Mining surface · Rock movement

1 Introduction

The national infrastructure highlights the problem of the scarcity of land resources. Therefore, many large factories, railway and highway construction should be built above the goaf. It is very probable that the overlying rock of goaf are broken and collapsed under the external loads, which would affect the stability of foundation and lead to instability and failure of the building. The squeeze pressure caused by the mining is transmitted to the road surface through the subgrade, which makes the moving vehicle running in the air, causing the rollover accident. And some underground mining may produce the additional stress, resulting in the house deformation exceed its resistance ability, the house is damaged. So it is important to study the

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surface deformation caused by comprehensive mining in a coal mine to prevent the occurrence of disasters. Many scholars have studied the problem and got some achievements, some of them studied the deformation of the ground in the process of mining, some of them studied the long term ground permanent deformation after mining, their studies show that the ground deformation can be very small when the support structure of the mine has enough strength, and it also has no influences to the ground building and road. This project is special: a large mine is deep in the ground, a small private mining is in a shallow position in the ground, and the private mining is short of enough supporting measures, so it would have some adverse conditions of the ground deformation, it is our research emphases.

2 Stability Analysis of Mining Area

2.1 Engineering Problems

In this article a China coal mine which locates in the northwest are studied. There is a private coal mining in the upper part, the depth of the large coal mining is more than 500 m, the exploitation of underground coal mining and exploitation of the private coal mines, resulting in local surface subsidence, building and road crack which and affect the mining area residents living and travelling safety seriously, it can be seen in Fig. 1.

Fig. 1. Site condition of the ground above the coal mine

This paper will carry out numerical calculation to study the influence of underground coal mining to the ground surface.

2.2 Selection of Physical and Mechanical Parameters of Stratum

The average mining length of the coal mining face is 830 m, the dip angle of coal seam is 15°– 48°, the length of the coal seam which perpendicular to the strike length is about 35 m. the calculate boundary range is 1630 m along the direction of coal seam and is 950 m along the vertical direction. In this paper, two sections are set up respectively along the strike direction and vertical direction, and finite element calculation are done to study the influence of underground coal mining to the ground surface.

The parameters of rock and soil layer in the study area is in Table 1 (The parameters come from indoor physical mechanical tests and some related literature), a thrust fault is in the study area, its dip angle is 30° – 60°, vertical drop is 42 m and the horizon drop is 2 m, in the calculation, the thrust fault is considered.

2.3 Model 1

2.3.1 Calculation Range and Boundary Conditions

The selected section is vertical to the working surface and locates in the center of the exploitation basins, the calculation result based on this section is reasonable to evaluate the surface safety. The calculation range, boundary conditions and finite element mesh of model 1 are shown in Fig. 2. The element is divided into 4689 parts and 5150 units.

2.3.2 Calculation Condition

Case 1: Half of the coal seam of the upper private coal mine has been exploited.
Case 2: Large coal mining face has been exploited completely.

2.3.3 Calculation Process

The principle of simulation calculation is to keep the calculation steps consistent with the actual construction process, and make sure the results reliable. The calculation procedure is as follows:

(1) Using the dead weight of rock and soil to simulate initial stress.
(2) Simulating the process of coal seam mining, the top coal collapse with coal mining, In the simulation, each calculate step of the coal seam mining is 1.2 m.
(3) Simulating roof falling process. The roof falling with the work face moving forward 7 m.

2.3.4 Calculation Result

In accordance to the calculation process, there are 84 nodes on the ground surface from A to B, and the ground surface horizontal displacement and vertical settlement situation are shown in Figs. 3 and 4.

The analysis of horizontal displacement and vertical settlement curve are shown in Figs. 3 and 4. The curves of horizontal displacement and vertical settlement are shown in Figs. 5, 6, 7 and 8.

In case 1, the small coal mining has been exploited, the center of the surface subsidence basin locates above the private coal mine, the maximum horizontal displacement in the northwest edge of the basin is 0.85 cm, the maximum horizontal displacement in the southeast edge of basin is 0.84 cm. The maximum vertical settlement of the surface is 1.98 cm.

In case 2, the large coal mine has been exploited completely, the maximum horizontal displacement in the northwest edge of the surface basin to the southeast is 4.39 cm, and the maximum horizontal displacement in the northeast of the surface basin is 3.30 cm. and the maximum settlement in the center of the subsidence basin is 11.10 cm.

Table 1. Physical and mechanical parameters of the model

Layer	Rock layer	Thickness (m)	Density ($kg \cdot m^{-3}$)	Elastic modulus (MPa)	Poisson ratio (μ)	Cohesion (MPa)	Internal friction angle (°)
1	Loess	10.5	1700	55	0.3	0.03	20
2	Sandy mudstone	73	2300	8000	0.255	3.5	33
3	Sandstone interbedded with mudstone	33.5	2300	13,060	0.25	21	44
4	Coal seam	3	1390	2000	0.3	2.8	28
5	Sandstone interbedded with mudstone	29.9	2300	13,060	0.25	21	44
6	Siltstone	41.1	2250	13,000	0.23	18	40
7	Sandstone interbedded with siltstone	39	2300	13,060	0.25	21	44
8	Sandy mudstone	26.5	2300	8000	0.255	3.5	33
9	Medium grained sandstone	29.6	2400	12,000	0.22	21	44
10	Sandstone interbedded with medium grained sandstone	35.12	2300	13,060	0.25	21	44
11	Sandstone	231.72	2300	13,060	0.25	21	44
12	Grit	4.9	2600	12,000	0.23	19	37
13	Siltstone	3.6	2250	13,000	0.23	18	40
14	Coal seam	7.7	1390	2000	0.3	2.8	28
15	Argillaceous siltstone	2.5	2300	13,000	0.23	18	40
16	Coarse sandstone	5	2600	12,000	0.23	19	37
17	Coal	1.8	1390	2000	0.3	2.8	28
18	Siltstone	16.1	2250	13,000	0.23	18	40
19	Coal seam	4.8	1390	2000	0.3	2.8	28
20	Coarse sandstone	50	2600	12,000	0.23	19	37

After the completion of mining face, comparing case 1 with case 2 it can be seen that: the subsidence basin range and deformation increases significantly, the maximum settlement of ground surface deformation increases about 9.12 cm.

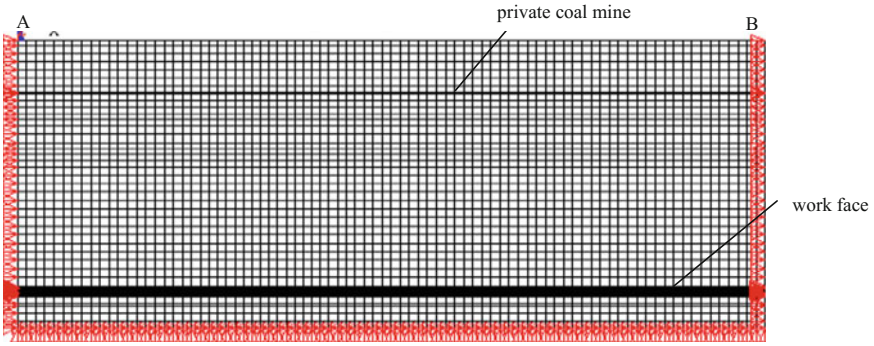

Fig. 2. The boundary condition and element partition of model 1

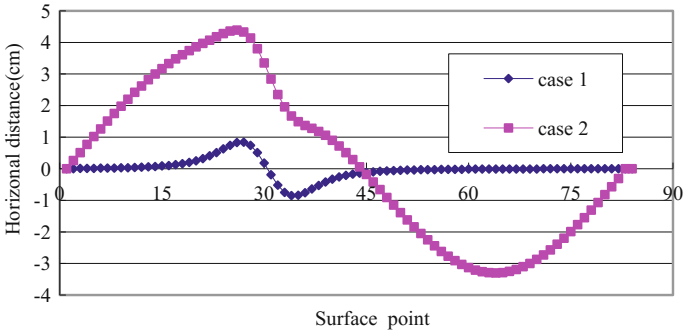

Fig. 3. The surface horizon displacement change curves of two work conditions

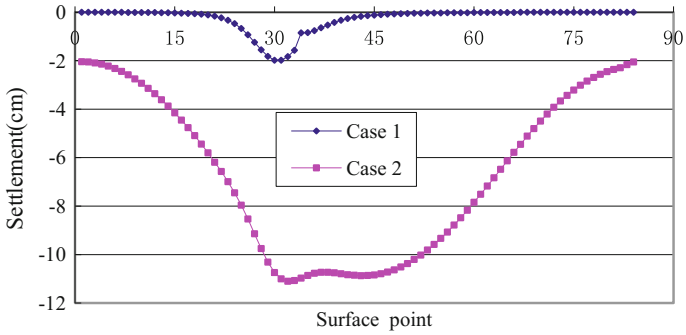

Fig. 4. The surface settlement change curves of two work conditions

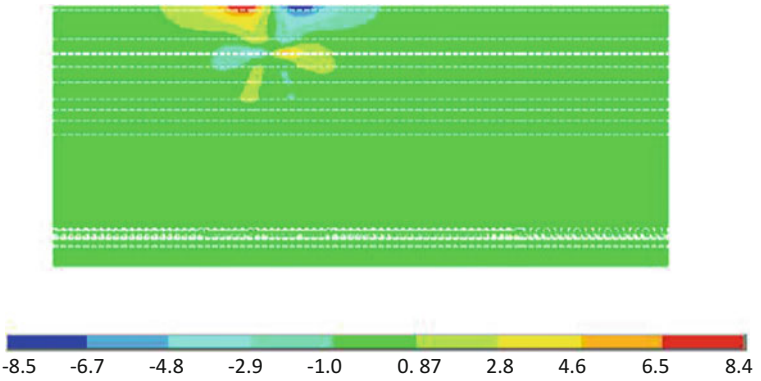

Fig. 5. Horizontal displacement nephogram of model 1 in case 1 (unit: mm)

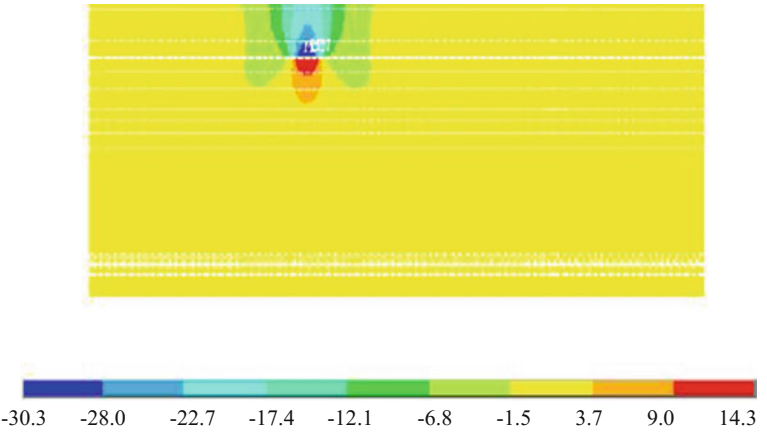

Fig. 6. Settlement nephogram of model 1 in case 1 (unit: mm)

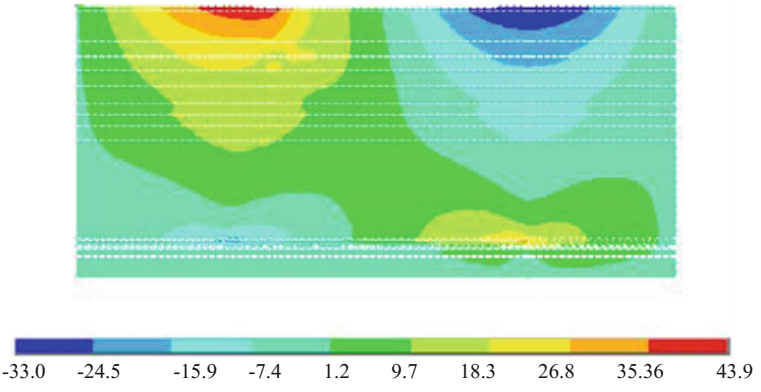

Fig. 7. Horizontal displacement nephogram of model 2 (unit: mm)

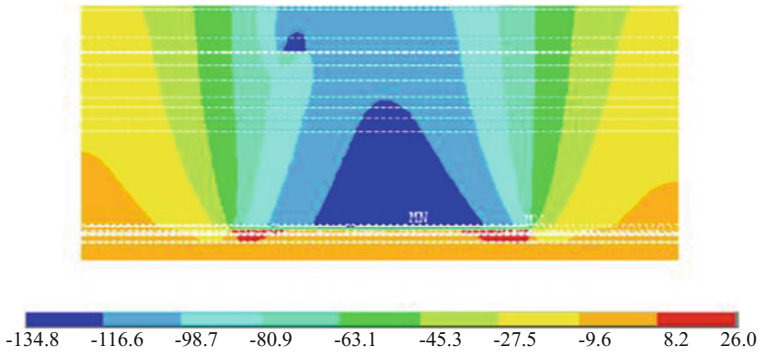

Fig. 8. Settlement nephogram of model 2 (unit: mm)

2.4 Model 2

2.4.1 Calculation and Boundary Conditions

The finite element mesh of model 2 is shown in Fig. 9. The length of the model along the vertical direction of the coal seam is 950 m. The model extends downward from the coal seam is 50 m. The model is divided into 2812 units, the nodes numbers are 2793.

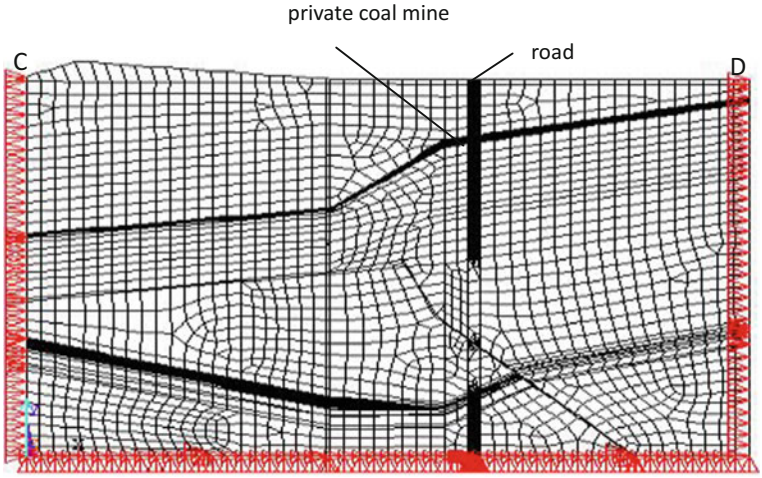

Fig. 9. The boundary condition and element partition of model 2

2.4.2 Calculation Condition

Case 1: The small coal mines has been finished.
Case 2: Large coal mining has been exploited completely.

2.4.3 Calculation Analysis

In accordance to the calculation process, there are 59 nodes on the ground surface from C to D, and ground surface horizontal displacement and vertical settlement situation are shown in Figs. 10 and 11.

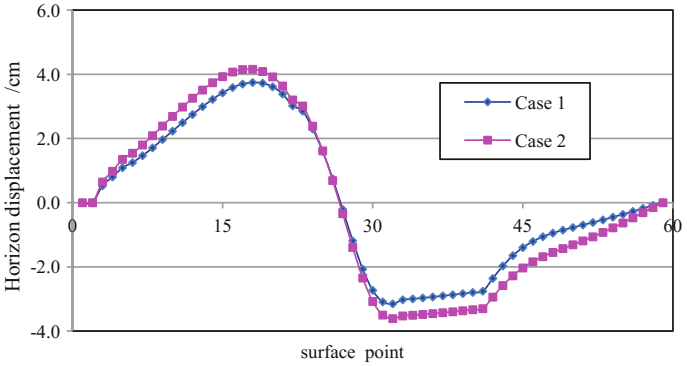

Fig. 10. The surface horizon displacement change curves of two work conditions

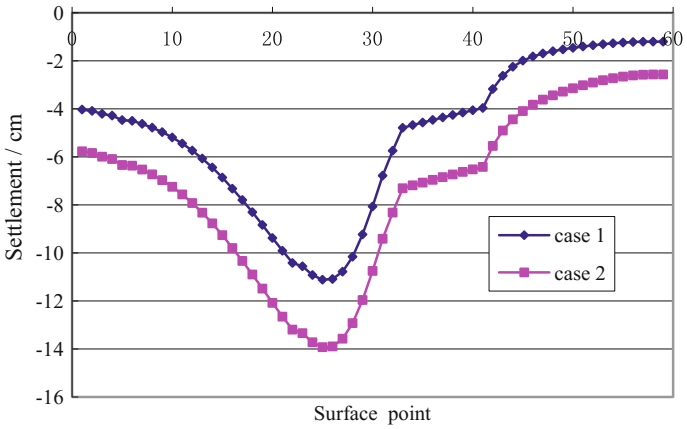

Fig. 11. The surface settlement change curves of two work conditions

This chapter summarizes the surface deformation law of the highway and the village near the 109 working face mining, analyzes the scope of the subsidence basin, and predicts the horizontal displacement and vertical settlement value (Figs. 12 and 13).

The surface horizontal displacement and vertical settlement are shown in Table 2. The calculation results are shown in Figs. 14 and 15.

The maximum vertical subsidence is 13.92 cm after the 109 working face mining completed in model 2, and in the region where we care about (the building roads and village locations), the maximum vertical settlement is expected to be about 7.31 cm, the tilt speed of the sinking region from the southwest to the center of the basin is 0.2 mm/m, the deformation curvature of the surface in the region where we care about is 0.013.

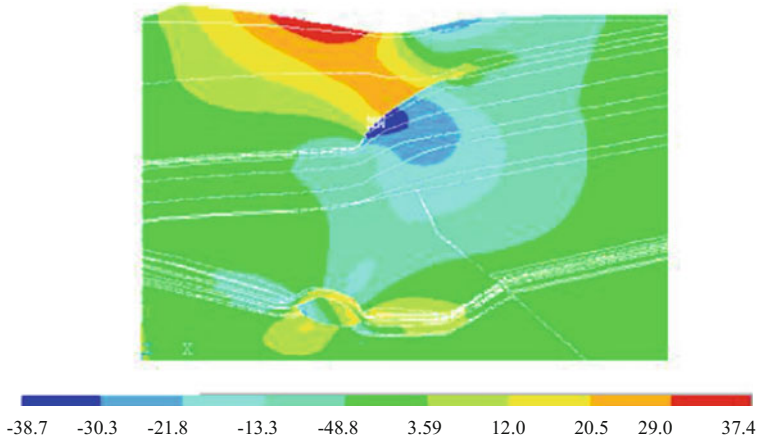

Fig. 12. Horizontal displacement nephogram of model 1 in case 1 (unit: mm)

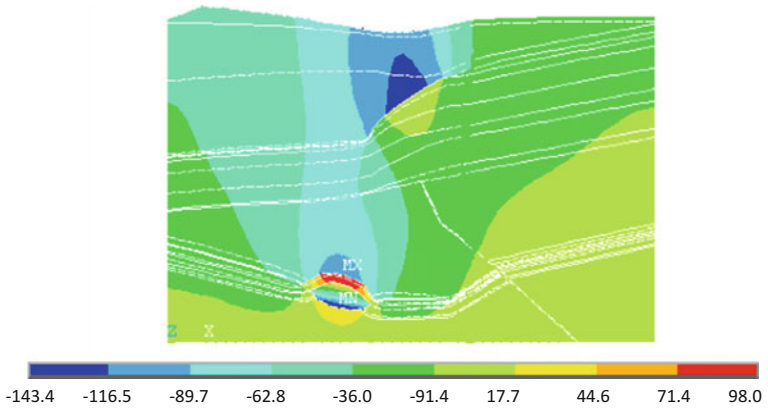

Fig. 13. Settlement nephogram of model 1 in case 1 (unit: mm)

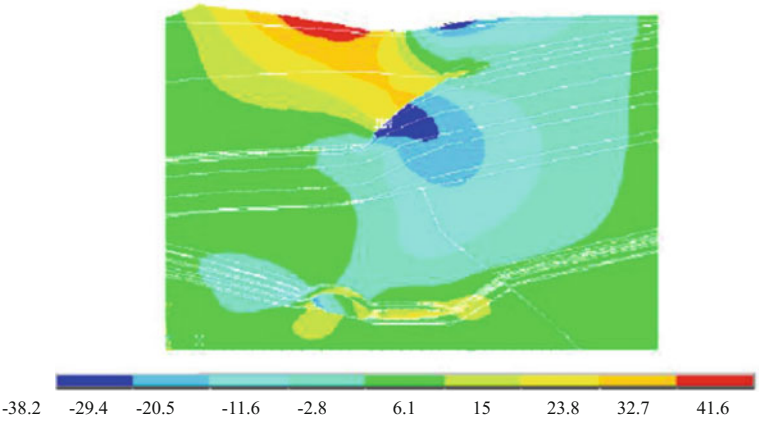

Fig. 14. Horizontal displacement nephogram of model 1 in case 2 (unit: mm)

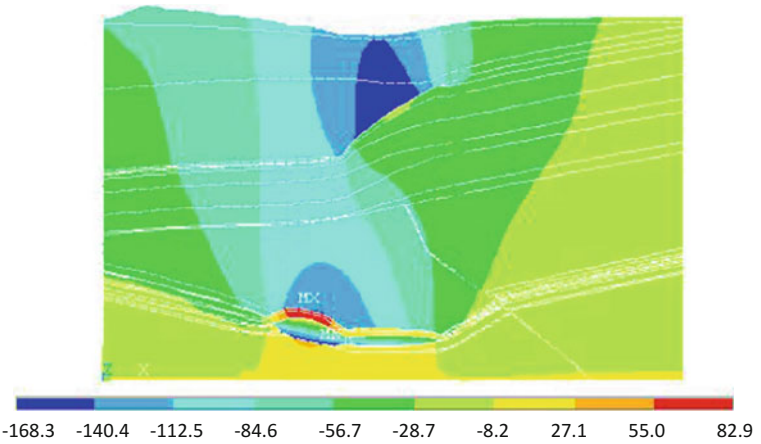

Fig. 15. Settlement nephogram of model 1 in case 2 (unit: mm)

3 Conclusion

In this paper, the numerical simulation is carried out to study the variation laws of the ground surface displacement under different work conditions:

(1) Surface deformation is stacked by the exploitation of two coal mining, the surface damage of the road is mainly caused by the private coal mine exploitation, the long term deformation caused by the large coal mine is not the main influence of the damage of the road and village.
(2) Mining subsidence caused by large coal mining has certain influence on road operation. The additional vertical displacement and horizontal deformation caused by mining are smaller, and the surface deformation can be ignored after the

completion of all the mining faces in the coal mine, and the surface building needn't to be maintenance.

(3) It is suggested to set up the surface deformation monitoring system, strengthen the monitoring, analysis the surface deformation law, to deal with the emergencies.

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