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Analysis of Interlayer Roof Structure and Breaking Model of Close-range Coal Seams

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Abstract. Based on the analysis of the breaking of the roof between the lower layers of the short distance thin coal seam group with different spacing, it is proposed that the roof of the short distance thin coal seam can be divided into three types according to its lithology and the development of joints and cracks: the unstable interlayer roof structure. Medium stable interlayer roof structure and stable interlayer roof structure. The breakage mode of roof under different roof structure is also analyzed in this paper. The 3DEC numerical simulation model of different interstory roof structures is established, and the displacement and stress distribution of the roof between different propulsive distances are analyzed. It is concluded that the unstable interstory roof structure is broken by loose body. The structure of medium stable interlayer roof is block broken and stabilized interlayer. The roof structure is plate broken.

Introduction

Due to the complexity and particularity of its occurrence conditions, coal seam groups in close distances will bring many uncertain factors and potential safety hazards to roadway excavation and mining of working face. The most important point in removing these uncertainties and safety hazards is to investigate the mechanism of the roof breaking during the mining process of coal seams in close range, so as to predict the occurrence of mine pressure, which is used for the coal mining process in the process of coal seams in close quarters. Roof control and mine safety production are important.

Interlayer roof structure classification

The three types of near-distance thin coal seam roofs are divided into three types according to their lithology and joint fissures development, namely: unstable interlayer roof structure, moderately stable interlayer roof structure. The stable roof structure is shown in Table 1 below. According to the three kinds of interlayer roof structures, the fracture patterns are divided into three types: unstable interlaminar roof structure is broken, interim stable roof structure is broken, and stable interlayer roof structure is plate fracture. In the following, we will analyze the mechanism of the three types of interlayer roof breaking.

Table 1 Coal seam direct top classification index

category	category 1 unstable roof	category 2 medium stable roof	category 3 stable roof
lithology and characteristic structure	mudstone, mud shale, joint fissure development or soft	dense mudstone, siltstone, sandy mudstone, joint fissures are not developed	sandstone, limestone, joint cracks

Unstable interlaminar roof breaking

This kind of interlayer roof structure refers to the interlayer roof with thickness of 4m or less, lithology mostly mudstone or shale, soft lithology, low strength, and well-developed joint fractures. Its model is shown in Fig.1.

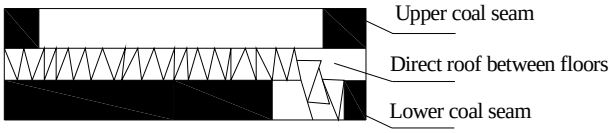
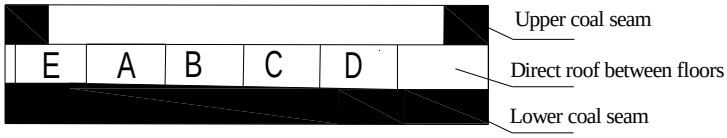


Fig.1 Fragmentation model

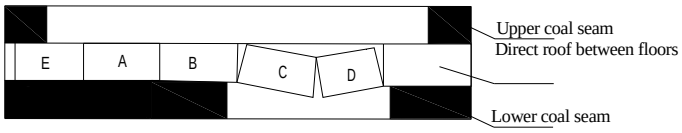
Such interlayer roofs are broken due to their own instability, and affected by the mining of the upper coal seam, the cracks in the interlayers of the interlayers are further expanded to cracks, thereby forming a bulk structure as shown in fig.1,The strength of the structure is small, and the direct roof between the layers will fall with the mining of the lower coal seam, and the falling mode is mainly the slip between the bulk blocks.This paper refers to this method of breaking as a broken body. In this type of interlayer,the mine pressure appears very weak during the mining process of the lower coal seam.

Moderately stable interlayer roof block breaks

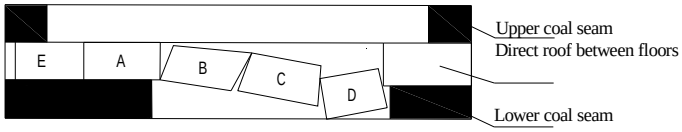
This kind of interlayer roof structure refers to a thickness between 4m and 8m.The lithology is mostly dense mudstone,siltstone,sandy mudstone,rock mass has a certain strength,and the joint roof is not developed.After being affected by mining of the upper coal seam, the direct roof between the layers is divided into individual blocks. As shown in Fig.2(a) below



(a) When the lower coal seam is not mined



(b) First break



(c) Secondary break

Fig.2 Block breaking model

After this kind of interlayer roof structure is affected by the mining of the upper coal seam, the direct roof between the layers is divided into various blocks.The damage of the interlayer roof is manifested as the collapse of the block during the mining process of the lower coal seam, which is called block breaking.When the lower coal seam is recovered to a certain distance, the top face of the coal mining face is broken for the first time. As shown in Fig.2(b),the middle blocks of the gob area C and D begin to slide down to form a occlusal support structure.When the coal seam working

face continues to move forward until block B is completely exposed, secondary fracture occurs directly at the top of the mining face as shown in Figure 2(c).At this point,the D block is completely degraded, and the B block is under a common support of the A block and the C block, and is in a relatively balanced state. The fall of this type of roof is so cyclical. Although the interlayer structure of such a layer has a certain supporting capacity, due to the existence of joint cracks, the working face of the lower coal seam will have a certain ore pressure during the mining process, but it is not severe.

Stable roof plate break

This kind of interlayer roof structure refers to an interlayer roof with a thickness of 8m or more, lithology mostly sandstone, tight sandstone and limestone, large rock mass strength, and basically no joints or cracks. Because of the large rock mass strength, this kind of interlayer roof structure is less affected by the mining of the upper coal seam. Therefore, this type of roof can be considered as a plate structure, as shown in Figure 3 below.

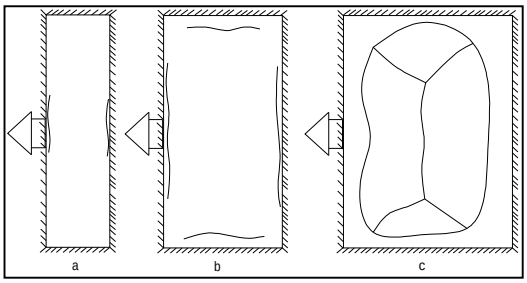


Fig.3 Plate breakage model

This type of interlayer roof structure is to study the mining working face directly as a thin plate. The collapse condition can be seen from Figure 3. As the working face of the lower coal seam advances, the fracture will be formed in the middle of the long side. As shown in Fig. 3(a), a crack is then formed in the middle of the short side, as shown in Fig. 3(b). As the lower coal seam continues to move forward, the cracks in the lower coal seam pass through and form an "O" shape. The moment will reach its maximum value, and then exceed the strength limit to form a fracture, and finally form an “X” shape failure, as shown in Fig. 3(c). Since the direct top rock layer in this kind of interlayer roof structure has a certain strength, it will form a certain degree. The support structure forms a cyclical pressure phenomenon, so its mine pressure appears more clearly.

Model establishment

According to the geological data provided by the Guandi Coal Mine, the model is 120m×40m×36m. The simulated rock formation includes 9 layers of 36m high rock layers including No. 2, No. 3 and No. 4 coal. The simulated rock layers are similar to the similar simulations. The basic parameters of each rock layer are shown in Table 2.

Table 2 Physical and mechanical parameters of coal and rock block

lithology	density kg/m^3	bulk modulus /10^{10}Pa	shear modulus /10^{10}Pa	cohesion /MPa	internal friction angle /°	tensile strength /MPa
medium sandstone	2.86	6.00	5.44	6.42	50	12.20
fine sand	2.64	5.67	4.76	5.54	45	10.43
sandy shale	2.57	3.21	1.98	1.26	30	108
coal	1.35	0.27	0.12	1.34	30	2.06

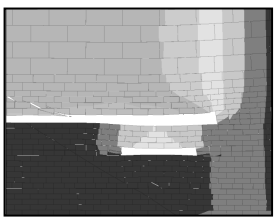
Numerical simulation results analysis

Simulated failure of unstable interlayer loose roof

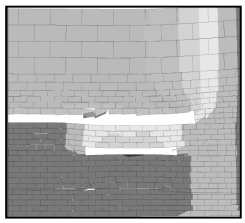
As can be seen from fig.4 (1), under the unstable interlayer roof structure, because the rock layers between the two seams are weak, there is not enough supporting capacity, After excavation of 5 m, the roof of No. 3 coal seam will appear "arch" shape subsidence and deformation, and the maximum deformation is about 0.75 m at the bottom of the roof edge of the coal seam.

From fig.4(2)(3)(4) with the continuous advance of the working face, the subsidence phenomenon of coal seam roof continues to increase, and the area of sinking "arch" continues to increase.

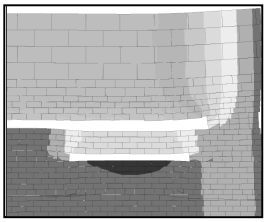
Based on the above analysis and combined with the classification of the roof structure, it can be concluded that for the unstable interlayer roof structure, the direct roof between the layers is weak shale and the joint fracture is developed, and the mining effect of the upper coal seam is added.



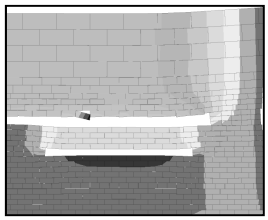
(1) Propulsion 5m



(2) Propulsion10m



(3) Propulsion 15m



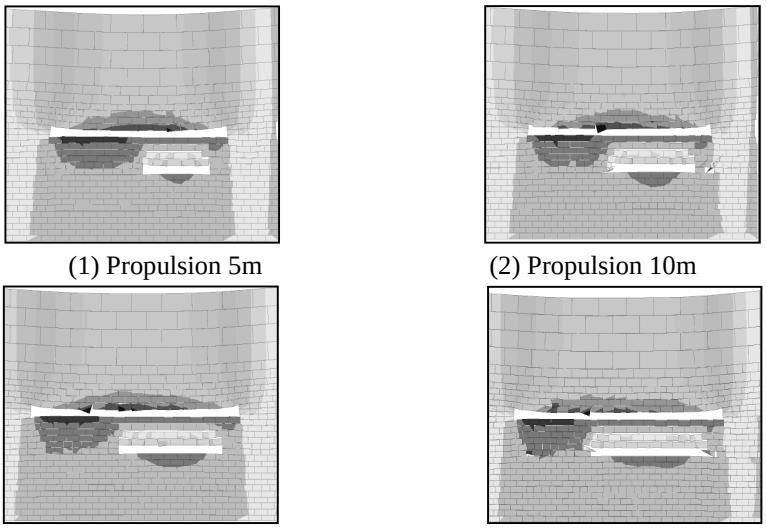
(4) Propulsion 20m

Fig.4 Roof displacement cloud map of 3 coal working face with different advancing distance

failure simulation of moderately stable interlaminar roof block

From fig.5 it can be concluded that the collapse of the interlayer roof layer changes obviously from 4m shale to 4 m sandy foliite under the medium stable interlayer roof structure. Fig.5(1) after the excavation of the coal face for 10 m, the roof of the No.3 coal seam face appears obvious "arch" shape subsidence and deformation, the maximum subsidence is about 0.5m,However, compared with the unstable interstory roof structure condition.

From the view of fig.5(2)(3)(4) with the continuous advance of the working face, the area of "arch" of subsidence also increases with the continuous subsidence of coal seam roof.



(1) Propulsion 5m (2) Propulsion 10m

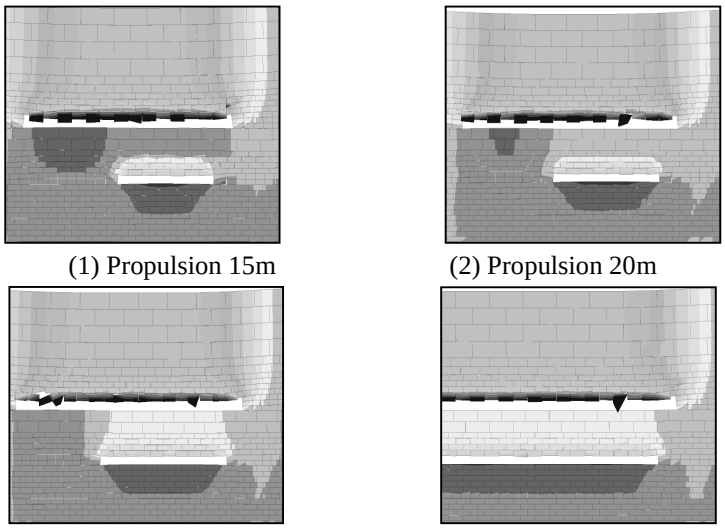
(3) Propulsion 15m (4) Propulsion 20m

Fig.5 Cloud Map of Roof distance displacement in different working face of No. 3 Coal Mining face

It can be concluded that in the mining process of medium stable interlayer roof structure, this kind of roof structure has certain supporting ability, and its direct roof collapse does not follow the mining process, which is different from that of unstable interlayer roof structure.

Slab breakage simulation of stable interstory roof structure

It can be seen from fig.6 that under the condition of stable interlayer roof structure, there is a relatively hard rock layer between the upper and lower coal seams, which makes the coal roof of No. 3 coal seam have certain bearing capacity. From 6(1),it can be concluded that when the working face advances to 15m, the roof of No.3 coal seam in the lower coal seam appears a certain amount of subsidence, and there is a sinking "arch",The average subsidence of the direct roof above the working face is about 0.1m, and the maximum subsidence is about 0.15m.At the same time you can see the sinking The arch is located in the direct top strata and does not extend to the direct top strata.



(1) Propulsion 15m (2) Propulsion 20m

(3) Propulsion 25m (4) Propulsion 45m

Fig.6 Cloud Map of Roof distance displacement of different working faces in No.3 Coal Mining area

It can be concluded from 6(2) that as the working face continues to move forward for 20 m, the roof subsidence of the lower coal face continues to increase but does not show a drastic increase, and the direct roof continues to sink.the roof subsidence of the working face increases significantly from fig.6(3) when it is pushed forward for 25m. The maximum value of the direct roof subsidence over the working face is 1.0 m,so it can be considered that the first fracture of the direct roof occurs in

the working face when mining to 25m, which leads to the sudden increase of the roof subsidence.
It can be concluded that for the stable interlayer roof structure,in the mining process of the lower coal seam, the hard rock layer in its direct roof forms a structure similar to the thin plate,so in the mining process,the phenomenon of initial collapse and periodic collapse can occur.

Conclusion

(1) According to the lithology and the development of joint and fissure, there are three kinds of roof in short distance thin coal seam. According to the three kinds of interlayer roof structure, the breakage form is divided into three types, that is, the unstable interlayer roof structure is broken apart. The structure of medium stable interlayer roof is broken by block, and the structure of stable interlayer roof is broken by plate.
(2) the 3DEC numerical simulation model of coal seam mining under three different roof structures is established. The roof subsidence and pressure of the working face under different propulsive distances are analyzed, and the broken forms of the three models are verified.

Acknowledgements

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