International Journal of Mining Science and Technology 24 (2014) 499–503

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

Feasibility analysis of gob-side entry retaining on a working face in a steep coal seam

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ARTICLE INFO

Article history:
Received 22 September 2013
Received in revised form 21 November 2013
Accepted 15 February 2014
Available online 5 June 2014

Keywords:
Gob-side entry retaining
Steep coal seam
Fully-mechanized mining
Feasibility analysis
Numerical simulation

ABSTRACT

Based on the decline in exploitation of coal resources, steep coal seam mining and mining face tensions continue to explore the feasibility analysis of steeply inclined faces in the gob. One of the key factors in utilizing the technology of gob-side entry retaining in steep coal seams is to safely and effectively prevent caving rock blocks from rushing into the gob-side entry by sliding downwards along levels. Using theoretical analysis and field methods, we numerically simulated the mining process on a fully-mechanized face in a steep coal seam. The stress and deformation process of roof strata has been analyzed, and the difficulty of utilizing the technology is considered and combined with practice in a steep working face in Lvshuidong mine. The feasibility of utilizing the technology of gob-side entry retaining in a steep coal seam has been recognised. We propose that roadways along the left lane offshoot body use a specially-made reinforced steel dense net to build a dense rock face at the lower head. The results show that the lane offshoot branch creates effective roof control, safe conditions for roadway construction workers, and practical application of steeply inclined gob.

1. Introduction

It is agreed that there are many advantages in gob-side entry retaining, such as a high recycling rate, a reasonable join in working face, a low rate of tunneling and therefore less production of coal gangue so that the problem in getting-driving relay is solved [1–10]. Studies of the technology of gob-side entry retaining have been carried out both in China and abroad over many years. Trials have also been conducted in large and medium-sized mines. Both success and failure have resulted where gob-side entry retaining has been adopted in working. Compared with more successful results in gently inclined coal seams, failures in steep coal seams or complex conditions arise because of various difficulties and an insufficiency of theoretical study [11–15]. This paper analyzes the feasibility of utilizing gob-side entry retaining on a fully-mechanized face in a steep coal seam.

2. A general introduction to a working face and technical difficulties

Most of the coal seams in the Lvshuidong mine are steeply inclined and of medium thickness. The method of backward mining from a long wall using fully-mechanized mining is adopted here. The 3123 working face is 368.5–464.1 m in depth, 684 m in length, 86 m in inclination and contains faults with a displacement of over 0.3 m. The coal seam is 2.09–2.65 m in thickness and the average thickness is 2.36 m. The coal seam dip angle is 40–53° with an average of 47.2°. The coal seam roof consists of calcareous mudstone in the immediate roof, 8.6 m in thickness, and a sandstone main roof of 7.2 m thickness. The coal seam floor is made up of carbonate mudstone in the immediate floor which is 0.70 m in thickness and a mudstone main floor of 6.60 m thickness. Whether to carry out the technology of gob-side entry retaining in this working face remains to be further theoretically analyzed for problems such as entry maintenance, tunneling and entry reduction, etc.

Falling rock blocks in the gob slide down along the floor when mining in a steep coal seam. First, the gob, which lies in the lower end along the tilt direction of the working face, needs to be filled to prevent the roof falling [16–21]. Therefore, a large room is produced in the upper end of the inclined working face into which the roof above the gob collapses so that fallen gangue can form an upside down egg-like mass which is loose at the upper end and thick at the lower end, which makes it more difficult to change the ex-conveyance road into an air-return roadway. Whether success is achieved in the adoption of gob-side entry retaining in a steep coal seam depends mainly on good maintenance and stability of the conveyance road behind the working face, which is different from the entry in gently-inclined coal seams.

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http://dx.doi.org/10.1016/j.ijmst.2014.05.013
2095-2686/

3. A numerical simulation analysis of mining in a steep coal seam

3.1. Calculation model

In order to analyze the feasibility of conducting gob-side entry retaining in a steep coal seam, the distribution of mine ground pressure in a steep coal seam and its behavior must be taken into account. The finite difference software FLAC3D has been used in three-dimensional numerical simulation analysis.

Considering coal resources in Lvshuidong mine, the complex geological conditions, the mining technology on a fully-mechanized face in a steep coal seam and the boundary effects in the three dimensional numerical model, in the three dimensional coordinate system, let the horizontal positive direction be the *X* axis, the vertical direction be the *Z* axis and the advance direction of the working face be the *Y* axis. As illustrated in Fig. 1, the size of the model is $x \times y \times z = 200\ \text{m} \times 600\ \text{m} \times 262\ \text{m}$. The boundary of the lower end is a restricting condition of the displacement boundary, the boundary of the upper end is a restricting condition of a stress boundary. The uniformly distributed vertical load is equal to the weight of the strata from floor to surface and the left–right boundary is a mixed boundary condition. The constitutive relation for the material uses a Mohr–Coulomb model, mechanical parameters of which are shown in Fig. 1.

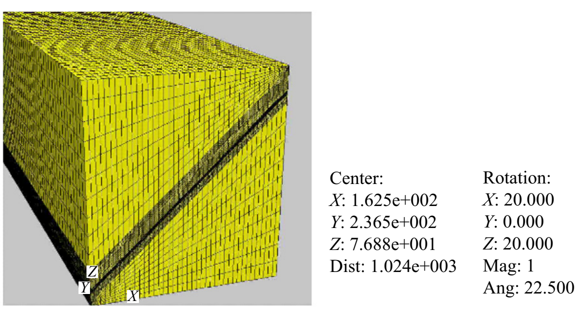


Fig. 1. Modeling diagram of numerical simulation.

The FLAC3D software is used in the numerical calculation. This is a three-dimensional finite difference calculation procedure which provides 11 types of constitutive models of similar material, based on the mixed discrete method. It is the proper professional software in geotechnical engineering which adapts to different lithologies and the demands of strata movement during mining and can be used to simulate non-linear excessive displacement and the movement of the roof after mining (Table 1).

3.2. Analysis of calculation result

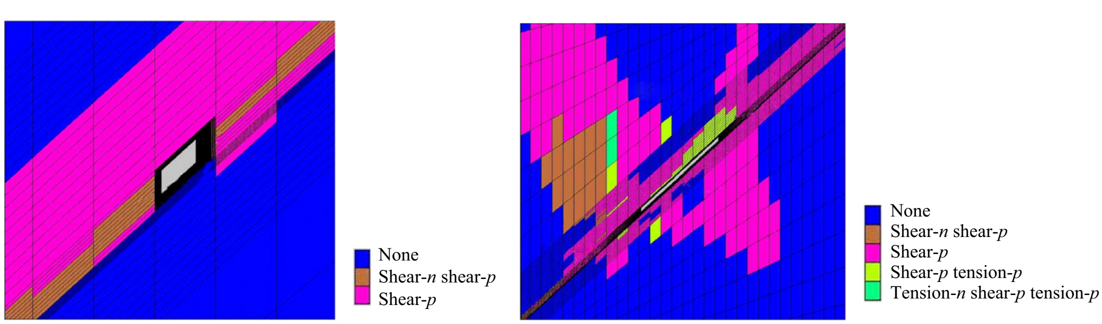
The mining procedure has been numerically simulated according to the geological conditions in 3213 steep seam working face. From the results of the simulation, after excavating the entry, the surrounding rock is broken mainly by shearing. After mining, the roof of the working face is broken mainly by both shearing and drawing, while the upper part is broken by shearing and drawing, and the lower part by shearing. The immediate roof of the conveyance road in the steep working face is broken mainly by shearing while the main roof is broken by drawing and the tunnel walls by shearing (Fig. 2).

The silhouette chart of the simulation of vertical and horizontal stress isoclines after entry excavation and mining activity is illustrated in Fig. 3.

After the entry has been excavated, the primary stress in the surrounding rock is redistributed. The vertical stress inside the surrounding rock is concentrated towards the corner of the tunnel walls, while there are clear stress-reducing zones nearby. The stress in the roof is less than that in the tunnel walls, because the load of surface mining has moved to the walls, which leads to a rise in stress in both sides of the roof, whereas the horizontal stress in the tunnel walls is a little less than that in the roof (Fig. 3a and b). With mining being conducted, the stress has increased gradually, and the highest vertical and horizontal stresses appear in the surrounding rock around the conveyance road with values

Table 1
Mechanical parameters of coal and rock mass.

Strata	Density (kg/m^3)	Bulk modulus (GPa)	Shear modulus (GPa)	Friction angle (°)	Cohesive force (MPa)	Tensile strength(MPa)
Overlying strata	2681	13.60	9.91	35	2.04	1.1
Main roof	2584	12.50	9.73	44	2.61	2.5
Immediate roof	2292	10.80	8.58	33	1.31	1.2
Coal	1402	2.05	1.02	35	1.28	1.1
Direct bottom wall	2541	13.03	9.81	41	2.14	2.8
Old floor rock stratum	2539	11.50	9.49	42	2.18	2.9
Bedrock	2403	9.24	8.26	40	2.62	2.0



(a) Roadway's excavation

(b) Working face mining

Fig. 2. Simulation destruction of state.