International Journal of Mining Science and Technology 25 (2015) 199–204

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Theoretical analysis on the deformation characteristics of coal wall in a longwall top coal caving face

Bai Qingsheng [*], Tu Shihao, Li Zhaoxin, Tu Hongsheng

School of Mines, Key Laboratory of Deep Coal Resource, Ministry of Education, China University of Mining & Technology, Xuzhou 221116, China

ARTICLE INFO

Article history:
Received 8 July 2014
Received in revised form 17 August 2014
Accepted 11 October 2014
Available online 21 March 2015

Keywords:
Longwall top coal caving face
Coal wall deformation
Torque equilibrium
Displacement method
Parametric analysis

ABSTRACT

Against the background of analyzing coal wall stability in 14101 fully mechanized longwall top coal caving face in Majialiang coal mine, based on the torque equilibrium of the coal wall, shield support and the roof strata, an elastic mechanics model was established to calculate the stress applied on the coal wall. The displacement method was used to obtain the stress and deformation distributions of the coal wall. This study also researched the influence of support resistance, protective pressure to the coal wall, fracture position of the main roof and mining height on the coal wall deformation. The following conclusions are drawn: (1) The shorter the distance from the longwall face, the greater the vertical compressive stress and horizontal tensile stress borne by the coal wall. The coal wall is prone to failure in the form of compressive-shear and tension; (2) With increasing support resistance, the revolution angle of the main roof decreases linearly. As the support resistance and protective force supplied by the face guard increases, the maximum deformation of the coal wall decreases linearly; (3) As the face approaches the fracture position of the main roof, coal wall horizontal deformation increases significantly, and the coal wall is prone to instability; and (4) The best mining height of 14101 longwall face is 3.0 m.

1. Introduction

In recent years, with the development of deep mining, coal wall spalling has become an increasingly serious problem. Coal wall spalling leads to expansion of the unsupported space in front of the shield support, causing collapse of the tip-to-face roof or top coal. Coal wall spalling and roof fall not only affect face advance speed and mining operation, but also lead to equipment damage and casualties, and become the major factors threatening safe mining of longwall faces [1,2]. In order to prevent and control coal wall spalling effectively, some scholars have carried out research on the mechanism of coal wall spalling and control technologies. Based on the elastoplastic mechanics theory, Niu et al. analyzed the stress state of the coal wall. They found that the mining height and internal friction angle are the two most sensitive factors affecting coal wall spalling. They also studied the relationship between the mining height and the extent of the damage zone of the coal wall and the required protective force [3]. By simplifying the integrated coal wall as resembling compression struts, Yin et al. [4] analyzed the deflection characteristics of the coal wall, where the upper part is prone to spalling. Jin et al. [5] considered the vertical splitted coal wall to be a compression strut, and established a catastrophic model of coal wall spalling. They held the view that coal wall spalling not only depends on the geometry and mechanical properties of the coal mass, but also relates to the magnitude of the external forces and the path it is applying to the coal wall. Using damage mechanics and the “wedge” stability theory, Yuan et al. [6,7] studied the microscopic mechanism and macro representation of coal wall spalling on large mining height longwall faces. Borrowing from the research results of slope stability, Hao and Zhang [8] established a coal wall slip-surface mechanical model. Based on the probability analysis method, they analyzed the relationships between the probability of failure of the coal wall and the following parameters: distribution, direction, cohesive and frictional coefficient of the fracture surfaces. Fang et al. [9] analyzed the stability of the weak surface in a soft coal wall, and determined the best mining height to maintain coal wall stability. They also researched the control function of bolts to soft coal wall spalling. Many scholars have used numerical methods to research the mechanisms and disciplines of coal wall spalling [10–13].

However, in most of the previous theoretical researches, the coal wall was regarded as an isolated object; the influence of the roof (top coal), shield support, face guard etc. on coal wall stability were ignored. In this paper, for the analysis of coal wall stability on 14101 fully mechanized longwall top coal caving face in Majialiang

---

[*] Corresponding author. Tel.: +86 13852489517.
E-mail address: bqshcumt2008@126.com (Q. Bai).

http://dx.doi.org/10.1016/j.ijmst.2015.02.006

coal mine, and based on the principle of torque equilibrium, a mechanics model has been established which includes the coal wall, roof and shield support. The displacement method in elastic mechanics was used to obtain the stress and deformation distributions of the coal wall. This study then researched the influence of support resistance, face guard pressure, fracture position of the main roof, and mining height on coal wall deformation.

2. Engineering conditions

Panel 14101 is the first longwall face in Majialiang coal mine. The width and length of the panel is 250 m and 2680 m, respectively, and the average depth below surface of #4 seam is 574 m. The thickness of #4 seam in the panel is 4.0–11.0 m, with an average value of 9.1 m, and the dip angle of the seam is 3–4°. A fully mechanized longwall top coal caving face is set up to extract the #4 seam. A 3.5 m high longwall face is operated at the floor of the coal seam. Four-pillar shield support ZF13000/25/38 is used to control the roof. A generalized stratigraphic column showing the coal seam, together with roof and floor strata, is presented in Fig. 1.

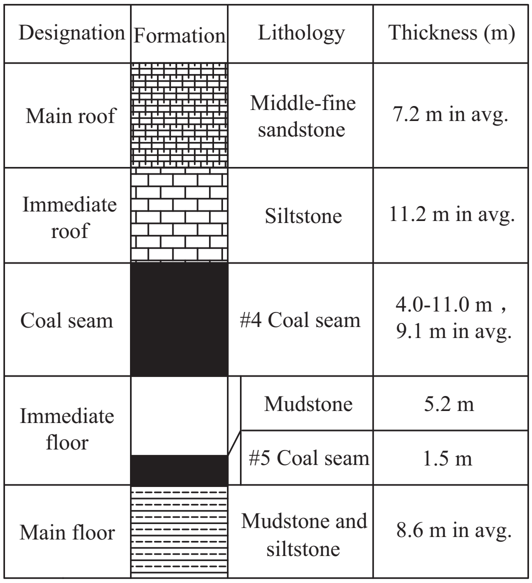
3. Bearing capacity mechanics model of the coal wall

3.1. Mechanics model

Based on the principle of torque equilibrium, and not considering the hinge between the fractured rock beams, the mechanics model for calculating coal wall stress is set up as shown in Fig. 2. In Fig. 2, O is the action point of the roof strata or top coal; H, R, Z and L are the cutting height of the longwall face, height of the top coal, immediate roof and main roof, respectively; θ is the revolution angle of the main roof; S_1 is the distance between the fracture position of the main roof and the coal wall; S_2 is the length of the support beam; P_1 and P_2 are braced forces to the roof supplied by the coal wall and the shield support.

The various forces in Fig. 2 take a torque to point o, and according to the torque equilibrium relations, we have:

$$M_R + M_z + M_L = M_{P_1} + M_{P_2} \tag{1}$$



Designation	Formation	Lithology	Thickness (m)
Main roof	▦	Middle-fine sandstone	7.2 m in avg.
Immediate roof	▦	Siltstone	11.2 m in avg.
Coal seam	■	#4 Coal seam	4.0-11.0 m , 9.1 m in avg.
Immediate floor	□	Mudstone	5.2 m
	■	#5 Coal seam	1.5 m
Main floor	▤	Mudstone and siltstone	8.6 m in avg.

Fig. 1. Stratigraphic column.

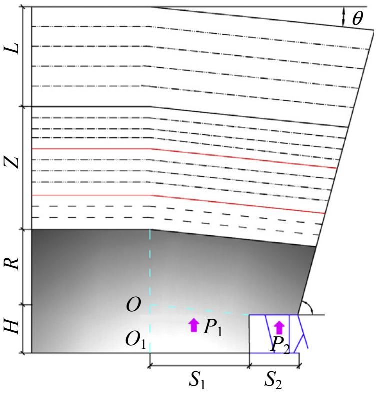


Fig. 2. Mechanics model.

where M_R, M_Z and M_L are torques on the point O generated by top coal, immediate roof and main roof, respectively; M_{P_1} and M_{P_2} are torques on the point O generated by the coal wall and shield support. According to the geometric relations in Fig. 2,

$$M_R = \frac{(l_{R1} + l_{R2})^2 R}{8} \rho_R g \tag{2}$$

$$M_Z = \frac{\rho_i g}{8} \sum_{i=1}^{n} (l_i + l_{i+1})^2 Z_i \tag{3}$$

$$M_L = \frac{(l_{L1} + l_{L2})^2 L}{8} \rho_L g \tag{4}$$

In the above equations:

$$l_{R1} = s_1 + s_2$$

$$l_{R2} = l_1 = l_{R1} + \tan\left(\frac{\pi}{2} - \alpha - \theta\right) R$$

$$l_{i+1} = l_i + \tan\left(\frac{\pi}{2} - \alpha - \theta\right) Z_i$$

$$l_{L1} = l_{R1} + \tan\left(\frac{\pi}{2} - \alpha - \theta\right)(R + Z)$$

$$l_{L2} = l_{L1} + \tan\left(\frac{\pi}{2} - \alpha - \theta\right) L$$

where ρ_R and ρ_L are the densities of top coal and main roof, respectively; n is the strata number constituting the immediate roof; ρ_i and Z_i are the density and thickness of the ith immediate roof stratum; and g is the acceleration due to gravity.

3.2. Stress calculation model for coal wall

In longwall face, a certain area in front of the coal wall will yield, and will be a plasticity problem. In this paper, by reducing the elastic modulus of the coal, this problem can be converted into an elastic problem for an approximate solution [14,15].

Because the roofs (main and immediate) and floor have greater stiffness than that of the coal seam, the upper boundary of the coal wall can be regarded as a given deformation boundary, while the lower and left boundaries may be considered as fixed boundaries. The protective pressure to the coal wall supplied by the face guard is q. So the stress calculation model for the coal wall can be established, as shown in Fig. 3, and this is a plane strain problem.

In plane strain problems, deformation energy can be expressed by the displacement component as follows [16]: