International Journal of Mining Science and Technology 24 (2014) 143–149

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

Technology of back stoping from level floors in gateway and pillar mining areas of extra-thick seams

Tu Hongsheng, Tu Shihao *, Zhang Xiaogang, Li Zhaoxin, Jia Shuai

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

ARTICLE INFO

Article history:
Received 16 September 2013
Received in revised form 16 October 2013
Accepted 18 November 2013
Available online 5 March 2014

Keywords:
Gateway-and-pillar goaf
Back stoping from level floor
Secondary mining
Numerical simulation
Stress evolution

ABSTRACT

According to the special requirements of secondary mining of resources in gateway-and-pillar goaf in extra-thick seams of Shanxi, this paper presents a technical proposal of back stoping from level floors. Numerical simulation and theoretical analysis are used to investigate the compaction characteristics of cavities under stress as well as an appropriate mining height of the primary-mining layer based on different mining widths and pillar widths. For Yangjian coal mine, the mining thickness of the first seam during back stoping from level floor is determined to be 3 m, which meets the relevant requirements. Gateway-and-pillar goaf of a single layer has a range of influence of 9 m vertically. If gateway-and-pillar goaf occurs both in 9-1 and 9-5 layers, the range is extended to within 11.2 m. When the mining width of a gateway is less than 2 m or larger than 5 m, the gateway-and-pillar goaf in the upper layer of the primary-mining seam can be filled in and compacted after stoping. When the working face is 2 m away from the gateway and pillar before entering into it and after passing through it, the coal body under the gateway and pillar is subjected to relatively high stress. During mining of the upper layer, moreover, the working face should interlock the goaf in primary-mining layer for 20 m.

1. Introduction

In most mines involved with resource integration, coal resources are sterilized where pillar mining is employed in small coal mines [1–3]. According to statistics, the recovery rate of coal resources in working faces in pillar mining is less than 30%, especially in thick seams [4]. With an improvement of mining equipment, coal mines enter the mass production stage and coal resources gradually become exhausted [5–11]. As a result, most integrated mines are faced with the need for secondary mining of sterilized areas created by pillar mining. Therefore, the research on safe and efficient technology used for secondary mining of thick seams in gateway and pillar mining areas is of universal significance.

For an effective release in the stress-concentrated area of gateway-and-pillar goaf, the technology of back stoping from a level floor can be accepted as an effective method [12]. At present, the feasibility of the technology can be assessed mainly with methods such as ratio assessment, "three zones" assessment, balance analysis of surrounding rock, and mathematical statistical analysis [13–18]. However, these methods, which work on the basis of the interval between upper and lower seams, do not apply to the assessment of back stoping from a level floor in a single-layer thick seam. For the purpose of safe and efficient secondary mining, this study has intensively investigated the stress distribution in a gateway-and-pillar goaf, the destruction characteristics of gateway and pillars, the appropriate mining height of the primary-mining layer during back stoping from a level floor, and other aspects, to provide new methods of secondary mining of coal reserves in the gateway-and-pillar goaf of thick seams.

2. Project overview

2.1. Occurrence characteristics of seams

To date, in Yangjian coal mine, among the 4#, 9# and 11# seams approved to be mined, the recovery of 4# seam is substantially completed, while mining of 11# seam has not yet started. The spacing between 4# and 9# seams is 64.3 m. After resource integration, incorporating many small mines, Yangjian coal mine has gradually raised its production, degree of mechanization and degree of intensive production. This causes a constant decrease in coal reserves and only one normal working face remains to be mined in 9# seam. Moreover, considering the take-over of the mines, secondary mining in the 412 gateway and pillar mining panel of 9# seam is necessary to improve coal recovery rate.

* Corresponding author. Tel.: +86 13852086048.
E-mail address: 13852086048@163.com (S. Tu).

http://dx.doi.org/10.1016/j.ijmst.2014.01.001
2095-2686/

For the 412 gateway and pillar panel in the southeast corner of the mine, the seam is 10.23–16.74 m thick, with an average thickness of 13.49 m. The compressive strength of the coal body is 17.2 MPa. The dip angle of coal seam is 3–5° and 4° on average; the average burial depth is 160 m. Five dirt bands exist in the seam. The whole panel is stable and exploitable. Currently, about 3.6 million tons of exploitable coal reserve is left. Due to the large thickness of the seam, small mines have adopted a gateway and pillar mining method to excavate the 9-1 and 9-5 layers. The former one has almost been mined out, while the latter has been partly mined. As a result of the poor mining technologies at that time, the mining thickness was mostly between 2 m and 3 m, leading to 8–11 m residual coal. Fig. 1 shows the integrated histogram of the seam.

The recovery rate of the gateway and pillar mining method is low. Calculation has determined that about 80% of the overall exploitable coal reserves in the 412-panel was left behind in mines.

2.2. Gateway and pillar stability analysis

Investigation and analysis conclude that in 9-1 and 9-5 layers, the mining width is 6 m and the pillar width is 4 m. In the dip direction, two working faces should be staggered by 3 m. Protective coal pillars of 8 m and 11 m should be designed at both open-off cuts of the working face. During stoping, the working face first advances 3 m in the strike direction, and then 30 m in the dip direction. In the area within 5 m of the mining gateway, each coal sidewall should be expanded by 1.5–1.75 m. If the thickness of a seam is less than 3 m, it is generally adopted as the mining height of the working face. The layout of working faces using the gateway and pillar mining method is sketched in Fig. 2.

According to the distribution pattern and size of gateway and pillar, as well as the size of the goaf in the working face, q, which stands for the force on gateway and pillars can be determined by the following formula:

$$q = \frac{a+b}{a}\gamma H \tag{1}$$

where γ (kN/m^3) is the average body force from overlying strata; H (m) the average burial depth of the seam in the gateway and pillar working face; a (m) the width of gateway and pillar and b (m) the width of gateway-and-pillar goaf. Put the actual parameters: a = 4 m and b = 6 m into Eq. (1), the force on gateway and pillars

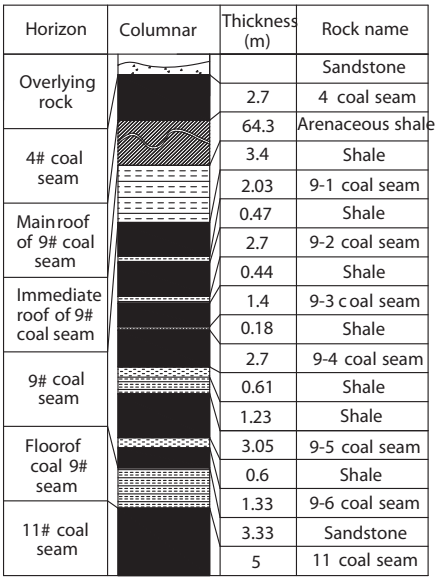

Fig. 1. Geological columnar section.

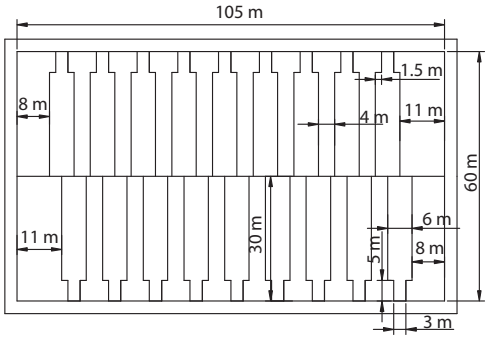

Fig. 2. Schematic diagram of gateway and pillar stoping.

from overlying strata is calculated to be 10 MPa. The stress from rock mass is 4 MPa and the stress concentration factor is 2.5. The uniaxial compressive strength of 9# seam is 17.2 MPa. Therefore it can be concluded that the gateway and pillar structure is stable before second mining.

3. Analysis of advantages and disadvantages of the method of mining by back stoping from a level floor

3.1. Decision on the design for secondary mining

When adopting the full-seam caving mining method, the goaf between pillars is in a stress-relaxed area, which may result in problems with top coal caving, insecure connection between support and roof and collapse of support. When the working face is under the gateway and pillar, problems such as high stress in supports and severe caving of coal wall may arise. Also, the 1.23 m-thick dirt band of shale between 9-4 and 9-5 layers may hinder top coal caving during full-seam caving. In the case of downward sublevel mining, due to the location of gateway-and-pillar goaf in 9-5 layer, cavities may occur in the upper layer during mining, resulting in a potential safety risk for the mining equipment.

Furthermore, over a relatively long period of time during gateway and pillar stoping, the gateway-and-pillar goaf may have undergone coal oxidation, metamorphism and geological penetration, resulting in accumulations of water, hazardous gases and other materials. All these problems are key aspects which determine the safety of secondary mining.

Taking into consideration the problems mentioned above, this paper proposes a scheme for sublevel back stoping, involving the excavation of a certain thickness of coal along the floor of 9# seam by fully-mechanized mining and then mining out the upper layer by top coal caving, thus mining the full seam.

3.2. Analysis of the relative merits of the back stoping scheme

The scheme of sublevel back stoping from a level floor has a number of merits as follows:

(1) Since the coal seam extracted in mining the primary-mining layer is relatively thin, safety can be ensured. Water, gas and other hazardous gases in overlying strata and seams can be released slowly and effectively through mining-induced fissures.
(2) Appropriate design of mining parameters of the primary-mining layer can help destroy the pillars in the gateway-and-pillar goaf and achieve compaction (see Fig. 3), so that the stress in the stress-concentrated area can be released to facilitate top coal caving in the upper layer.