An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds)
©2014 China University of Mining and Technology Press, Xuzhou, ISBN 978-7-5646-2437-8

Fundamental Concept of Indication Layer in Coal Floor Mining under Water Pressure

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Abstract Coal of Carboniferous and Permian period are exploited in North China. The thinner limestone layers in the Taiyuan group and thicker limestone layer in the Ordovician system are the main flooding aquifers. Comparing with other aquifers, the water yield property of the Ordovician limestone aquifer is the strongest. The hydraulic connection between the Ordovician limestone aquifer and the Taiyuan group limestone aquifer happened frequently through fissures, fault zones and Karst collapse columns. In order to control the Ordovician limestone water bursting hazards, based on the review of assessment theory and methodology regarding coal floor water bursting, in point of hydrogeology, fundamental concept of indication layer in the coal floor mining under water pressure was proposed. Also, discrimination method and procedure was given.

Keywords indication layer, thinner layer limestone aquifer, ordovician limestone aquifer, mining under water pressure

Introduction

Coal of Carboniferous and Permian period are exploited in North China. The thinner limestone layer in Taiyuan group and thicker limestone layer in Ordovician system are the main flooding aquifers. Comparing with other aquifers, the water yield property of Ordovician limestone aquifer is strongest. The hydraulic connection between Ordovician limestone aquifer and Taiyuan group limestone aquifer happens frequently through fissures, fault zones and Karst collapse columns. Then coal floor water bursting takes place through floor conducting structures (Hu 2005). The water inrush yield of Ordovician limestone is larger and steady, even causes coal mine flooding disaster, and the economic losses are huge. For example, in 1993, Ordovician limestone water bursting happened in Guojiazhuang coal mine, the maximum yield was 32,970 cubic meter per hour, the economic loss reached one hundred million of Yuan (Liu 1997). In 1996, the water bursting through Karst column happened in Renlou coal mine, the maximum yield was 34,570 cubic meter per hour, and the economic loss reached three hundreds million of Yuan (Hu 2009).

Coal floor water bursting is a phenomenon which associated with rock mass stress release, destruction of floor aquiclude rock structure, and sudden change of local hydrogeological condition. So coal floor water bursting is a nonlinear dynamic problem affected by multiple factors (Wu 2007). As the exploiting depth extends and the down coal seam exploits, the water busting of mining under water pressure will be emerging frequently in China.

In the light of fact that there is certain hydraulic connection among Ordovician limestone Karst aquifer, thinner limestone aquifer of Benxi group and thinner limestone aquifer of Taiyuan system, based on the review of assessment theory and methodology regarding coal floor water bursting, in point of hydrogeology, fundamental concept of indication layer in coal floor mining under water pressure was proposed.

The assessment theory and methodology regarding coal floor water bursting

Since 1930s, researchers all over the world have done more work on coal floor water bursting mechanism and assessment methodology. So far, the main theory and methodology are as follows.

Beam and plate Theory

In 1930s, the former Soviet Union scholar Slisalif raised the beam and plate theory. According the coal floor aquiclude gravity, the coal floor aquiclude tensile strengthen and water pressure of confined aquifer, using plate theory, the minimum thickness of aquiclude can be calculated (Pan 1986). This was the first theory of predicting coal floor water busting applying structural mechanics.

Water bursting coefficient theory

In 1960s, on the basis of summary analysis of many water bursting cases in China, water bursting coefficient was raised by Xi'an Research Institute,CCTEG. It was an empirical discriminating formula.

The water bursting coefficient was defined as the ratio of the maximum water pressure and the aquiclude thickness. The value was equal to reciprocal of relative aquiclude thickness. Its expression was as below.

$$T_s = P/M \tag{1}$$

Where as:

T_s—the water bursting coefficient, MPa/m;

P—the water pressure of confined aquifer, MPa;

M—the thickness of coal floor aquiclude, m.

On the guideline of above mentioned coefficient, some coal mining area like Zibo, Feicheng, Jingxing, Handan, Fengfeng and Jiaozuo in North China put it into practice, a large amount of coal was exploited safely. And the critical water bursting coefficient was put forward respectively (table 1).

Table 1 *Empirical values of critical water bursting coefficient in some North China coal mines*

Mining area	Critical water bursting coefficient (MPa/m)
Fengfeng, Hebei province	0.066~0.076
Handan, Hebei province	0.066~0.10
Jiaozuo, Henan province	0.06~0.10
Zibo, Shandong province	0.06~0.14
Jingxing, Hebei province	0.06~0.15

The water bursting coefficient has following property that its physical concept is simple, the calculation is convenient, and application in field is easy. So it has been the main methodology for coal floor water bursting assessment in China (Wu 2007). It has an active function in solving coal floor water bursting and was written to the regulation of preventing and curing water hazard in national standard form in 2009.

The down three zones theory

In 1970s, Shandong University of Science and Technology and other research units have detected coal floor deformation in situ for several years. Combined with indoor simulation experiment and numerical simulation, the down three zones theory was proposed.

Like the classification of mining overlying strata, the down three zones theory divided the coal floor rock mass into three zones, they are permeable fissure zone, effective aquiclude protection zone and confined water flowing zone. The water resistance ability is defined by effective aquiclude protection zone. Permeable fissure zone and confined water flowing zone have little water resistance. The formation and temporal shape of the three zones is associated with the thickness of aquiclude, mechanical properties of rock, mining technique, confined water pressure and geological structure.

The key strata theory

In 1990s, China academician Qian Minggao proposed that the strata located below the coal floor destroyed zone and upon the confined aquifer is called coal floor key strata. Thus the key strata theory is formed (Qian 1996).

This theory assumed that the confined water pressure is negative load imposed on the key strata, the key strata and its above rock mass gravity is positive load on the key strata deformation. Affected on the confined water pressure, when the exploitation reached the fractured span, "OX shape" fissure emerged in the key strata.

In the view of force balance and rock mass structure, the key strata theory explained the coal floor destruction shape and water inrush mechanism. Its concept is clear, physical significance is explicit.

Water-resisting key strata in water-preserved mining

Since 2000, in consideration of serious water inrush hazards and destruction of water resource and environment in China, Professor Miao Xiexing suggested the water-preserved mining technological system. Water-resisting key strata in water-preserved mining are defined as follows (Miao 2007). Whether the confined aquifer is located above or below the key strata, if the key strata don't be broken after exploitation, the key strata can act on water-resisting. The model of water-resisting key strata has following three meaning: lithologic water-resisting with weak rock layer, structure water-resisting with hard rock layer and water-resisting with the fracture passage closing. The principle of water-resisting key strata is consist of four steps(Miao 2008) , including the position determination of water-resisting key strata, structure stability determination and controlling, seepage stability determination and controlling , and the seepage mutation passage controlling.

The vulnerable index method

In 2007, on the basis of establishment of the main controlling index system of the coal floor water bursting, Professor Wu Qiang put forward the vulnerable index method. The method applies the multi sources information integration theory, coupling the geographic information system (GIS) and the artificial neural network (ANN), or the weight of evidence, or the logistic regression, or the analytic hierarchy process (AHP). This method has written to the regulation of preventing and curing water hazard in national standard form in 2009.

Concept of indication layer in coal floor mining under water pressure

For coal floor mining under water pressure in North China coal mines, thinner limestone aquifer is direct flooding aquifer; Ordovician limestone aquifer is indirect flooding aquifer. Analyzing the water inrush cases, Ordovician limestone is the water bearing strongest aquifer in North China, and the recharge source of other aquifers especially thinner limestone. For example, Xujiazhuang limestone in Zibo, the third and fourth limestone layers in Feicheng,

the eighth limestone layer in Jiaozuo, Daqing and Fuqing limestone in Fengfeng are all recharged by Ordovician limestone aquifer.

In the light of hydrogeology, the author suggests that fundamental concept of indication layer in coal floor mining under water pressure can be described as: in the exploiting process of coal mining under Ordovician limestone water pressure in North China coal mining area, the thinner limestone located between coal and Ordovician limestone aquifer is called indication layer. The indication layer has hydrogeological information such as groundwater level, water quality and water yield.

The indication layer has following properties.

It is Benxi group or Taiyuan limestone aquifer, its thickness is several meters, and its geological position is between the coal and thicker Ordovician limestone.

Compared with Ordovician limestone aquifer, the indication layer has individual hydrogeological information. The information includes groundwater level, water yield, water quality indexes (such as pH, potassium ion, sodium ion, calcium ion, magnesium ion, chloride ion, sulphate ion, bicarbonate ion, carbonate ion, salinity, total hardness), isotope(δD, $\delta^{18}O$) and trace elements.

According to the above mentioned properties, the discrimination method and procedure of indication layer can be summarized as follows.

Geological and hydrogeological condition of coal mine should be investigated in detail. The research focus is on the strata lithology, sequence assembly and water yield property. Screening one thinner limestone aquifer (Taiyuan or Benxi group) used as the indication layer initially.

For the initial indication layer, dewatering test should be done. Before and in the process of the dewatering test, the groundwater level and water yield of Ordovician limestone aquifer and the indication layer should be monitored respectively. Simultaneously, collecting Ordovician limestone aquifer and the indication layer water samples, water quality measurement, isotope content and trace elements content should be done. The measurement indexes are as above mentioned.

Analyzing the hydrogeological information and its dynamic changes comprehensively, the hydrogeological meaning and function of the indication layer can be determined. If the hydrogeological information of the indication layer is different from Ordovician limestone aquifer, the hydraulic connection between them is weak, the integrity of coal floor is good, and the mining under water pressure is safe. If the hydrogeological information of the indication layer is close or similar to Ordovician limestone aquifer, the hydraulic connection between them is strong, the integrity of coal floor is poor, and there will be hazard of Ordovician limestone water bursting. In this condition, grouting of the indication layer can be used, and the safety of mining under water pressure will be guaranteed.

Conclusions

In the light of hydrogeology, in the exploiting process of coal mining under Ordovician limestone water pressure in North China coal mining area, the thinner limestone located between coal and Ordovician limestone aquifer is called indication layer. The indication layer has hydrogeological information such as groundwater level, water quality and water yield.

For a specific coal mine, the discrimination method and procedure of indication layer can be summarized as follows. According to the strata lithology, sequence assembly and water yield property between the coal and Ordovician limestone aquifer, screening one thinner limestone aquifer (Taiyuan or Benxi group) used as the indication layer initially. By dewatering test, the groundwater level and water yield of Ordovician limestone aquifer and the indication layer should be monitored respectively. Simultaneously, collecting Ordovician limestone aquifer and the indication layer water samples, water quality measurement, isotope content and trace elements content should be done. Analyzing the hydrogeological information and its dynamic changes comprehensively, the hydrogeological meaning and function of the indication layer can be determined.

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