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ANALYSIS OF WATER INSULATING EFFECT OF WATER-RESISTING KEY STRATA IN FLOOR

Mei-mei FENG, Xie-xing MIAO, Xian-biao MAO

China University of Mining & Technology, School of Sciences
Xuzhou, Jiangsu, CHINA
fm7906@126.com

ABSTRACT

An abundant supply of water in Ordovician limestone is a big hidden trouble in safety production in coal fields of north China. The water-burst from floor above the confined aquifer is closely related to the water insulating effect of the water-resisting strata. To predict exactly the failure and damnification depth of the key strata (KS) in floor and to analyze the insulating effect of the KS can provide a theoretic reference for the safe mining above the confined aquifer. Based on the concept of water-resisting key strata, the mechanics model of the key strata is established according to the structural characteristics and the mechanical properties of the floor rock layers of the working face in a particular coal mine. The characteristic of the deformation, the failure, and the water seepage is simulated by using the rock failure process analysis (RFPA2D), obtaining the corresponding distribution of stress, deformation, the flow volume and the developed depth of the fractures induced by mining. The results can be a good guidance in understanding the water insulating effect of the water-resisting strata and in effectively predicting the water-burst from floor.

Key words: water-burst from floor, water insulating effect, water-resisting key strata, water seepage, numerical simulation, mechanical analysis.

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INTRODUCTION

Water-burst hazard of Ordovician limestone from floor is the biggest threat to safety production in mines, which also is significance technical problems in mining above confined aquifer. Many scholars have carried out explorations of the mechanism of floor water-bursts in coal mines and obtained a large number of research results over the past four decades. Some methods and theories such as the burst coefficient method, the water-rock-stress method, the highly permeable passage theory, the major strata theory and the three zone theory below coal seams have been proposed to explain the mechanism of water-bursts and some prediction methods are given based on their corresponding theories [1-7]. The water-burst from floor above the confined aquifer is closely related to the water insulating effect of the water-resisting strata. The concept of water-resisting key strata has

been presented recently [8], which provides a new way to look at the problem of water-bursts from roofs. The main viewpoint supposes that, if the aquifer over the coal seam is above the structure key strata (SKS) or the aquifer below the coal seam is under the SKS, then the SKS has an insulating effect on condition that it remains intact after mining the coal. In this case, the SKS is surely a water-resisting stratum. On the other hand, if the SKS is broken, but the fractures are filled with soft rock layers, a water-burst passageway can't be formed. In that case, the SKS and the soft rock layers form the water-resisting key strata (WKS). This hypothesis explains comprehensively the load-bearing capacity and water-resisting function of the key strata (KS).This explanation has taken the soft rock layer into consideration in the study of water-resistance. So, based on the viewpoint that the instability of the water-resisting key strata induces water bursts, the behavior of water-bursts in deep mining is studied to predict roof water bursts and, accordingly, to take preventive measures, which is of much importance to ensure safe production in coal mines.
Based on the concept of water-resisting key strata, the mechanics model of the key strata is established according to the structural characteristics and the mechanical properties of the floor rock layers of the working face in a particular coal mine. The characteristic of the deformation, the failure, and the water seepage is simulated by using the rock failure process analysis (RFPA2D), obtaining the corresponding distribution of stress, deformation, the flow volume and the developed depth of the fractures induced by mining. The results can be a good guidance in understanding the water insulating effect of the water-resisting strata and in effectively predicting the water-burst from floor.

NUMERICAL CALCULATION MODEL OF WATER-RESISTING KEY STRATA IN FLOOR

The calculation model is established based on geologic condition of working face 21201 in Longgu mine, which with a length of 500m and a width of 150m (Figure 1.). There are 20 layers after incorporating strata with homothetic mechanical property, taking the weakness layer with little strength between heavy layers as joint. The numerical calculation adopted plane strain model with 500×150=75000 square elements. The extraction step is 10m and 10 steps together. In the model, the layer brightness represents the value of mechanics parameter (elastic modulus, compression strength, etc), the value is bigger and the color is more tasteless.

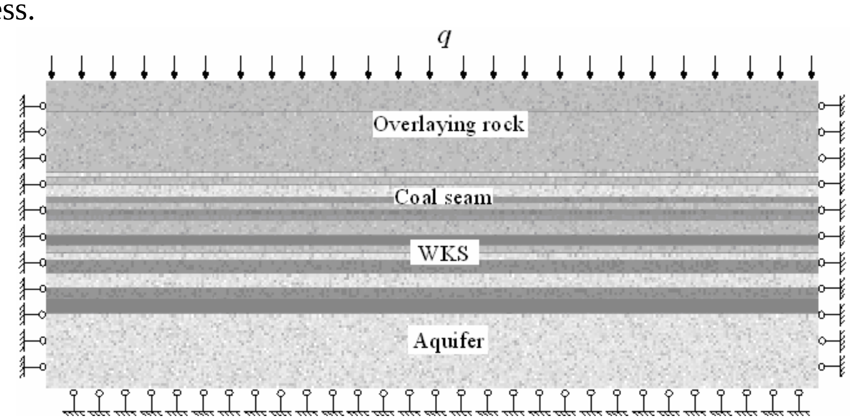


Figure 1.: Mechanics model of the water-resisting key strata in floor.

The Water-Resisting Key Strata in Floor contains 5 hard layers and 4 soft layers, which in the middle of the model, and the aggregate thickness of Water-Resisting Key Strata is 45m; There is a coal seam with 2m thick and 450m buried depth above the key strata and below is limestone aquifer; Both sides of the model as well as the bottom can simply be regarded as supporting restrictions and the upper boundary is subjected to equivalently distributed loads *q*, the gravity of the basement rock. If the given density of basement rock is 2500kg/m3, then *q*=11Mpa, the water head applied to lower aquifer is 450m. The specific mechanics parameters of every layer are in Table 1.

Table 1.: The rock mechanical parameters of the floor.

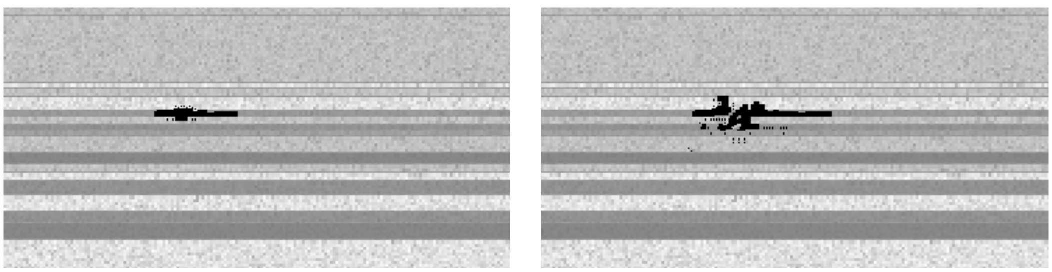
Rock Name	Thickness (m)	Elastic modulus *E* (GPa)	Compression/tensile strength	Poisson's ratio	Density $/10^{-5}$	Friction angle (°)	Porosity /%	Pore water pressure coeff.
Silty packsand	17	20.0	70/5	0.3	2.7	30	10	0.001
Siltstone	23	21.3	87/4.1	0.3	2.75	36	10	0.001
Limestone	2	30	100/6	0.35	2.6	40	15	0.5
Siltstone	3	21.3	87/4.1	0.3	2.75	36	10	0.001
Limestone	5	30	100/6	0.35	2.6	40	15	0.5
Coal	2	10	30/1.5	0.25	1.32	38	10	0.001
Siltstone	3	21.3	87/4.1	0.3	2.75	36	10	0.001
Mudstone	2	7.8	38/1.68	0.27	2.0	34	1	0.001
Siltstone	2	12	54.8/2.55	0.25	2.5	33	10.5	0.5
Silty packsand	6	21	70/5	0.3	2.7	30	10	0.001
Claystone	4	5	10/1	0.27	2.0	25	1	0.001
Siltstone	3	21.3	87/4.1	0.3	2.75	36	10	0.001
Limestone	3	30	100/6	0.35	2.6	40	15	0.5
Mudstone	5	7.8	38/1.68	0.27	2.0	34	1	0.001
Limestone	6	30	100/6	0.35	2.6	40	15	0.5
Mudstone	4	7.8	38/1.68	0.27	2.0	34	1	0.001
Allite	6	5	10/1	0.27	2.0	25	1	0.001
Limestone	24.5	30	100/6	0.35	2.6	40	15	0.5

ANALYSIS OF WATER INSULATING EFFECT OF WATER-RESISTING KEY STRATA IN FLOOR

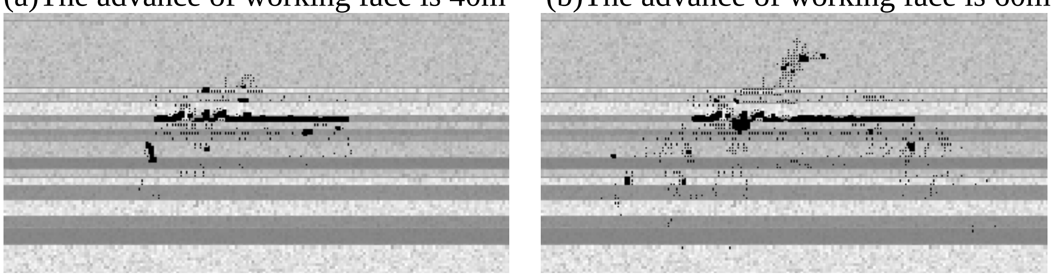
Affected by mining, the original balance of stress, deformation, pore pressure and the groundwater flow field in the surrounding rock of the working face are broken and redistributed. The water-resisting ability of CWKS can be evaluated from several aspects, such as damage of surrounding rock, deformation, stress of the surrounding rock and water flux.

Damage of surrounding rock

The water inrush from floor is resulted from the damage of WKS in floor above aquifer, and the damage degree is related to the safe production of coal face. Figure 2. shows the damage process of WKS in floor with the advance of workface. It is can be known that, the roof start falling as the advance length is 40m, When coal face reaches 60m, the collapse area increases, and the immediate floor damage clearly, which has spread to the top of WKS. When the coal face reaches 80m, the floor failure is much more clearly and the damage zones reaches 25m. Then the damage is more serious and the cracks develop excellently with the mining and reach 45m when the workface is 90m， now the two zones are connected, which formed the water channel, then, the high pressure water in aquifer afflux to working face along the two side crack channels in water resisting key strata in floor, thus water bursting.



(a)The advance of working face is 40m (b)The advance of working face is 60m

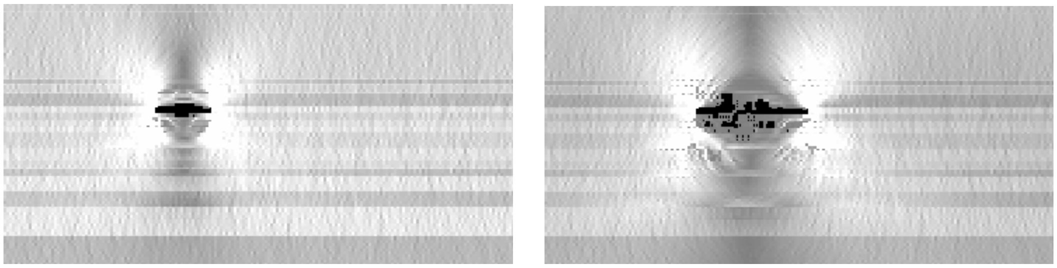


(c)The advance of working face is 80m (d)The advance of working face is 90m

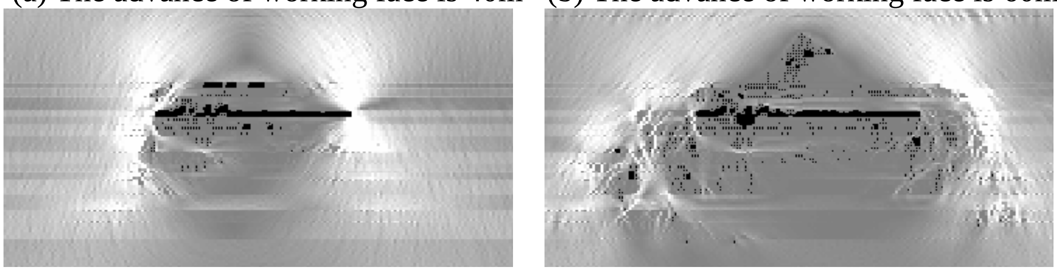
Figure 2.: Damage of surrounding rock.

Stress changing with the mining

The damage of WKS in floor is mainly due to the shear deformation. Figure 3 is the shear stress in different advances. It is can be known that, the shear stress of surrounding rock of the cut is larger in two sides above and down, which distribute symmetrically as the advance length is 40m, With the mining , the shear stress is much larger and larger, then the damage is more serious and the cracks at bottom of WKS develop excellently and a lot of new fracture grow rapidly with the mining and reach 45m when the workface is 90m， and the two zones are connected at last.



(a) The advance of working face is 40m (b) The advance of working face is 60m



(c) The advance of working face is 80m (d) The advance of working face is 90m

Figure 3.: Shear stress change with mining

Figure 4. is the curve of the shear stress immediate floor changes with the mining .The stress of the floor is increased with the longer of the L especially the shear stress ,the top value of the stress changes with the length L also and the value changes greatly with it, which is caused with the pressure of the two sides of the mining working face .The stress of roof and floor of the face decreasing with the mining, the shear stress occurs in the two sides rock mass ,and the range of shear stress increasing with the L so it is with its value.

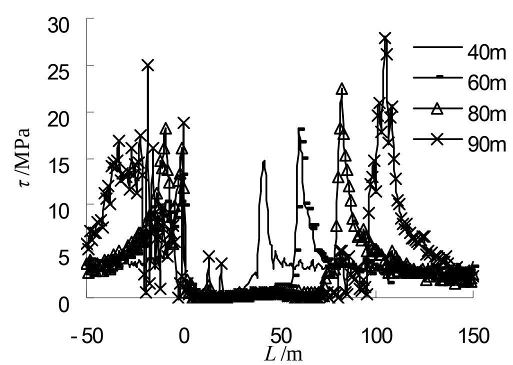


Figure 4.: Shear stress changing of the immediate floor with mining

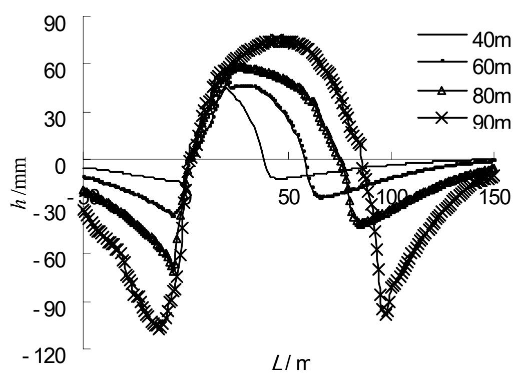


Figure 5.: The floor heave changing with mining

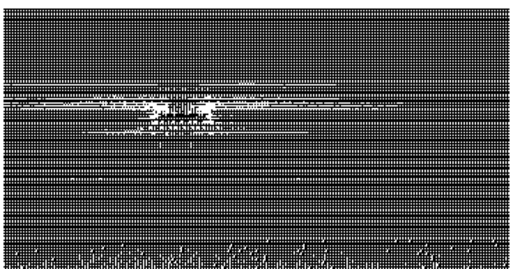
Changing Law of deformation with mining

Figure 5. is the curve of the floor heave changing with the mining, L stands for the distance between the initial working face, h stands for the floor heave. The two sides of the working face is under pressure and its displacement value is negative, and also the floor of working

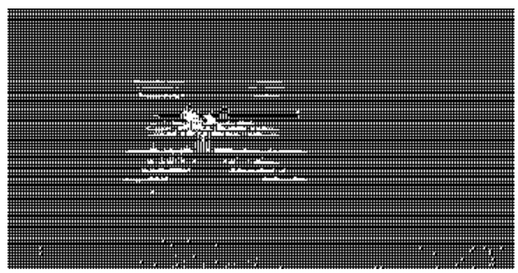
face occurs floor heave but the displacement is positive. The value of the floor heave increases with widen of the working face L as while the top value of the floor heave changes with it .

Changing Law of water flow with mining

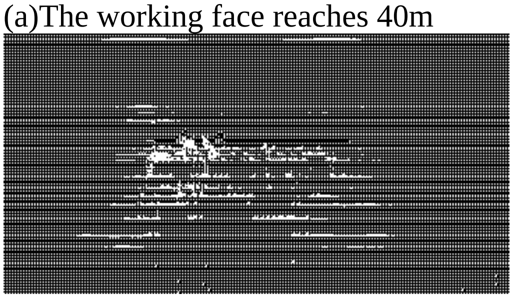
When coal face reaches 40m, the plastic collapse had been done to immediate floor and seepage filed of surrounding rock in working faces had been changed, but this change had not effect to the water-resisting key strata in floor; and it did not threaten to working face that a small amount of crack water around the goaf infiltrated to gob; When coal face reaches 60m, the crack water in water-resisting key strata influx to fractured zone resulted by shear failure; When coal face reaches 80m, the cracks in shear failure zones interrelated mutually, the volume of crack water was increased, but it was not connected with depth of damage zone by high pressure water in aquifer, the water-resisting key strata had a extent water-resisting ability, and this ability was very weak, it had been threatened by water bursting from floor; the key strata under floor was broken, the cracks were very developed, and the damage depth of floor reached 45m which caused by confined water and mining, and the two zones connected, which formed the water channel, then, the high pressure water in aquifer afflux to working face along the two side crack channels in water resisting key strata in floor, thus water bursting.



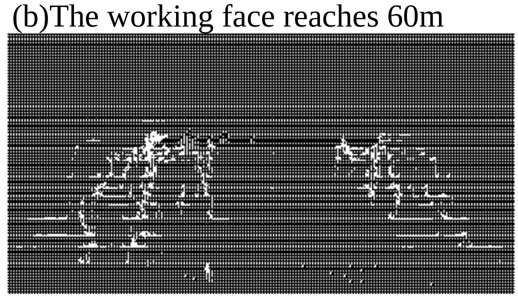
(a)The working face reaches 40m



(b)The working face reaches 60m



(c) The working face reaches 80m



(d) The working face reaches 90m

Figure 6.: water flow volume distribution of different extraction distances.

CONCLUSIONS

With the mining, the stress field and seepage field of water-resisting key strata in floor are disturbed, together with the water insulating effect. Through the above analysis, the following conclusions are drawn:

(1) The mining in working face breaks up the floor strata directly. With the advance of the working face, the destructiveness is increasing gradually, and spreading to the top of water-resisting key strata, which reduce the effective thickness of water-resisting key strata, and then the water-resisting ability is lowered.
(2) The stress distribution of surrounding rock in working faces is changed by the mining, especially, the combined effect of abutment pressure in two side of gob and water pressure in aquifer to the gob floor, which accelerating the floor heave and breakdown, then low the water-resisting ability.
(3) The mining influences the distribution of stress field as well as the seepage field, the longer advancing length, the much more influence to the seepage field, and the damage to water-resisting key strata by water pressure in aquifer is much serious.

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