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Failure mechanism of the high pressure water in the Weibei on the top of the seams floor aquifers

Ordovician limestone aquifer of Weibei Chenghe mining area with abundant water, characteristics of water pressure, and No. 5 coal seam floor aquifer from Ordovician limestone top interface is relatively close distance, so it is a threat for No. 5 coal production safety. Before the coal seam mining, the floor water layer of No. 5 coal seam is in a stable equilibrium state. After the coal seam is mined, coal seam floor aquifer will cause the strata above the coal seam floor rock from the top to the bottom of the formation of coal seam floor damage, effective protection of aquifuge and water flowing zone because of the impact force of rock pressure and confined waterpressure. The floor mining failure will occur at the top of the water resisting layer and form the mining failure zone of the floor; at the same time, the change of the mechanical structure of the floor will cause the pressure of the confined water at the bottom of the aquiclude to lead up and down along the primary fracture and form a confined water rising belt. With the continuous exploitation of the coal seam, the mining failure zone of the floor may be connected with the ascending zone of the confined water, thus causing the floor water bursting along the through fracture formed by the mining. The current literature does not give a definite answer about the pressure of water on the floor mining failure with the formation of the influence of mining damage depth in the end how much, but from a simple numerical simulation and physical simulation study cannot fully reveal the phenomenon. Therefore, it is necessary to carry out research on failure mechanism of Ordovician limestone confined water on rock layer at the top of water resisting layer of coal seam floor, and from the point of view of mechanical action mechanism, the influence of confined water pressure on the mining failure depth of bottom plate is analyzed, which makes up the blank in this field. The research results of this paper play a key role in the study of the coupling mechanism between the confined water pressure and the mine pressure for further study and can provide reference for similar coal mines in North China type coalfield.

Keywords: Ordovician limestone confined water; the top rock of an bottom aquiclude; the floor failure mechanism; the coupling action of mine pressure and confined water pressure; the equivalent water pressure

1.0 Introduction

Under the influence of the combined action of the mining rock pressure and the water pressure of the floor pressure, the floor rock of coal seam will form a floor mining failure zone, an effective water resisting layer and a draft zone of confined water (Fig.1). The water resisting capacity of the water resisting layer of the coal seam floor mainly depends on the water separation capacity of the effective water separation protection layer, and only the effective water separation protection layer can effectively resist the threat of confined water. Ang Li [1-2] established the numerical model of floor rock structure of No. 5 coal seam in Dong Jiahe coal mine under the coupling of seepage field and stress field, because rock seepage and stress coupling analysis system is adopted, then the numerical simulation is conducted to analyze the influence of the bottom plate on the mining stress and seepage. Finally, it reveals the characteristics of mining failure, stress distribution and seepage characteristics of the coal seam floor water resisting layer, which is of guiding significance for analyzing the water inrush law of floor No. 5 coal seam in Dong Jiahe.

Before coal mining, the bottom plate is in a state of stress equilibrium but the confined water in the Bottom aquifer will form the "original flowing zone" ascending upward along a fracture or fracture zone in water resisting layer, and the floor water can pull out from this belt if it can overcome along resistance. When the coal seam is mined, the bottom of the goaf is in the state of unloading, and the pressure of the confined water destroys the ground stress balance, under the coupling action of the mining stress field and the seepage field, the original fracture develops further and forms the

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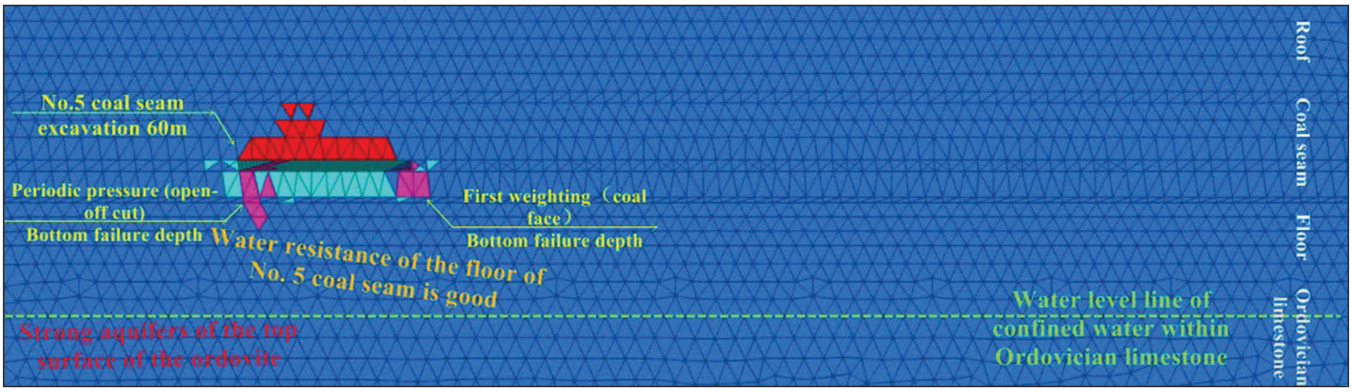
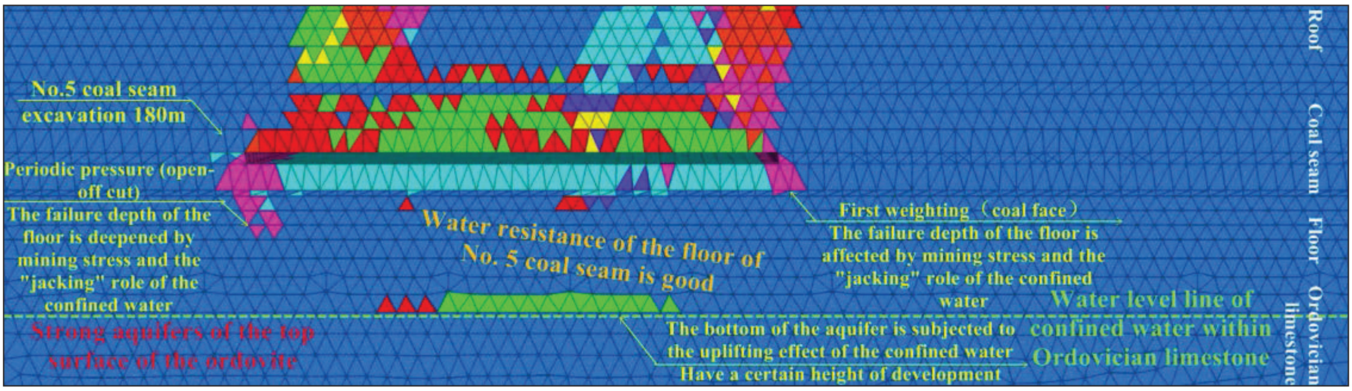
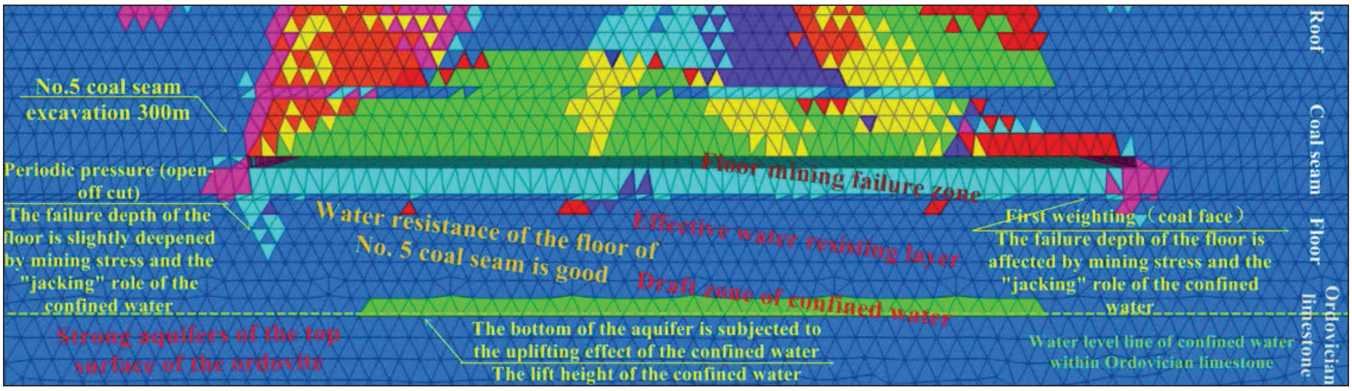


(1) No. 5 coal face advancing 60m



(2) No. 5 coal face advancing 180m



(3) No. 5 coal face advancing 300m

Fig.1: A simulation results about mining stress field and seepage field coupling failure depth of floor confined water and "jacking" function

new fracture, then, the "original flowing zone" develops upward to form a "mining lift belt". In addition, the water resisting floor is jacked by confined water pressure, the "mining failure zone" of aquifuge top and the "mining lift belt" of the bottom confined water are communicated, then form a water guiding passage, resulting in water inrush from the baseplate. Therefore, the pressure of water on the floor aquifuge effect mainly on function of "jacking" and "guide rise" for bottom waterproof layer (Fig.1). This paper aims at the mechanism of aquifer pressure of Ordovician limestone on the water resisting layer of coal seam floor make sense out of mechanical analysis about the pressure of water on the aquifuge "jacking" role.

2.0 Research status at home and abroad

One of the major disasters is the problem of inrush from coal mine floor in the coal production in our country. Many experts and scholars have made great contributions to the anti inrush mechanism of coal mine floor, and have accumulated rich experimental data and practical experience [1-3], many new ideas, new theories and new technical methods have been put forward.

The geological background of Ang Li is the Weibei coalfield of No.5 coal seam in coal mining with pressure, based on the linear elastoplastic softening model of coal body, the elastoplastic analytical solution for rock mass analysis of rock floor under semi infinite plane is derived, analyzes the mechanism of confined water pressure on the aquifuge floor, forming a comprehensive research system of Dongjiahe No.5 coal mine water inrush theory and technology. Banghua Yao, Xianbiao Mao and etc. based on the theory of broken rock seepage theory; solid-liquid two-phase flow; ground water dynamics, and considering the particle migration of collapse column liquid-solid coupling dynamics model, and combined with the engineering practice of the collapse column inversion particle porosity, seepage velocity, pore water pressure, fluid volume fraction, water inflow parameters such as the variation with time. Guoliang Bai, Bing Liang et al. and based on Biot's consolidation theory, established a coupled mathematical model of water and rock in an equivalent continuum, and through the built-in Fish language and the finite difference method, the fluid solid coupling module is applied to the field practice, and obtained evolution law of the aquifer seepage field under the influence of mining. Ang Li [7] explored the permeability of Chenghe mining area of main coal seam floor rock from the angle of water rock coupling and selected four kinds of soft and hard rock samples including representatives of coarse sandstone, mudstone, siltstone and limestone in Dongjiahe coal mine No.5 coal seam, according to the test results, the full stress-strain process of the four rock samples and the curves of the permeability and stress and strain are obtained. The relation between the permeability and the stress before the failure of rock samples is analyzed. Ang Li and Shuancheng Gu and et al. [9] carried out related research on the mining failure depth caused by mining No.5 coal seam in Dong Jiahe coal mine, by combining theoretical analysis and numerical simulation method, and the dynamic representation of the entire floor rock progressive failure process, and obtains the maximum failure depth of floor strata is 10~11m, the result is in consistent with field measurement. Zhaoning Gao and etc. [19] applied the three-dimensional elastic plate theory, and analyzed the mechanical effect and failure mechanism of the coal seam floor under the condition of mining confined water coupling, and the deformation and failure law of coal seam floor aquifer during mining is revealed. Ang Li around the influence factors of water inrush from coal seam floor under mining with pressure the fluid solid coupling numerical model and the mathematical model of mining support pressure and confined water pressure, and the characteristics of mining failure and the mechanism of water inrush under the coupling of fluid and solid field are systematically studied. Finally, the research results provide scientific guidance for the prevention and control of water flooding in Weibei mining area. Ang Li [2] by theoretical analysis and numerical calculation method applied in Dongjiahe coal mine 5 coal seam 22507 working face floor grouting renovation project, realized safety mining, and achieved good economic and social benefits. In future, It will provide valuable experience for Dongjiahe coal mine and the lower part of Taiyuan formation in Chenghe mining area prediction and prevention of No.5 coal seam floor karst water in Ordovician limestone.

In addition, Yinlong Lu, Lianguo Wang [12] is adopted the method of numerical simulation to research the evolution law of floor fracture and water inrush caused by stress - damage - seepage in mining process, the stress distribution, acoustic emission evolution and fracture development, as well as the formation of water inrush channel have been reproduced, which are of practical value for the prevention of water inrush in the floor. Hongfei Duan and Zhenquan Jiang and Shuyun Zhu and other [13] have adopted the finite difference method FLAC3D to research the deformation and failure of the floor under the plastic zone of the bottom plate is studied by numerical simulation, the results of the study are in good agreement with the actual strain measurement system used in the field. Huiyong Yin and Jiuchuan Wei [14] in 4196 working face as the engineering background, and used RFPA software to analyze the shear stress field, damage field and seepage field of the floor during coal mining, and simulate the whole process of the formation of the bottom plate from the fracture to the fracture channel. Xiaorong Zhai and Jiwen Wu and so on [15] take the Huaibei coal mine bottom group coal floor as the research object, to explore the different strata combination bottom board to the confined water barrier effect, and based on FISH language, the FLAC3D software was developed two times. Under the condition of convection and solid coupling, the dynamic stress and permeability of the different features of the floor were analyzed comprehensively. Ang Li [10] used Taiyuan Chenghe mining area No.5 coal mining group as the background, analysis and calculation of numerical model using FLAC3D analysis software built in different mining width and depth of coal seam floor conditions, got different parameters of the maximum failure depth. Based on the distribution law of the supporting pressure in front of the working face, Xiangrui Meng et al. [16] established an elastic mechanical model for calculating the stress at any point of the bottom plate based on the actual engineering, using the study of the floor failure effect with depth numerical simulation method. Finally, the research results and the field measurement theoretical study is consistent.

The above results are the study of the bottom failure depth induced by two factors, including confined water pressure and coupling effect of mine pressure, or only the single factor of mine pressure. The effect of confined water of Ordovician limestone on the top rock layer of coal seam floor water barrier was not considered. For low pressure water pressure, the influence of the mining failure depth was mainly caused by the mine pressure, for large pressure water pressure, the influence of the bottom mining failure depth should be considered not only the mine pressure, but also the control effect of the confined water pressure on the rock stratum at the top of the impermeable layer. But the current research in the field is less, it is necessary to carry out research on Ordovician limestone bearing water on coal seam floor aquifer strata on the top of the failure mechanism, to fill the gaps in this field, the research of floor water governance at this stage can play an active role in promoting.

3.0 Establishment of mechanical model

The Ordovician limestone can be vertically divided into three groups and six sections, include: the two members of Fengfeng formation, the two members of upper Majiagou Formation and the two members of lower Majiagou formation. The lower section of each group is limestone strong aquifer, and the upper section of each group is relative water resisting layer. The lithology is grey, fine, crystalline, medium thick, layered limestone and quasi limestone interbedded, inclusions in dolomitic limestone, thin sand and mudstone, with gentle wavy bedding. Calcite is the main component, accounting for 80%~95%, dolomite accounts for 4~15%. Fissure and cave development, fracture rate of 4%, which is rich in water in karst fissure confined water aquifer; and it is the most important source of water inrush and the threat of No. 5 coal mining Chenghe mining area [1].

As we all know, the Ordovician limestone strong aquifer is composed of the framework and the confined water filled with the crevice of the aquifer. According to hydrogeology, the overlying rock weight acting on the aquifer is shared by the framework of the aquifer and the confined water in the aquifer. When the hydrostatic pressure of the aquifer remains constant, the change of overlying load will only cause changes in the stress of the aquifer framework, and the stresses on the aquifer framework are always in balance with the overlying load and the hydrostatic pressure of the aquifer.

As for the effective water resisting layer of the floor after coal mining, a pressurized zone will be formed near the coal wall and the pillar of the coal seam, and the supporting pressure will increase, the load and weight of the lower part of the compression zone acting on the pressure bearing aquifer of the floor also increases and the stress of the framework of the aquifer will be changed. According to related studies, the change of pressure has little influence on the water pressure of confined water, and the increase of abutment pressure leads to the increase of load weight, which is entirely borne by the framework of aquifer, in this moment, as a balance force, the water pressure has no effect on the stress change in the water resisting stratum and the vertical stress of the aquifer framework. In the mined out area, the water pressure in the aquifer remains the same although floor water separation rock stratum in the floor is in a state of unloading; moreover, the water pressure and the stress of the aquifer framework are still in balance with the overlying load. At this time, the floor water resisting strata in the lower aquifer confined water pressure on the floor aquifuge provides effective "jacking", become a kind of active jacking force. It will make the floor deformation and displacement of the free surface water resisting strata gob pressure relief formed, resulting in formation of a floor caused by the additional stress field of confined water aquifer, causes the changes of stress of aquifuge floor.

3.1 Solution of internal force and moment of section

The additional produced backwater effect of aquifer hydrostatic pressure of the water is in the floor strata stress field using material mechanics method, The length of the inclined direction of the coal seam along the mining face is much larger than the span of the goaf along the seam toward

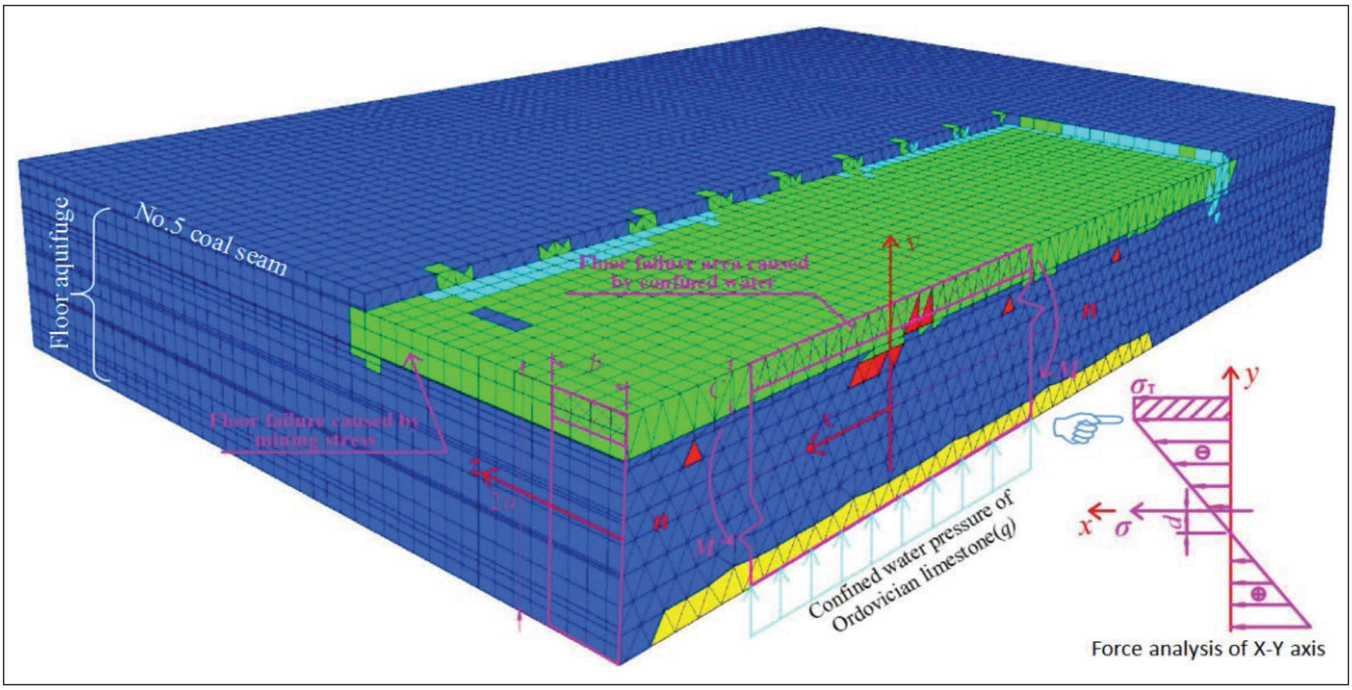


Fig.2: Section stress analysis of bottom water resisting layer under the influence of confined water pressure

the empty area (goaf), therefore, the water resisting layer of the bottom plate can be regarded as a fixed rectangular beam structure subjected to vertical uniform water pressure, thus, the plastic zone distribution law of the floor caused by the action of confined water is obtained. Now analyze the stress state of this beam structure, as shown in Fig.2.

In the diagram:

M – Interfacial bending moment;
c – Plastic zone height due to confined water, m;
d – The neutral axis deviates from the X axis, m;
σ_T – Tensile strength at top of impermeable layer, MPa;
b – The width of the cross section of a beam, set up b=1;
2a – Thickness of water resisting layer of coal seam floor, m;
⊕– Compression zone;
Θ – Tension zone.

When the maximum tensile stress reaches the ultimate tensile strength σ_T at the top of the bottom layer of the diaphragm, a plastic fracture zone is formed at the top of the impermeable layer, Thereafter, the bearing capacity of the tensile stress zone decreases, and the offset distance of the neutral axial compression zone is d. Thus, the pressure (N_c); tensile force (N_T) and yield force (N_Y) are equal to those in the compression section corresponding to the σ_C :

$$N_c = \int_{d-a}^{0} \frac{b \cdot \sigma_T}{a+d-c} y \cdot dy = -\frac{b \cdot \sigma_T (a-d)^2}{2(a+d-c)} \tag{1}$$

$$N_Y = b \cdot c \cdot \sigma_T \tag{2}$$

$$N_T = \int_{0}^{a+d-c} \frac{b \cdot \sigma_T}{a+d-c} y \cdot dy = \frac{b \cdot \sigma_T (a+d-c)}{2} \tag{3}$$

The bending moments produced by the pressure (N_C), the tension (N_T) and the yield force (N_Y) are M_C, M_T and M_Y, respectively, so:

$$M_c = \int_{d-a}^{0} \frac{b \cdot \sigma_T}{a+d-c} y^2 \cdot dy = -\frac{b \cdot \sigma_T (a-d)^3}{3(a+d-c)} \tag{4}$$

$$M_Y = N_Y \cdot \left(a+d-\frac{c}{2}\right) = bc\sigma_T\left(a+d-\frac{c}{2}\right) \tag{5}$$

$$M_T = \int_{0}^{a+d-c} \frac{b \cdot \sigma_T}{a+d-c} y^2 \cdot dy = \frac{b \cdot \sigma_T (a+d-c)^2}{3} \tag{6}$$

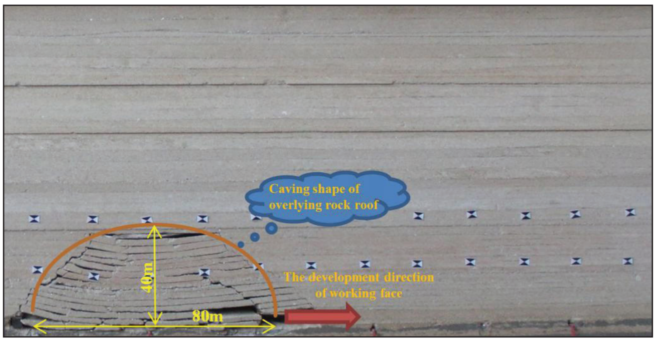
According to the equilibrium condition:

$$N_C + N_T + N_Y = 0 \tag{7}$$

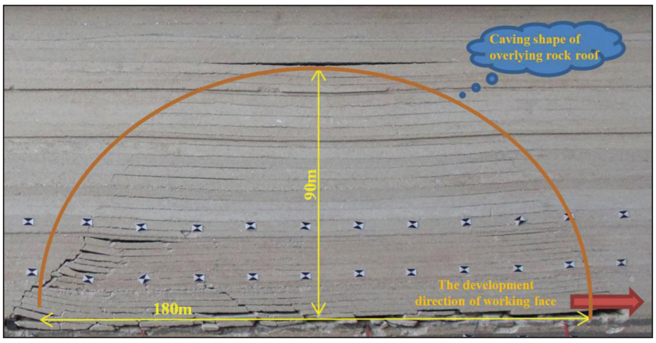
$$M_C + M_T + M_Y = M_{max} \tag{8}$$

3.2 Solution of equivalent water pressure

It is assumed that the pressure of the Ordovician confined water is q_0 at the bottom of the bottom layer of the coal seamfloor, considering the weight of the water resisting layer and the weight of the gangue. The results of rock pressure research show that the combined movement of overlying strata in coal seams is developed according to the law of arch. The arch of each arch is defined by the position of the rock beam where the layer has just separated, each of the two adjacent arch foot is the distance between the initial pressure and periodic weighting, similar material simulation is an important parameter in the development process of the [17-18] arch: The ratio between the height of the arch (falling height) and the span of the arch (length of mining face) can be measured according to 1:2, that is falling height; Mining face length of = 0.5, therefore, Chenghe mining area No.5 coal roof in goaf caving form can be seen in Fig.3.



(1) When the work face is pushed up to 80m



(2) When the work face is pushed up to 180m

Fig.3: Similar simulation results

We can see from Fig.3, Chenghe mining area No.5 coal seam roof of goaf overburden rock caving form, in the face of initial pressure and the 3~5 cycle pressure, roof rock caving can be approximately regarded as the semi-circular arch, gob caving coal diagram as shown in Fig.4.

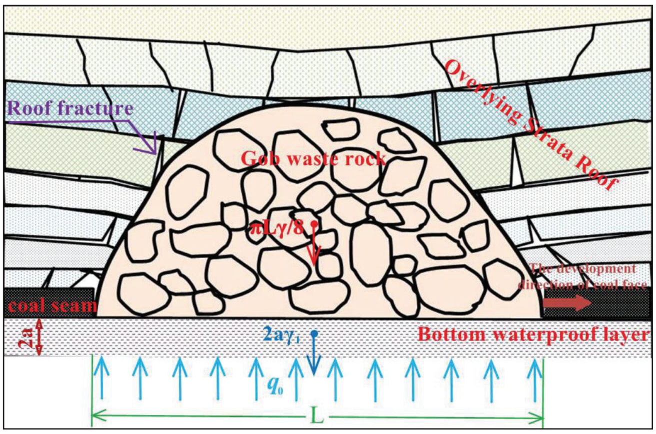


Fig.4: Sketch map of mechanical calculation of waste rock falling out in goaf

As can be seen from Fig. 4, the equivalent water pressure (q_e) in the water resisting layer of the coal seam floor can be given by the water pressure (q_0), the weight of the aquifer and the deadweight of the gangue in the mined out area:

$$q_e = q_0 - 2a \cdot \gamma_1 - \frac{\pi L \gamma}{8} \tag{9}$$

In the formula:

q_e – Equivalent water pressure of water resisting layer of coal seam floor, Mpa;

γ_1 – Equivalent severe of coal seam floor water resisting layer, kN/m^3 ;

γ – Equivalent gravity of mined out gangue in goaf, kN/m^3;

L – Distance of coal face advancing, m.

3.3 Solution of plastic zone height at the top of bottom diaphragm

When the equivalent water pressure under the bottom waterproof layer is q_e and the strike length of the work face is L, the formula (1)~(3) and (4)~(6) are replaced by type (7)~(8), and the maximum bending moment of the fixed beam is determined, so:

$$M_{\max} = q_e \cdot L^2 / 12 \tag{10}$$

The above formula can be turned into:

$$c^2 = 4\ ad \tag{11}$$

$$4a^3 + 12ad^2 - 3ac^2 - 3c^2 d + c^3 = v(a + d - c) \tag{12}$$

In the formula: $v = \frac{q_e \cdot L^2}{2\sigma_T}$,(b=1), σ_T – Tensile strength of rock at the top of the bottom diaphragm, Mpa.

Solutions, formulas (11) and formulas (12) can be derived:

$$c^3 - \left(3a + \frac{v}{4a}\right)c^2 + v \cdot c + 4a^3 - v \cdot a = 0 \tag{13}$$

The formula (13) is obviously a unary three equation, and the following formula (13) is solved:

Hypothesis:

$$\alpha = -\frac{\left(12a^2 - v\right)^2}{48a^2} \tag{14}$$

$$\beta = 2\left(a - \frac{v}{12a}\right)^3 \tag{15}$$

$$\Delta = \frac{\beta^2}{4} + \frac{\alpha^3}{27} \tag{16}$$

(1) If $\Delta > 0$, the formula (14) and formula (15) are substituted into formula (16), and the real root solution of formula (13) can be obtained by deducing:

$$c = \left(-\frac{\beta}{2} + \left(\frac{\beta^2}{4} + \frac{\alpha^3}{27}\right)^{\frac{1}{2}}\right)^{\frac{1}{3}} + \left(-\frac{\beta}{2} - \left(\frac{\beta^2}{4} + \frac{\alpha^3}{27}\right)^{\frac{1}{2}}\right)^{\frac{1}{3}} + \frac{12a^2 + v}{12a} \tag{17}$$

(2) If $\Delta = 0$, the formula (14) and formula (15) are substituted into formula (16), and the real root solution of formula (13) can be obtained by deducing:

$$c = \frac{q_e \times L^2}{12a \times \sigma_T} - a + \frac{v}{12a} \tag{18}$$

In formula (14) and formula (15) substitution (16), we can see that $\Delta = 0$, formula (18) is established.

In order to find the solution in formula (18), formulas (10) and $v = \frac{q_e \cdot L^2}{2\sigma_T}$ can be substituted into formula (18), and finally the height of plastic zone (c) caused by the pressure of confined water is obtained, so:

$$c = \frac{q_0 \cdot L^2}{8a \cdot \sigma_T} - \frac{L^2 \cdot \gamma_1}{4\sigma_T} - \frac{\pi L^3 \cdot \gamma}{64a \cdot \sigma_T} - a \tag{19}$$

Finally, the height of plastic zone (c) caused by the pressure of confined water is solved by MATLAB software.

4.0 Engineering background and example analysis

4.1 Engineering background

Chenghe mining area working face of Carboniferous Upper Taiyuan formation is the main coal bearing strata in shaft area, the coal bearing 2~5 layer is numbered 5, No.5, No.6, No.9 and No.10 coal seams. The total coal thickness is 6.52m, and the coal content coefficient is 16.56%. The coal seam can be two layers, namely No.5 and No.10 coal. The depth of No.5 coal is 173.64~420.04m, and the buried depth of No.10 coal is between 190.50 ~ 452.50m, No.5 coal is the main recoverable coal seam in the coal mine, and No.10 coal is the most unstable coal seam. The study was carried out in a coal seam of No.5 coal seam, the face is located in the eastern part of the two mining belt, down the south, near the mined out area, separated by the 30m coal pillar, and the northern part is the real area, and the coal seam is well developed inside the working face, and the thickness is about 1.5 to 4.0m, with an average thickness of 3.0m, there is a large area of thin coal belt in the east of the face, and the thickness of coal seam varies from 1.5 to 3.5m. The elevation of the ground is +644.2 to +680.7m, the elevation of the working face is +255 to +273m, the strike length of the working face is 910m, and the length of the slope is 114m. The overall performance of monocline in the south than in the north, and the change of dip angle of coal seam working face is large, in the range of 0^0~15^0. There are several faults to be exposed in tunnel driving, but most of them are located outside the stopping line, so the mining is less affected. According to the results of 3D seismic measurements, there may be a fault around 4m in the west of stopping face of the working face, which needs further investigation in the mining process. The roof of No.5 coal seam is composed of medium grained sandstone and other sandstone formations, and the bottom plate is quartzite and other sandstone formations. According to the known data, the hydrogeological condition of the face is complicated, and it belongs to the working face of pressure mining, The distance between the floor of No.5 coal seam and the top of Ordovician limestone is small, and exist the possibility of water inrush from Ordovician limestone.

4.2 Example analysis of mechanical model

According to Chenghe mining area No. 5 coal seam in a working face floor aquifuge thickness 2a = 22~26m and the related parameters are shown in Table 1.

We can obtain a variation curve that the plastic zone height (c) increases with the thickness of the bottom layer (2a); tensile strength at top of impermeable layer (σ_T); confined water pressure of Ordovician limestone (q_0), (Figs. 5~7).

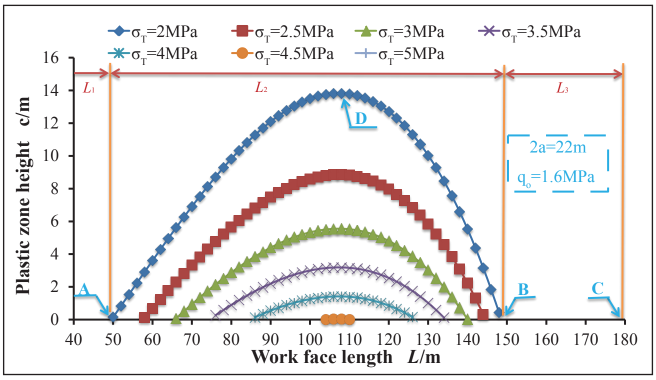


Fig.5: Relationship between the height of plastic zone (c) and the advancing length (L) of the working face under different tensile strength

The variation curves of the plastic zone height (c) versus the advancing length (L) of the working face under different tensile strength are given in Fig.5.

As can be seen from Fig. 5, the plastic zone height (c) and the advancing length (L) of the working face are nonlinearly distributed in the case of tensile strength (1) at the top of the impermeable layer at the bottom of the floor, the shape is an opening downward parabola, and the curve shape is similar under different tensile strength (T).

The generality of these curves lies in, with different coal mining working face cut mining began to a certain distance (L1), before A point, the stress produced by the Ordovician limestone confined water does not cause plastic damage to the top of the diaphragm, as the working face continues to advance to a certain distance (L1+L2), between the A~B points, the rock layer at the top of the bottom layer of the water resisting layer reaches the yield limit, and the plastic tensile failure depth (c) gradually increases. At this time, as the waste rock in the goaf increases gradually and the bottom plate is compacted, the plastic tensile failure depth (c) increases to the extreme point (D point), and the plastic tensile failure depth (c) gradually decreases to zero (B point). After that, as the working face continues to push forward to the C point, the pressure on the bottom of the floor is gradually compacted by the waste rock that has been received from the goaf, and the rock failure at the top of the bottom layer of the floor will no longer be caused by B~C points.

Therefore, the influence of the bottom plate confined water pressure on the floor water resisting layer under the condition of no structure is mainly focused on the initial pressure and the 1~5 periodic pressure period.

The difference between the curves is that the smaller the tensile strength (T) of the rock at the top of the bottom diaphragm is, the greater will be the peak point (D point) of the lower parabola for maximum plastic tensile failure (c_{max}). With the increase of tensile strength (σ_T) at the top of the rock, the maximum plastic tensile failure of each curve is smaller, When σ_T = 5MPa; q_0 = 1.6MPa; 2a = 22m, the corresponding plastic tensile failure extreme value (c_{max} = 0.03m) tends to taper out, after T > 5MPa, the pressure of the confined water will no longer cause the plastic damage of the floor. The mining failure of the floor is mainly caused by the rock pressure.

Therefore, the lithology of the first floor of the coal seam is softer (such as mudstone), the greater the plastic fracture of the bottom of the goaf near the center of the goaf due to confined water, and the mining failure depth of the floor

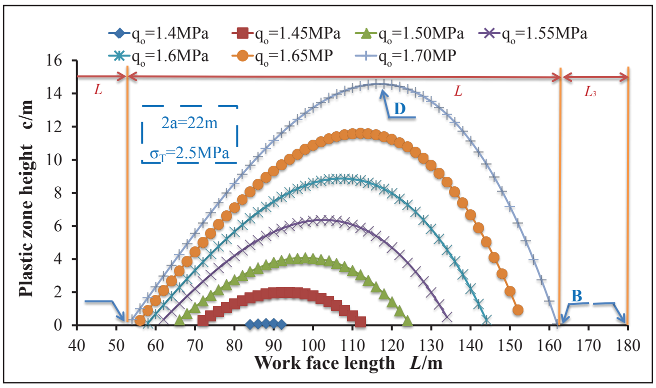


Fig.6: Relationship between the height of plastic zone (c) and the advancing length (L) of working face under different confined water pressure

Table 1 Physical and mechanical parameters of rock

Parameter name	Thickness of bottom water resisting layer 2a/m	Tensile strength of rock at the top of floor water resisting layer σ_T/MPa	Pressure of Ordovician confined water q_0/MPa	Work face length L/m	Equivalent floor water depth γ_1/kN/m^3	Equivalent gravity of mined out gangue in goaf γ/kN/m^3
Option 1	22	2~5	1.6	0~180	0.021	0.018
Option 2	22	2.5	1.4~1.7	0~180	0.021	0.018
Option 3	26~32	1.5	1.7	0~180	0.021	0.018

is the result of the combined action of the confined water pressure and the mine pressure; on the contrary, the harder the lithology of the first floor of the coal seam is (such as K2 limestone), the smaller will be the plastic failure of the floor near the center of the goaf due to confined water, and the influence of the mine pressure is mainly considered in the mining failure depth of the floor.

The variation curves of plastic zone height (c) versus the advancing length (L) of the working face under different confined water pressures are given in Fig.6.

It can be seen from the Fig.6, under different Ordovician confined water pressure (q_0) conditions, the height of plastic zone (c) and the advancing length (L) of the face are nonlinear, the shape of the parabola is asymmetric downward, and the curve shape is very similar under different pressure water pressure (q_0).

The generality of these curves lies in: Along with the coal mining face cut begins to advance to a certain distance from the opening (L_1), the corresponding A points in Fig.6, during the 0~L1, the pressure of water on the floor aquifuge the top strata has almost no effect, at this time, the failure depth and damage extent of the floor are mainly caused by the pressure of the mine. As the work continues to push forward to the B point, in the L1~L1+L2 interval, the rock bottom at the bottom of the goaf will appear tensile failure because the tensile stress reaches the yield limit, and the damage depth (c) increases with the increase of heading length, as a result of the increase of the caving height of the goaf, the amount of gangue increases, the failure depth (c) reached the plastic failure depth extreme point (c_{max}), then decreased with the advancing of the mining face, finally, the B point is tapered out. In this interval, a composite failure depth pattern is formed because the confined water pressure and the coupling action of the mining pressure are affected; then with the mining face advance to C, in the range of L1+L2~L1+L2+L3, the influence of the confined water pressure on the rock stratum at the top of the bottom layer of the bottom of the goaf is disappeared, at this time, the mining failure depth of the floor is still dominated by the mine pressure. Therefore, for the case of no structure, the influence of confined water of Ordovician limestone on the floor water resisting layer is mainly concentrated in the initial pressure and the period of previous several periodic weighting.

The difference between the curves is that, the greater the compressive pressure (q_0) of the Ordovician limestone at the bottom of the bottom of the bottom layer is, the greater the plastic zone height (c_{max}) of the rock will be at the top of the impermeable layer, so the greater the range of the lower parabola formed, the influence of the high pressure water pressure on the mining failure of the floor is not less than the influence of the mine pressure, and even plays a leading role, For example, when T = 2.5MPa, q_0 = 1.7MPa and 2a = 22m, the plastic tensile failure depth at the top of the water resisting rock floor caused by the confined water reaches 14.9m, and it is easy to induce the water inrush from the floor; when the bottom layer is weak stratum and the water layer is thinner, high pressure water pressure may lead to unstable floor rock formations, the plastic failure zone at the top of the water resisting layer is very likely to conduct the ascending zone of the confined water and form a strong channel to induce water inrush from the floor.

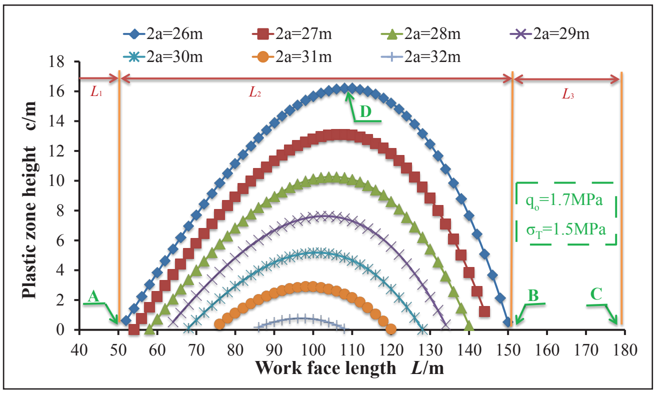


Fig.7: Relationship between the height of plastic zone (c) and the advancing length (L) of the working face under different thickness of the impermeable layer

In Fig.7, the variation curves of plastic zone height (c) with the advancing length of the working face (L) are given under different thickness of the impermeable layer.

It can be seen from the Fig.7, the plastic zone height (c) and the advancing length (L) of the working face are nonlinear distribution under the condition of different bottom layer water thickness (2a), the form is a downward opening parabola, and the curve shape is similar under thickness of water resisting layer of different floor (2a).

During the working face of cut mining from first cut to A, the extraction distance is L1, at this stage, there is no tensile failure zone at the top floor of the bottom waterproof layer, and It is shown that the confined water of Ordovician limestone does not affect the impermeable layer in the lower part of the aquifer, the mining failure at the bottom of this stage (0~L1 interval) is mainly caused by the pressure caused by the mining of the coal seam; with the face advancing to B point, mining distance (L1) ~ (L1+L2), the influence of the confined water on the plastic tensile failure at the top of the diaphragm increases first and then decreases with the increase of the mining face, then this curve taper out at B point. It is indicated that the influence of confined water on the water resisting layer of bottom plate disappears at B point, and the mining failure of the floor is affected by the coupling action of the confined water pressure and the mine pressure, the coupling problem should be considered simultaneously when calculating. As the work continues to push forward to the C point, at this stage, the "semicircle arch" formed at the top of the goaf increases gradually, and the amount of waste rock falling increases in the goaf, and the goaf floor is gradually compacted, at the same time, the mechanical effect of confined water pressure on the top of its diaphragm is less and less, and it will no longer cause rock burst at the top of the water-resisting layer. In this stage, the mining failure depth of the floor is again transformed into the mine pressure, and the mine pressure plays a dominant role. Therefore, in the case of no tectonic basement, the influence of the thickness of the bottom layer on the mining failure of the floor is mainly concentrated in the initial pressure and the duration of previous several periodic weighting.

The difference between the curves is that, the smaller the thickness of the bottom aquifer (2a) is, the more obvious will be the influence of the pressure of the confined water of the Ordovician limestone on the mining failure of the floor, and the peak point (D point) corresponding to the maximum plastic tensile failure maximum (c_{max}) of the lower parabolic curve is greater, the failure depth of the bottom plate is also greater; on the contrary, the larger of the bottom aquifer thickness (2a) is, the less will be influence of the pressure of the confined water of the Ordovician limestone on the mining failure of the floor, and the peak point (D point) corresponding to the maximum plastic tensile failure maximum (c_{max}) of the lower parabolic curve is smaller, the failure depth of the bottom plate is also smaller. When σ_T = 1.5MPa; q_0 = 1.7MPa; 2a = 32m, the plastic tensile failure limit (c_{max}) corresponding to the curve is only 0.76m. When the thickness of the bottom water resisting layer is greater than 32m, the pressure water at the bottom of the floor will no longer affect the rock mass at the top of the impervious floor of the floor. At this time, the influence of the mining failure of the floor is mainly controlled by the mine pressure. Therefore, for the same pressure under the water pressure, the water resisting floor having smaller thickness of floor aquifer is more prone to flooding accident, the coal mining must take measures to prevent the water inrush in advance to prevent flooding accident occurred.

5.0 Conclusions

After coal seam mining, under the coupling of the mining stress field and the seepage field, the original height guide belt develops upward to form the mining guide rising belt, the confined water have "jacking" effect to the top of the bottom waterproof layer, based on the mechanical model is established, to fill the gaps in the field, provides a useful supplement for later research on water inrush mechanism of floor and Chenghe mining area in North China coalfield, and it can play a reference role. The main conclusions are as follows:

(1) According to the mechanical method of the material, the additional stress field produced by the confined water pressure of the Ordovician limestone to the top of the water resisting layer of the floor is solved, at the same time, we consider the length of the inclined direction of coal seam mining, and sufficient mining is taken at the existing mining width, which can be treated as plane strain, and the water resisting layer of the bottom plate is approximately treated according to the fixed rectangle beam structure that subjected to vertical uniform water pressure, at the same time, the pressure of confined water, the weight of the water resisting layer and the deadweight of the gangue in the mined out area are regarded as the equivalent water pressure of the water resisting layer of the coal seam floor. Finally, the mechanical expression of plastic zone height at the top of the water resisting layer caused by the pressure of the confined water is given by mechanical derivation.

(2) Chenghe mining area No.5 coal mine as the engineering background, then substitutes the relevant mechanical parameters, using MATLAB mathematical software to solve the problem, The relationship between the height of the plastic zone and the advancing length of the working face under the influence of the tensile strength of rock at the top of each water resisting layer, the artesian pressure and the thickness of bottom water resisting layer is given respectively. The analysis shows that the less of the thickness of the bottom layer is, the bottom waterproof layer will be more likely of the water flooding accident. The softer the lithology of the first floor of the coal seam, the greater will be the plastic fracture of the bottom near the center of the goaf due to confined water; The greater the compressive water pressure in the bottom plate is, the greater will be the plastic tensile failure caused by the confined water, and the influence even exceeds the influence of the mine pressure on the mining failure of the floor. The floor is prone to flooding accident.

(3) High pressure water pressure may lead to unstable floor rock formations, the plastic failure zone at the top of the water resisting layer will probably lead to the ascending zone of the confined water and form a strong channel to induce water inrush from the floor. Therefore, under the high pressure water pressure, the grouting of the bottom slab should be carried out, and even the artificial fracture grouting reinforcement of the weathering crust rock body of the Ordovician peak Fengfeng formation should be carried out, to prevent the water inrush from the floor, and as far as possible to avoid property damage and casualties occurred.

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