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Development Characteristics of Roof Separation of Coal Seam Based on UDEC

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ABSTRACT: The formation, development and fracture of the separation space of the coal seam roof are accompanied by the formation of water hazard of the separation layer of the working face. Using UDEC numerical simulation method, taking a certain working face of a mine as the research object, the dynamic development process of the separation space of overburden of the coal seam roof during the mining process of the working face is analyzed, and the separation development position and three-zone height are determined, which provides theoretical basis for the formation mechanism of water hazard of the separation layer of the mine.

KEYWORDS: Coal mine; Roof separation; UDEC； Three belt theory; Ionospheric flood

I. INTRODUCTION

Influenced by objective factors such as geological conditions and coal mining history, China's coal mine hydrogeological conditions are extremely complex, and the area and type of water threat, as well as the severity of water threat, are rare in the world. Surface water, old air water, alluvium water, floor water and other types of water hazards are complete.

Most of China's coal resources are buried deep underground. After decades of mining, there are few shallow coal left. With the increase of mining depth, the water inrush disaster caused by overburden separation has gradually become a common disaster. The geological condition of overburden separation is that the lithology of the two adjacent strata is quite different, the hardness of the upper strata is relatively large, and the hardness of the lower strata is relatively different from that of the upper strata. For example, in the roof overburden, there are hard medium-coarse sandstone on the top and soft mudstone on the bottom. If it is disturbed by mining, it is easy to produce separation. If the overburden separation layer breaks, it may cause surface subsidence. If there is water supply near the separation space, such as fissure water, river supply, etc., with the advance of the mining face, the separation fracture will suddenly release the water contained in it, which is called separation water disaster. The separated layer water has the characteristics of large instantaneous quantity, short duration, relatively concealed and strong burst. The water disaster in the separation layer poses a great threat to the construction and safety of the mine. On April 25, the water flooding accident in Tongchuan Coal Mine caused 11 deaths and flooded the working area. On May 13, 2016, water inrush occurred several times in 1306 working face of Guojiahe Coal Mine in Yonglong, Shaanxi, with water inrush reaching 1000m ³/ h. As a result, the production of the working face is stopped and the ventilation is interrupted. Therefore, relevant research is needed to provide certain opinions and theoretical guidance for the safe construction of the mine.

Wang Lei, Wang Shuming, Chen Xing, etc. used UDEC software to simulate the formation and development of the separation space in Wenjiapo Coal Mine, and gave corresponding control measures. Xing Pengfei, Sun Yuhao, Wu Yahua and others used UDEC to simulate the roof condition of auxiliary haulage roadway in Tashan Coal Mine, Shanxi Province, and drew the conclusion that the roadway buried depth, roadway width, and the nature of surrounding rock are the main factors affecting the roof separation of the roadway along the bottom of the extra-thick coal seam.

II. GENERAL SITUATION OF COAL MINE

Pore Diving - confined water aquifer group

From top to bottom, the aquifer is composed of five aquifers from Quaternary Holocene to Neogene in the Cenozoic, with burial depths of 0~40m, 40~100m, 100~150m, 150~300m and more than 300m respectively.The lithology of the aquifer rock group is sandy soil. Due to the complex structure of loose sediments, poor continuity of sand distribution along the horizontal direction, and often occurring as lenticular bodies, the interlaced results of various aquifers (aquifers) will inevitably lead to great differences between the lithology, thickness, and water inflow of each water-bearing rock group.Quaternary Holocene (buried depth 0~40m) pore aquifer contains pore phreatic water, and other aquifers contain confined water.The Quaternary Holocene and the first section of the lower Neogene strata are the most developed, with strong water yield, and the unit water inflow is 0.0011~6.74L/s·m.The buried depth of groundwater is 0.5~4.0m, and the west and southwest of the coalfield are artesian areas with good water abundance. The hydrochemical type of shallow phreatic water is HCO_3－Ca;In the middle and deep layers, the salinity of confined water and the content of sulfate ions have increased, and the hydrochemical type is HCO_3－Na·Mg.

Fracture confined water aquifer group

It consists of Permian Shihezi Formation, Shanxi Formation medium-fine sandstone and Yanshanian magmatic rocks. Sandstone fissures are unevenly developed and water-rich differences are obvious. Cracks in crude sandstone and K5 sandstone of Upper Shihezi Formation K6 are relatively well developed with unit water inflow of 0.121-0.627 L/s·m. Cracks in roof sandstone of lower Shihezi Formation III coal seam and Shanxi Formation II coal seam are generally undeveloped with unit water inflow less than 0.1 L/s.m and weak water-rich, mainly with static reserves. The water inflow per unit of fractured water in magmatic rocks is less than 0.003 L/s·m and the water content is poor, which does not constitute the main water source for filling water during coal seam mining.

Karst fissure confined water aquifer group

Carbonate aquifer is composed of Carboniferous Taiyuan Formation and Ordovician karst fissure aquifer.

The water-bearing rock group of Taiyuan Formation consists of 9-13 layers of limestone with a limestone thickness of 40-50m, of which L2, L9 and L11 limestone deposits are stable, karst fissures are developed, the development degree and permeability of karst fissures are gradually weakened along the vertical direction to the deep part, with inhomogeneous anisotropy, water inflow per unit of 0.000432-5.551L/s·m, water-rich weak-very strong development, fast water pressure transfer, 2-3g/L mineralization, water chemical type:SO_4-Na·Ca,SO_4-Na·Mg, SO_4-Ca·Na, etc.

The lithology of Ordovician carbonate aquifer is composed of limestone and dolomitic limestone. The exposed area of carbonate rock has a unit water inflow of 5~20 L/s·m and strong water yield; The hydrochemical type is HCO_3－Ca·Mg. The development of karst fissures in the buried area is extremely uneven, resulting in extremely uneven water yield. The unit water inflow is 0.00843 ～ 3.152L/s·m. Compared with the exposed area, the water yield is relatively weak, and the hydrochemical type is SO_4 － Ca·Mg; Controlled by the structure, the shallow burial area of Ordovician carbonate rocks in the south of Yongcheng Anticline (near Dawangzhuang Iron Mine) has a strong water yield. Controlled by the development law of karst fissures and recharge conditions, the water abundance in the deep buried area is relatively weak.

III. THEORETICAL ANALYSIS

When the coal seam is not mined, the stress state of the overburden rock is in a relatively balanced and stable state. Once mining starts, strata within a certain range of coal seams will be disturbed, resulting in stress redistribution. With the continuous development of mining, the scope of goaf increases continuously, and the more unbalanced the stress of overburden rock in coal seam, some destructive movement phenomena will occur in overburden rock of coal seam, which generally has four stages:

Deformation stage: With the increase of goaf, the span of overburden rock mass increases continuously. Overburden exposed rock mass can be regarded as a single-span static fixed beam. Under the action of uniformly distributed forces, the rock mass will undergo downward deformation with little degree of deformation, which is within the bearing range of rock mass.

Separation stage: In this stage, the deformation of the overburden rock mass is still within the bearing range of the rock mass, but the deflection deformation of different strata is different due to the different lithology of the strata. With the advance of the working surface, there will be a gap between the strata and the strata, i.e. the separation layer.

Fracture stage: with the increase of the goaf, the separation layer also increases. The separation layer decreases continuously due to the increase of span and the tensile stress between the upper rock mass, which leads to the acceleration of deformation and rapid formation. When the tensile strength of the rock mass exceeds, the fracture will occur. The fracture mostly occurs in the middle and both ends of the rock mass.

Collapse stage: At the beginning of coal mining, some rock falls may occur at the top of the goaf. However, when the goaf gradually increases to the breakage of the separation layer, the direct roof will collapse and the broken rock mass will irregularly fill the entire goaf to form a new stable structure, which is a cycle of destroying and moving of the overburden rock of the coal layer.

IV. NUMERICAL SIMULATION

UDEC is a two-dimensional software, which reflects well the laws of overlying strata and surface displacement affected by the mining of working face in this paper, and can quantitatively analyze the stress, strain and displacement at any point, as well as monitor the whole process. Visual images and data expressions can be described more concisely and clearly.

A. Model establishment

The content of this paper is the water inrush mechanism of coal mine roof, and the research object is one of the working faces. Therefore, the constitutive model of UDEC block is selected as the Coulomer model. It is assumed that the direction of x-axis is the direction of strata strike and the direction of Y is the depth of strata buried. The direction of coal seam mining is 200 m along the direction of coal seam. Geometric models with a length of 460 m in X direction and 200 m in Y direction are established. Geometric models and grid partition are shown in the following drawings, which are divided into 13 strata. There are 2 strata under the coal seam and 10 strata above the coal seam. The thickness of exploited coal seam is 3.5m. The displacements on the left and right boundary and the bottom boundary of the model are restrained, with the free boundary at the top.

In order to simplify the study model, the vertical stress load is applied to the upper part of the model without affecting the study of the coal seam area. The calculation formula is:

$$\sigma_z = \gamma H$$

Formula γ is the volumetric force of the overburden layer (KN/m)^3）； H is the top buried depth (m) of the model.

The buried depth at the top of the model is 533.5m and σ_z is 13.5MPa, so the uniform load applied at the top of the model is 13.5MPa.

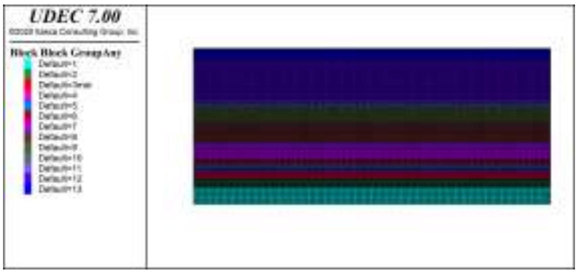
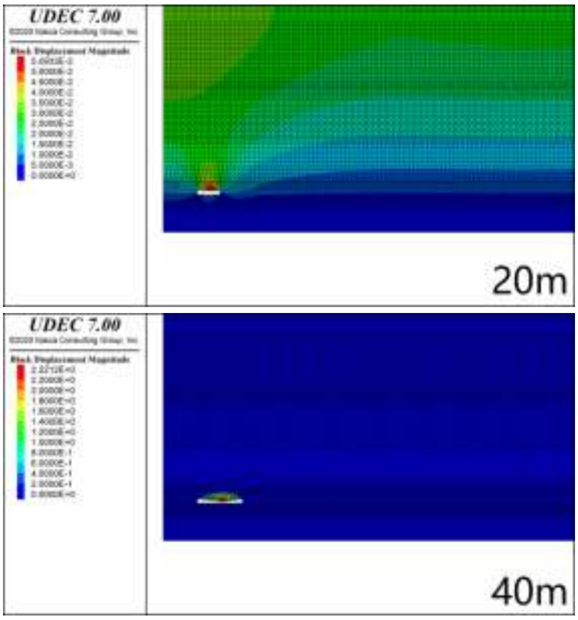


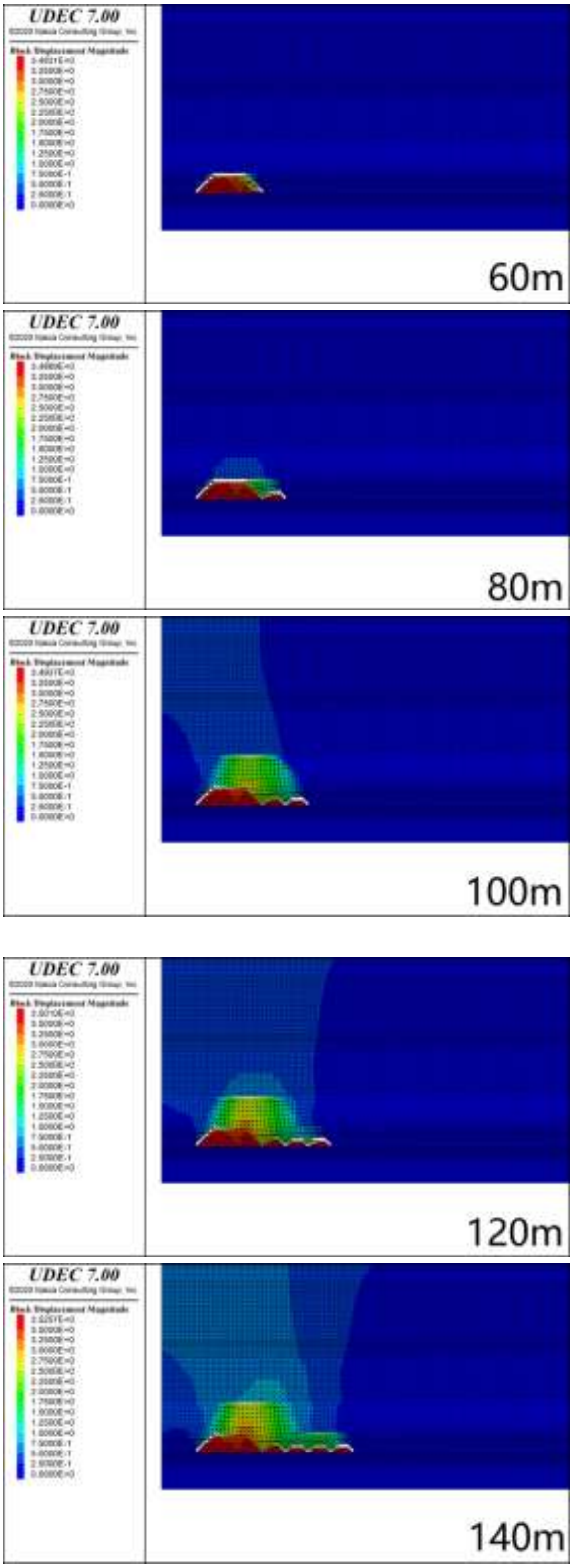
Fig 1. Numerical model diagram

B. Data analysis

According to the "Key Stratum Theory" put forward by Academician Qian Minggao, the strata which play a decisive role in the whole or part of rock mass activities become the key strata, the former is the key strata for rock movement and the latter is the sub-key strata. According to the relevant characteristics of key strata, combined with the analysis of Figure 7-3 and Figure 7-4, when the coal layer is excavated to 20m, the overburden rock of the coal layer deforms but has not yet fallen. When the coal seam is excavated to 40m, the mudstone at the top of the coal seam begins to deform and generate small fissures. The earlier the fissures develop, the larger the fissure space nearest to the coal seam has become from the initial stage to close gradually after reaching the maximum value that the rock at the top of the fissure space can bear. When the coal seam is excavated to 60m, the overburden rock mass of the coal seam partially breaks and falls, up to 14.5m away from the top of the coal seam. With the fracture of the upper mudstone layer of the coal seam, the upper mudstone layer also breaks. When the coal seam is excavated to 80m, the overburden in the upper part of the coal seam continues to fracture and fall within the range of 14.5m. When the coal seam is excavated to 100m, the overburden strata of the coal seam continue to collapse at 14.5m. Separation and fissures occur within the range of 14.5m to 41.5m from the top of the coal seam, and the 4th strata of the coal seam from bottom to top bend and sink with the 3rd stratum, but do not break. Separation occurs in the 4th and 5th strata, indicating that the 3rd stratum is a sub-key layer. When the coal seam is excavated to 120m, there is rock collapse within 8.5m from the top of the coal seam, and there is a trend of separation between the 2nd and 3rd layers. The separation space between the 4th and 5th layers becomes larger. When the coal seam is excavated to 140 m, there is rock collapse within 8.5 m from the top of the coal seam. Separation occurs between the 2nd and 3rd layers, and there is little change between the 4th and 5th layers, indicating that the separation has reached its maximum level. When the coal seam is excavated to 160m, there is rock collapse within 8.5m from the top of the coal seam, and the two separation layers between the 2nd, 3rd and 4th and 5th layers become smaller. When the coal seam is excavated to 180m, the separation occurs between the 2nd, 3rd, 4th and 5th layers above, and the separation space is small, which is already the closing stage. When the coal seam is excavated to 200 m, the separation space is also reduced except for rock collapse within 8.5 m of the top of the coal seam.

From the above results analysis, during the excavation of the coal seam, no separation layer occurs in the 6th layer and above of the top of the coal seam. With the synchronization of the 5th layer, the 5th layer of the upper coal seam is the main key layer and the 3rd layer is the sub-key layer. Falling zone height 11 m.





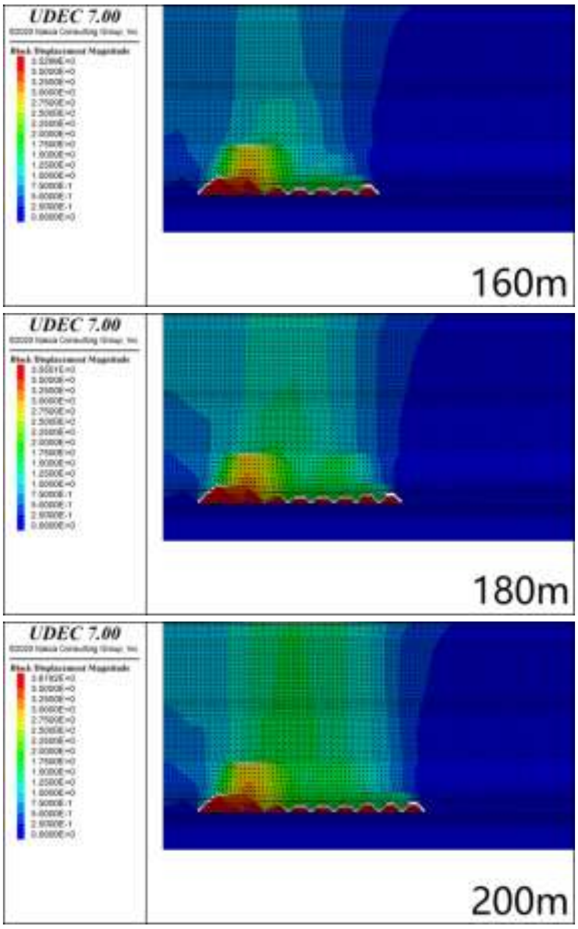


Fig 2. Vertical displacement nephogram change caused by UDEC simulation mining

CONCLUSIONS

Through numerical simulation and analysis of working face, the following conclusions are drawn:

(1) According to the occurrence of the separation layer, the 5th layer in the upper part of the coal seam is the main key layer and the 3rd layer is the sub-key layer. Because each mining span is 20m, there is only a small space between the 3rd and 4th layers, and the 4th layer may also be the sub-key layer.

(2) According to the rock falling condition, the maximum height of the falling zone is 11m.

(3) During the excavation of 0-60m distance from the coal seam, there is a large displacement change at the top of the coal seam, with a large number of cracks and bedding separation occurring. During the 60-200 m excavation, the displacement of the top of the coal seam varies greatly except in the range of the falling zone, and a few fissures occur in other strata, which is relatively stable.

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