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Stability and deformation of surrounding rock in pillarless gob-side entry retaining ☆

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ABSTRACT

We analyzed the stability of the retained gob-side entry in four different Chinese coal mining sites and evaluated the influencing factors of roadway deformation such as mining depth, support strength and area of gob-side hanging roof. It was found that the length of cantilever roof block above roadway has a major impact on the deformation, whereas the impact of mining depth is minor if the depth is less than 500 m. Minimum support resistance of 0.3 MPa is essential to effectively confine the deformation of a retained roadway. We performed physical experiments to further study the features of roof fracturing and their impact on roadway deformation under three typical immediate roof conditions, i.e., thick-immediate roof, thin-immediate roof and non-immediate roof. In addition, equations to calculate desired support resistance of filled gob-side wall were derived based on superimposed continuous laminate model. The results provide valuable theoretical and practical guidance for implementing pillarless gob-side entry retaining in engineering practices.

1. Introduction

Gob-side entry retaining refers to maintaining either a maingate or tailgate behind mining face by constructing a fill-in sidewall on gob-side with special support to be reused for the next panel (Yuan, 2008). Pillarless gob-side entry retaining can effectively increase coal recovery, reduce roadway development, and mitigate outburst risk. Since the 1950s, pillarless roadway has been practiced worldwide and extensive research has been carried out on support resistance (He, 2000; Xie et al., 2004), stability control principles (Zhang et al., 2003; Ma and Zhang, 2004) and related technologies (Qi et al., 1999; Jiang, 1993). Since 2005, gob-side entry retaining has been further developed as a key technology for integrated coal production and methane extraction in China (Yuan, 2008), which serves an important role in providing safe and long-term room for drilling and maintaining gas drainage boreholes. Nowadays, this coal extraction method has become a safe and efficient approach for mining gassy coal seams.

The gob-side retained roadway has quite special deformation characteristics due to its special roof structure and stress change. The dynamic pressure loaded to a retained roadway is much higher than the abutment pressure ahead of mining face. This high dynamic pressure often results in excessive roadway deformation and rapid shrinkage. As the mining depth increases, maintaining a pillarless gob-side roadway becomes more and more difficult. Therefore it is crucial to clearly define the impact factors of deformation and the structural stability conditions of retained roadway to meet the requirement of complex mining environments.

2. Typical geological conditions and engineering results

2.1. Engineering and geological conditions

Four cases in different mining areas of China were selected here for comparison. These geological conditions are very representative and common in China. Detailed information is shown in Table 1.

2.2. Section shape and supporting strength of retained gob-side entry

Maintenance of a retained gob-side entry subjected to strong mining influence is difficult. Incompatible deformation often

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Table 1
Engineering and geological conditions of the four selected cases.

Panels	E1403 of Tiefa	12418 of Huainan	154307 of Jincheng	1205 of Fenxi
Face width (m)	220	200	180	180
Mining depth (m)	405	638	200	406
Coalseam dip (degree)	3	13.6	6	12
Coal thickness (m)	2.1	3.1	2.2	1.8
Coal stiffness	$f = 1.5$	$f < 1$	$f = 2.2$	$f \leqslant 2$
Main roof	Sandstone, 5.9 m thick	Sandstone, partly mingled with carbonaceous mudstone, 5.85 m thick	Limestone, unique quality and density, UCS 116 MPa, 9.1 m thick	Compound roof, no stable layer
Immediate roof	Mudstone, 4 m thick	Mudstone, 4.65 m thick		Mudstone, 1.1 m thick
Immediate floor	Siltstone, 3.4 m thick	Mudstone, 4.45 m thick	Mudstone, 8 m thick	Sandy shale, 1.5–3 m thick
Surrounding faults	One small fault	Seventeen faults, including two large faults with more than 2 m throw.	Three to four small faults	Three small faults

occurs, which can lead to roof separation, sidewall convergence, and eventual failure of surrounding rock. Field tests showed that passive shed support, such as contractible U-shaped steel support, does not work under strong mining influence.

The support resistance of the prop can be obviously improved only when the surrounding rock deformation fully fills up the space behind the support. However, it was observed that incompatible deformation often makes the prop turn pointed, flat or distorted and easily causes failure of supporting structure. In contrast, the high-performance pre-tensioned bolt has demonstrated high adaptability for avoiding incompatible deformation induced by mining (Hou et al., 1999; Zhang and Yuan, 2006). As a primary means of support, the pre-tensioned bolt is able to reinforce fractured surfaces and strengthen loose rocks immediately after installation to prevent roadway deformation as well as layer separation. Further supplementary measures can also be taken to satisfy the stability requirements of gob-side entry retaining during the mining stage.

The fill-in sidewall of each site has the same height as its mining height and was filled with the same special concrete. The width–height ratio (wall width divided by mining height) is 1.0–1.2 and the wall width varies from 2.2 m to 2.4 m. The roof along mining-affection side will undergo the biggest subsidence even though its load was sustained by both the fill-in sidewall and the coal sidewalls. If supplementary support such as single hydraulic prop was promptly employed, incompatible deformation and excessive layer separation could be avoid. In addition, hydraulic props will spread roof load to floor and thus help to prevent floor heaving.

The primary bolt support, the supplementary support in the roadway and the backfilling along the roadway constitute the "three-in-one" surrounding rock control technology of gob-side entry retaining (Fig. 1). The bolt support and hydraulic prop provide active support to achieve pre-tension or high initial load, whereas the backfilling along the roadway comes into effect only when the amount of roof subsidence offsets the amount of the insufficient roof-contact. Therefore, in the calculation of roof support strength, the capacity of bolt and hydraulic prop support are considered, and in the calculation of coal sidewall support strength, only the capacity of pre-tensioned bolts is considered. Mining section and supporting parameters of gob-side entry retaining are shown in Table 2.

2.3. Engineering results

Fig. 2 shows the typical variation of roadway deformation rate as drawn from the field observation data. The surrounding rock deformation rate clearly shows two stages of development. During the roadway excavation period (stage I), the surrounding rock deformation rate first peaked and then declined and stabilized. During the mining period and until the gob-side entry is fully

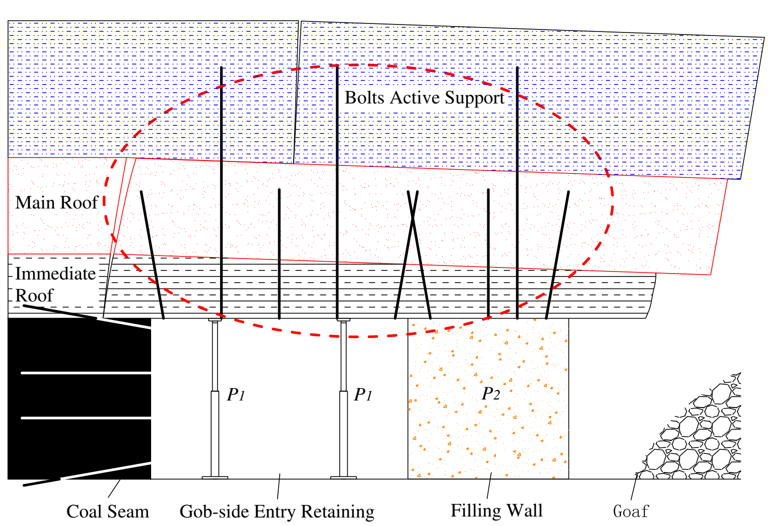

Fig. 1. The "three-in-one" control principle of gob-side entry retaining.