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ARTICLE

Study on the Manifestation Patterns of Rock Pressure in Transport Roadways of Downward Mining Face and Support Countermeasures

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ABSTRACT

This paper employs numerical simulation methods to conduct a systematic analysis of the surrounding rock response and stability during close-proximity coal seam down-cutting mining. Research indicates that the 5MPa vertical stress formed on the right side of the initial mining coal seam (Seam 8) significantly impacts the stability of the haulage drift. The plastic zone of the mining face rock mass is dominated by shear failure. The vertical stress at the centre of the goaf is approximately zero, while significant stress concentration occurs around the periphery. A pronounced advance support pressure zone exists ahead of the working face. During the downward mining phase, the plastic zone of the lower coal seam roadway's surrounding rock exhibited vertical expansion, with the failure mode shifting predominantly to tensile failure. A combined support scheme utilising full-section anchor cables coupled with rock bolts was proposed as the permanent support form for the haulage roadway, effectively controlling surrounding rock deformation.

1 Introduction

During downward mining of coal seam groups, the mining activity in the upper seams alters the stress state of the surrounding rock in the lower seams, thereby affecting the stability of the lower roadways. Research indicates that the key prerequisite for feasible downward mining lies in the continuity between the lower seams and the roof. Consequently, determining the depth of damage to the coal-rock strata at the floor caused by repeated mining in the upper seams holds practical significance for studies on the feasibility of downward mining in the lower seams.

Huang Qingxiang et al. [1] investigated support methods for haulage roadways affected by primary mining activities; Zhao Xiangzhuo et al. [2] examined the impact of upper coal seams on lower seam extraction, resolving roadway support issues during downward mining operations; Dai Wenxiang et al. [3] examined the layout and support methods for highly disturbed roadways during close-proximity downward mining of coal seams; Zhang Liang et al. [4] investigated the deformation failure patterns and influencing factors of dynamic pressure roadways in

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the southern wing; Fang Wanwei et al. [5] studied zone-coordinated support techniques for roadways along variable coal pillars; Li Songfeng et al. [6] investigated rock mass support techniques for roadways in extremely close-proximity coal seam downward mining;Ren Yuqi et al. [7] analysed the characteristics of floor failure under repeated downward mining of coal seam groups. The present study examines support schemes for the haulage drift of a downward mining face at the 10909 working face of a certain mine.

2 Project Overview

The 10909 working face constitutes the fifth section of the southern wing in the first mining area, specifically the 9 coal seam working face. The 10909 haulage drift has a designed strike length of 2240m, with the 10809 working face exhibiting an inclination length of 220m. The drift elevation ranges from +280.818m to +362.0m, with a burial depth of +857m to +938m. The 10809 working face directly above was mined during 2019-2020.

The 9-1 coal seam has an average thickness of 2.78m with a f-value of 1.37. The interbedded sandstone between 9-1 and 9-2 seams averages 0.76m thick, classified as semi-hard rock with an f-value of 3.62. The 9-2 seam has an average thickness of 2.63m with f=1.2. The immediate roof consists of limestone, averaging 1.2m thick, classified as a hard rock layer with f=5.46; the old roof comprises siltstone, averaging 9.75m thick, classified as a semi-hard rock layer with f=2.43; the immediate floor comprises siltstone, averaging 4.15m thick with f=3.85; The old floor comprises Coal Seam 10 and siltstone, f=3.75, with respective thicknesses of 1.67m and 15m. The 10909 working face haulage drift is being excavated directly beneath the 10809 working face haulage drift. Due to mining disturbance from Coal Seam 8, the 9 coal seam haulage drift requires reinforcement support measures.

3 Model Construction

Based on the actual geological conditions of the 10909 transport drift, a FLAC3D numerical simulation model was established. The model dimensions are: length × width × height = 180m × 224m × 80m. The 8 coal seam and 9-2 coal seam are inclined at a dip angle of 15°. As illustrated in Figure 1. Parameters were assigned to the model based on the engineering profile of the 10909 transport drift. Given the drift's burial depth of 800m, a vertical pressure of 20MPa was applied to the model's roof. The 8 coal working face was excavated first, followed by the development of the 9 coal transport drift, which was subsequently supported.

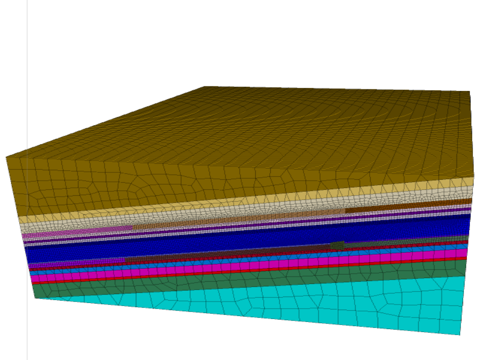

Fig. 1 Numerical Simulation Model

4 Numerical Simulation Analysis

The simulation results for the No. 8 coal seam excavation are shown in Figure 2. As evident from Figure 2, the disturbance zone generated by the 8 coal seam mining has extended to the location of the 9 coal transport drift. The mining activities disrupted the original mechanical equilibrium of the rock mass system in the 8 coal area, leaving the 8 coal seam floor exposed and causing a floor heave exceeding 10 cm. This resulted in a vertical stress concentration zone of approximately 5 MPa on the right side of the 9 coal working face, compromising the stability of the 10909 transport drift. The plastic zone formed by the 8 coal mining exhibits predominantly shear failure. The roof strata of the 8 coal seam simultaneously contain zones of shear failure and tensile failure. The tensile failure zone in the floor extends to the roof of the 9-2 coal seam and the area where the 10909 haulage drift is arranged.

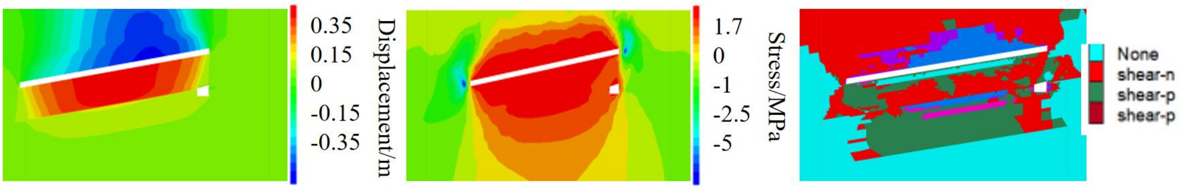

Fig. 2 Simulation Results for Coal Seam 8 Excavation

Post-extraction roof stresses in the 8th coal seam goaf, as illustrated in Figure 3. As evident from Figure 3, the entire 8th coal seam goaf collapsed post-extraction to form a pressure-relief zone. vertical stresses within the entire goaf approach zero. Conversely, significant stress concentrations occur in the roof sections interconnected with the surrounding rock mass. As the working face advances along the strike, stress concentrations around the goaf exhibit an increasing trend. The diagram indicates the presence of a high-pressure zone for advance support ahead of the working face. Consequently, the support strength for the roof in the working face must be further enhanced during mining operations.

Slicing analysis along the model trend reveals changes in the plastic zones ahead and behind the working face at excavation distances of 10m, 20m, 30m, and 40m for the No. 8 coal working face, as shown in Figure 4. As evident from Figure 4, the excavation-induced plastic zone expands significantly with increasing mining distance, primarily exhibiting substantial vertical growth. This zone initially extends vertically before undergoing minor horizontal expansion. Crucially, the plastic zones both ahead and behind the working face do not expand proportionally with mining distance and consistently manifest as shear failure. At an excavation depth of 10 metres, the plastic zones in both the roof and floor strata predominantly exhibit tensile failure. At 20 and 30 metres, the roof plastic zone shows a combination of tensile and shear failure, while the floor plastic zone predominantly exhibits shear failure. At 40 metres, the roof plastic zone again predominantly exhibits tensile failure, whereas the floor plastic zone largely shows shear failure, with a minor portion exhibiting tensile failure.

The excavation simulation results for the 10909 haulage drift are shown in Figure 5. As illustrated, the plastic zone formed after excavation of the haulage drift overlaps with that generated by the 8 coal seam excavation, thereby further expanding. The plastic zone created by the haulage drift excavation primarily exhibits tensile failure. This excavation has caused secondary disturbance to the rock mass system beneath the 8 coal seam, resulting in a broader area of stress concentration.

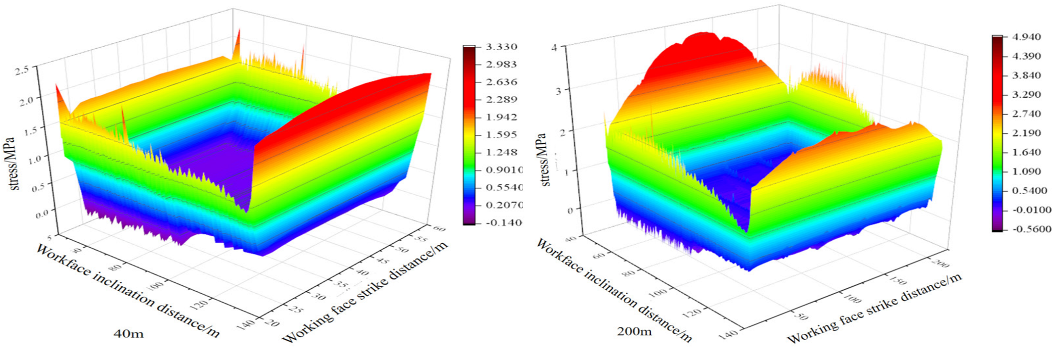

Fig. 3 Roof Stress in the Abandoned Mine Area

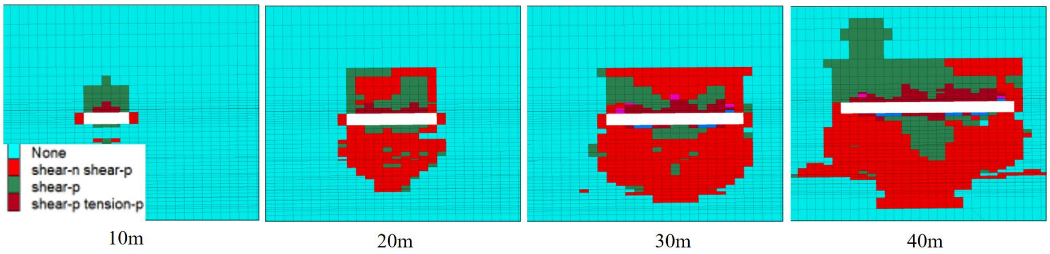

Fig. 4 Plastic zone after excavation

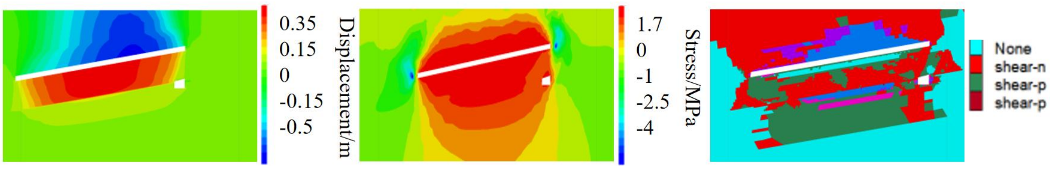

Fig. 5 Simulation Results for the 10909 Transport Longwall Face Excavation

Following the excavation of the 9th coal seam, the roof collapse in the goaf extended through to the floor of the 8th coal seam, forming an extensive pressure-relief zone, as illustrated in Figure 6. At the left-hand ventilation drift location of the working face, the roof did not fully collapse due to cantilever beam effects, resulting in a stress concentration zone. Conversely, at the right-hand 10909 haulage drift location, roof cutting interrupted force transmission within the roof, eliminating the cantilever beam effect and thus preventing the formation of a stress concentration zone.In summary, as the excavation distance increases, the plastic zone expands and the failure patterns become more complex. Consequently, more meticulous support measures must be devised during mining operations to control deformation in the roof and floor strata, thereby ensuring safe production.

5 Support Scheme for the Transport Longwall

Owing to the relatively deep burial depth and large cross-sectional area of the 10909 haulage drift, coupled with its classification as a soft rock tunnel, numerical modelling was employed to synthesise support case studies for soft rock tunnels. This determined that permanent support for this drift should adopt a combined mesh-cable support system, featuring full-section cable reinforcement with coupled cable-to-bolt support.

Anchor bolts employ Φ22×2400mm left-hand threaded steel rods, material grade MSGLW-500, with a spacing of 800×800mm, totalling 16 units; anchor bolt plates are 150×150×10mm disc-shaped iron plates, material grade Q-335; Roof cables employ Φ21.8×6300mm steel strands, while sidewall cables utilise Φ21.8×4300mm steel strands integrated with belt reinforcement for support (lower sidewall spacing adjusted to 800×1600mm). Corner anchor cables employ Φ21.8×4300mm steel strands, while floor anchor cables utilise Φ21.8×5300mm steel strands. Anchor cable spacing is 1600×2400mm, with 12 cables in total; anchor cable trays are 300×300×16mm disc-shaped steel trays; The mesh panel utilises Φ6.5 steel reinforcement mesh with a mesh size specification of 100×100mm.

Following the implementation of support measures in the transport drift, displacement in both the roof and sidewall regions markedly diminished. The stress concentration zones induced by excavation were substantially reduced, with the tensile failure zone within the plastic zone diminishing. The shear failure zone exhibited an even greater reduction relative to the tensile failure zone. Consequently, the deformation of the surrounding rock within the supported drift was effectively controlled, as illustrated in Figure 7.

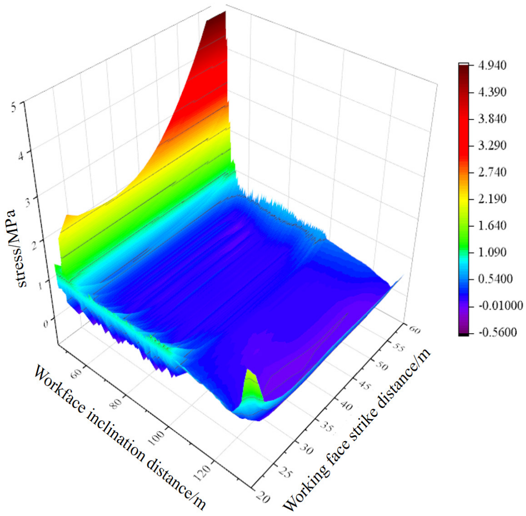

Fig. 6 Trends in Rock Mass Stress Variation

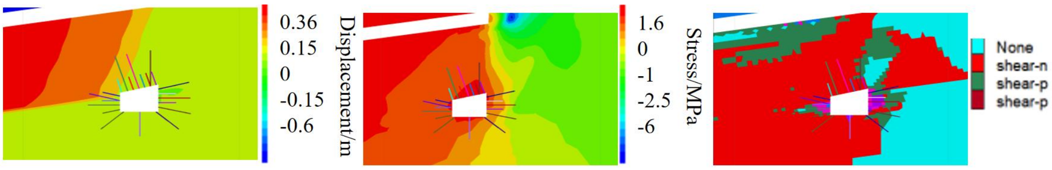

Fig. 7 Simulation Results for the 10909 Transport Longwall Support

6 Conclusions

1) Numerical simulation analysis indicates that the vertical stress on the right side of the working face is 5 MPa, affecting the stability of the haulage drift. The plastic zone formed during coal seam 8 extraction exhibits predominantly shear failure, with vertical stress in the entire goaf tending towards zero. Stress concentration around the perimeter of the mining area shows an upward trend, and a zone of high advance support pressure exists ahead of the working face.

2) During downward mining, the plastic zone in the haulage drift extends vertically, with tensile failure as the primary failure mode. This induces secondary disturbance to the coal seam 8 floor rock mass system, resulting in a broader range of stress concentration.

3) Permanent support for the drift employs a combined mesh-anchor-cable system, featuring full-section cable reinforcement coupled with anchor rods for integrated support.

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