Numerical simulation research on the gob-side coal pillar width and surrounding rock deformation characteristics

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Abstract. Taking the Gaohe Coal Mine working face gob-side in Shanxi as the research object, the FLAC3D numerical simulation software was used to construct a numerical calculation model to analyze the coal pillar width and the surrounding rock deformation characteristics of the working face gob-side in the mining face during the mining process. The width of the coal pillars along the gob-side was determined, and the change law of the surrounding rock stress and deformation of the roadway with the advancing face was obtained. The research shows that the reasonable coal pillar width along the gob-side in the working face of Gaohe coal mine shall not be less than 36m. With the advancement of the working face, the stress and deformation of the surrounding rock of the roadway gradually increase, and the deformation amount and deformation range of the coal gang are both greater than the corresponding value of the flexible form gang, and the vertical stress of the coal gang is less than the stress of the flexible form concrete gang. The difference in deformation is the main reason for the difference in stress. The results of the study provide a reference for the safety of the gob-side along the coal mine.

1. Introduction

With the increasing depth and intensity of coal mining, the engineering geological environment of the surrounding rock of coal mine roadways is becoming more and more complicated, the rockburst and gas increase, and the deformation of the surrounding rock is fierce, which makes the roadway support more difficult and poses a huge threat to coal mine production. With the development of coal mine technology, the gob-side technology is widely used in coal mining, and has achieved good results [1]. The gob-side technology refers to retaining the original mining roadway along the edge of the goaf behind the coal mining face of the coal mine. The mining work will cause the roof to move violently in the face of gob-side. At the same time, due to the support of the side of the roadway, the deformation of the surrounding rock exhibits unique characteristics. At present, many scholars at home and abroad have conducted in-depth research on the relevant theories and technologies of gob-side, and have obtained rich research results [2-6].

During the mining process, the stress changes of the roadway bolts can better reflect the deformation characteristics of the surrounding rock of the roadway, but due to the combined effects of the lateral pressure coefficient of the roadway, the shape of the roadway, the ground stress, the excavation activity
and the cracks. It cannot fully reflect the whole stress and deformation state of the surrounding rock. Therefore, the numerical simulation method can be used to analyze the coal pillar width, filling body, supporting effect and surrounding rock structure features along the gob-side. Liang Xingwang et al. [7] used FLAC2D to simulate the displacement and stress of surrounding rock when setting coal pillars with different widths along the gob-side in fully mechanized caving. Fan Guocheng et al. [8] used UDEC2D3.1 simulation software to simulate the stress distribution law of coal pillars and the stability of roadway surrounding rock under different width conditions along the air side of 80509 fully mechanized caving island face of Yangquan No.2 Mine. Under the condition of 5.5m, the surrounding rock deformation of the gob-side is the best. Lin Dongcai et al. [9] used numerical simulation methods to study the deformation and stress distribution of surrounding rock along the gob-side. Zhao Jian et al. [10] used the FLAC3D software to study the supporting effect of the side roads along the gob-side in the Shenhua Xuehu Coal Mine 2106 working face. When the coal wall of the lagging face is 25m, it is the best time for roadside support. Zhou Rui [11] used the Cvisc model in the FLAC3D software to study the creep characteristics of the backfill along the gob-side. Zheng Qiangqiang et al. [12] conducted a numerical simulation study on the effect of backfills with different width roadways in the first mining face of 1252(1) Panyidong Coal Mine, and verified that the effect of leaving roadways along the gob-side is best when the filling width reaches 2~3m. Therefore, the FLAC3D software was used to carry out in-depth numerical simulation analysis of coal pillar width and surrounding rock deformation along the gob-side in the working face of Gaohe Coal Mine in Shanxi to provide a theoretical reference for the optimized design of the supporting roadway along the gob-side.

2. Construction of numerical model

The numerical simulation software FLAC3D is used to numerically simulate the stress of the bolts along the gob-side and the deformation of the surrounding rock of the roadway along the gob-side in the Gaohe Coal Mine of Shanxi. The constructed numerical calculation model is shown in Figure 1. The geometric dimensions of the model is 200m×120m×60m, and the physical and mechanical characteristics of the surrounding rock of the tunnel are shown in Table 1.

![Figure 1. Numerical calculation model](image)
Table 1. Physical and mechanical parameters of coal seam and its rock floor

| No. | Lithology     | Density /kg.m⁻³ | Bulk modulus/GPa | Shear modulus/GPa | Cohesion/MPa | Internal friction angle/° | Tensile strength/GPa |
|-----|---------------|-----------------|------------------|-------------------|--------------|---------------------------|----------------------|
| 1   | Siltstone     | 2550            | 11.61            | 6.05              | 4.00         | 24                        | 3.96                 |
| 2   | Sandstone     | 2500            | 10.82            | 5.31              | 0.52         | 14                        | 0.62                 |
| 3   | Mudstone      | 2650            | 14.82            | 5.82              | 4.30         | 29                        | 4.96                 |
| 4   | Coal seam     | 1410            | 2.15             | 0.85              | 0.50         | 14                        | 0.6                  |
| 5   | Mudstone      | 2515            | 10.78            | 5.38              | 3.59         | 20                        | 3.48                 |
| 6   | Fine sandstone| 2580            | 16.59            | 6.59              | 4.40         | 31                        | 5.20                 |

3. Analysis of numerical simulation results

3.1. Coal pillar width analysis
It mainly simulates the roadway deformation and plastic zone distribution of different coal pillar widths (32m, 34m and 36m) under unsupported conditions. Under the conditions of different coal pillar widths, the vertical stress, displacement and plastic zone distribution clouds around the gob-side are shown in Figure 2 ~ Figure 4.

Figure 2. Vertical stress distribution cloud/Pa

Figure 3. Vertical displacement cloud/m

Figure 4. Distribution cloud of plastic zone
It can be seen from Figures 2 and 3: as the width of coal pillars continues to increase, the amount of tunnel deformation decreases, and the amount of tunnel deformation exceeds 1m. Therefore, the distribution range of the maximum deformation of the roof and the distribution of the deformation of the upper part can reflect the influence of the change in the width of the coal pillar. As the width of the coal pillars increases, the distribution range of the maximum deformation of the roof of the roadway is gradually concentrated toward the center of the roadway, and the distance to the roof is gradually reduced from 1.5m to 0.8m. The deformation of the roadway upper part is also gradually reduced from 1~1.5m to 0.5~1m, and the stability of the roadway side is greatly enhanced. It can be seen from Figure 4: as the width of the coal pillar increases, the range of the plastic zone of the roadway gradually decreases. Among them, the plastic zone of the pillar pillar is very small when the width of the coal pillar is 34m, but the depth of the plastic zone of the roof exceeds 4m. When the width of coal pillar is 36m, the depth of roof plastic zone in tunnel plastic zone is reduced. Therefore, it can be determined that the width of the coal pillars remaining along the gob-side is not less than 36m.

3.2. Surrounding rock stress changes under the influence of mining

Figure 5 shows the variation characteristics of the stress distribution in the vertical direction of the datum plane (the cross section of the roadway at the initial advancement of the working surface to 40m) with the increase of the working surface advancement distance.

![Stress distribution in the vertical direction of the datum plane at different propulsion distances](image)

**Figure 5.** Stress distribution in the vertical direction of the datum plane at different propulsion distances

It can be seen from Figure 5: with the advancement of the working face, the stress distribution of the surrounding rock of the tunnel has changed significantly. On the coal side, as the working face advances, its vertical stress shows a trend of increasing first and then decreasing.

3.3. Deformation characteristics of surrounding rock under the influence of mining

Figures 6 and 7 show the horizontal and vertical deformation cloud diagrams of the surrounding rock of the roadway as the working face advances. During the advancement of the working face, with the increase of the goaf, the deformation of the surrounding rock of the roadway will produce significant changes, and the deformation of the surrounding rock is the root cause of the change of the surrounding rock stress and the axial force of the bolt.

![Horizontal cloud (X) direction deformation cloud image after the working face is propelled](image)

**Figure 6.** Horizontal cloud (X) direction deformation cloud image after the working face is propelled
With the advancement of the working face, the deformation of the surrounding rock of the roadway gradually increased, and the deformation of the surrounding rock in all three locations increased linearly. The advancement distance of the working face increased from 3.6m to 13.2m, and the coal gang deformation increased by 13.31% (22.62cm to 25.63cm), 13.72% (12.53cm to 14.25cm), 2.26% (2.21cm to 2.26cm).

4. Conclusion
(1) The numerical simulation of FLAC3D software was used to study the deformation law of surrounding rock along the gob-side in the working face. It is determined that the width of the coal pillar is not less than 36m.
(2) With the advancement of the working face, the stress and deformation of the surrounding rock of the roadway gradually increase, and the deformation amount and deformation range of the coal gang are larger than the corresponding value of the flexible form, and the vertical stress of the coal gang is less than the stress of the flexible form concrete. The difference in deformation is the main reason for the difference in stress.
(3) The results of the study provide a reference for the safety of the gob-side along the coal mine.

Acknowledgments
The study was supported by the National Key R&D Program of China (2018YFC0808305).

References
[1] Hua Xinzhu. Development Status and Improvement Suggestions of Supporting Technology along Goafs in my country[J]. Coal Science and Technology, 2006, 34(12): 78-81.
[2] Kang Hongpu, Niu Duolong, Zhang Zhen, et al. Deformation characteristics and supporting technology of surrounding rock in deep remaining roadway[J]. Journal of Rock Mechanics and Engineering, 2010, 29(10): 1977-1987.
[3] Han Changliang. Stress optimization and structural stability control of surrounding rock along the remaining lane[D]. Xuzhou: China University of Mining and Technology, 2013.
[4] Xu Jun, Hao Shengpeng, Yang Jianxiang, et al. Research on surrounding rock failure characteristics and control technology of goafs along gob under coal pillars[J]. China Coal, 2015, 41(7): 58-61.
[5] Zhou Rui, Li Yuanhui, Yan Binyi. Determination of the parameters of the filling body along the empty lane under the condition of the basic roof fracture position [J]. China Mining Industry, 2016, 25(12): 76-81, 93.
[6] Zhang Jiayun, Wu Meiping. Technical practice of remaining along the empty roadway in softly inclined working face of steeply inclined medium-thick coal seam[J]. China Coal, 2017, 43(10): 60-65.
[7] Liang Xingwang, Wang Lianguo, He Xinghua, et al. Determining the reasonable width of narrow coal pillars along goafs[J]. Mining Research and Development, 2007, 27(2): 29-31.
[8] Fan Guocheng, Yang Xiaocheng, Gao Rui, et al. Research on reasonable width of coal pillars for
roadway protection along gob in fully-mechanized top-coal caving in Yangquan mining area[J]. Energy Technology and Management, 2014, 39(3): 99-101.

[9] Lin Dongcai, Zhao Yixian, Luan Hengjie, et al. Research on the rationality of the supporting strength of the wall beside the lane along the road[J]. Coal Engineering, 2016, 48(2): 47-49.

[10] Zhao Jian, Zhang Peng. Study on the given deformation of surrounding rock along the goaf and the timing of roadside support[J]. Coal Engineering, 2017, 49(2): 68-71.

[11] Zhou Rui. Numerical simulation of creep characteristics of backfill along the empty roadway[J]. Coal Mine Safety, 2018, 49(3): 218-221.

[12] Zheng Qiangqiang, Xu Ying. The effect of the width of the filling body on the effect of leaving the road along the goaf[J]. Coal Technology, 2018, 37(3): 43-36.