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Effects of in-situ stress on the stability of a roadway excavated through a coal seam

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A B S T R A C T

Roadways excavated through a coal seam can exert an adverse effect on roadway stability. To investigate the effects of in-situ stress on roadway stability, numerical models were built and high horizontal stresses at varying orientations were applied. The results indicate that stress concentrations, roadway deformation and failure increase in magnitude and extent as the excavation angle with respect to the maximum horizontal stress increases. In addition, the stress adjacent to the coal-rock interface sharply varies in space and evolves with time; coal is much more vulnerable to deformation and failure than rock. The results provide insights into the layout of roadways excavated through a coal seam. Roadways should be designed parallel or at a narrow angle to the maximum horizontal stress. The concentrated stress at the top corner of the face-end should be reduced in advance, and the coal seam should be reinforced immediately after excavation.

1. Introduction

Stability of roadways has been a primary concern in underground coal mining practice [1–3]. Roadways excavated through a coal seam are a common situation, which can exert an adverse effect on the stability of the roadway [4,5]. If the coal seam is subjected to high in-situ stresses, the roadway will collapse or undergo irreversible deformations, posing a major threat to miners' lives, facilities and coal production [6]. A classic example of a horizontal roadway excavated through a 45° inclined coal seam is given in Fig. 1 [7]. The stress field in the surrounding rock rapidly evolves with sequential roadway advance, resulting in huge energy release. Unforeseen failures such as squeezing, collapsing or arch cracking may occur because of the lithology mutation and stress variation in the vicinity of the coal-rock interface.

To investigate the mechanical behavior of roadways excavated in uniform rocks, numerous theoretical analyses, field tests and numerical simulations have been made [8–14]. However, the stability of roadways excavated in non-uniform rocks (especially strata containing coal seams) characterized by lithology mutations has not been explicitly revealed.

Feng et al. analyzed the deformational feature of the soft-hard rock contact zone surrounding a tunnel [15]. The results indicate that stress concentrations and differentiations are formed near the soft-hard rock interface immediately after excavation; the soft rock stratum undergoes smaller stresses but larger deformations than the hard stratum. Kang et al. conducted a numerical simulation of a roadway passing through composite strata and revealed that the shear stress along the interface of the strata is much higher than that in the inner parts [16]. Wang et al. performed theoretical analyses and field tests on the stress characteristics of a mineshaft excavated through a coal seam, demonstrating that the coal-rock interface is most vulnerable to instabilities [5].

It is known that in-situ stress is a crucial factor in designing underground openings [17,18]. Individual components of the three-dimensional in-situ stress tensor are always different in different orientations, which plays a major role in influencing roadway tightness and stability [19,20]. Kang et al. indicated that the maximum horizontal in-situ stress is approximately twice the minimum, and the two stress components are almost perpendicular to each other [21,22]. It has been demonstrated that rock roadways excavated at a large angle with respect to the maximum horizontal stress suffer significantly more fracturing than those excavated at a relatively narrow angle [23–25].

Despite these great efforts, the effects of in-situ stress on the stability of a roadway excavated through a coal seam remains unknown. In this study, an attempt has been made by using

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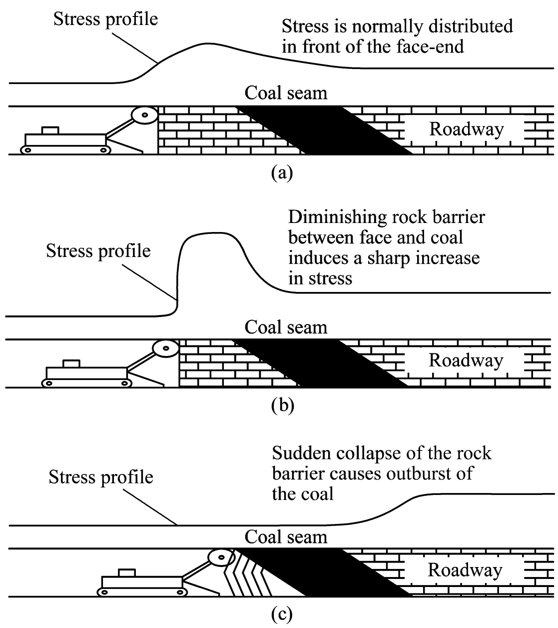

Fig. 1. Stress evolution around a roadway excavated through a 45° inclined coal seam [7].

FLAC3D to examine the stress redistribution, roadway deformability and failure characteristics of a roadway excavated through a coal seam under distinct in-situ stress states.

2. Methods

2.1. Presentation of the study site

The Bailongshan Coal Mine is located in Yunnan Province, China. In-situ stresses within the mining area were measured using the hollow inclusion gauge. The results show that the maximum and minimum horizontal stresses are −24.28 MPa and −12.2 MPa, respectively, and the vertical stress is −14.03 MPa. The orientation of the maximum horizontal stress is N40.9 °E. According to the classification of in-situ stress fields [26], the in-situ stress of the Bailongshan Coal Mine belongs to the tectonic stress field which is characterized by high horizontal stresses. The material properties of the Bailongshan Coal Mine were conven-

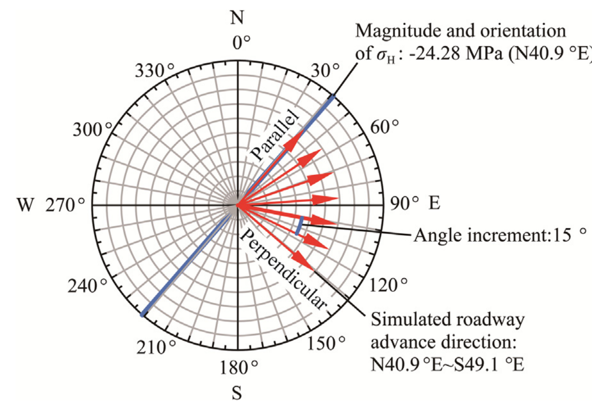

Fig. 3. Roadway excavations with varying orientations to the maximum horizontal stress.

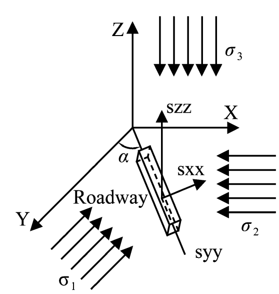

Fig. 4. Conversion of in-situ stress tensors.

Table 1
Material properties.

Parameter	Bulk modulus (GPa)	Shear modulus (GPa)	Friction angle (°)	Cohesion (MPa)	Tensile strength (MPa)	Density (kg/m^3)
Coal seam	2.08	0.73	25	1.00	0.10	1400
Roof and floor	26.80	7.00	34	2.72	1.17	2600

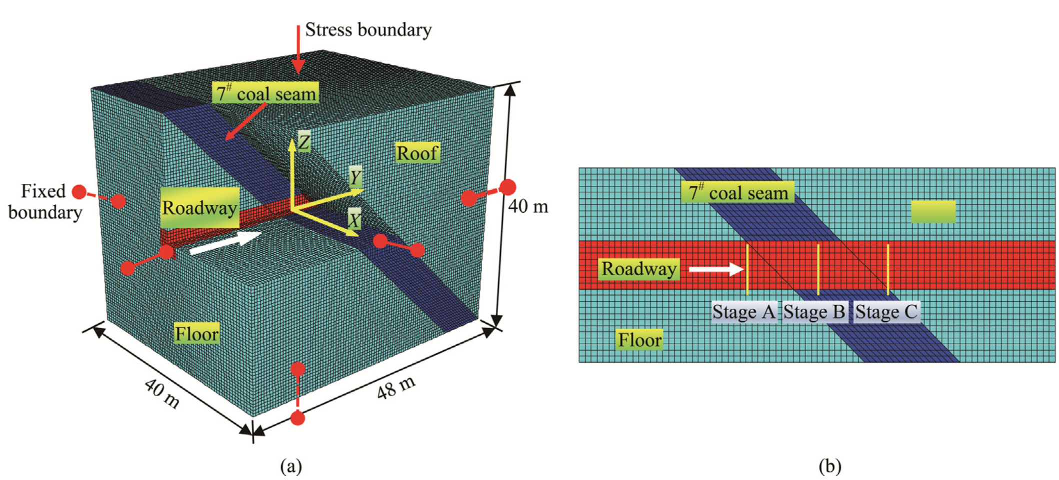

Fig. 2. Numerical model (a) Model geometry and boundary conditions; (b) Stages of roadway excavation.

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