Strata Movement Law and Support Capacity Determination of Upward Inclined Mining in a Fully Mechanized Top-Coal Caving Face

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ABSTRACT

Support capacity determination is the key of surrounding rock control of Topple Mining in a full-mechanized caving face. In view of the difficulty of stope surrounding rock, taking panel 8102 as background, The strata movement and roof broken law of working face 8102 are analyzed by using UDEC2D.What's more, the influencing factors of support capacity are analyzed and the support capacity is calculated. The result shows that: When working advancing is 20 m, top-coal is caving, while the immediate roof initial caving step distance is 25m, the first weighting interval of main roof is 40m and the periodic weighting interval 8~10m; Compared with the level face of full-mechanized top-coal caving, the roof is not easy to form structure, and the periodical weighting with more severe mine pressure is more frequent; The influencing factors of support capacity are the mechanical properties of top-coal, topple mining angle and the dirt band, the support capacity of 5858kN is determined by solving the ultimate bearing capacity of the top-coal coal body.

KEYWORDS: Fully-mechanized top-coal caving face; upward-inclined mining; strata movement; support capacity

INTRODUCTION

In recent years, with the advantages of high yield, high efficiency and excavation of the whole thickness of coal seam, the fully-mechanized top-coal caving technology has become one of the main mining methods for thick coal seams in China [1-3]. But if it encounters the complex geological conditions, for example, the roof is not easy to form structure and the broken main roof acting directly on the support when the caving face advancing in uphill, the stability of coal face will become lower [4-5]. Therefore, it is needed to study the movement law of the overlying strata and the roof structure of the inclined top-coal caving face to obtain the reasonable support resistance, so as to ensure the safe, efficient and rapid advancing. At present, some researches have been carried out on the upward-inclined fully mechanized

caving mining technology in China. Yang Shengli[6-7] established the coal face failure mechanical model of the upward-inclined mining face, at the same time, achieved a good control effect after strengthening coal face using the “manila + grouting” technology. The mechanical model and the condition of the stability of coal face and end face roof are established by Guo Weibin and the relationship between the initial support force of the support, the inclined angle in uphill and the rake angle of the column is discussed [8]. The factors affecting the stability of the end face is obtained and the corresponding face roof control technology is put forward through theoretical analysis by Pan Weidong [9-10]. In view of this serious problem of No. 4 mine work face mining caused by coal face spalling and caving face, Suo Yonglu [11] has analyzed the surrounding rock stress characteristics at the 6 kinds of upward mining angle using FLAC3D.

At present, the researches on the inclined fully mechanized caving mining have found that the stability of the coal face can be guaranteed by studying the end face stability of working face. However, it is not enough to confirm the movement law of overburden rock movement and the support work resistance of the upward-inclined caving face. Therefore, taking the 8102 working face as the engineering background, the movement of the overlying strata of the upward-inclined fully mechanized caving face at different advancing distance is simulated using UDEC2D so as to determine the roof broken characteristics, and then determine the working resistance of the support.

ENGINEERING BACKGROUND

The coal seams mined in upward-inclined fully-mechanized top-coal caving 8102 are coal seam 7+8#. With the mining depth of 250~312m, the average thickness of coal seams 7+8# is 9.1m, and the hardness coefficient of working face coal is less than 1.2. The length of the working face is 160m, and the advancing distance of working face is 510m. The geological and mining conditions of the working area are more complex. With the average angle of 14°, the maximum angle of working face is 23°, and the upward inclined angle of working face is 16°. With a smaller variation in thickness, the immediate roof is limestone and the thickness is 14m, besides, there are joints and cracks on the immediate roof. The mining method of panel 8102 is the longwall mining of the upward inclined fully mechanized caving face and the ratio of the mining and caving height is 1:2. There are a dense joint and fracture distribution of the working face. The coal face failure destruction is serious when the working face inclined forward. Therefore, it is needed to study the movement rule of overlying rock and support resistance to ensure the stability of the surrounding rock.

UDEC SIMULATION OF MOVEMENT LAW OF OVERBUDEN STRATA OF WORKING FACE

MODEL BUILDING

Taking the geological and mining conditions of working face 8102 as background, considering the boundary effect, the model adopts the plane strain model. The calculation length of the model is 160m and the height is 100m. The model consists of 3354 blocks, 5304 units and 11833 interfaces, and the shape of unit is quadrangular. The selected calculation memory of computer is 512MB.There is four boundaries in the model, of which the upper boundary is stress boundary with the vertical stress of 5MPa on it. The left, right and lower boundary of model is the displacement boundary. With the gravitational acceleration of 9.8 m/s2, the calculated model is Mohr-Coulomb constitutive model. The numerical model is shown in fig.1 and the physical and mechanical parameters of coal and rock mass are shown in tab.1.

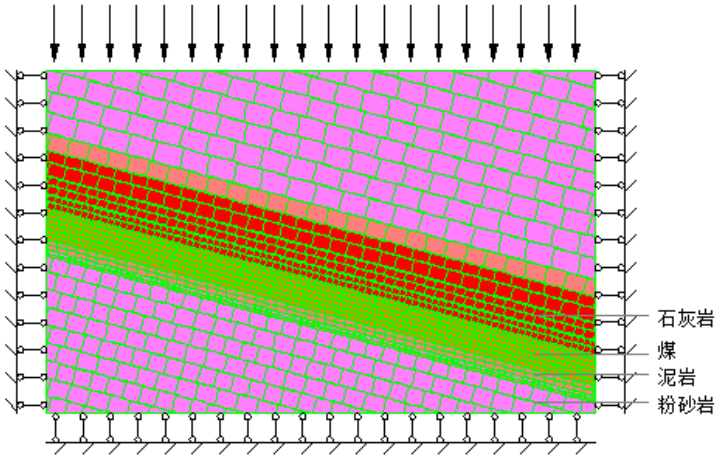


Figure 1: Numerical model diagram

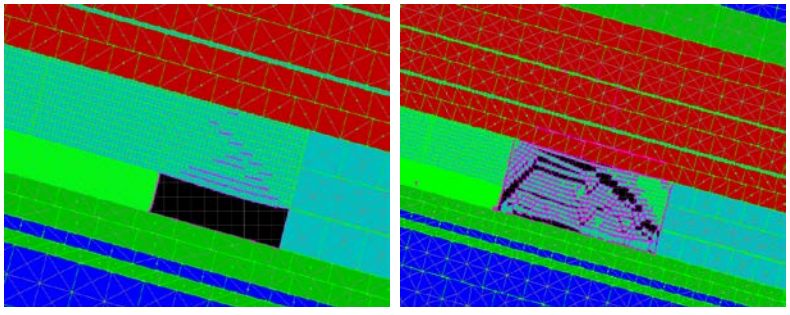
Table 1: Physical and mechanical parameters of coal and rock mass

Rock	Density kg/m^3	bulk /GPa	shear /GPa	cohesion /MPa	tension /MPa	friction /°
siltstone	2712	8.1	4.1	1.45	3.15	40
mudstone	2240	5.2	2.40	2.53	1.78	35
coal	1440	2.3	1.38	0.78	0.64	25
limestone	2630	8.3	4.12	3.43	2.14	37

SIMULATION RESULT ANALYSIS

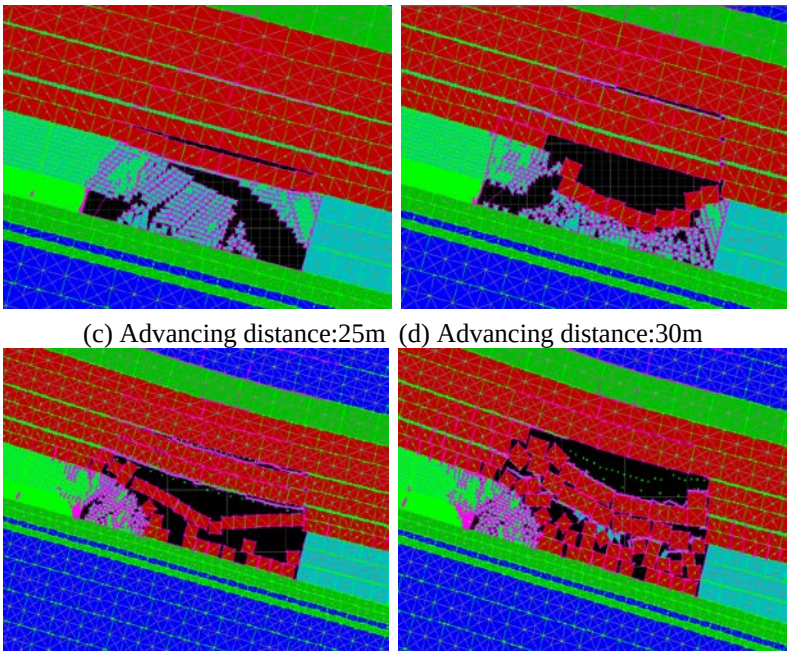
(1) Movement law of overlying strata

Combined with the actual top-coal caving mining, the cutting of the front coal mining machine and the rear top coal caving proceeded simultaneous, and the spacing is 5m. With the interval 5m between mining and caving, the coal cutting without caving has carried out in the first 20m of advancing distance in numerical simulation. The overburden strata failure characteristics of working face at different advancing distance is shown in figure 2.



(a) Advancing distance:10m (b) Advancing distance:20m

Figure 2: *Continues on the next page*



(c) Advancing distance:25m (d) Advancing distance:30m

(e) Advancing distance:40m (f) Advancing distance:50m

Figure 2: Movement law of overlying strata under different advancing distance

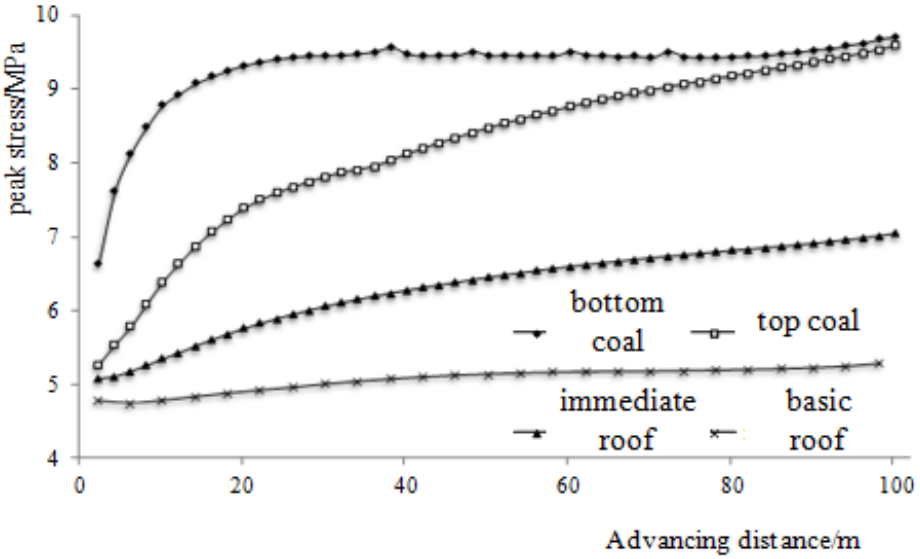
It is concluded from figure 2:

1) When the working face advancing 10m, the cracks of top coal has developed but the top coal is not collapse. When the advancing distance is 20m, top coal caving appears and the immediate develops upward with bed-separation space occurs. The working face to continue to advance, With the advancing of working face, the caving zone is gradually rising, and the falling range is also increased with the caving angle of 75°or so.

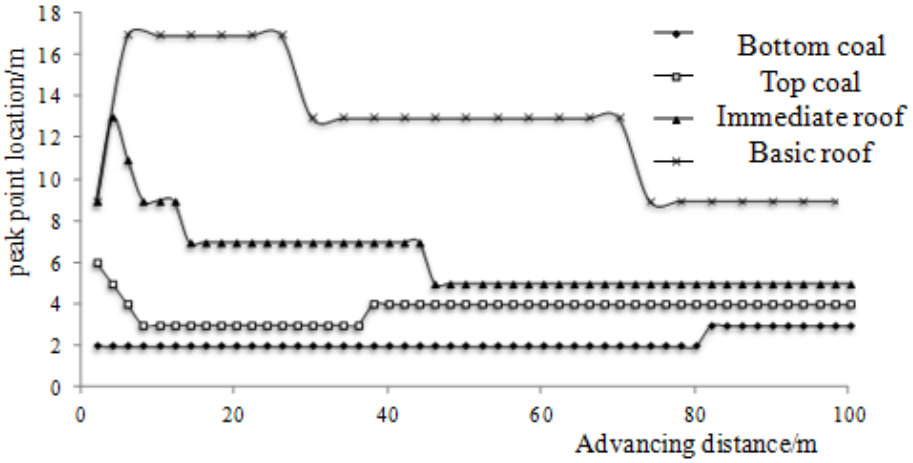
2) When the working face advances to 25m, the interface separation between roof limestone and coal seam occurred with the appearance of immediate roof caving. When the working face advancing is 30m, the overall separation and caving of immediate roof occur with the caving height of 4.5m. The caving height and range of the overlying strata have increased with the sustained increase of advancing distance. When the advancing distance is 40m, the immediate roof has been all falling to the bottom and the basic roof has broken, forming the first weighting. While the advancing distance of working face is 50m, the first periodic fracture occurs at the top of the roof, which is the first periodic weighting of the working face. After that, the periodic fracture of basic roof will occur once every 8~10m of working face is advanced, that is, the periodic weighting length of basic roof is 8~10m.

(2) Abutment pressure distribution

Fig.3 is the curve of the abutment pressure peak and the peak position at different advancing distances of working face.



(a) The curve of stress peak value and advancing distance



(b) The curve of the peak point location and advancing distance

Figure 3: The variation curve of peak value of abutment pressure and position of different strata

As shown in figure 3:

1) With the advancing of working face, the roof hanging area is gradually increasing and forming a stable structure when it reaches a certain value, at the same time, the abutment pressure peak value has little change; The variation of stresses in the bottom coal are very large during the first advancing distance of 20m, but the variation in the basic roof is little. It shows that the top coal seam has entered into the caving zone due to the influence of mining action, and the caving zone height is increasing and developing to the upper immediate roof, and some strata of basic roof has entered into the caving zone simultaneously. Meanwhile, the fractured zone and bend subsidence zone have developed to the upper strata; The abutment stress peak decreases gradually from the bottom coal to the top coal, immediate roof, basic roof and the bottom coal zone is the most stress concentrated area.

2) The higher is the peak value of abutment stress, the distance from the coal face is greater from the bottom coal up to the top layer. On the whole, the peak of the abutment pressure in the coal seam is far away from the coal face with the advancing of working face, and the peak of the abutment pressure peak in immediate and basic roof are gradually close to the coal face. This may be because that the vertical displacement of coal and rock trending to

the goaf is greater than the horizontal displacement, and the limit span is large due to great basic roof stiffness, however, the direct roof and coal seam is relatively soft, and the peak value of abutment pressure of basic roof is far from the coal face due to the intense mining disturbance when transporting to the goaf; The peak value location of abutment pressure in the coal seam is closest to the coal face, and the distance of abutment pressure peak in the bottom coal is 2-3m far away from the coal face. The peak value location of abutment pressure in the top coal seam keeps 3-4m far away from the coal face during the normal advancing of working face. The abutment pressure peak value location of the immediate roof and basic roof increase at first then decrease with the advancing of working face, and the peak value location of abutment pressure in the immediate roof and basic roof are 5-13m and 9-17m far away from the coal face.

CALCULATION OF SUPPORT WORKING RESISTANCE

Through the above analysis, the roof is not easy to form a stable after breaking off during upward inclined mining, due to the influence of inclination angle. The force of the overlying strata can be divided into two components, one component is perpendicular to the support, and the support resistance is determined based on the component. Another component paralleling to the support beam, will make support have a downward trend. Experience shows that the working resistance of support in the fully-mechanized top-coal caving mining face is far less than that of a large-cutting-height mining face.

THE BASIS FOR DETERMINING THE SUPPORT WORKING RESISTANCE

(1)The mutual effect of top-coal and the support-surrounding rock.

In fully-mechanized top-coal caving mining, the top coal with low strength between roof and support is added as direct roof, which acts as a "cushion" of overburden strata activities. Top coal plays a fundamental role in the roof subsidence movement of fully mechanized top coal caving mining, and it is also the intermediate layer of the roof rotary sinking on the support, the mechanical properties of which play a key role in the relationship of the support and surrounding rock. After the test and research on the mine pressure of fully-mechanized top-coal caving, the top coal with the low strength and the multi structure face has obvious influence on the support-surrounding rock. In the study of the interaction, we should fully understand and study the physical and mechanical properties of the top coal

(2) The influence of the inclined angle

If the working face has an inclined angle, it is upward inclined or downward inclined mining, the pressure on the support by top coal is divided into two parts. One part is perpendicular to the support force, and the support working resistance can’t be less than the size of force, or the danger of hydraulic support pushed down would occur; the other part is a force parallel to the support beam, which can be offset by the working face anti slip device. Therefore, it can be determined that in a certain depth of buried and roof-floor combination of the case, the support working resistance in the upward or downward inclined mining face is less than of the support working resistance of the level working face.

(3) Dirt Band effect

If the dirt band is very thick and the occurrence is stable, which is like a natural anchor occurred in the coal seam, playing a role enhancing coal strength. With the advancing of working face, the damage degree of top coal is greatly weakened during the migration and destruction process of top coal, and the ability to transfer vertical stress is stronger due to the insufficient of top coal failure. However, in the actual production process, if the coal gangue

thickness is generally small and the strength is not high, the effect on working resistance by dirt band is small.

DETERMINATION OF SUPPORT WORKING RESISTANCE

A large number of experimental results show that the support working resistance of fully mechanized caving face depends on the deformation pressure of the direct roof and top coal transferring to the support without dynamic load. So the influence of static load on the working resistance of the support is only considered in the calculation.

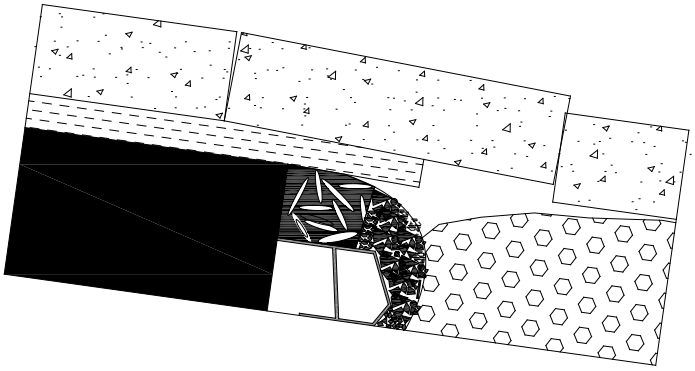


Figure 4: The roof mechanical model of a upward inclined top coal caving mining face

After mining, the top coal body is caving under the roof pressure and the sustained support action of the hydraulic support and become loose solid due to loss of mechanical contact with the front coal body. So it can be considered that the level stress of the top coal in the back of the hydraulic is equal to zero. And the horizontal stress of coal face is approximately equal to the initial stress. It is assumed that the horizontal stress from the upper part to the back of is reduced by exponential form. The initial horizontal stress is $\sigma_h = \mu\gamma H$, taking the coal face as the original point, the horizontal stress near the goaf side is $\sigma_3 = \sigma_h e^{ax}$.

The relationship between the three-axial compressive strength and the confining pressure and uniaxial compressive strength of the top coal:

$$R = R_c + \sigma_3 \frac{1+\sin\varphi}{1-\sin\varphi} \tag{1}$$

The coal body of top coal appears different failure degree under the action of roof pressure. It is assumed that the broken coal body of top-coal behind the support is completely destroyed, remaining residual stress, and the top coal body above the coal face is in a false three direction pressure with slight strength. In order to simplify the calculation, according to the previous studies, the variation stress of the top coal above the top of the control area is in accordance with the negative exponential curve. Thus, the maximum principal stress from coal face to the roof caving area is $\sigma_1 = Re^{bx}$.

According to the elastic mechanics, the stress which is perpendicular to the support beam can be expressed in formula (2).

$$\sigma_n = \frac{1}{2}(\sigma_1 + \sigma_3) + \frac{1}{2}(\sigma_1 - \sigma_3)\cos(2\alpha) \tag{2}$$

Putting σ1, σ3 into the following formula (2), the top-coal stress of a fully mechanized caving face with the inclination angle of θ which is perpendicular to the support beam can be obtained, as shown in formula (3).

$$\sigma_n = \frac{1}{2}\left(Re^{bx} - \sigma_h e^{ax}\right) + \frac{1}{2}\left(Re^{bx} + \sigma_h e^{ax}\right)\cos(2\theta) \tag{3}$$

The support working resistance of a upward inclined caving face can be obtained by the integration of the support control caving area, as shown in formula (4).

$$P = \int_0^{L_k} \sigma_n dx = \int_0^{L_k} \left[\begin{array}{l} \frac{1}{2}\left(Re^{bx} - \sigma_{hi} e^{ax}\right) + \\ \frac{1}{2}\left(Re^{bx} + \sigma_{hi} e^{ax}\right)\cos(2\theta) \end{array}\right] dx \tag{4}$$

The initial horizontal stress is 1MPa, and the compressive strength of coal body is 13.8MPa. The strength of coal body above the coal face is decreased under the mine pressure and the sustained support action of hydraulic support, and the strength of coal face is 2.8MPa, which is about 1/5 of the intact coal strength. The top coal residual strength is 0.05MPa and the accused of zenith distance is 5.08m with the support width of 1.5m, and the inclined angle of working face is 15 degrees.

Putting the above parameters into the formula (4), the support working resistance can be obtained: $P = 5858kN$ .Thus, it can be seen that the selected support working resistance for 7000KN can meet the production requirements.

CONCLUSIONS

(1) UDEC2D simulation was used to study the movement law of overlying strata and the roof caving characteristics of the upward-inclined fully-mechanized top-coal caving under different advancing distances, the research results show that: When the advancing distance is 20m, the top coal is caving. The first caving length of the immediate roof is 25m and the first weighting length is 40m. And the periodical weighting length 8~10m; Compared with the level face of full-mechanized top-coal caving, the roof is not easy to form structure, and the periodical weighting with more severe mine pressure is more frequent.

(2) Compared with the level face of full-mechanized top-coal caving, the abutment pressure influent range is larger and the stress concentration degree increases with the forward of abutment stress peak point in the upward-inclined mining. The reason is that loosening range of coal face enlarges due to the large horizontal stress caused by syncline structure. The coal face spalling prevention of a upward-inclined mining face is the key of the stope surrounding rock control.

(3) Physical and mechanical properties, the upward-inclined mining angle, the dirt band and the other factors affecting the determination of support working resistance are analyzed through theoretical analysis. The static model of the force on the support in the upward-inclined fully-mechanized caving mining is established to determine the reasonable working resistance of the support by calculating the ultimate bearing capacity of top-coal. The engineering practice shows that the selected support working resistance can meet the requirements.

ACKNOWLEDGEMENTS

The financial support from the National Natural Science Foundation of General Program (No.51574244) and (No.51574093) and the Joint Funds of the National Natural Science Foundation of China (No.U1361209) are greatly appreciated.

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Editor's note.
This paper may be referred to, in other articles, as:

Dezhong Kong, Wenjibin Sun, and Yang Liu: "Strata Movement Law and Support Capacity Determination of Upward Inclined Mining in a Fully Mechanized Top-Coal Caving Face" *Electronic Journal of Geotechnical Engineering*, 2017 (22.01), pp 91-100. Available at ejge.com.