Monitoring and numerical simulation of water inrush pathway caused by coal mining above karstic confined aquifer with high water pressure

Yajun Sun, Zhimin Xu

School of Resources and Geosciences, China University of Mining and Technology, syj@cumt.edu.cn

Abstract

Mining-induced floor failure and formation of water conducted pathway is the necessary conditions for water inrush in coal mine,which are the basis for monitoring and predicting water inrush. In order to study the formation and evolution of floor failure and water conducted pathway caused by coal mining above karstic confined aquifer with high pressure in Xinyi coalmine,Henan province, China,field monitoring and numerical simulation methods are introduced in this paper. Subsequently,the variations of electrical resistivity, stress and pore water pressure of floor during mining process are analyzed. The result shows that the floor failure caused by coal mining under karstic confined aquifer with high pressure is influenced significantly by advanced supporting stress of coal mining and the failure depth of floor of panel 11011 is about 25 m, which is greater than general empirical value. Based on fluid-solid coupling theory,the established numerical simulation model of mining-induced floor failure can reflect the influencing factors of floor failure more accurately and objectively；and the maximum failure depth is up to 23.75 m,which is very close to field monitoring result. The variations of electrical resistivity,stress and pore water pressure can better reflect the whole process of mining-induced floor failure formation,water inrush pathway evolution and water filling. The conclusion indicates that the above-mentioned parameters can be used as the precursor information for monitoring and short-term predicting the water inrush hazards in coalmines.

Key words: coal mining above karstic confined aquifer；floor failure；field monitoring；numerical simulation, precursor information

1 Introduction

Coal mining operations in China are threatened by various kinds of groundwater during coal extractions. The most serious water disaster affecting the safe operation of coalmines is water inrushes from the coalseam floor in Northern China (Wu and Jin 1995). 8 The confined karst aquifer contains abundant groundwater with a very high water pressure. Furthermore, the aquifuge between coal seams and the aquifer is relatively thin, varying in thickness from 30 to 60 m. Due to these characteristics of the aquifer, in addition to floor aquifuge failure and inherent geological structures (such as water conducting faults, fractures), high pressure groundwater can break through the floor aquifuge and inrush into the working face. Therefore, water inrushes from the aquifer occur frequently, and coalmines often suffer from serious water disasters during mining.

In this case, coal mining above confined water with high pressure conditions which proposed along with the exhaustion of shallow coal recourses in China, the complication of mining conditions, the increasing depth of mining is a high level of difficulty production technology under certain special geological backgrounds. In the water disaster prevention practice of deep mining above aquifer, there is always a basic contradiction between the floor aquifuge with different structures and the water pressure that the aquifuge is subjected to. Therefore, the further study and understanding on the floor structure and mining-induced failure characteristics, the high pressure water inrush models and precursors are significant for efficiently prevention of the water inrush hazards.

2 Research Methods

This paper focuses on the complex structure aquifuge failure in the floor and characteristics of confined water inrush with high pressure over 5MPa induced by deep coal mining. The occurrence and

influencing factors of floor water inruch, interaction between water and rock, temporal-spatial distribution were analyzed based on numerous water inruch materials. And then, two basic patterns of floor water inruch, integrated and fractured floor water inrush pattern, were summarized. The floor failure, physical geographic characteristics, changes of floor stress and pore water pressure were also studied according to field measurement and numerical simulation. Three scaled models, including simplex structure, multilayer structure and faultage structure for floor water inruch with high pressure were established based on the high pressure water inruch simulation equipment. The whole procedures of conformation of water inrush pathway and after that the high pressure water inruch during the coal mining were simulated. Furthermore, the basic characteristics of floor water inruch under different floor structure conditions were summarized.

3 Numerical Simulation

The deep mining-induced failure features under different floor aquifuge structure were revealed. The Flac^{3D} numerical simulation model is based on the geological and mining conditions of Xinyi coalmine, and the size is 300×200×180m，mining depth is 900m，thickness is 2.5m，the width and length is 100m and 160m，the thickness of aquifuge is 58m.According to figure 1 and table 1，under the same aquifuge structure and mining conditions，water pressure has a great influence on the failure depth. In addition， the failure depth and range is increasing with greater water pressure. And under the working face，the shape of aquifuge failure range transits from “inverted saddle” to “inverted trapezoid”

Table1 *Failure depth varies with water pressure values*

Water pressure （MPa）	0	2.5	5	7.5	10
failure depth （m）	14.15	17.36	23.75	29.56	35.73

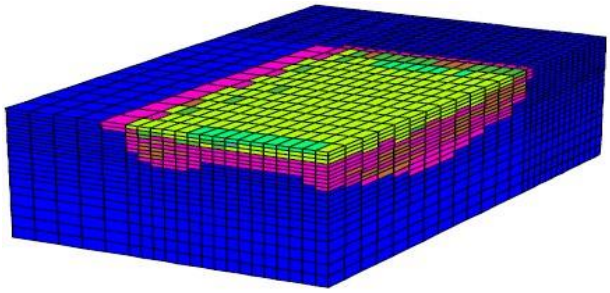

Figure 1 *Numerical model diagram in FLAC^{3D}*

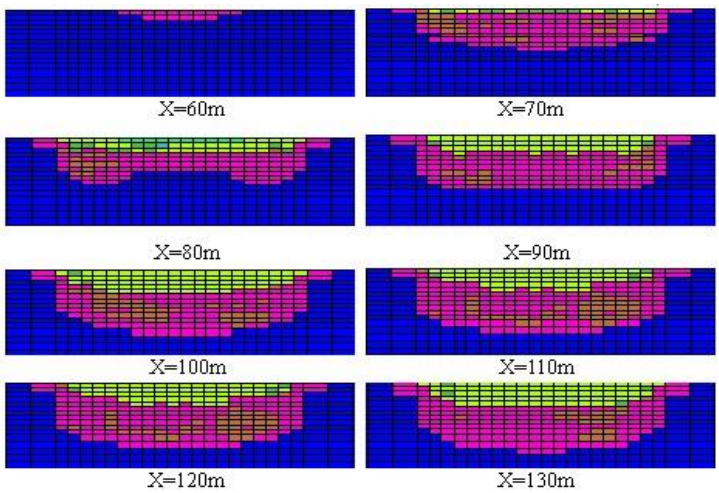

Figure 2 *The aquifuge damage depths under the working face floor*

The results show that, with the condition of confined water pressure over 5MPa that the aquifuge is subjected to, the floor failure is influenced significantly by advance stress and the failure depth is about 23.75 m. The failure depth and range are enlarged with the increasing of water pressure under the same floor structure and mining conditions. There are some differences of the failure range exist from the area under the working face to the goaf, the ranges change gradually from "inverted saddle shape" to "inverted ladder shape".

4 Field Monitoring

In order to test the variations of electrical resistivity and stress in floor during the mining process, field monitoring is tested under the floor of Panel 11011(Fig.3).

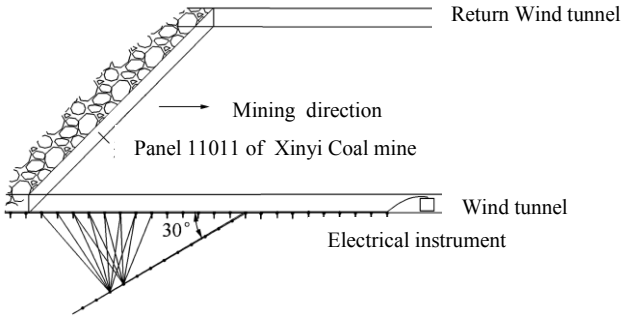

Figure 3 *Sketch of field monitoring for floor failure*

Fig.4 show that the floor aquifuge failure was systematically studied according to field measurements from the point of view of efficient monitoring and "gradual change process" of floor aquifuge failure induced by coal mining. Also, the failure depth of floor of Panel 11011 is about 25 m, which is greater than general empirical value.

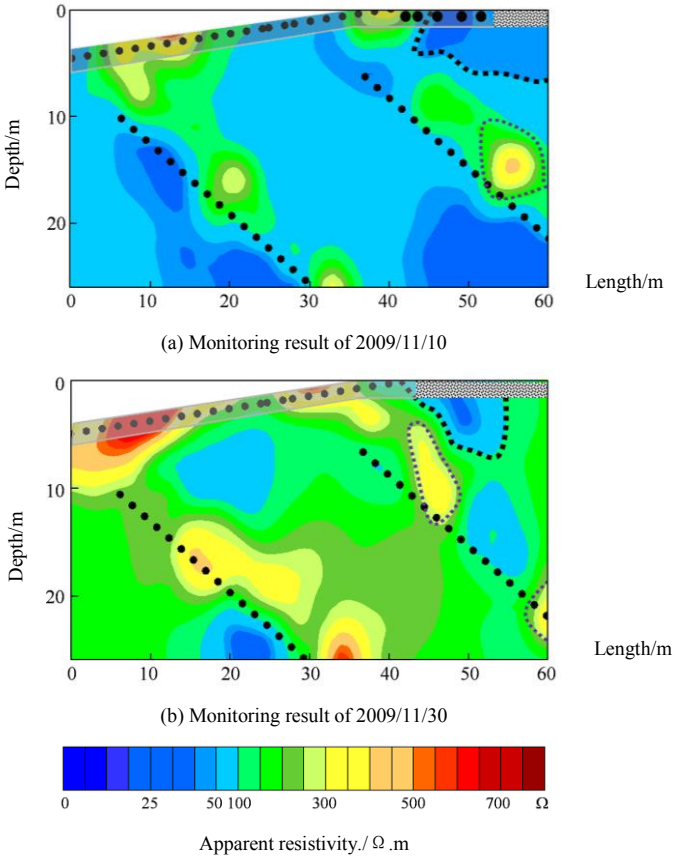

Figure 4 *Detection results of floor failure*

5 Laboratory test

Three scaled models with different floor structures were designed and accomplished to study the precursors of floor water inruch with high pressure.Three scaled models, including simplex structure, multilayer structure and faultage structure for floor water inruch with high pressure were then designed and established based on the high pressure water inruch simulation equipment, which can be used to carry out overburden and floor water inruch simulation experiments using a size of 1.4 ×1.6 m rock sample and can provide 3 MPa vertical load.

Figure 5 *Laboratory test device*

The laboratory test show that: the basic characteristics and laws of stress and pore water pressure variation during the water inruch process with high pressure induced by coal mining under different floor aquifuge structures were also systematically summarized on the basis of the experimental results. The periodic fluctuation of the floor stress and pore water pressure due to coal mining are closely related to the mining progress. During the conformation of mining-induced water inrush pathway, all the parameters increase sharply and fluctuate violently. When the water inrush into the working face, all the parameters decrease considerably and then at a certain range of a low level for a long period. It can be deduced from these results that the floor stress and pore water pressure can be significant precursors for monitoring and forecasting the water inrush hazards in coalmines.

6 Conclusions

(1) The result shows that the floor failure caused by coal mining under karstic confined aquifer with high pressure is influenced significantly by advanced supporting stress of coal mining and the failure depth of floor of panel.

(2)The variations of electrical resistivity, stress and pore water pressure can better reflect the whole process of mining-induced floor failure formation, water inrush pathway evolution and water filling. The conclusion indicates that the above-mentioned parameters can be used as the precursor information for monitoring and short-term predicting the water inrush hazards in coalmines.

(3) The conclusion indicates that the above-mentioned parameters can be used as the precursor information for monitoring and short-term predicting the water inrush hazards in coalmines.

The achievements of this paper lay an important basis for monitoring and forecasting the water inrush disasters in deep underground coalmines, and for safety coal mining above aquifer with high pressure.

Acknowledgements

The authors would like to acknowledge the financial support from the National basic research program of China (No. 2013CB227901) and the National Natural Science Foundation of China (No. 41502282); considerable thanks are due to the Xin'an Coal Mine for its co-operation.

References

Wu Q, Jin YJ (1995) The mine water management decision system of North China coal field. China Coal Industry Publishing House,Beijing

Bai Y (2009) Analysis for coal water bursting the reason and the preventive technologies. Coal Technol 28(11):85–87

Wu Q, Wang M (2006) Characterization of water bursting and discharge into underground mines with multi-layered groundwater flow systems in the north China coal basin. Hydrogeol J 14(6):882–893

Wu Q, Wang M, Wu X (2004) Investigations of groundwater burstinginto coal mine seam floors from fault zones. Int J Rock MechMin Sci 41(4):557–571

Yu B, Zhu W, Xu J (2007) Numerical simulation of surface subsidence characteristics during deep mining. J Min Saf Eng 24(4):422–426

Gui H, Sun B (2005) Study meaning and the core content of the control theory about water inrush from bed bottom in deep mining. J Anhui Univ Sci Technol (Natural Science) 19(3):1–4

Zhang Y (2004) Analysis for spraied water mechanism of karst water.Shanxi Coking Coal Sci Technol (9):20–21