Study on Mechanism Analysis and Treatment Measures of Karst Water Disaster in Mines

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[3]*College of Safety and Environmental Engineering, Shandong University of Science and Technology, Qingdao, Shandong 266590, China Abstract*

Abstract

According to the theory of rock mechanics and fracture mechanics combined with the actual geological conditions of the coal seam floor, the coupling of water and rock is analyzed, and it is believed that the karst pore water pressure has a greater influence on the strength of the floor rock. The method of numerical simulation is used to analyze the stress change of the floor and the failure of the plastic zone during mining at a water pressure of 1-8 MPa. It is believed that when the water pressure is greater than 4 MPa, the floor has a greater impact.

Keywords: water-rock coupling, water barrier, karst water, numerical simulation

Introduction

With the development of coal mining technology and detection technology and the location of coal seams gradually concentrated in the deep, the threat of shallow surface water damage and traditional mining water damage has gradually decreased. The main threat in the process of deep mining comes from floor karst water. The floor karst water is in the original equilibrium state with the floor rock under hydrostatic pressure (Wu et al. 2015; Liu 2016). When mining is carried out, the original equilibrium state is broken, the hydrostatic pressure becomes the hydrodynamic pressure, and the water pressure is in a state of fluctuation. At this time, the floor water barrier will be destroyed. The possibility of water inrush (Krzysztof et al. 2016). At present, domestic and foreign experts and scholars have conducted some research on the mechanism and law of floor water inrush caused by karst water. Zhang Peisen et al. used the fluid-solid coupling model of FLAC3D to simulate the whole process from the formation of floor mining cracks, the damage and destruction of hidden faults to the formation of water inrush channels in the coal mining process. It is believed that the coupling effect of mining stress and water pressure causes cracks in the floor rock to initiate and expand until penetration and water inrush (Zhang et al. 2018). Sun Yunjiang et al. used the ESG microseismic monitoring system to monitor the formation process of the water-conducting fracture zone in the floor in real time, and explored the relationship between fault fracture expansion and confined water pressure (Sun et al. 2017). Gao Saihong et al. considered the damage and fracture mechanism of fractured rock mass under the action of water, and deduced the stress intensity factor of the crack under the action of water (Gao et al. 2012). Sun Jian et al. established a three-dimensional fluid-structure coupling model through the secondary development of FLAC3D software. Numerical simulation is used to explore the relationship between the pressure change of confined water in the inclined coal seam floor and the threat of water inrush as the mining proceeds (Sun et al. 2018). Odintsev and Miletenko established a confined hydraulic fracturing model and found that natural hydraulic fracturing is restricted by natural stress and induced stress, groundwater hydrostatic pressure and mining sequence

(Odintsev and Miletenko 2015). Shi Longqing et al. used a non-linear risk evaluation method to evaluate and analyze water inrush from coal seam floor, and optimized the inaccuracy of the water inrush coefficient method. The above experts and scholars lack the research on the damage and destruction of the aquifer caused by mining under different pressures of karst water (Shi et al. 2017). Based on this, the article uses theoretical analysis and numerical simulation methods to explore the damage and treatment methods of the aquifer under the action of karst water (Liu 2015).

Water-rock coupling analysis

According to the actual geological conditions of coal mining, the floor rock during the mining process can be divided into the upper failure zone, the middle semi-humid zone, and the lower complete water-rock coupling zone. The upper area is directly damaged by mining activities, mainly compression and shear damage. As shown in Figure 1(a), it is simplified as a uniform load q, and the inclined cracks as shown in the figure appear under the action of pressure. Starting from the middle area of the floor rock there is water. This part is not only affected by the mining disturbance, but also partly by the pressure of the confined water. The force is shown in Figure 1(b). The part of the area under the floor that is in direct contact with karst water will have slow seepage under hydrostatic pressure. This part is saturated or half-saturated. When mining activities occur, the pressure of the confined water will also change. This part is disturbed by mining, and a large number of secondary cracks will be derived from primary cracks. The karst water penetrates the lower area of the floor under the action of water pressure, and complete water-rock coupling appears. According to some experimental research results, sandstone can lose 15% of its strength when it is close to saturation. In most cases, the biggest influence on rock strength is the water pressure in the voids and fissures.

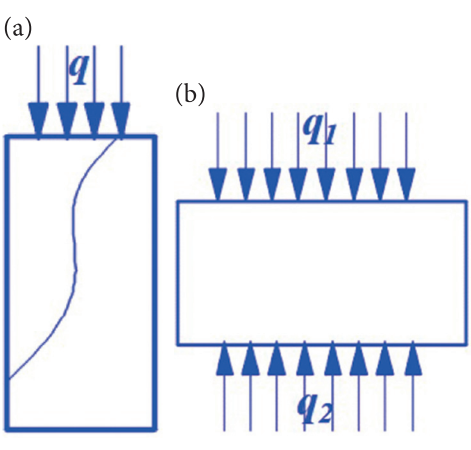

Figure 1 *Types of damage.*

According to the research of many rock mechanics experts, as long as there is a connected fracture system in the rock, Terzaghi's effective stress law can be applied (Xu 1981).

$$\sigma^1 = \sigma - p \quad (1)$$

Where σ is the total stress (MPa), p is the pore water pressure (MPa), and σ1 is the effective stress (MPa).

According to the Mohr-Coulomb strength theory, under the action of pore water pressure, the shear strength of the rock in the complete water-rock interaction coupling region under the floor rock is

$$\tau_f = c + \sigma^1 tg\varphi$$
$$\tau_f = c + (\sigma - p) tg\varphi \quad (2)$$

It can be seen that the pore water pressure in the rock reduces the strength of the rock, and the degree of strength reduction is determined by the pore water pressure.

Influence of karst water pressure

Model establishment

Taking the 1311 working face of Yangcheng Coal Mine as the geological background, a three-dimensional geological model was established (Fig.2). According to the actual geological data, it is determined that the length of the model is 200 m, the width is 200 m, the height is 130m, and the coal seam thickness is 5 m. The model is divided into 80,000 units and 85,731 nodes. The front and back, left and right boundaries of the model are set as horizontal constraints, the upper boundary is free boundary, and the bottom boundary is full constraint. Each step along the strike length is 10m, a total of 10 steps. Considering the boundary effect, the left and right boundaries of the model are both 50m

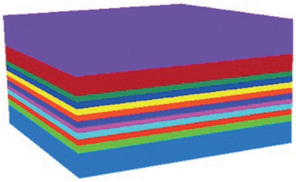

Figure 2 Three-dimensional geological model.

from the open cut and the coal pillars left on the stop line of the working face; the distance between the front and back boundaries of the model for roadway protection coal pillars is both 50m. In the simulation process, the Mohr-Coulomb plastic constitutive model and the Mohr-Coulomb failure criterion are used to calculate the coal seam floor mining failure characteristics. According to the test principle of the controlled variable method, the water pressure is set as a single variable, the water pressure range is 1-8 MPa, and other conditions remain unchanged.

Result analysis

Vertical stress analysis

Set the water pressure to 1-8 MPa, perform excavation simulation on 8 groups of models, and get the vertical stress cloud diagram. Because the number of cloud images obtained by simulation is too large, four sets of simulation results of water pressure of 1 MPa, 3 MPa, 5 MPa, and 7 MPa are selected. Select the stress value of the node (85, 86, 40) to draw the stress curve (Fig. 3).

According to Figure 3, as the working face continues to advance, the vertical stress on the bottom plate first increases and then decreases. The position where the maximum stress appears is basically in the middle of the mining face. After the water pressure is applied, the effect of water pressure is not obvious in the early stage of mining. When the mining face advances for about 30 m, the stress begins to increase rapidly. The greater the water pressure, the faster it will increase. When the water pressure reaches 3 MPa, when the water pressure increases, the magnitude of the stress increase does not change much. Comprehensive analysis suggests that when the karst water pressure of the floor is greater than 3 MPa, stress concentration is likely to occur, and the vertical stress of the floor is increased.

Plastic zone analysis

According to the numerical simulation under the condition of 1-8 MPa water pressure, the following plastic zone failure cloud map is obtained (Fig. 4). Due to the large number of cloud images obtained by the simulation, the cloud images of the plastic zone at the time of excavation 100 m under the conditions of 1 MPa, 3 MPa, 5 MPa, and 7 MPa were selected for display.

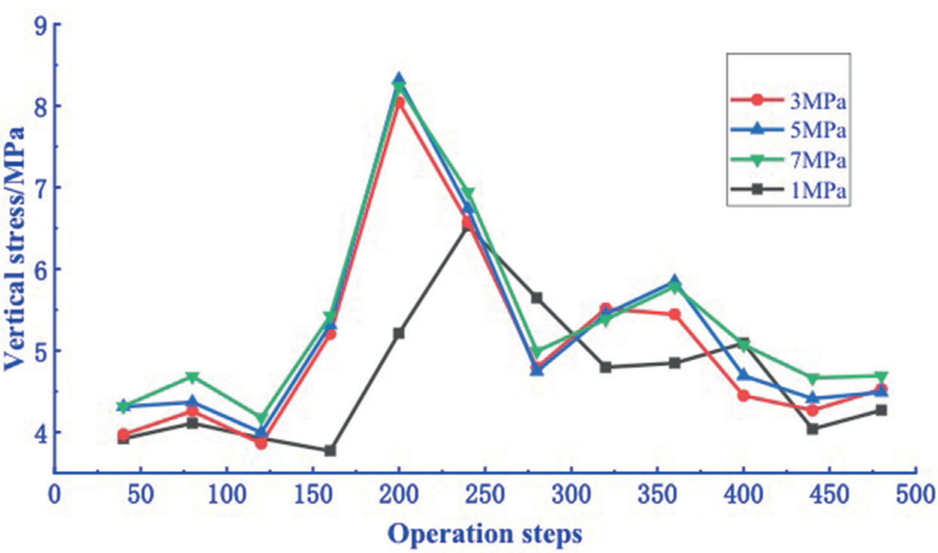

Figure 3 Stress curves under different water pressures.

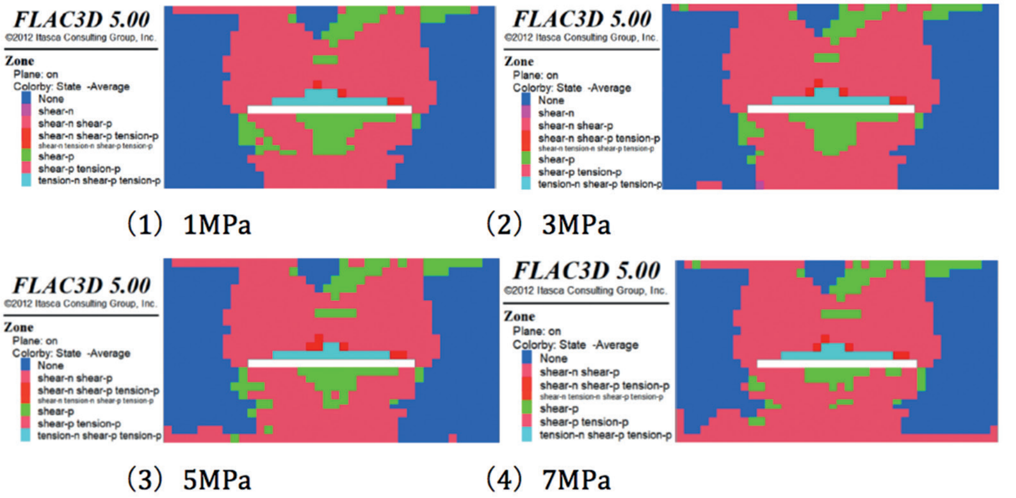

Figure 4 *Cloud map of plastic zone under different water pressure.*

It can be seen from Figure 4 that with the progress of mining, the vertical and horizontal extents of floor damage are increasing. When the working face is mined to 100 m, the damage of the floor shows a hemispherical shape, the closer to the floor, the greater the damage range, and the damage range away from the floor shrinks. When the karst water pressure is small, the impact on the floor failure is small. As the water pressure increases, the damage depth and damage range are increasing. When the water pressure is greater than 3 MPa, the bottom plate begins to be affected by stronger water pressure. When the water pressure reaches approximately 5 MPa, the floor is severely affected by the water pressure while the mining is disturbed.

Water pressure analysis

Set the water pressure to 1-8 MPa, and perform excavation simulation on 8 groups of models, and the water pressure change values of all nodes can be obtained. Because the amount of data obtained by the simulation is too large, the water pressure change values of the nodes (95, 96, 60) when the water pressure is 1 MPa, 3 MPa, 5 MPa, and 7 MPa are selected to draw different water pressure change curves (Fig. 5).

It can be seen from Figure 5 that as the mining progresses, the water pressure changes less in the early stage of mining, indicating that the mining disturbance is weak at this time. When the advancing distance of the working face is about 30 m, the water pressure begins to change suddenly, and the sudden change point is roughly located in the middle of the mining face. When the karst water pressure value is large, the pore water pressure value of the node increases rapidly.

Conclusions

(1) According to the knowledge of rock mechanics, the water-rock coupling between the lower part of the coal seam floor and the aquifer is analyzed. It is believed that the pore water pressure in the rock reduces the strength of the rock, and the degree of strength reduction is determined by the pore water pressure. Water-rock coupling seriously damages the stability of the floor.

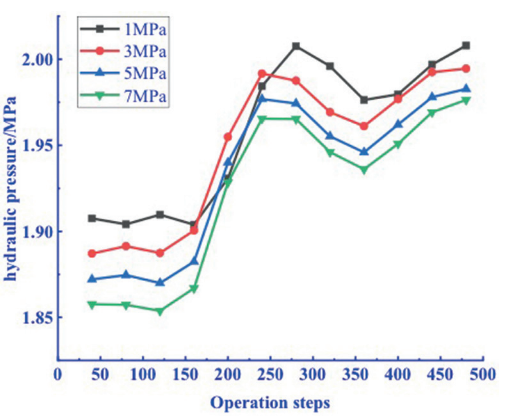

Figure 5 *Variation curves of different water pressures.*

(2) The method of numerical simulation is used to simulate the disturbance of the floor when the karst water pressure is 1-8 MPa. According to the simulation results, it is believed that when the water pressure is less than 4 MPa, the vertical stress on the bottom plate does not change much. Begin to have a strong influence on the damage of the bottom plate. When the water pressure reaches 5 MPa, under the action of mining disturbance, it has a great influence on the plastic damage of the floor, which leads to an increase in the depth and scope of the damage of the floor. When the karst water pressure increases, the pore water pressure of the floor rock will increase accordingly.

Acknowledgements

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