International Journal of Mining Science and Technology 24 (2014) 441–445

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

Spontaneous caving and gob-side entry retaining of thin seam with large inclined angle

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ARTICLE INFO

Article history:
Received 30 August 2013
Received in revised form 26 November 2013
Accepted 15 January 2014
Available online 6 June 2014

Keywords:
Large inclined angle
Gob-side entry retaining
Spontaneous caving
Thin seam
Field test

ABSTRACT

Based on the research method of combining simulation analysis with field testing by distinct element process UDEC, we have analyzed the roof deformation and failure laws and roadway support technology of gob-side entry retaining in a thin seam with a large inclined angle. The results show that during exploitation in seams with large inclined angle, rotational subsidence of the main roof under the gob area is small and can maintain balance, so there is no need to provide artificial permanent support resistance for the main roof near the upper side to control rotational subsidence. Obstructed by the dense scrap rail, waste rock from the immediate roof caving slides from the upper gob area to the lower area and fills it, which strikes a balance between the immediate roof under the goaf after it fractures into large pieces and filling waste rocks.

1. Introduction

Gob-side entry retaining has a number of advantages, including enhancing coal recovery rate, reducing roadway drivage ratios, lowering the cost of coal production, extending the service life of a mine, and alleviating the conflict between mining and development replacement, as well as preventing mining disasters caused by remaining coal pillars [1,2]. There has been much research carried out both at home and abroad related to mining without pillars in horizontal seams, low inclination thin seams, and medium thickness seams with good roof and floor conditions. However, studies on seams with large inclined angles and other complicated geological conditions are not fully developed to date. Consequently, through taking the actual mining conditions of a mine as an engineering background, on the theoretical basis of motion laws in the roof strata of gob-side entry retaining and strata movement rules in mining with large inclined angle as well as key strata theory [3–19], adopting the methods combining numerical analysis and field test, the research makes a comparative analysis of different support schemes of gob-side entry retaining in fully-mechanized faces in thin seams with large inclined angle. Finally, we propose a reasonable scheme of roadside and entry support.

2. Project situation

The tests were carried out on a fully-mechanized working face in a single thin seam with large inclined angle. The seam has a low gas content and the coal does not undergo self-ignition. The average thickness of the seam is 1.3 m with an average inclination of 43°. The strike length is 450 m while the dip length is about 108 m. In addition, the immediate roof is a dark-gray sandy mudstone with a thickness of 5.01 m. The main roof is a medium-grained quartz sandstone with a thickness of 10.5 m and the immediate roof is dark-gray carbonaceous mudstone with a thickness of 1.57 m. The immediate floor of the seam is a medium-grained quartz sandstone with a thickness of 45.7 m. The physical and mechanical parameters of coal and rock are as shown in Table 1.

The original conveyor entry is designed as a trapezoid section 3 m high and 3.6 m wide. The roadway roof is supported by anchor cables with steel belts. The steel anchor is left-hand thread with a diameter of 20 mm. The row space is 0.8 m with a length of 2.3 m. The anchor cable is installed near the middle of the roof and close to the upper and lower working slope. The one close to the upper working slope is perpendicular to the horizontal plane and is 5 m in length. In the middle of the roof, the anchor cable is perpendicular to the roof and 4 m in length. The included angle between the anchor cable close to the lower working slope and the horizontal plane is 25° and is also 4 m in length. The row spaces are all

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http://dx.doi.org/10.1016/j.ijmst.2014.05.004
2095-2686/© 2014 Published by Elsevier B.V. on behalf of China University of Mining & Technology.

Table 1
Physical mechanics of coal petrology.

Rock stratum	Bulk modulus (GPa)	Shear modulus (GPa)	Density (kg/m^3)	Cohesion (MPa)	Angle of internal friction (°)	Tensile strength (MPa)
Hazel	12.58	8.50	2600	12.0	40.0	3.00
Mudstone	11.13	7.09	2670	11.9	38.0	3.60
Coal	2.30	1.08	1450	1.2	20.0	1.27
Sandy mudstone	7.79	5.34	2550	5.7	32.1	3.77

2.4 m. Moreover, the upper and lower working slopes are supported by an anchor network combined with steel belt. The steel anchor is also left-hand thread with a diameter of 20 mm. The length is 2.3 m and the row spacing of the upper working slope is 0.8 m. The interval in the lower working slope is 0.6 m while the row spacing is 0.8 m. In the roadway, 11# steel joists are used at intervals of 1.6 m to permanently strengthen the support.

3. Numerical simulations and determination of support schemes

3.1. Schemes of gob-side entry retaining

In order to study the technology of steeply inclined gob-side entry retaining, three supporting schemes are designed in this paper.

Scheme one: The roadway retained is 3 m high and 3.6 m wide. The roadside is supported by steel joists combined with a single row of dense scrap rails which are 0.5 m away from the roadside. Normal blasting for roof cutting has been used around 1 m of the roof. In the advance and lag strengthening area of the roadsides, temporary strengthening support measures are taken. In addition, at a point 30 m in front of the working face and 60 m behind it, a single hydraulic prop DZ2500-25/100 is selected to set up a strike shed for strengthening the support. The strike interval is 0.8 m, and the support pattern is 'one beam and two pillars', as shown in Fig. 1.

Scheme two: In common with scheme one, entry supports are both cable anchors, while the difference is that single dense scrap rail props are used for support 1 m away from the roadside. The dip is filled with waste rock that collapses spontaneously.

Scheme three: On the basis of scheme two, scheme three uses more steel joists which provide increased support beside the roadside in the goaf.

3.2. Establishment of numerical model

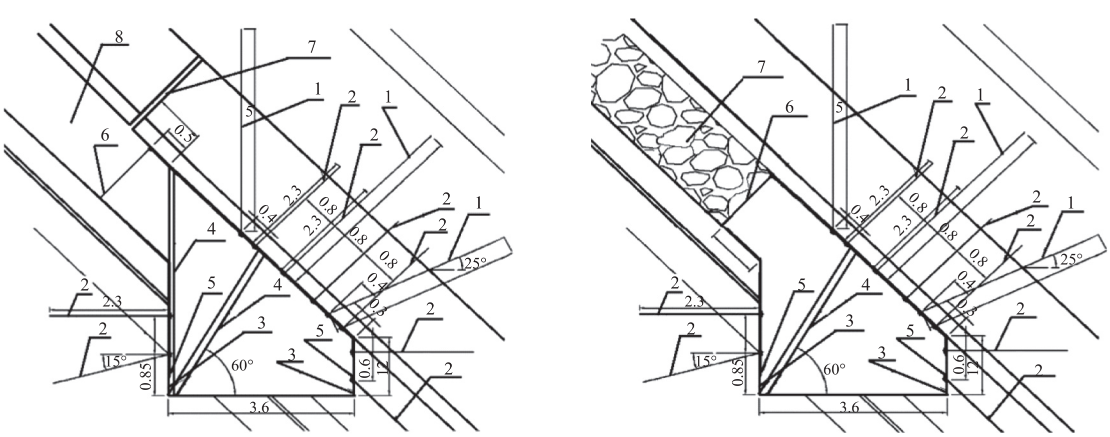
In the research described in this paper UDEC numerical simulation was used to study the three schemes above, analyzing displacement changes of two working slopes, to select the optimal one for engineering practice. According to the specific geological and mining conditions, model size (length × height) is determined as: 100 m × 100 m. The bottom boundary of the model is fixed while the left and right boundaries are fixed in the horizontal direction. Gravitational stress corresponding to a depth of 300 m is applied to the top boundary. The support structure of each simulation can be strengthened by using the structure provided by UDEC, for instance, anchor, anchor cable, steel joist and so on. The analysis model is shown in Fig. 2.

The numerical simulation of an excavation sequence is: establishing model and calculating the initial force balance → excavating and supporting coal seam roadway → coal seam excavating and gob-side entry retaining supporting → obtaining the results of surrounding rock deformation.

3.3. Results of numerical simulation and analysis

In order to study the deformation characteristics of the surrounding rocks, displacement observation lines in the roof and floor and working slopes are set respectively to obtain deformation values. The deformation values of roof and floor and working slopes are as shown in Fig. 3.

It can be seen from Fig. 3a and b that the best roof displacement control scheme is the third one, in which the displacement value at the roof center is 62.51 mm. The worst scenario is scheme one, in which the value is 307.07 mm. Floor-heave values are not high in all schemes although the highest value (74.22 mm) is in scheme one. The lowest floor-heave value at the floor center is in scheme three, with a value of 52.03 mm.



1. Anchor; 2. Bolt; 3. W-steel belt; 4. Joist steel; 5. Metal mesh; 6. Scrap rail; 7. Cut the roof line; 8. Gob

(a) Roadside support for scheme one

1. Cable bolt; 2. Anchor bolt; 3. W-steel belt; 4. Joist steel; 5. Metal mesh; 6. Scrap rail; 7. Gangue

(b) Roadside support for scheme two

Fig. 1. Schematic diagram of roadside support.