

Plastic Damage Characteristics of Roadways under the Influence of Overlying Working Face Mining

Weiyu Zhang

School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo, Henan 454003, China

Abstract: In order to investigate the influence of mining back from the upper working face on the lower roadway, this paper takes the south roadway of the -655m level of Hebi 8 Mine as the research object, and studies the plastic damage characteristics of the roadway surrounding rock under the influence of mining disturbance of the 3107-working face in the south roadway of the -655m level. Through numerical simulation, this paper explores the stress distribution and plastic damage characteristics of the roadway peripheral rock in the -655m horizontal south roadway of Hebi eight mine, and clarifies the deformation and damage range of the roadway peripheral rock.

Keywords: Numerical Simulation; Ground Stress; Stress Distribution; Plastic Damage.

1. Introduction

According to research on China's coal industry [1,2], coal remains the central energy source in the current and foreseeable energy sector. Thus, the safe and efficient exploitation of coal resources is vital to maintaining the stability of China's energy structure and economic growth. However, as shallow coal resources become exhausted, mining deeper seams has become imperative. This transition introduces complexity and diversity in mining conditions, posing numerous challenges to safe coal extraction. Roadways in fractured rock mass, influenced by geological stress and adjacent engineering activities, often exhibit significant deformation characteristics, such as rib spalling, floor heave, and roof falls. Moreover, deformations in these roadways tend to be non-uniform and rapid [3-5], which increases the difficulty of roadway support and significantly constrains the safety and economic benefits of coal mining enterprises [6-10].

At present, the -655m level south roadway of Hebi 8 mine is affected by the burial depth and the mining influence of the overlying 3107 working face, and the roadway perimeter rock is in the stress environment of three highs and one perturbation, which makes the roadway perimeter rock evolve into a broken rock body with complicated physical structure and mechanical properties. This environment prompted the deep roadway rock to show significantly different deformation and damage characteristics from the shallow peripheral rock. Therefore, it is of great significance to study the plastic damage characteristics of the roadway rock in the -655m level south aisle under the influence of the mining of the overlying 3107 working face.

This paper takes the south roadway of -655m level in Hebi 8 mine as the research background, the average depth of this roadway is 800m, and there is 3107 working face at about 32m above the roadway, and the coal seam where the working face is located is the 21 coal seam, which is a stable and mineable coal seam, with the thickness of 7m, and the inclination angle of the coal seam is 31° on average. In this paper, Flac3D numerical simulation method is used to study the plastic damage characteristics of the roadway under the influence of mining disturbance of 3107 working face in -655m level south roadway.

2. Model Building

The numerical simulation is established based on the actual geological conditions of Hebi eight mines, -655m level of the average depth of the south roadway is about 800m, the roadway is a semi-circular arch section, the net width of the roadway is 4.6m, and the net height is 3.8m, and the roadway is about 32m above the 3107 working face, and the coal seam where the working face is located is the 21 coal seam, which is a stable and mineable coal seam, and the thickness of the coal seam is 7m, and the inclination angle is 31° on average. The average inclination angle is 31° . The size of the numerical model is $185\text{m} \times 50\text{m} \times 105\text{m}$, where X direction is the direction of working face arrangement, Y direction is the direction of working face advancement, and Z direction is vertical upward. The two sides, bottom and front/back interfaces of the model are constrained by displacement and stress boundaries, and the top interface of the model applies the initial vertical load according to the depth of burial, the average depth of burial of the roadway is 800m, and the pressure of the overlying rock layer is about 20MPa, and the numerical model adopts the Moore-Coulomb intrinsic criterion, and the three-dimensional schematic diagram of the numerical model is shown in Figure 1, and the rock mechanical parameters used in numerical simulation are shown in Table 1. The rock mechanical parameters used in the numerical simulation are shown in Table 1.

After achieving initial geostress equilibrium, the excavation of the -655m level south roadway is carried out, followed by the advancement of the 3107 working face by 20m, simulating a 20m progression of the working face. The purpose is to investigate the impact of the engineering disturbance caused by the mining of the 3107 working face on the underlying -655m level south roadway. Finally, the 3107 working face is completely excavated to simulate the effects on the -655m level south roadway after the complete extraction of the 3107 working face.

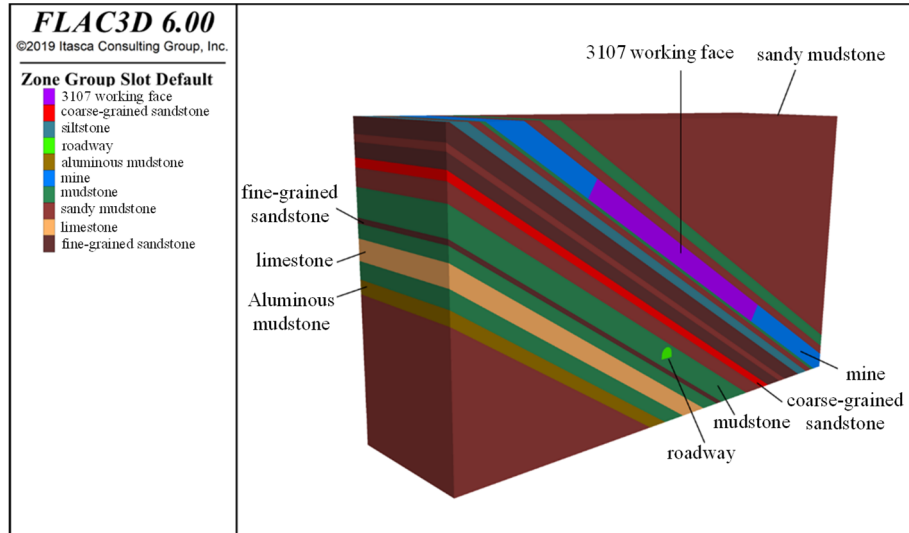


Figure 1. Schematic Diagram of Numerical Model

Table 1. Three Scheme comparing

Rock	Bulk Modulus (GPa)	Shear Modulus (GPa)	Densities (kg/m ³)	Internal friction Angle (°)	Cohesive (Mpa)	Tensile Strength (MPa)
Mudstone	1.96	1.76	2560	26.0	1.7	0.74
Mine	1.40	1.35	1930	20.0	1.2	0.35
Sandy Mudstone	8.47	8.11	2560	30.0	1.0	2.10
Fine-grained sandstone	2.01	1.45	2580	40.0	2.4	2.17
Coarse-grained sandstone	2.01	1.45	2620	40.0	2.2	2.01
Aluminous mudstone	9.50	7.30	2650	30.0	5.9	4.50
Limestone	5.57	4.53	2800	38.0	11.4	6.70
Siltstone	10.83	8.13	2460	38.0	2.75	1.84

3. Analysis of Stress Distribution Features in Surrounding Rock

3.1. Stress Distribution before Mining of the 3107 Working Face

Figure 2 shows the cloud map of vertical stress distribution in the surrounding rock of the -655m horizontal south aisle before the mining of the 3107 working face. From Figure 2, it can be seen that when it is not affected by the mining of the working face, a stress reduction zone will be formed at the top and bottom plates after the roadway is excavated, and stress concentration zones will be formed at the two gangs of the roadway, and the peak value of the stress concentration is 28.4MPa, and the vertical stresses are symmetrically distributed as a whole.

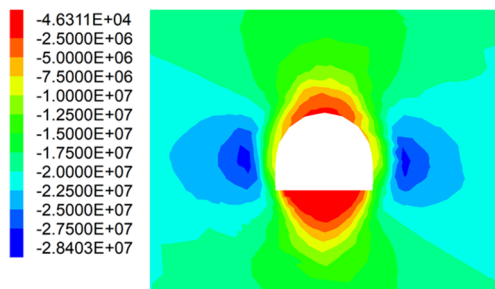


Figure 2. Vertical stress distribution before mining of 3107 working face

3.2. Stress Distribution during the Mining of the 3107 Working Face

When the 3107 working face is mined back to the appropriate position, the numerical simulation results at 5m, 10m, 15m and 20m in front of the 3107 working face and its lower roadway working face are intercepted respectively, and the vertical stress distribution is shown in Figure 3.

By comparing the vertical stress distribution at 5m, 10m, 15m and 20m in front of the working face, it can be seen that when 3107 working face is mined, the top and bottom plates of the -655m horizontal south roadway will form a stress reduction zone, and the closer to the working face, the bigger the range of the stress reduction zone is; at the same time, there is an obvious stress concentration area at the right gang of the roadway, and the size of vertical stress shows a trend of increasing first and then decreasing with the distance of overrunning of the working face. At the same time, there is an obvious stress concentration area at the right gang of the roadway, and the size of vertical stress increases and then decreases with the distance ahead of the working face. According to the characteristics of vertical stress distribution in front of the working face, the peak of vertical stress at 5m in front of the working face is about 28.7MPa, at 10m is about 32.2MPa, at 15m is about 27.8MPa, and at 20m is about 26.2MPa, and the order of the vertical stresses from big to small is 10m>5m>15m>20m, which shows that the vertical stresses are firstly increasing and then decreasing in front of the working face.

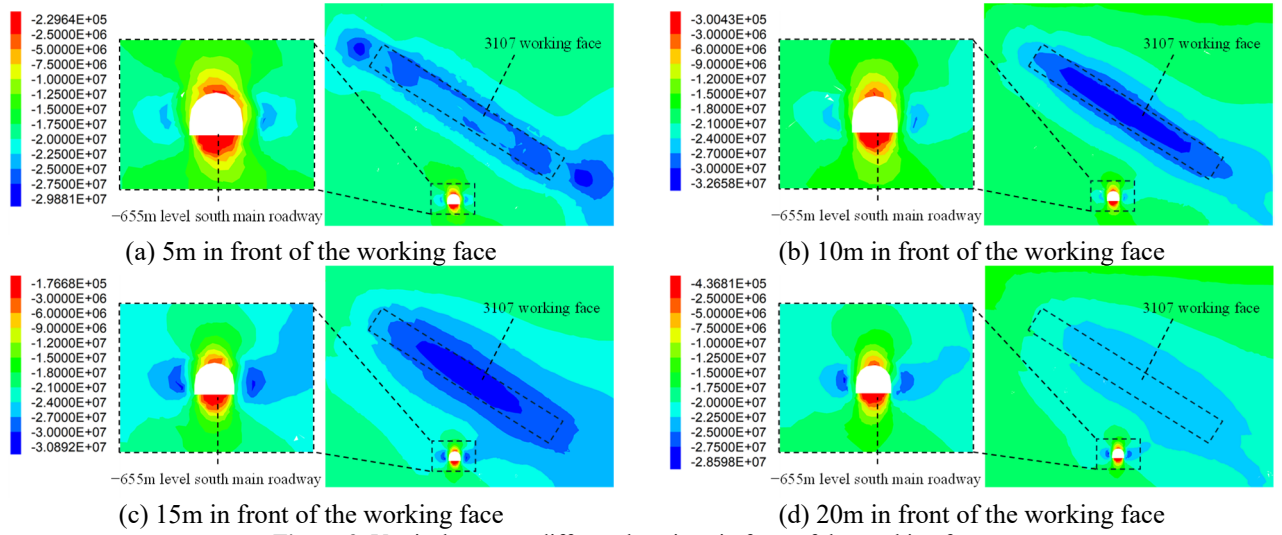


Figure 3. Vertical stress at different locations in front of the working face

3.3. Stress Distribution after Mining of the 3107 Working Face

When the 3107 working face mining is completed, under the combined influence of the working face mining and the air pocket, the -655m horizontal south roadway periphery will inevitably produce a large stress concentration, resulting in the expansion of the roadway plastic zone in the form of a

butterfly. Figure 4 shows the cloud diagram of vertical stress distribution in the surrounding rock of the -655m horizontal south aisle after the mining of the 3107 working face, from which it can be seen that after the 3107 working face is mined back, the vertical stress around the roadway will appear obvious non-uniform distribution, and at this time, the angle of the main stress deflection around the roadway has reached 45° .

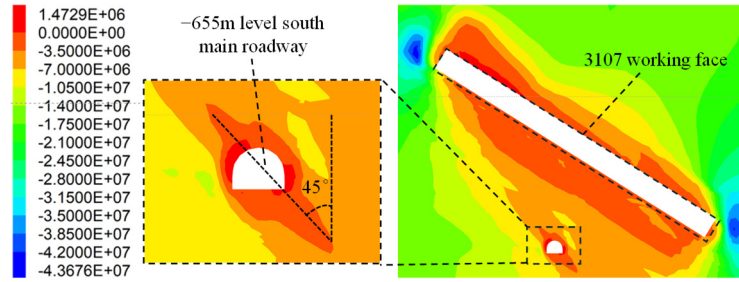


Figure 4. Vertical stress distribution after mining of 3107 working face

4. Analysis of Plastic Damage in Surrounding Rock

4.1. Plastic Damage before Mining of the 3107 Working Face

Figure 5 shows the distribution of the plastic zone of the surrounding rock in the south aisle of the -655m level before the mining of the 3107 working face. From the Figure 5, it can be seen that when it is not affected by the mining, the shape of the plastic zone of the surrounding rock in the south aisle of the -655m level is approximately circular, and the depth of the plastic damage is about 2.3m.

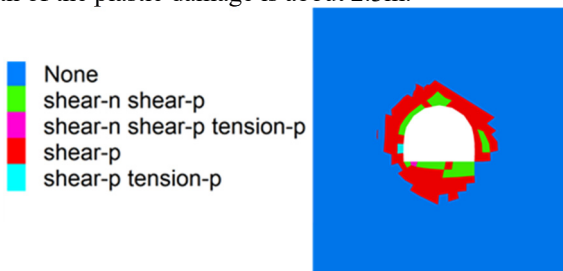


Figure 5. Plastic damage in surrounding rock before mining of 3107 working face

4.2. Plastic Damage during the Mining of the 3107 Working Face

In order to investigate the impact of 3107 working face mining on the lower -655m level of the south roadway, respectively intercepted 3107 working face mining 5m, 10m, 15m, 20m ahead of the working face and the working face lagging 5m, 10m, 15m, 20m at the roadway plastic damage calculation results, the distribution of the plastic damage as shown in Figure 6.

As can be seen from Figure 6, when 3107 working face is being mined, due to the influence of mining disturbance by the working face, the stress environment around the -655m level south roadway is worse, and the deformation and damage of the roadway peripheral rock is more serious, and the closer it is to the working face, the bigger the range of plastic damage of the roadway is; with the increase of the overrun distance, the influence of the roadway by mining is reduced, and the plastic damage of the roadway is gradually reduced. The area of plastic damage gradually decreases. By comparing Figure 6 (a) and (e), (b) and (f), (c) and (g), (d) and (h), it can be seen that the lagging area of the working face is affected by the combined effect of the working face mining

and the collapse of the void area, the plastic damage range of the roadway surrounding rock is larger than the working face overrun area, and with the increase of the lagging distance is

increasing. At this time, the plastic damage of roadway surrounding rock is mainly concentrated in the top of the roadway, and the depth of plastic damage is about 3.2m.

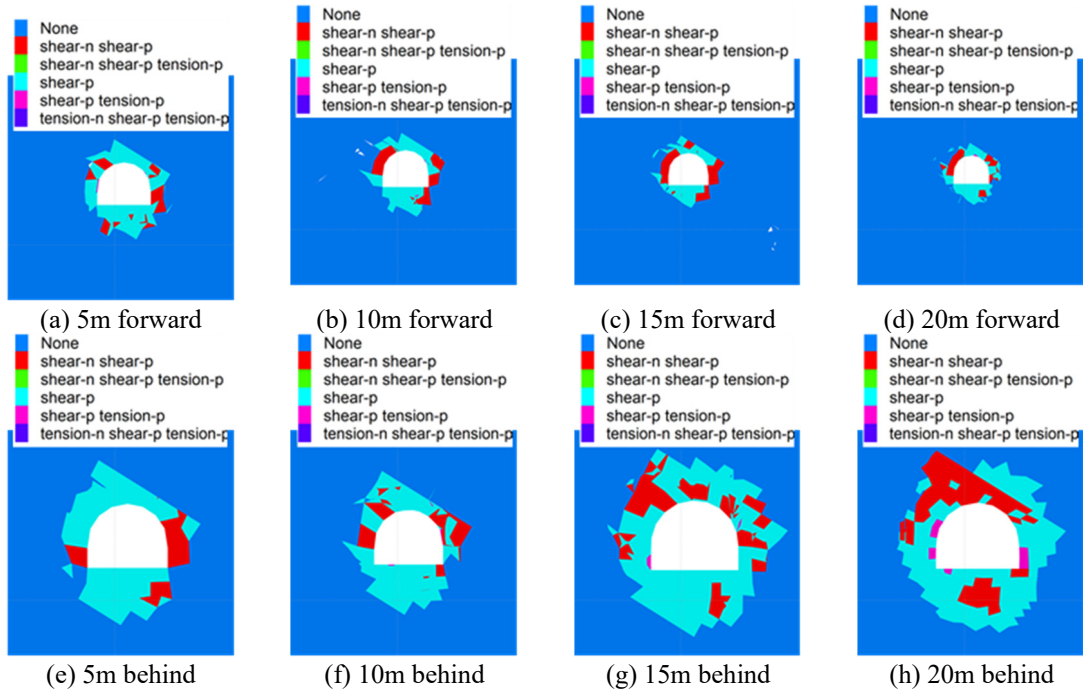


Figure 6. Plastic damage in surrounding rock during the mining of 3107 working face

4.3. Plastic Damage after Mining of the 3107 Working Face

Figure 7 shows the result of plastic damage after 3107 working face mining is completed and the roadway surrounding rock is stabilized. From the Figure 7, it can be seen that the -655m level south roadway is affected by the 3107 working face's mining airspace and the leftover coal pillar, resulting in unequal compressive stress environment around the roadway, which makes the plastic damage range of the surrounding rock in the roadway show obvious non-uniform distribution characteristics, and the plastic damage area is the same as that of the area with large principal stress ratio given in the previous section, and the plastic damage area is mainly concentrated in the top plate and the lower right corner of the roadway. The plastic damage area is mainly concentrated in the top plate and the lower right corner of the roadway, and its maximum depth can be up to 6.3 m. Due to the large plastic damage range of the peripheral rock of the roadway, the effect of the traditional support is reduced, and the roadway is prone to roofing and ganging accidents.

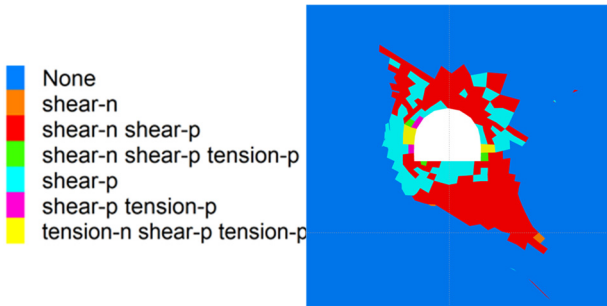


Figure 7. Plastic damage in surrounding rock after mining of 3107 working face

5. Conclusion

By combining theoretical analysis and numerical simulation, this paper analyzes the stress distribution characteristics such as maximum principal stress, principal stress direction, principal stress ratio and principal stress difference around the deep roadway, determines the distribution area of high stress ratio and difference around the roadway, and clarifies the main control factors of deformation and damage of surrounding rock.

(1) Before the 3107 working face was mined back, the south roadway was in a more stable stress level, and the overall vertical stress around the roadway was symmetrically distributed.

(2) During the mining back of 3107 working faces, the peak of vertical stress in the gang section of the south roadway appeared at 8.5 meters ahead of the working face, which was 33.6MPa, and the stress concentration in the gang section of the roadway was more obvious. In the lagging area of the working face, the main stress angle around the roadway was obviously deflected due to the influence of the coal pillar left in the mining area.

(3) After the mining of the 3107 working face was completed, there was an area with a large principal stress ratio between the top slab of the south roadway and the lower right corner, and there was shear damage to the roadway perimeter rock.

(4) Through numerical simulation, the distribution characteristics of the plastic zone around the -655m level south roadway are grasped. The -655m level south roadway is affected by the mining of 3107 working face and the leftover coal pillar, the plastic damage area is mainly concentrated in the roadway roof and the lower right corner, and the maximum depth of the plastic zone can be up to 6.3

m. The scope of plastic damage around the roadway is large, and the effect of the traditional bolt support is reduced.

References

- [1] H.P. Xie, J.H. Wang, B.H. Shen, et al: New idea of coal mining: scientific mining and sustainable mining capacity, *Journal of China Coal Society*, Vol. 37 (2012), No. 7, p. 1069-1079.
- [2] J.W. Teng, Y.H. Qiao, P.H. Song: Analysis of exploration, potential reserves and high efficient utilization of coal in China, *Chinese Journal of Geophysics*, Vol. 59 (2016), No. 12, p: 4633-4653.
- [3] H.Z. Wang, D.S. Zhang, X.F. Wang, et al: Study on bolt-mesh-anchor support technology of open-off cut with compound roof and large cross section, *Coal Science and Technology*, Vol. 46 (2018), No. 04, p: 105-109.
- [4] P. Zhang, N.J. Ma, W. Jiang, et al: Combined Support Technology of Large Section Roadway in High-stress Fractured Surrounding Rock, *Procedia Engineering*, Vol. 26 (2011), p: 1270-1278.
- [5] W.L. Zhai, Q.J. Wang, T. Li, et al: Application of High Strength and High Pretension Anchor Network Support Technology in Deep Mine Roadway Along Gob, *Safety in Coal Mines*, Vol. 49 (2018), No. 12, p: 79-82.
- [6] Z.J. Hou, L.S. Guo, P.F. Gou: *Coal Roadway Bolt Support* (China University of Mining and Technology press, China, 1999)
- [7] J. Yang, S.B. Yu, Z.G. Tao, et al: On the deformation and failure characteristics of the Tertiary soft rock roadway and coupling control measures, *Journal of Mining & Safety Engineering*, Vol. 31 (2014), No. 03, p: 373-378+384.
- [8] G.F. Zhang, S.B. Yu, G.F. Li, et al: Research On Complementary Supporting System Of Constant Resistance With Load Release For Three-Soft Mining Roadways In Extremely Thick Coal Seam, *Chinese Journal of Rock Mechanics and Engineering*, Vol. 30 (2011), No. 08, p: 1619-1626.
- [9] Y.D. Jiang, W.G. Liu, Y.X. Zhao, et al: Study On Surrounding Rock Stability Of Deep Mining In Kailuan Mining Group, *Chinese Journal of Rock Mechanics and Engineering*, Vol. 11 (2011), p: 1857-1862.
- [10] H.P. Kang, J.H. Wang, J. Lin: Case Studies Of Rock Bolting In Coal Mine Roadways, *Chinese Journal of Rock Mechanics and Engineering*, Vol. 29 (2010), No. 04, p: 649-664.