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Numerical research on stability control of roofs of water-rich roadway

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ABSTRACT

In order to study the strength-weakening law of roofs of water-rich roadway, this study used FLAC software, and simulated and analyzed the failure characteristics of the surrounding rock of water-rich roadway under the condition of different cross sections and support parameters, finally obtained the stress distribution of the principle stress of the roadway as well as the displacement variation of its surrounding rock. Results indicate that the roof stability of roadway with semicircular cross section is better than the roadway with inclined rectangular cross section under water-rich condition. Besides, the surrounding rock deformation of roadway under the action of water shows a pronounced increase compared to the roadway without the action of water due to the fact that water will obviously weaken the surrounding rock of roadway, especially its roof. It is very beneficial to control roof stability of water-rich roadway and guarantee the roadway stability during its service life by improving the pretension of bolt and cable as well as decreasing inter-row spacing of the bolt.

1. Introduction

In the last decade, stability control of coal roadway has been improved significantly due to the promotion of bolt support technology in our country. However, stability of coal roadway, especially control of roof stability, has not been solved in complicated and difficult conditions due to the complex stress conditions [1].

Based on the analysis and investigation of several roof fall accidents in coal roadway of Ning Dong, Liang Huai and Ji Ning mining area in recent years, it concluded that over 50% of these accidents occur due to strength weakening of roof strata caused by water absorption or water loss. Actually, water content is known as one of the most notable factors that weaken the strength of rocks [2].

In water-rich mines, roadway excavation and its disturbance will induce the dilation of soft and weak strata of the immediate roof, leading to a number of fissures, which provides a channel for the contact of rock particles with water, eventually causing the failure of the soft and weak strata under the action of water. Besides, the failure of the soft and weak strata leads to further extension of fissures in roof strata, and causes the change of moisture content in water bearing sand whose strength significantly weakens during the process of water absorption or water loss. In view of these facts, considerable studies have been carried out to investigate the rock strength under both dry and water saturated conditions [3–5].

Strength weakening of the soft and weak strata as well as the water bearing sand leads to the instability of the roadway roof under the action of water [6–8]. Therefore, study on strength-weakening mechanism of roadway roof under water-enriched conditions has become one of the significant theoretical and technical problems in mining circle. For this purpose, setting water-rich roadway in Mei Huajing Coal Mine affiliated to Shen Hua Ning Mei Group as its research objection, this study used FLAC numerical simulation software, and simulated and analyzed the deformation and failure characteristics of water-rich roadway with different cross sections as well as its surrounding rock with different technical parameters of bolt support that are with the action of water and without the action of water, respectively. Finally, we determined the strength-weakening law of roof strata in water-rich roadway, enriching the idea and method for controlling roadways with similar conditions.

2. Establishment of numerical model

The haulage roadway in 114202 coal face of Mei Huajing Coal Mine is 4440 m on the strike, 250 m on the dip. The thickness of the coal seam is 2.9 m with a buried depth of 210 m. The confined aquifer, located in the fissures and pores in the sandstone which is

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between 2nd and 6th coal seam, will exert its influence on the coal face. The aquifer has a stable position whose lithology consists of sandstone and mudstone with different grades (grey, greyish white and dark grey) as well as the coal seam. The aquifer is a weak or extreme weak aquifer, whose thickness changes from 6.85 to 124.65 m, with 69.24 m on average. Predicted water inflow is 88 m^3/h. And the roof mainly consists of sandstone with various grades, containing a small amount of mudstone or siltstone. The thickness of sandstone changes from 0.87 to 19.76 m, and generally 23 m, while the thickness of siltstone changes from 0.66 to 15.59 m, and generally 1–3 m. False roof of this coal seam consists of mudstone and carbon mudstone. And floor of the coal seam contains siltstone with a thickness of 0.39–12.46 m, generally 1–3 m, including a small amount of mudstone and fine sandstone.

Based on above mentioned geological settings, we set up the geometrical model for numerical simulation, as shown in Fig. 1. In this model, we adopted Mohr–Coulomb criterion as its constitutive relation, using FLAC embedded seepage module and regarded the rock mass as equivalent and continuous medium. The flow of the fluid in the medium was based on Darcy law, in the meantime, satisfying Biot equation [9–12]. The cross section of roadway in this model is semicircular and inclined rectangle, respectively. And the size of cross section is 4.0 m in width and 3.0 m in middle height. Table 1 shows the mechanical parameters of the coal and rock stratum.

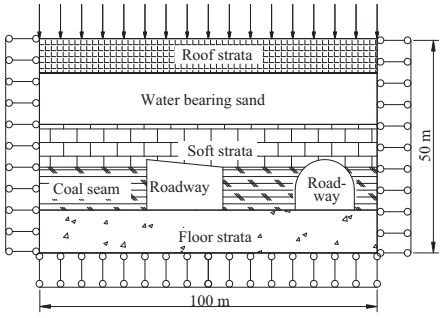


Fig. 1. Diagrammatic sketch of geometric model.

3. Deformation characteristics of the surrounding rock of roadway with different cross sections

Roadway is the main passage in coal production, whose cross section plays a pivotal role in excavation and maintenance. Actually, a number of factors exert influences on roadway stability, among which the shape of the roadway's cross section is paramount due to the fact that stress intensity and stress distribution in surrounding rock are closely related to it [13,14]. Using numerical simulation software FLAC^{2D}4.0, this paper studied the distribution law of the major principle stress and surrounding rock displacement in semicircular and inclined rectangular roadway under the action of water, as shown in Figs. 2–4.

3.1. Distribution and evolution law of the major principle stress in roadway

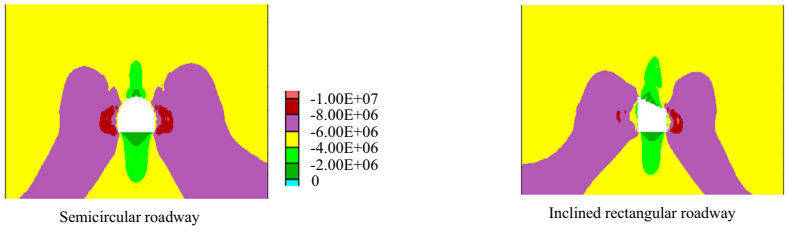
According to Fig. 2, we can find that: under the action of water, the disturbance scope of roof in inclined rectangular roadway is larger than that in semicircular roadway. However, as for the disturbance scope of the floor, the inclined rectangular roadway is smaller. Thus, we can safely draw the conclusion that the roof of the semicircular roadway is easier to be controlled and maintained.

3.2. Displacement of the surrounding rock of roadway

As shown in Figs. 2–4, we can see that roof subsidence and rib displacement in semicircular roadway are smaller than that in

Table 1
Mechanical parameters of the strata.

Type	Elasticity modulus (GPa)	Poisson ratio	Cohesion (MPa)	Friction angle (°)	Density (kg/m^3)	Tensile strength (MPa)
Roof	15.2	0.28	5.20	34	2500	3.76
Aquifer	4.5	0.25	5.10	32	2680	2.50
Soft strata	3.0	0.28	2.81	29	2510	1.57
Seam	2.8	0.33	1.67	27	1400	1.63
Floor	9.6	0.28	4.35	35	2610	3.26



(a) 7000 step of excavation

(b) 21000 step of excavation

Fig. 2. Distribution of major principal stress in roadway with different cross sections.