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Predictions of Groundwater Inrush into Coal Mines and Size-limited Structures in China

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Abstract Groundwater inrushes often occur from the aquifers underlying and overlying coal seams along the permeable size-limited structures (SLS) in the coal mines of China. Because this kind of water hazard is affected by many factors, data collected from various sources need to be evaluated and to predict their occurrences. This paper introduces some innovative approaches in which the water inrush risks are represented by the method of three maps and two predictions, and the vulnerability index method. These methods combine the geographic information system, the artificial neural network, the hierarchy analysis process, and the numeric techniques. The geographic information system is applied to deal with and to analyze the space data. The artificial neural network and the analytic hierarchy process are used to estimate the weight of each factor. The numeric method is used to simulate and to predict the inflows of active working faces, and to predict the developed height of the roof collapse caused by mining.
Keyword vulnerability index method, three maps and two predictions method, size-limited structure, multi-sources information Integration.

Introduction

China is rich of coal resource and its development and utilization is an important part of our national economic development and established national policy (Shen and Li 1992). However, serious threats to the safety of coal mining, huge economic losses and negative social impacts were continue to be caused by complicated coal field hydrogeological conditions, and a various of water bodies in the coalmines such as the aquifers from underlying or overlying coal seams and goaf water etc (Chu 1995, Dong and Song 2000).

Water inrush into coal mines from aquifers underlying coal seams refers to a sudden inflow into mining areas, and often causes the increase of mine discharge or the disaster of mine submergence. The water inrush problems are even more serious for the mining of the bottom group of coal seams, as the aquifers underlying the bottom coal seams are of the characteristics of complicated hydrogeological conditions, high groundwater pressure and the stronger water yield. According to the statistics of the former Ministry of Coal Industry, there are 60% of the country's total coal reserves in the North China, but more than 20 billion tons coal reserves are threatened by the water inrush from aquifers underlying coal seams, as a result about 40% of the coal cannot be mined normally (Gao 1985, Wu and Wang 2006).

Water inrush into coal mines from aquifers overlying coal seams is widespread in China. The overlying aquifers mainly consist of the sandstones in Jurassic and Permian coal formations, and the thin-bedded limestone or sandstones in Carboniferous coal formations. The coal mining creates the caving and fissure zone above the mining coal seams, which is permeable to water and can function as a passageway connecting the overlying sandstone or thin-bedded limestone aquifers. The water inrush from the overlying aquifers happens when the development height of the caving and fissure zone reaches the bottom of the sandstone aquifers or the thin-bedded limestone aquifers (Wu 1995).

Groundwater inrush from aquifers underlying the coal seams

The coal seams are mainly extracted in both the Permo-Carboniferous coal field in north China and the Late Permian coal fields in south China. A large amount of water can suddenly

inrush into the coal mines from aquifers underlying the coal seams in the above coal fields in China, and cause significant economic losses and casualties.

The most commonly used method in China is to use the water inrush coefficient as a parameter to predict if the water inrush may occur. The water inrush coefficient is a ratio between the piezometric pressure of the underlying aquifer and the thickness of the geologic barrier. It is obvious that the method considers only two factors and their influent weights are treated equally. The coefficient method is too simple to describe the nonlinear and multiple factor-controlled processes involved the water inrushes from aquifers underlying the coal seams.

The main index system controlling the water inrushes from aquifers underlying the coal seams is established. It contains 5 main factors and 16 sub-factors. The 5 main factors are respectively the aquifer(s) underlying the coal seams, the hydrologic barrier, the geologic structure, the destruction of mining activities and the ineffective geologic barrier.

As we can see that the main index system controlling the water inrushes is complex and variable, and the controlling factors in the main index system are numerous. In this paper the modern theories of multi-source information integration and geography information system (GIS) have been used to describe the characteristics of the main index system, and the vulnerable index method of the water inrushes from aquifers underlying the coal seams has been presented to predict the risk of the water inrush, and to substitute the water inrush coefficient which can only considers two controlling factors. The vulnerable index method can really reflect the main index system controlling the water inrushes, a very complicated inrush mechanism. It can be much better than the water inrush coefficient to solve the predictions of groundwater inrush into coal mines from aquifers underlying the coal seams (Wu 2009).

Groundwater inrush from aquifers overlying the coal seams

Groundwater inrush from the aquifers overlying coal seams is one of the common geo-hazard problems in the coalfield in China. The roof collapses caused by extracting coal seams could increase the densities and openings of fractures in the rock above the openings and connect to the upper aquifers of coal seams. For example, nearly half of the mines in Kailuan in China have suffered from groundwater inrush from the overlying aquifers. At Jinggezhuang Mine in Kailuan, the three main groundwater disasters that occurred in 1979 were caused by water inrush from the overlying sandstone aquifers.

In order to solve the serious groundwater inrush problems from overlying aquifers in China, the method of “three maps and two predictions” has been proposed for the quantitative assessments and the predictions in the paper. This new method is based on the risk analysis of the caving and fissure zone (Itasca Consulting Group 1997, Liu 2006, Liu and Yang 2006) and the water abundance analysis for the overlying aquifers. It couples groundwater flow models with rock mechanics analysis. The method is successfully applied to prediction of the water inrush from the overlying aquifer at many coal mines in China. The “three maps” consist of (1) risk map of roof collapses according to safety factors; (2) distribution of water production in the overlying aquifer; (3) risk map of water inrush from the overlying aquifers. The” two predictions” consist of (1) groundwater flux rate prediction in natural condition; (2) groundwater flux rate prediction in artificial controlling condition. Visual Modflow is used to simulate the inflows at the two different conditions (Wu 2008).

Prediction of the size-limited structures in the front of coal seam laneways

Size-Limited Structures (SLS) refer to those faults within 5m displacements and relative small-scale fissures. These structures not only form the main inrush path into coal mines but also threaten the stability of roof and floor of coal seams. More than 85% of the total water inrush accidents in China are caused by SLS during mining processes. A great deal of efforts are paid to predict them (Wu and Wang 2004). The previous researches on SLS prediction mainly included two approaches, one is geophysical prospecting (Chen 1999), and the other is to predict them according to pattern analysis of regional tectonic system.

A new SLS prediction approach has been presented in the paper on the basis of the principle of the integrate multi-sources information. It mainly contains following steps for the SLS prediction. Firstly, the factors relevant to the SLS have to be determined according to the geological conditions, the information and materials owned by the coal mine. These factors used for SLS prediction consist of Coal Seam Dip Angle, Coal Seam Thickness, Coal Seam Water Discharge, Coal Seam Gas Content, Coal Seam Temperature, Coal Seam Fissure Type, and Coal Seam Fissure Density etc. The data collections and treatment for each factor are the second steps for the prediction approach. They are observed and collected respectively in the destroyed district, influenced district and normal district from the numerous coal laneways in the study mine. The weighting coefficient for the individual factor is thirdly trained and calculated using artificial neural network (ANN) with a number sets of collecting data (Cao and Jiang 2002). Finally the prediction model for the SLS can be established and be verified by using known data. Normally, if the fitting ratio can reach as high as about 90%, the model could be considered as real one. Otherwise, the model parameter has to be revised and the calculations have to be carried out again (Wu and Ye 2008).

Conclusions

(1) The vulnerability index method is much better than the water inrush coefficient method, as it can consider multiple factors that may control the water inrush from aquifer underlying coal seams, and can describe in detail the non-linear dynamical processes involved in the water inrushes.
(2) The method of "three maps and two predictions" proposed in this paper is effective to predict and to zone water inrush risk from aquifers overlying coal seams. The "three maps" consist of (1) risk map of roof collapses according to safety factors; (2) distribution of water production in the overlying aquifer; (3) risk map of water inrush from the overlying aquifers. The" two predictions" consist of (1) groundwater flux rate prediction in natural condition; (2) groundwater flux rate prediction in artificial controlling condition.
(3) The prediction model for the size-limited structure with the integrate multi-sources information is an efficient tool for the SLS prediction improvement. It is of great significance for reducing a lot of water inrush accidents in coal mines in China.

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References

Chu S L, (1995) Applications of geophysical prospecting in coal mine, Coal Industry Publishing House, Beijing
Chen SP (1999) Introduction to Geographic Information System. Science Press, Beijing

Cao LW, Jiang ZQ (2002) Research on application of artificial neural network in predicting mining subsidence, J Journal of China University of Mining & Technology 31(1): 23-26
Dong XT, Song YP (2000) General patterns of small geological structures in Datong Mining Area by radio tunnel perspective, J Shanxi Coal 20(4): 29-31
Gao H, Lin Z (1985) Regional characteristics of mine-hydrogeological conditions of coal deposits in China .Hydrogeology and Engineering Geology 12(2): 14-17
Itasca Consulting Group, Inc (1997) Flac3D, Fast lagrangian analysis of continua in 3 dimensions, user's manual. 2nd ed. Minneapolis, USA: Itasca Consulting Group, Inc
Liu TB, Shi LQ, Han J (2006) Hydraulic conductivity fracture zone height calculation. Journal of China Coal Society 31: 93-96
Liu ZH , Yang BS (2006) The use of numerical simulation methods to determine the water flowing fractured zone development of a high degree. Mining Safety and Environmental Protection 33(5): 16-19
Shen G, Li B (1992) Theory and practice of specific mining in coal mine, Publishing House of Coal Industry, Beijing
Wu Q (1995) The Mine Water Management Decision System of North China Coal Fields. China Coal Industry Publishing House, Beijing
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. Hydrogeology Journal 14(6):882-893
Wu Q, Wang M, Wu X (2004) Investigations of retarded groundwater bursting along fault zones in seam floor in coal mines. Int J Rock Mech Mining Sci 41: 557-572
Wu Q, Ye SY (2008) The prediction of size-limited structures in a coal mine using Artificial Neural Networks.International Journal of Rock Mechanics and Ming Sciences 45(6): 999-1006
Wu Q (2008) Prediction of inflow from overlying aquifers into coalmines: a case study in Jinggezhuang Coalmine, Kailuan. China Environmental Geology 55: 775-780
Wu Q, Wang J, Xie S (2009) Prediction of groundwater inrush into coal mines from aquifers underlying the coal seams in China: Application of vulnerability index method to Zhangcun Coal Mine, China.Environmental Geology 57(5): 1187-1195