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Research Article

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Study on The Width of Coal Columns Retained in Deep Air Tunnels Dased on FLAC3D Simulation

Zhang Yu

School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo 454000, China

Abstract: The rationality of the width of the coal columns in the tunnel along the air tunnel is related to the stability of the tunnel surrounding rock and the safe and efficient production of the working face. Through domestic and foreign research and analysis of the coal column reserve width, with the goal of improving coal mining rate and stabilization control of tunnel surrounding rocks, FLAC3D numerical simulation study was conducted in combination with the deep air tunnel along a mine in central China, and the surrounding rock stress evolution law was analyzed at different widths of narrow coal columns in deep air tunnels. The coal column reserve width of test tunnel was designed according to the actual situation. By monitoring the displacement of surrounding rocks along the air tunnels of 5m narrow coal columns on site, the feasibility of designing the design of 5m narrow coal columns along the air tunnels along the air tunnels was verified.

Keywords: Research status; numerical simulation; narrow coal column.

1. Introduction

With the continuous mining of world coal resources, the depth of coal seams is gradually increasing, and the retention of coal columns along deep airways and the stability control of surrounding rocks have become key issues. At present, the proportion of roof accidents in China is gradually declining every year, but the number of deaths caused by roof accidents accounts for the largest proportion of the five major coal mine disasters, so reasonable and effective regulation of roofs is still the focus of coal mine work [1]. The geological conditions of deep coal seams are complex, such as high ground stress, high temperature, abundant groundwater, etc., which leads to increased difficulty in coal mining. The deep-altitude recovery tunnel is in a multi-action environment of high ground stress field, goaf strong pressure disturbance and working surface recovery disturbance, resulting in strong mine pressure, deepening the development of cracks inside the top slab rock layer, and expanding the plastic area of the tunnel surrounding rock. The practice of mining in a large number of deep coal mines has shown that only by fully mastering the instability effect of coal columns along the skyway under the influence of complex conditions and formulating a coal column retention plan to effectively control the stability of surrounding rock along the skyway can we ensure that the airway meets the requirements of safe and efficient production of the mine. For deep hollow tunnels, reasonable coal column width is the key to improving coal utilization and stability of the surrounding rock on the top plate of the tunnel. Taking the skyway along the deep working face of a mine in central China as the experimental tunnel as the research object, we analyzed and studied the current research status of coal column storage and the evolution law of surrounding rocks in the tunnels based on FLAC3D numerical simulation of the width of narrow coal columns at different times, providing scientific solutions for the reasonable width of coal column storage in deep air tunnels in the future.

2. Research Status at Home and Abroad

By controlling the width of the coal column, the stability of the surrounding rock along the hollow tunnel can be effectively improved and the difficulty of tunnel maintenance can be reduced. As coal mining moves to deeper, the mining environment becomes more complex. Scholars at home and abroad have conducted many research on the technology of retaining and supporting coal columns in deep airways. By studying the reasonable width of coal columns to improve the stability of surrounding rocks along the airways, we can achieve the goal of making full use of coal resources and improving coal mining rates. However, due to the large differences in the presence of coal seams and the surrounding rock geological conditions, domestic and foreign scholars have different views on coal columns along the skyway [2-4].

Before applying narrow coal columns, some scholars believed that the width of the coal column that supports and stabilizes the roof of the hollow tunnel should be greater than 20m, and the larger the width of the coal column, the stronger the pressure resistance of the tunnel. With the in-depth study of the pressure distribution of coal columns, the technology of retaining narrow coal columns has emerged. The narrow coal columns sometimes have more stable control effects on surrounding rocks along the hollow tunnels [5-6]. Through research on the stress and ultimate strength of the coal columns in the lane protection, foreign experts and scholars believe that during the tunnel digging along the air, the stress of the coal columns in the lane protection changes. When the coal columns are under pressure exceed the ultimate strength of the coal column, the coal columns lose their original ability to resist stress, and the failure of the coal columns is a change from local failure to overall failure [7-9].

Ghasemi E[10] determined the limit width of the coal column through research and analysis. According to the study and analysis of the width continuity of coal columns, a coal column pressure bearing model was established, and the load capacity limit value of the tunnel guard coal column was calculated based on the rock mass yield limit theory, and the previous conditions for the stability of the coal columns were determined. Foreign experts [11-13] have studied and analyzed the mechanism of coal column damage, and revealed that two forms of damage may exist in coal column damage. One is that the uneven load in the coal column in the tunnel guarding coal column causes a crack to appear first in places where the coal column is under great force, and then continues to expand and extend, eventually causing the coal column to rupture, and its load-bearing capacity gradually weakens, which eventually leads to the failure of the coal column. This failure theory is called the gradual failure theory; the other is that the instability of the coal column is transient, and when the coal column is under greater than the maximum capacity of its bearing capacity, it will rupture. This theory is called "extreme equilibrium".

To sum up, domestic and foreign scholars currently provide rich theoretical basis and technical reference for the reasonable width of coal columns in the air tunnel, the application of narrow coal columns and the support technology of narrow coal columns through different research methods and research angles, laying the foundation for the continued development of deep air tunnels. However, there are few studies involving the influence of the coal column width affecting the internal stress and deformation damage degree of the two surrounding rocks along the air tunnels. Therefore, through the study of the stress evolution law of surrounding rocks along the air tunnels along the air tunnels, analyzing the internal stress magnitude of the two surrounding rocks under different widths of narrow coal columns is of great significance to the establishment of narrow coal columns along the air tunnels along the air tunnels.

3. Establish FLAC3D numerical calculation simulation

In order to study the influence of the width of coal columns left in this test tunnel on the stability control of the surrounding rock of the tunnel, a FLAC3D numerical simulation calculation model was established. The coal seam inclination angle is 8° in the model of 6° to 12°, the average thickness of the coal seam is 2.1m, the model size is 100m×150m×70m. In the calculation model, there are 11 layers of coal seams and rock layers. The trapezoidal section size along the hollow tunnel is 5.0m×3.0m, and the tunnel section area is 15m^2. The numerical calculation model is established as shown in Figure 1.

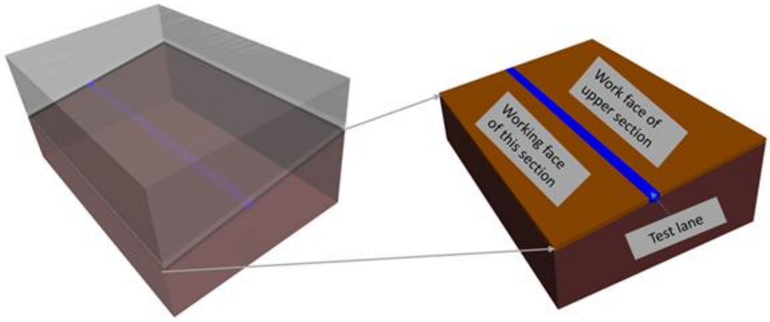

Figure 1: Numerical calculation model for goaf-side roadway excavation

Moore-Cullen constitutive model for geological conditions of the working face. The average capacity of the rock layer overlying the coal seam is 2.5kN/m^3, and the average buried depth of the working surface is 900m. Therefore, a uniform distribution load of 22.5MPa (vertical downward) is applied above the model, and the side pressure coefficient is 1.1. The displacement boundary of the bottom of the model and the surrounding displacement boundary are fixed. The numerical calculation model is excavated according to the actual mining order (return to the working surface of the upper section → dig along the air tunnel → return to the working surface of this section).

4. The Evolution Law of Surrounding Rock Stress

In order to study the effect of the dimensional parameters of the tunnel guard coal column on the stability mechanism of the surrounding rock in the advance support section of the tunnel along the air tunnel, a FLAC3D three-dimensional numerical simulation software was used to construct a surrounding rock stress under the action of mining stress. By comparatively analyzing the stress redistribution characteristics of the surrounding rock under the four operating conditions of the width of the tunnel guard coal columns of 3m, 5m, 7m and 12m respectively.

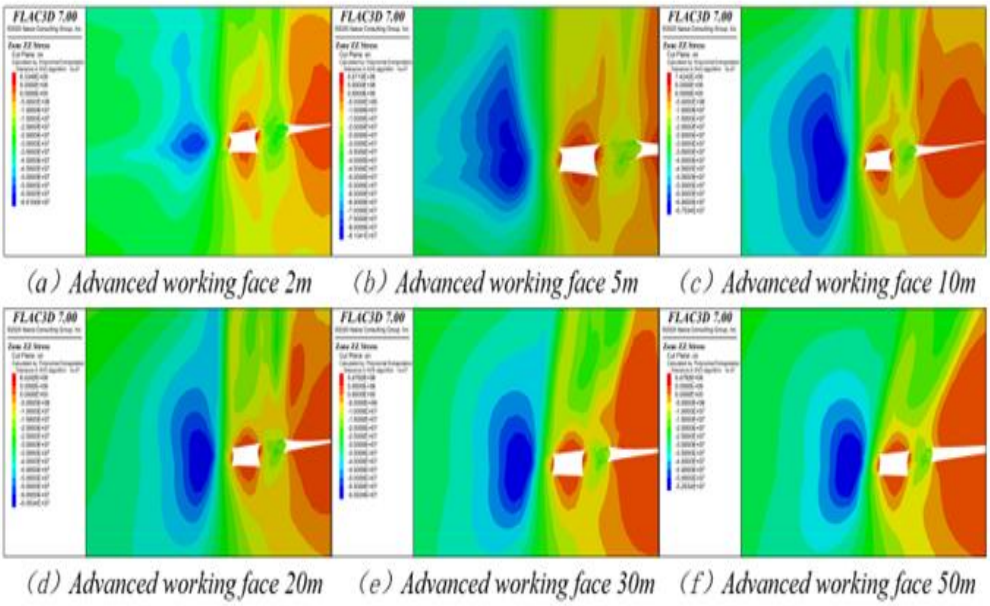

Figure 2: Cloud map of surrounding rock stress distribution in advance dynamic pressure area along the skyway (width of the coal column for protection is 3m)

According to the analysis of Figure 2, it can be seen that when a 3m narrow coal column protection tunnel is used, the residual mining stress in the upper section of the gou area showed significant transfer characteristics, mainly distributed to the coal body along the back mining side of the locust tunnel. On the basis of bearing the residual stress of the adjacent gou area, the coal body in this area is superimposed on the retrieval disturbance stress of the working face of this section to form a composite stress concentration effect, which makes the stress difference between the surrounding rocks of the two tunnels, and the stress in the back mining side of the coal body is higher, and the impact of the coal body on the back mining side is more prominent.

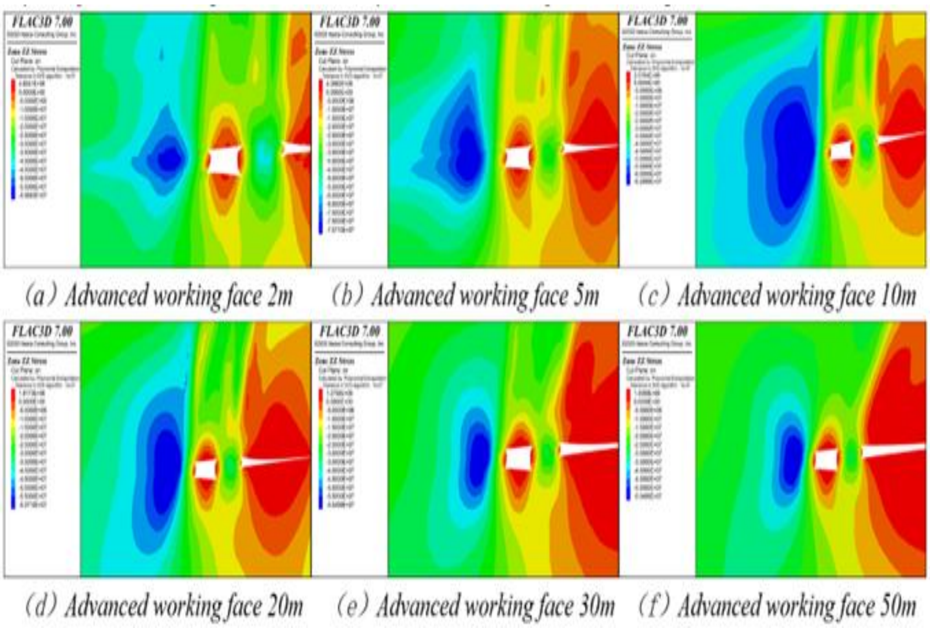

Figure 3: Cloud map of surrounding rock stress distribution in advance dynamic pressure area along the skyway (width of the coal column for protection is 5m)

According to Figure 3, when using a 5m wide lane guard narrow coal column, the residual stress in the upper section of the goaf shows a dual-path transmission feature - a small part is carried by a narrow coal column, and most of it is carried by a coal body on the back-mining side. The re-mining disturbance of the working face of this section leads to a stress superposition effect between the narrow coal column and the back-mining side. Both of the two groups have mining effects, while the mining impact on the back-mining side is significant.

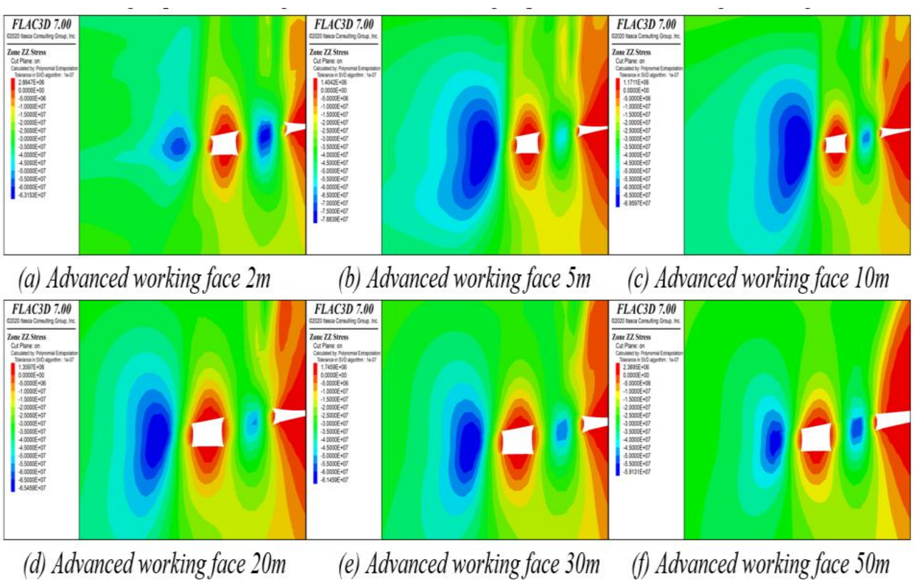

Figure 4: Cloud map of surrounding rock stress distribution in advance dynamic pressure area along the skyway (width of the coal column for protection is 7m)

According to the analysis of Figure 4, it can be seen that when a 7m-wide tunnel protection coal column is used, the coal column coal body and the coal body on the mining side form a double main bearing structure. The residual mining stress in the upper section of the gouge is carried together by the double main bearing structure. Then, affected by the mining disturbance of the working face of this section, the two coal bodies along the skyway are in a high stress state, resulting in a significant impact on the mining of the two tunnels.

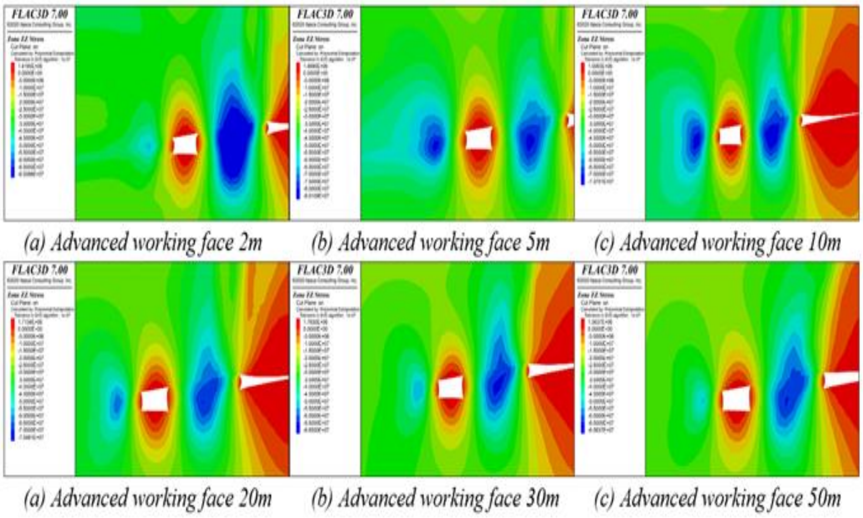

Figure 5: Cloud map of surrounding rock stress distribution in advance dynamic pressure area along the skyway (width of the coal column for protection is 12m)

From the analysis of Figure 5, it can be seen that when a 12m tunnel guard coal column is left, the stress in the two surrounding rocks along the front dynamic pressure area along the skyway is in a high state when the width of the tunnel guard coal column is 12m. The residual stress in the upper section of the gouge is jointly carried by the two surrounding rocks, and when a 3m (or 5m, or 7m) narrow coal column is left, the impact range of the mining disturbance in the front dynamic pressure area of the tunnel is increased.

5. Conclusion

When the width of the coal column is 3m or 5m, the tunnel shows asymmetric deformation characteristics. The coal body on the mining side forms a stress-dominated area, and its deformation is significantly higher than the internal stress of the coal column, which mainly carries the mining stress. At this time, high-strength prestressing support needs to be implemented in the advance disturbance area to control the stability of the mining and prevent it from being in a high-stressed state. However, as the width of the narrow coal column gradually increases (greater than 5m), the deformation of the coal column along the hollow tunnel increases, and the deformation of the mining and the surrounding rock mechanics system undergoes an essential change. The coal column side gradually develops into an important part of the dual-load structure, and together with the mining side form a composite stress field bearing mechanism. At this time, the two tunnels along the hollow tunnel are prone to undergo major deformation in the advance dynamic pressure area of the tunnel, and the maintenance difficulty of the two tunnels along the hollow tunnel increases. Support should be strengthened at the same time. From the above, it can be seen that according to the analysis of the stress and displacement evolution laws along the tunnel in the deep area, it is determined that 5m coal columns are left to open the test tunnel at the edge of the adjacent goaf.

References

[1]. Zhang Peisen, Niu Hui, Zhu Huicong, et al. Analysis of my country's coal mine safety production situation from 2019 to 2020 [J]. Coal Mine Safety, 2021, 52(11): 245-9.

[2]. Zhao Xuechen. Research on the reasonable width of coal columns in the 15207 working face of Lingzhida Coal Mine [J]. Energy and Energy Saving, 2020, (10): 44-5+8.

[3]. Guo J, Feng G, Wang P, et al. Roof Strata Behavior and Support Resistance Determination for Ultra-Thick Longwall Top Coal Caving Panel: A Case Study of the Tashan Coal Mine [J]. Energies, 2018, 11(5): 1041.
[4]. Lu Shuai. Determination of reasonable coal column widths of narrow coal columns along the air tunnels of isolated island working face [J]. Journal of Shanxi Energy University, 2023, (4): 4-6.
[5]. Guo Chongtuo, Li Jie, Bai Jianbiao, et al. Research on the reasonable width of coal columns in the comprehensive and relaxed mining of extra-thick coal seams [J]. Coal Engineering, 2022, 54(02): 19-24.
[6]. Chen Xiaoxiang, Fu Donghui, Wang Leichao. Research on the deformation mechanism and control technology of surrounding rocks in widened narrow coal column tunnels [J]. Journal of Henan University of Science and Technology (Natural Science Edition), 2015, 34(06): 764-9.
[7]. Han C, Yuan Y, Zhang N, et al. Thick-Anchored Dual-Layer Locking Supporting Technique in Gob-Side Entry Driving with the Narrow Pillar: A Case Study [J]. Geofluids, 2022.
[8]. Wang Y, Li Y, Yu Z, et al. Research on the Surrounding Rock Control Technology of Gob-Side Entry with a Narrow Coal Pillar Reserved in a Fully Mechanized Caving Face with Large Mining Height [J]. Geotechnical and Geological Engineering, 2021, 40(1): 1-16.
[9]. Zha W, Shi H, Liu S, et al. Surrounding rock control of gob-side entry driving with narrow coal pillar and roadway side sealing technology in Yangliu Coal Mine [J]. International Journal of Mining Science and Technology, 2017, 27(5): 819-23.
[10]. Ghasemi E, Ataei M, Shahriar K. An intelligent approach to predict pillar sizing in designing room and pillar coal mines [J]. International Journal of Rock Mechanics & Mining Sciences, 2014, 65(75 (Pt 2)): 86-95.
[11]. Li Z, Dou L, Cai W, et al. Fault-pillar induced rock burst mechanism of thick coal seam in deep mining [J]. Yanshilixue Yu Gongcheng Xuebao/Chinese Journal of Rock Mechanics and Engineering, 2013, 32(2): 333-42.
[12]. He F, Zheng Z, Zhu H, et al. Research on Failure Mechanism and Strengthening of Broken Roadway Affected by Upper Coal Pillar [J]. Advances in Civil Engineering, 2019, 2019(4): 1-13.
[13]. Jiang Y, Zhao Y, Wang H, et al. A review of mechanism and prevention technologies of coal bumps in China [J]. Journal of Rock Mechanics and Geotechnical Engineering, 2017, 009(001): 180-94.