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Safety Study of Coal Mining under Dan River

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Abstract

The purpose of studying coal mining technology under water body is to realize the safe extraction of coal resources under water body. Compared with the mining problem under general conditions, it has higher risk and complexity. It is necessary to analyze the feasibility of coal mining under rivers in combination with geological and hydrological conditions of working face Ⅲ2317 before mining under water bodies. The empirical formula of "two zones" height calculation value and the engineering analog calculation value are compared and analyzed, and the comprehensive analysis determines that the development height of "two zones" mining under the geological conditions are 18.4 m and 93.8 m respectively. According to the calculation value, the reasonable height of waterproof safety coal pillar is 112.3m and that of collapse pillar is 35m. The safety of coal mining under river in working face Ⅲ2317 is analyzed comprehensively.

Keywords

Coal Mining Under Water Body; "Two Zones" Development Height; Mining Safety.

1. Introduction

Many scholars have done a lot of research on the damage scope of overlying rock, and put forward the development law of "three zones" of overlying rock failure, and put forward the technical measures of safe mining under water bodies. Liang Yunpei quantitatively divided the "three zones" of mining overlying rock based on the composite rock beam theory, and obtained that the incongruous deformation between rock groups led to the generation of dynamic fractures between layers [1]. Zhang Jun analyzed the "three zones" of mining overburden from the perspective of fracture mechanism and fracture development and distribution characteristics[2]. Based on the grey correlation theory, Yandebin analyzed the main controlling factors affecting the water-conducting fracture zone and obtained the properties of overburden rock and the main influencing factors affecting the failure height of overburden rock during mining thickness[3]. Due to the continuous research and practice of many scholars, the main controlling factors and development process of water-induced fracture zones have been clearly understood in our country[4].

2. Geological Mining Conditions of Coal Mines

2.1 Topographic, Geomorphic and Meteorological Features.

The Changping coal mine field is adjacent to Qinshui Basin in the west and Taihang Mountain in the east, which is a typical river erosion landform. The mine terrain is low hills + 1310.7m in the west and Dan River bed + 878.8m in the east at the lowest elevation. The elevation difference between mountains and valleys in the east and west reaches 432.7m. The Danhe River flows from north to south at the eastern boundary of Changping Mining area. It is the main river in the mining area. The river flow is small in the dry season and increases in the rainy season.

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2.2 Hydrogeological Condition

The upper part of the coal seam mainly contains two layers of sandstone aquifer water, K_8 and K_{10}. According to the analysis of nearby drilling holes, the thickness of K_8 layer is 4.45m, and the thickness of K_{10} layer is 2.15m. The roof of No. 3 coal seam is 34.5m away from K_8 layer and 105.21m away from K_{10} layer. After the mining of working face, the direct water gushing source is mainly K_8 sandstone aquifer, indirect water gushing source is K_{10} sandstone aquifer, K_8 and K_{10} sandstone aquifer are the main water filling source of the mining of working face.See Figure 1.

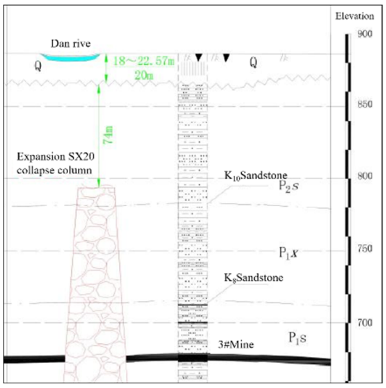

Fig 1. Vertical section of the relative position of the opening and collapse column of the working face

2.3 Regional Tectonics.

The working face III2317 is located in the eastern part of the Changping coal mine field. It is mainly a northeast-dipping monoclinal structure with a dip Angle of about 4°. The overall structure is simple. Only 3 collapse columns are developed on the working face and its side, among which 1 is within the range of the working face and 2 are on the side, as shown in Figure 1.

3. Safety Analysis of Coal Mining

3.1 Calculation of Development Height of Caving Zone and Water-Conducting Fracture Zone.

(1) According to the Code, the formula for calculating the height of caving zone[5] and water-channeling fracture zone[6-8] in top coal mining in thick coal seam is as follows:

$$H_k = \frac{M}{(K-1)COS\ \alpha} \tag{1}$$

$$H_k = 6M + 5 \tag{2}$$

$$H_{li} = \frac{100M}{0.23M + 6.10} \pm 10.42 \tag{3}$$

$$H_{li} = 20M + 10 \tag{4}$$

Where H_k is the caving zone height, m; K is the crushing expansion coefficient of rock, and 1.2 is taken in this study to ensure safety. α is the coal seam dip Angle, which is 4°; H_{li} is the height of water-conducting fracture zone, m; M is the mining thickness, 4.85 m;

Table 1. Calculation Results of Collapse Zone and Water-Conducting Fracture Zone

Coal thickness (m)	Caving zone height (m)		Height of water conduction fracture zone (m)	
	Formula 1	Formula 2	Formula 3	Formula 3
4.85	24.3	34.1	77.78	107

(2) According to the Evaluation Standard of Hydrogeology, Engineering Geology and Environmental Geology of Coal Mine (MT/ T1091-2008), the maximum height calculation formula of caving zone and water-conducting fracture zone (including caving zone) of single mining of fully mechanized top coal caving is as follows:

$$H_c = (4 \sim 5)M \tag{5}$$

$$H_f = \frac{100M}{2.4n + 2.1} + 11.2 \tag{6}$$

Where: Hc is the height of the fall zone, m; Hf is the water-conducting fracture zone, m; M is the cumulative production thickness, 4.85m; n is the number of layers.

Table 2. List of calculation results of maximum height of collapse zone and water diversion crack zone

Coal thickness (m)	Caving zone height (m)	Height of water conduction fracture zone (m)
	Formula 5	Formula 6
4.85	19.4~24.3	119.0

3.2 The Development of "Two Zones" is Highly Engineering Analog.

Due to the influence of rock lithology and its combination characteristics, and the degree of primary fracture development, the development height of "two zones" in different regions is significantly different. Therefore, the measured results of this mining area are relatively more reliable. According to the measured results of "two belts" of overlying rock on the III4304 fully mechanized mining face in Changping Coal Mine, the mining height of III4304 working face is about 5.7m, two boreholes are constructed on site, and the failure height of overlying rock is measured. The maximum development height of the measured water-conducting fracture zone is 96.2 ~ 110.3 m, which is 16.9 ~ 19.4 times of the mining height. The maximum development height of caving zone is 19.4 ~ 21.6 m, which is 3.4 ~ 3.8 times of mining height, as shown in Table 3.

Table 3. Measured "Two Zones" Development Height Table of Working Face III 4304

Hole number	Mining height (m)	Caving zone height(m)	Ratio of caving zone height to mining thickness	Height of water conduction fissure zone(m)	Ratio of fracture zone height to mining thickness
1#	5.7	21.6	3.8	110.3	19.4
2#	5.7	19.4	3.4	96.2	16.9

According to the measured results in the table above, the measured heights of caving zone and water-conducting fracture zone are 3.4~3.8 times and 16.9~19.4 times of mining height, respectively. The average mining thickness of III2317 working face is 4.85 m, the calculated height of caving zone is 16.5~18.4 m, and the height of water fracture zone is 81.8~93.8 m. In order to ensure the safety of coal mining under rivers, the maximum values are 18.4 m and 93.8 m, respectively.

3.3 The Development of "Two Zones" is Highly Determined

The development heights of caving zone and water-conducting fracture zone obtained by empirical formula and engineering analogy calculation are compared and analyzed, and the specific values are shown in Table 4 below.

According to the analysis in Table 4 above, Formula 2 is used to calculate the maximum caving zone height, and the values calculated by the empirical formula are greater than those calculated by the engineering analogy. The height of water-conducting fracture zone calculated by formulas 4 and 6 is greater than that of engineering analogy, while formula 3 is smaller than that of engineering analogy.

To sum up: for the sake of safety, the caving zone height can be calculated by formula 1 or 5; The height of water-conducting fracture zone can be calculated by formula 4.The development height of caving zone is 18.4 m, and the development height of water-conducting fracture zone is 93.8 m.

Table 4. Comparative analysis of calculation results of caving zone and water flowing fractured zone

Caving zone height (m)			Height of water conduction fissure zone (m)		
Empirical formula		Engineering analogy	Empirical formula		Engineering analogy
Formula1	24.3	18.4	Formula3	77.8	93.8
Formula2	34.1		Formula4	107	
Formula5	24.3		Formula6	119	

4. Safety Analysis of Coal Mining under Rivers

4.1 Safety Analysis of Collapse Column.

Collapse column is a kind of special geological structure encountered in the mining process. The layout and advance of fully mechanized mining face containing collapse column will have a great influence. It is difficult to realize normal layout in the mining face with collapse column, which leads to reduced mining efficiency and increases the possibility of water inrush in the working face [9, 10].Three collapse columns are developed within the mining range of III2317 working face and at its side, including one within the working face and two beside the working face . The expanded SX20 collapse column has a great influence on the mining of the working face (see Figure 1).

(1) According to the Angle of collapse

The caving Angle is determined according to the stability of the roof strata of coal seam. The direct roof and old roof of coal seam are mainly sandstone and sandy mudstone, belonging to stable roof, and the caving Angle is 45° , as shown in Figure 2 and Table 5.

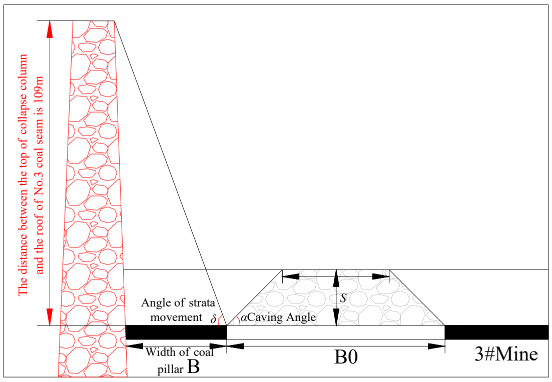

Fig 2. Schematic diagram of retaining coal pillar for collapse column protection

Table 5. Measured "Two Zones" Development Height Table of Working Face III 4304

Roof type	Comparative roof breakage	Breaking roof	Moderately stable roof	Stable roof	Tight roof
Caving Angle (°)	90	75	60	45	30

According to the analysis results of the above section, the height of caving zone obtained by numerical simulation can be used as the overburden failure height under this geological condition, so the maximum development height of caving zone is 18.4m, and the width of coal pillar protected by collapse column can be calculated as follows:

$$B = \frac{H_K}{\tan\alpha} \tag{7}$$

Where: B is the width of coal pillar, m; H_k is caving zone height, m; α -- rock displacement Angle, °.

According to the above caving Angle calculation formula, the width of protective coal pillar is 18.4 m.

(2)In terms of rock displacement Angle

According to the analysis results of the above section, the development height of the water-conducting fracture zone obtained by comprehensive analysis can be used as the overlying rock failure height under this geological condition. Therefore, the maximum development height of the water-conducting fracture zone is 97.1 m, and the overlying rock mainly consists of mudstone, sandy mudstone and sandstone interbed. The rock displacement Angle is 72 ~ 74°, and 72° is selected. The width of collapse column protection coal column can be calculated according to the following formula:

$$B = \frac{H_d}{\tan\alpha} \tag{8}$$

Where: B -- width of coal pillar, m; H_d -- height of water-conducting fracture zone, m; α -- rock displacement Angle, °.

According to the above formula of rock displacement Angle, the width of protective coal pillar is 30.5m.

(3)According to the height of coal seam roof collapse column

The height of collapse column above the coal seam roof is 109 m, and the rock displacement Angle is 72 ~ 74°, and 72° is selected. According to Formula 9:

$$B = \frac{H}{\tan\alpha} \tag{9}$$

Where: B -- width of coal pillar, m; H -- height of collapse column above the roof, m; α -- rock displacement Angle, °.

According to the above calculation formula, the width of protective coal pillar is 35.4m.

(4)Safety evaluation of collapse column

To sum up: the width of the collapse column protected coal column calculated according to the caving Angle is 18 m, and the remaining protective coal column is much larger than the calculated value, with high safety. It does not constitute the destruction of the collapse column and its surrounding rock, which can maintain the original stable state and exclude the communication with the surface river caused by the activation of the collapse column induced by mining disturbance. The width of the protected coal pillar calculated by the displacement Angle is 30.5m. If the protected coal pillar is larger than the calculated value, the influence of overburden migration on the mining face is small. According to the height of the collapse column of coal seam roof, the width of the collapse column is 35.4m, and the 35 m of the protective coal column is slightly less than the calculated value. It is speculated that it can affect the weak contact surface of the surrounding rock above the collapse column, and may form a channel for the infiltration of sandstone fissure water. However, sandstone fissure aquifer mainly contains weak to medium water, which does not pose a threat to the mine water filling. That is to say, the coal pillar protected by the collapse column is 35 m in the mining of the working face of III2317, which can realize the safe mining.

4.2 Waterproof Safety Coal Pillar Shall be Set up.

According to the provisions of "Three Coal Mining Regulations", the size of waterproof safety coal pillar can be calculated by the following formula:

$$H_{sh} \geq H_{li} + H_b \tag{10}$$

Where: H_{sh} -- vertical height of waterproof safety coal (rock) column, m;H_{li} -- height of water conduction fracture zone, m;H_b -- thickness of protective layer, m.

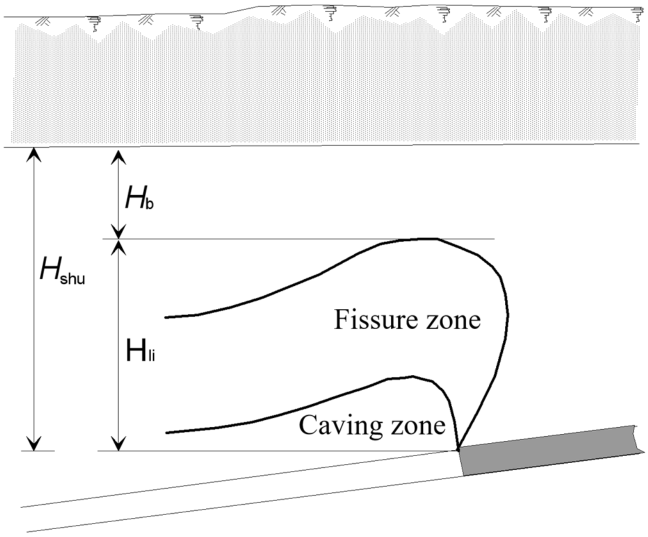

Fig 3. Design diagram of waterproof safety coal (rock) colum

That is, the vertical height Hsh of the waterproof safety coal pillar is greater than or equal to the maximum height of Hli of the water-conducting crack zone and the thickness of the protective layer Hb. See Figure 3.

According to the comprehensive evaluation of the lithology of the overlying strata of coal seam, it is weak, and the thickness of the cohesive soil layer at the bottom of the loose layer is greater than the accumulated mining thickness, namely:

$$H_b = 2M \tag{11}$$

Where: H_b -- Thickness of protective layer, m;M -- Cumulative thickness, 4.85m.

Through the above calculation, it can be concluded that the protective layer thickness of waterproof safety coal pillar is 9.7m when top coal caving mining.

According to the above calculation results, the maximum development height of the water-conduction fracture zone is 93.8 m, which is calculated by engineering analogy, and the overlying strata is relatively weak, so the thickness of its protective layer should be 9.7 m. In conclusion, the size of waterproof safe coal pillar is 103.5m. Due to the thickness of the overlying soil layer of 18.1m, the minimum thickness of the overlying strata of No.3 coal seam is 202.3m, which is far higher than the required waterproof safety coal pillar height of 103.5m.

5. Conclusion

(1) The development heights of caving zone and water-conducting fracture zone under this geological condition are obtained by comparative analysis of the development heights of the empirical formula and the engineering analog calculation results. The development heights of the "two zones" are 18.4 m and 93.8 m respectively.

(2) Combined with the obtained height value of "two belts", the width of SX20 collapse column protection coal pillar in the working face area is calculated and analyzed, and the reasonable width of protection coal pillar is 35 m.

(3) Combined with the obtained height value of "two belts", a reasonable waterproof safety coal pillar is set up, and based on this, a comprehensive analysis of the safety and feasibility of coal mining under the Dan River.

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