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Research on Method of Water-resisting Coefficient for Distinguishing Floor Water Inrush Danger

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Abstract

The water-inrush coefficient is usually used as the gist on extracting water-prevention barrier when the coal seam suffered to floor water inrush. The method based on water-inrush coefficient shows some deficiencies in the process for change of mining depth, lithology and aquifer water-rich property. This paper adopts the water-resisting coefficient of the rock layer to evaluate the water-blocking performance of coal floor rock. And we use the water-resisting coefficient to appraise the danger of Ordovician limestone water invasion in the exploitation of lower 21# coal in Longgu Mine. The evaluation results are compared with the mining practice, and the method water-resisting coefficient is more rational than that of the method of water-inrush coefficient.

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Keywords: floor water inrush; water-resisting coefficient, water-resisting performance, water inrush danger

1. Introduction

The Longgu Mine is located in the northeast of Datun mining area, whose major coal seam is 21# coal belonging to Carboniferous Taiyuan Formation. Since in the Xuzhou Datun mining area the Ordovician water was burst, they were submerged many times, resulting in heavy losses, producing serious threat to the safety of production. 21# coal has also been victims of Ordovician limestone water in Longgu Mine. Especially with the increase of mining depth, the threat will become even more serious. Therefore, it

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needs to assess the water inrush risk for 21# coal mining, and provide the technical basis for water damage control project when exploiting above the confined water.

Engineering geological condition is a key factor in the water inrush during the deep mining. Water blocking factor is indicator and parameter which respects the average water-blocking ability of rock bottom impermeability. It is a very important element in water inrush risk assessment. Water-blocking factor test is often used in situ drilling hydraulic fracturing tests in recent years. Professor Chen of China Petroleum University got water-blocking factor of large size rock using hydraulic fracturing test in the laboratory [1].The author also got water-blocking factor of small size rock in laboratory using the hydraulic fracturing test [2].

2. Analysis of hydrogeology condition in 21# coal mining

12# limestone is the directly roof and the direct water-filled aquifer for 21# coal mining. The indirect aquifers of 21# coal are 14# and 15# limestone which belong to Benxi Formation and the Ordovician limestone.

According to the pumping test data in the exploration stage, the water-rich property of 12#、14th、15# limestone water is weak .The main recharge is the static reserves, and take the less impact on the mining activities. As Ordovician limestone is the regional strong aquifer, with the stronger water-rich property, therefore it is a major indirect water-filled aquifer while 21# coal mining and it also is the focus of prevention and treatment during the mining.

The floor aquifuge of 21# coal is mainly composed by sandstone and limestone with higher strength and the mudstone with low intensity. The engineering geological properties of three types of rocks are quite different. They have large differences in water-blocking ability too. The block-water capability of the floor is combined effect of three types of rock composition. Whether the water inrush from Ordovician limestone or not is depended on the water pressure of Ordovician limestone and the water-blocking capability of the aquifuge between the Ordovician limestone and 21# coal. The water-blocking properties are mainly reflected in aquifuge thickness and water-resisting ability (water-resisting coefficient) [3] [4].

3. Determination method of Water-resisting coefficient

3.1. Measure method of water-resisting coefficient

The water-resisting coefficient is not only the true reflection of the average water-blocking ability of the floor aquifuge, but also is the important parameter for keeping the safety coal and rock pillars in mining above water body, and it is usually measured by the hydraulic fracturing experiments [5]. The water-blocking ability of rock layer is the comprehensive result of the strength and structure of the floor aquifuge and the stress of the water and rock. Firstly, wall of water-pressuring hole produces fissures by the water pressure, and then gradually expanded and extended to the observation hole. The whole process is complicated and irregular. The actual calculation is very difficult. It assumed that there are cracked together for convenience. Thus, according to the site drilling hydraulic fracturing test data, the following formula of water-blocking strength of floor layer is made:

$$\xi = \frac{P_b}{R} \tag{3-1}$$

where, ξ —average water-blocking strength of rock, MPa/m, P_b—rock fracture pressure, MPa, which is related to the geostress and tensile strength of rock mass and is determined in the site; R— interval between water-pressuring hole and observation hole, m.

3.2. Evaluation method of Water-resisting ability of floor rock mass

Seam floor has the layered structure and is mainly composed of sandstone, siltstone, mudstone and limestone. Their water-resisting ability is different by different lithology. Taking into account the water-resisting performance of the mining disturbance zone of floor, the evaluation formula of the water-resisting ability of the floor rock is as follows:

$$Pz = \sum_{i=1}^{n} m_i \xi_i \tag{3-2}$$

$$\sum_{i=1}^{n} m_i = M - D_{cp} \tag{3-3}$$

Where, Pz — total water-resisting ability value of floor aquifuge, MPa; Dcp — thickness of mining disturbance zone of floor f, m; mi — thickness of the i sub-layer of aquifuge, m; ξi — water-resisting strength of the i sub-layer of aquifuge, MPa / m; M — total thickness of aquifuge, m.

The formula also can apply to the water-resisting capacity of fault zone, and only water-resisting strength ξ is different. From the above evaluation formula it can be seen that if an accurate assessment of water inrush want to make, the key issue is to determine the parameters ξ.

3.3. The determination of evaluation parameters

The determination of water-resisting strength is obtained mainly through site testing. Longgu Mine has not the test data in this aspect at present time. The value is got in this paper according to the relevant test results as the calculation basis for the evaluation of reference. The results of hydraulic fracturing tests in Yangzhuang Coal Mine (Huaibei) are shown in Table 1

Table 1 The test results of water-resisting ability of the table

name of experimental section		lithology	Water-resisting strength, MPa/m
Normal area	upper Section	Sandstone and mudstone interbed	0.533
	middle Section	Sandstone	0.022
	lower Section	Marine facies mudstone	0.092

"Regulations on coal pillar leaving under buildings, water body, rail and major roadway and under-coal mining " give the various results of various hydraulic fracturing rocks tests [6], see Table 2 and Table 3.

According to the test of Xinze minefield in Shandong by Shi Huaihu et al, it also puts forward the water-resisting pressure strength values of different rocks, see Table 4. The values are smaller than those in the above table. The formation structure of that area is close to the Lonhgu Mine. For safety reasons, the values of this evaluation are taken as: sandstone about 0.10 MPa/m, mudstone about 0.07MPa/m, limestone about 0.10MPa/m, and fault zone 0.05MPa/m.

Table 2 Water-resisting coefficient data of floor by drilling water-pressuring collusion failure test

Test site	Lithology	Water-resisting coefficient, MPa/m
Fengfeng No.2 Mine	Sandy shale (within the mining disturbance zone)	＞0.124
Fengfeng No.3 Mine	Within shale	＞1.000
		＞1.471
Fengfeng No.3 Mine	Sandy mudstone filling in the ancient collapsed column	＞2.7～2.9
Wangfeng Mine	Fine sandstone	0.50
	Aluminous mudstone	0.43
Wangfeng Mine	Fault zone	0.22
No.1 pit of Wangfeng Mine	Siltstone, medium sandstone, aluminous mudstone	0.092

Table 3 Test data of coefficient of water-resisting in rock bottom by drilling hydraulic fracturing

Test site	Lithology	Water-resisting coefficient, MPa/m	Remarks
Zhaogezhuang, Kailuan	Medium sandstone	0.331	On-site borehole hydraulic fracturing test, rupture radius R is taken as 43m
	Fine sandstone	0.258	
	Siltstone	0.194	
	Mudstone	0.293	
	Bauxite	0.114	
	Medium-coarse sandstone	0.491	Hydraulic fracturing results of indoor triaxial direction confining pressure test:
	Medium sandstone	0.377	
	Fine sandstone	0.302	σ_1 = 24.0~24.5MPa;
	Fine sandstone	0.209	σ_2 = 13.1~14.2MPa;
	Mudstone	0.393	σ_3 = 19.0~20.5MPa
Jiulishan, Jiaozuo	Limestone	0.339	Hydraulic fracturing results of indoor triaxial direction confining pressure test: σ_1 =8.94MPa; σ_2 =3.84MPa; σ_3=2.95MPa;

Table 4 The water-resisting pressure strength values of aquifuge layer

Rock name	Water-resisting pressure strength MPa / m
Mudstone, calcareous mudstone, marl, bauxite, clay and fault clay	0.05
Non-karstificated fresh water limestone, limestone	0.10
Sandy shale	0.07
Sandstone (Oligocene)	0.10
Fracture zone	0.035

4. Assessment of Ordovician limestone water irruption based on coefficient of water-resisting

4.1. Determination of water-pressure of Ordovician limestone water irruption

The Longgu Mine has two observation boreholes of Ordovician water which named 5-2 and 0-7 boreholes. The Longdong Mine, which belongs to Datun coal-electricity company and takes Zhangzhuang fault as boundary to Longgu Mine, has Longdong East W12 and Longdong West W9 boreholes as references of Ordovician water level observation. Table 5 shows the water level elevation.

Table 5 The water level of observation boreholes in Longgu and Longdong Mines (Unit: m)

Date \ Borehole	5-2	0-7	Longdong East W12	Longdong West W9
2007-1-10	-71.68	-70.0	-74.15	-81.36
2007-7-10	-78.08	-70.0	-75.30	-81.51
2008-1-10	-79.34	-70.0	-76.20	-76.20
2008-2-10	-78.36	-70.0	-76.20	-82.60
2008-3-10	-78.36	-70.0	-76.10	-82.60

It can be seen from Table 5 that the Ordovician water levels in observation boreholes of Longdong East W12 and Longdong West W9 in Longdong Mine and 5-2 in Longgu Mine have little difference. The recent hole head pressure of supplementary hydrogeology exploration borehole FO_2 is 3.4MPa. The elevation of hole head is -435.5m and -88.5m in water level terms.

As we don't have the water level data of 5-2 borehole after March 2008 and the water level of it shows a downward trend, as well no large hydrostatic activities since 2008, we may deduce that the recent water level of 5-2 borehole is less than -78.36m. The water level of Longdong West W9 borehole in Longdong Mine is -82.60m which fits the analysis. Thus, we take data from FO_2 borehole, -88.50m, as the Ordovician water irruption level. We use -90m as approximate data for calculating easily.

4.2. Assessment and district division of water irruption risk

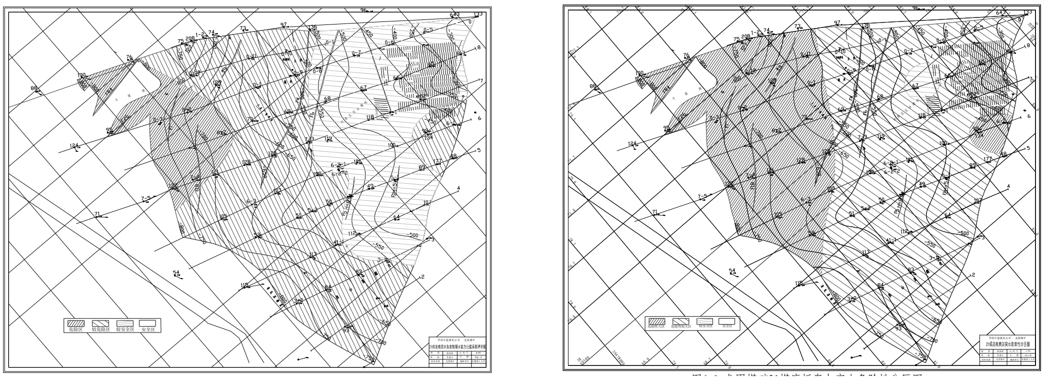
We substituted these data into formula 3-2 and calculated the whole water blocking capacity of each borehole and displayed in Table 6. What's more, we calculated the whole water blocking capacity ratio parameter *Tz* (the ratio of water pressure and whole water blocking capacity of coal seam floor). When the ratio parameter is large than 1, it means the water pressure is greater than whole water blocking capacity of coal seam floor and the water irruption is easy to occur. The calculation formula is as follow:

$$Tz = P / \sum_{i=1}^{n} m_i \xi_i \qquad (4\text{-}1)$$

The distribution map of ratio parameter of water blocking capacity of coal seam floor is compiled based on Table 6. Fig.1(a) shows the district division for water irruption risk of 21 # coal floor on the basis of risk classification Table 7. The region above -550m is safe except the area around 134# borehole in East No.3 district and the water irruption risk is high below -550m.

Table 6 The result of water blocking capacity of 21# coal floor

No. of borehole	Thickness of effective aquifuge between 21# coal and Ordovician limestone (m)	Water- blocking capacity (MPa)	Water pressure of Ordovician limestone (MPa)	Tz	Water irruption risk
5-1	40.22	5.33	4.53	0.85	More safe
0-7	38.61	5.21	4.48	0.86	More safe
134	26.40	3.84	4.26	1.11	More risky
6-2-1	42.72	6.19	5.45	0.88	More safe
112	40.68	5.39	5.07	0.94	More safe
3-1	38.22	5.06	5.08	1.00	More risky
8-2	32.85	3.95	6.23	1.58	Very risky
51	37.99	4.55	5.4	1.19	More risky
6-2-2	36.89	5.13	5.35	1.04	More risky
6-3	37.25	4.59	6.11	1.33	More risky
LO_2	49.00	6.54	4.06	0.62	More safe



(a) (b)

Fig. 1. The district division of seam floor water irruption by (a) water-blocking coefficient; (b) water-bursting coefficient

Table 7 The risk grading by water-blocking coefficient method

Divided district		District division index, *Tz*
Risky district	Very risky district	$Tz \geq 1.5$
	More risky district	$1 \leq Tz < 1.5$
Safe district	More safe district	$0.6 \leq Tz < 1$
	Safe district	$Tz < 0.6$

5. The comparison of water-bursting risk classification and the practical mining

Fig.1(b) shows the Ordovician water-bursting danger appraisal and district division of 21# coal floor based on conventional water bursting coefficient. It states clearly that the studied areas are labeled more risky or risky. And, Fig.1(a) shows the Ordovician water-bursting danger appraisal and district division of 21# coal floor on basis of water blocking coefficient. The lightest zone was occupied most of the studied area which represents safe. Depending on the practical mining data, mining engineering has existed in security area and no water bursting happened during the coal mining. It follows that this area is safe.

The comparison of Fig.1(a) with Fig.1(b), supported by practical mining data, shows preliminarily that the district division by water blocking coefficient more accords with real mining engineering. It means water blocking coefficient is more scientific and rational than traditional water bursting coefficient, especially in the situation of deep mining and with complete floor.

6. The brief summary

(1) Depending on the analysis of 21# coal water-filling condition in Longgu Mine, the Ordovician limestone floor water irruption danger exists in mining coal21 seam.

(2) This paper evaluated different districts for Ordovician limestone water irruption danger of 21# coal mining under pressure in Longgu Mine on basis of water blocking coefficient, a token of real water-resisting capacity of rock.

(3) In general, there are risks of Ordovician limestone water irruption of 21# coal mining under pressure. However, there also have certain safe districts. We should deploy the Ordovician loimestone water prevention and control work for safely mining.

(4) Combination of the risk assessment and district division of Ordovician limestone water, compared with water-bursting coefficient, supported by practical mining, the water-blocking coefficient is more scientific and rational in evaluating the water irruption risk of coal seam floor. It is worth to be popular.

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