NUMERICAL SIMULATION ON RESISTING SEEPAGE CAPACITY OF WATER RESISTING KEY STRATA IN MINED ROCK MASS

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ABSTRACT

In many Chinese mining areas, the prevention and cure of water disaster bring about great economy and environment burden, however, lack of water is an another serious problem over there. This study objective is to exploit both coal and water as resources together, and this is one of the important green mining technologies.

Many researches have been focused on structural key strata which play a main part in bearing the overlying load and controlling the failure structure of mined overlying rock mass. The definition of the water resisting key strata is given according to the analysis of the relationship between it and the structural key strata.

The water resisting key strata are almost composite rock strata, and its resisting seepage capacity is simulated by the code RFPA^{2D}. The plane strain model of water resisting key strata in mined rock mass is built. Five calculation schemes are designed based on the five constituting patterns of the composite rock strata.

The failure rules, fissures distribution and the seepage passages of the five schemes are obtained from the calculated results directly. After analyzing the seepage and distribution characters of the composite rock strata in each scheme, the capability of resisting seepage can be compared, and the best constituting pattern of the water resisting key strata is found.

The analysis results are beneficial to estimate whether the mined rock mass can form the water resisting key strata. It's very useful to guide the waterproof mining, and has been successfully applied in some mining areas.

Key words: water resisting key strata, seepage, mined rock mass, green mining.

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INTRODUCTION

In many Chinese mining areas, the prevention and cure of water disaster need plenty of manpower, money and material resources, which cause great economy and environment burden. However, lack of water is another serious problem over there, which becomes more and more serious. What’s more, less rain and more vaporization in Chinese droughty and semiarid region induce frailty of the environment, and the mining activity makes it more seriously. The research on waterproof theory and technology has certain innovative significance, and it is one of important contents of green mining technology[1-2].

The traditional key strata[3-5] are the structural key strata which play the main part in bearing the overlying load and controlling the structure of mined rock mass. The water resisting key strata of waterproof mining can be defined as: if the aquifer is above the structural key strata, and the structural key strata won’t break after mining, it is the water resisting key strata; If the structural key strata broken, but the water inrush passages won’t form because the cracks is filled by the soft strata [6], the structural key strata and the soft strata are combined to form composite water resisting key strata. Almost all water resisting key strata are made by composite strata.

MODEL AND SCHEMES OF NUMERICAL SIMULATION

Numerical simulation model of water resisting key strata in mined rock mass is shown in figure 1. Its horizontal length is 300m, vertical length is 200m, thickness of coal seam is 3m, and deepness of mining is 580m. The 400m upper rock strata are loaded by equivalent uniform distributed load, the bottom is fixed up, and the both sides are brought to bear horizontal displacement restriction. Folia are added between each rock stratum. This plane strain model is divided into 60000 foursquare cells. The gradation of grey represents the data of its mechanical parameters (such as elastic modulus, compressive strength), the brighter of the gradation, the greater of its value[7-8].

The second stratum is the aquifer, and 40m water resisting key strata are made by hard rock strata and soft ones. The 300m water head boundaries are set at both sides of the aquifer, the others are water resisting boundaries, and the water head is set zero at goaf.

The whole thickness of the water resisting strata is 40m, each hard rock stratum is 10m, and these remain unchanged. Changing the combination of the thickness of soft rock strata to form five different models of water resisting strata, and five corresponding calculation schemes are designed (shown in table 1). The mining process from left to right is simulated. Mining width is 100m, 100m pillars of both sides are reserved, and each mining step is 10m. The mechanical parameters of rock strata are shown in table 2.

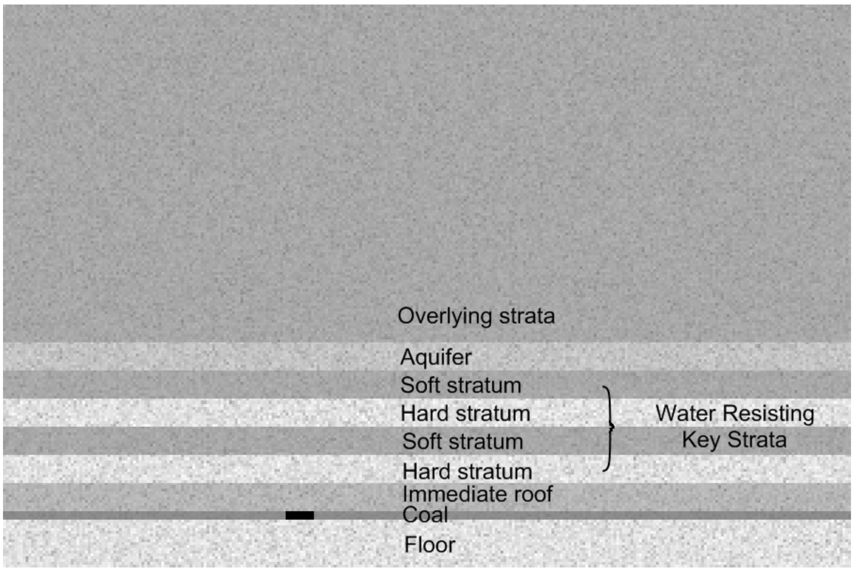


Figure 1.: Numerical Simulation Model of Water Resisting Key Strata in Mined Rock Mass.

Table 1.: 5 Schemes of Numerical Simulation.

		Scheme 1	**Scheme 2**	**Scheme 3**	**Scheme 4**	**Scheme 5**
Water Resisting Key Strata	Soft stratum (m)	0	5	10	15	20
	Hard stratum (m)	10	10	10	10	10
	Soft stratum (m)	20	15	10	5	0
	Hard stratum (m)	10	10	10	10	10

Table 2.: Mechanical Parameters of Each Stratum in Numerical Simulation Model.

Lithology	**Elastic Modulus (GPa)**	**Compression Strength (MPa)**	**Weight (10^{-5}N/mm^3)**	**Thickness (m)**	**Seepage coefficient**	**Porosity ratio**	**Poro-water pressure coefficient**
Overlying strata	20	20	2.0	120	0.001	0.01	0.01
Aquifer	30	25	2.3	10	1	0.1	0.1
Hard stratum	40	40	2.5		0.01	0.01	0.01
Soft stratum	20	20	2.2		0.001	0.01	0.01
Immediate roof	25	20	2.3	10	0.01	0.01	0.01
Coal	10	15	1.4	3	0.1	0.1	0.1
Floor	40	40	2.5	17	0.01	0.01	0.01

THE RULES OF MINED ROCK MASS FRACTURE AND CRACKS DISTRIBUTION

Fracture process of mined rock mass of scheme 1 is described in figure 2. Only five representative processes are chosen. When working face advanced to 10m, there are no obvious transmutation and fracture of upper rock strata. It can be seen from the figure that part of direct top is broken when the working face advanced to 30m. The two hard strata don't form composite structural key strata at 40m, the nether one which plays a second role in structural key strata failed first, and its transmutation and fracture bring the movement of the soft interbedded rock strata which are between the two hard strata, however, the upper one bears the most weight of all above rock strata, and its fracture induce the large-scale movement, including the aquifer over it.

Cracks distribution can be shown clearly in the figure. With advancement of the working face, the cracks develop upwards along the boundary of the stratum fracture, and they also develop very well in the middle of the stope and between rock strata. The cracks change continuously with mining, and preliminary ones may be closed.

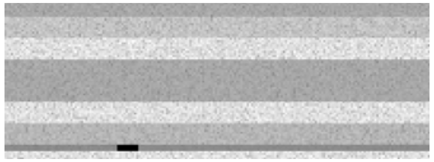
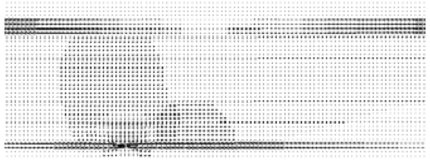
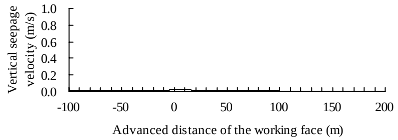
The process of mined rock mass fracturing and falling in scheme 2 is similar to the scheme 1. Because the soft interbedded rock strata that the second key stratum bears is thinner than scheme 1's, its fracture length should be smaller, and the function of strata bearing become more evident. There is a soft rock stratum whose thickness is 5m between the main key stratum and the aquifer.

In scheme 3 and 4, the two hard rock strata can be founded to keep transmutation synchronously, and composite structural key strata comes into being, whose structural bearing effect enhance evidently. Structural bearing effect of composite key strata in scheme 4 is better.

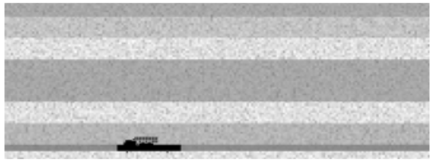
The two hard strata form super thick hard strata in scheme 5, which maintain the structural stability overlying strata while mining. Though cracks of mined rock mass develop obviously, the structure keeps integrative basically.

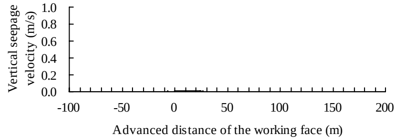
THE RULE OF SEEPAGE DISTRIBUTION

The seepage distribution rule of scheme 1 is shown in figure 3. Before the stope advanced to 30m, not many obvious penetrated cracks exist and the seepage distribution is basically equivalent in overlying strata, because the structural key strata still work. With advancement of the stope, the cracks continuously develop upwards and plenty of penetrated cracks form gradually. As soon as they finally connect with the aquifer, seepage will inevitably happen there with absolute advantage. Obviously, penetrated cracks mainly appear in the middle and two sides of the stope, which is coincident with the fracture rule of the mined rock mass former discussed.

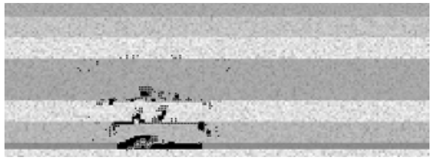
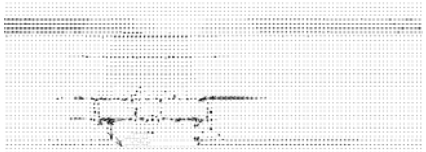
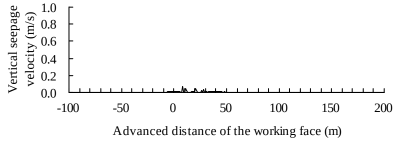




a) Working face advanced to 10m

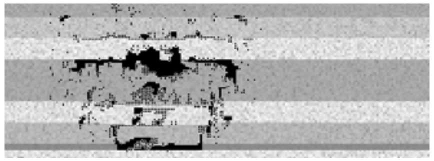


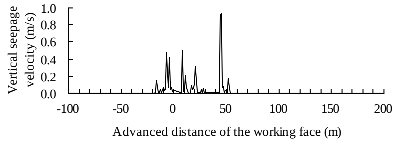


b) Working face advanced to 30m

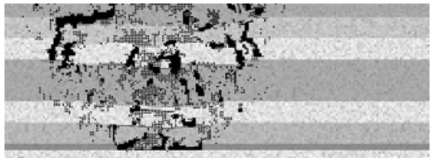




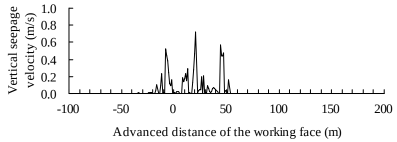
c) Working face advanced to 40m (one of iterative process)





d) Working face advanced to 40m (two of iterative process)





e) Working face advanced to 40m (three of iterative process)

Figure 2.: Fracture processes and cracks distribution (Scheme 1)

Figure 3.: Seepage vector distribution (Scheme 1)

Figure 4.: Vertical seepage velocity and its distribution (Scheme 1).

The structural key strata serve as water resisting key strata before broken, which can be seen from not only the beginning of stope advancing, but also the integrality of the composite structural key strata in scheme 4 and super thick structural key strata in scheme 5. Now the bed gaps between rock strata are the main seepage passages.

According to the definition of water resisting key strata, the main water resisting function is borne by the soft water resisting rock strata after the structural key strata broken and losing the water resisting capacity. The distribution and combination of soft rock strata decide the water resisting capacity of water resisting key strata.

Scheme 1's seepage quantity and distribution rule of water resisting key strata in mined rock mass are described in figure 4. With advancement of the stope, seepage quantity increases gradually at first, but when the main structural key strata broken, that is, penetrated cracks are connected with the aquifer, a sharp increase occurs with the maximum of 0.9m/s in front of the working face. It can be seen from figure 4(d) and 4(e) that the main seepage passages are concentrated in the back of goaf, the front of working face and the middle of the stope, where the main passages of roof water inrush practically.

The seepage quantity of scheme 2 also change abruptly after the structural key strata broken, the maximum is up to 0.7m/s, which also happen in front of the working face ,but the obvious seepage region is less than scheme 1. The two hard rock strata in scheme 3 form composite structural key strata, which promote the bearing pressure capacity of structure largely, and the maximal seepage quantity in front of the working face is only 0.2m/s before its broken, but up to 0.6m/s after its broken. The peak value of seepage quantity is up to 0.9m/s, which appeared in the back of the goaf.

The composite structural key strata work at all times in scheme 4, and the maximal seepage quantity in fore-and-aft area of goaf is up to 0.4m/s and 0.6m/s respectively. Compared to the scheme 4, the cracks of overlying strata develop not very well in scheme 5 because of the bearing function of the super thick structural key strata. The bed gaps between rock strata are the main seepage passages, and the maximal seepage quantity is 0.3m/s in the front of working face.

THE WATER RESISTING CAPACITY OF DIFFERENT WATER RESISTING KEY STRATA

The 5 former numerical simulation schemes, which are the rules of rock fracture, cracks distribution, seepage distribution, and seepage quantity of the water resisting key strata in different combination pattern, have been discussed detailedly. Total seepage quantities of the goaf in 5 schemes are listed to analyze and compare the water resisting capacity.

It is can be seen from the figure that water resisting capacity of water resisting key strata increases gradually from the scheme 1 to 5.

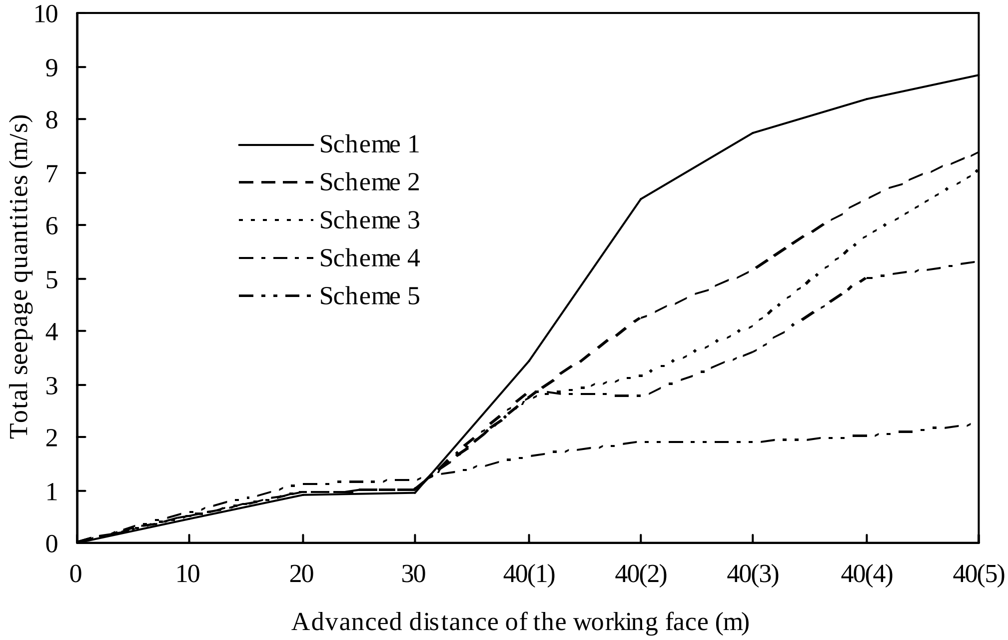


Figure 5.: Total Seepage Quantities on the Goaf of the 5 Schemes.

According to the former analysis, the two hard rock strata play the role of the main structural key stratum and the second one respectively without forming composite structural key strata. The structural key strata resist water before the main key strata broken, so it is the water resisting strata. After the fracture of the structural key strata, it is mainly the soft rock strata to resist water. In the scheme 2, after the fracture of the main key stratum, the 5m water resisting stratum between it and the aquifer filled part of cracks, reducing water inrush passages to resist seepage, so the capacity of resisting seepage is better than the scheme 1.

The hard rock strata in scheme 3 and 4 form composite structural key strata, whose bearing pressure capacity is promoted largely compared with the two former schemes, therefore, it will be better to resist water. According to the calculation, it can be found that the composite capacity of hard rock strata in the scheme 4 is better than the scheme 3's, furthermore, the structure basically keep unchanged with advancement of the stope, so the resisting seepage capacity of scheme 4 is better. However, in the scheme 3, the water resisting stratum between the key strata and the aquifer plays an important part in jamming seepage passages, so the resisting seepage capacity is better than the scheme 2's.

In the scheme 5, not only the super thick structural key strata keep structure steady, but also the super thick soft water resisting strata can fill the appeared cracks to form very nice water resisting key strata, so its water resisting capacity is the best. In fact it is very difficult to reach the condition, but it is useful to search for the appropriate water resisting key strata, that is, looking for favorable structural key strata and water resisting strata.

CONCLUSIONS

In this paper, the definition of water resisting key strata is given based on the structural key strata. According to the 5 designed numerical simulation schemes, the resisting seepage capacities of water resisting strata are analyzed.

(1) If the aquifer is above the structural key strata, and the structural key strata won't break after mining, it is the water resisting key strata; If the structural key strata broken, but the water inrush passages won't form because the cracks is filled by the soft strata, the structural key strata and the soft strata are combined to form composite water resisting key strata.

(2) The water resisting key strata can be made by optimizing the combination of structural key strata and water resisting strata. According to the analysis in this paper, the principle is to ensure the bearing pressure capacity of structural key strata first, secondly, enough thick water resisting strata should exist on top to ensure filling the cracks or even passages after the structural key strata broken.

(3) It can be achieved by manual control method to realize the excellent composite water resisting strata. The bearing pressure capacity of structural key strata can be increased according to designing mining technics and reinforcing the rock strata. After the structural key strata broken, seepage passages not only can be filled with inartificial soft water resisting strata, but also may be manual controlled, such as grouting, to form man-made water resisting key strata.

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