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Numerical simulation of overburden and surface movements for Wongawilli strip pillar mining

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ABSTRACT

The Wongawilli strip pillar mining technique, which combines the strip pillar mining layout and Wongawilli mining technology, is a new high efficient mining technology for mining under surface structures. The Wongawilli strip pillar mining technique was studied in this paper using theoretical analysis and numerical simulation. As an example, the geological and mining conditions of a coal mine were used to design the Wongawilli strip pillar plans, including the support parameters of the entries and the mining technology. In order to control the surrounding rocks and manage the roof effectively during coal mining, the stress fields, displacement fields and plastic zones were studied by numerical simulation. The stress fields, displacement fields, and plastic zones generated by Wongawilli strip pillar mining were obtained. And the surface movement and deformation were also determined after mining was completed and its effects on surface structures were analyzed and evaluated. The results demonstrate that it is feasible to mine under surface structures with the Wongawilli strip pillar mining technique. This mining method can protect the surface structures from damages.

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1. Introduction

There is a great amount of coal (about 140 billion tons) left unmined under the surface structures, water bodies, railways (referred to as the "three-body"). Coal mining under "three-body" especially that under surface structures has become a major problem in the mining area [1]. The key problem of mining under surface structures is to control overburden strata and surface movements [2]. At present, the major surface subsidence control methods are strip pillar mining, backfilling mining method, room and pillar mining, grouting of bed separations, harmonic mining, and so on [3]. Wongawilli mining method is a high-efficient shortwall mining method developed based on the room and pillar mining, and named after the first successful trial in Australia "Wongawilli" coal seam [4,5]. The room and pillar mining equipment such as continuous miner is employed in this method. Its major advantage is flexible face layout which can be used to mine the small wedge coal blocks and those that are difficult to be mined with retreat longwall mining method. It requires less capital investment, short lead time for production, flexible equipment operation and face move and high productivity [6]. It has been applied in some China's coal mines [7–9].

The Wongawilli strip coal mining technology is a new coal mining method for mining under surface structures. It combines the strip mining longwall layout and Wongawilli high efficient mining technology. This technology can fully utilize the advantages of both the strip pillar and Wongawilli mining methods, and overcomes the disadvantages such as frequent face move, and low mining efficiency in strip pillar mining, and poor ventilation condition and poor long-term stability problems of coal pillars. In this paper, the Wongawilli strip mining method was designed for Wangtaipu Mine and its feasibility was studied using numerical modeling and surface subsidence prediction.

2. Geological and mining conditions

At present, most of the No. 15 coal seam reserves totaling 377.07 million tons in Wangtaipu mine are located under surface structures. In order to mine the coal under the surface structures, the Wongawilli strip mining method was employed. An appropriate panel was selected for trial and the surface movement monitoring lines were set up. The trial area is located in panel XV2214 (east) (Fig. 1). In this area, the floor elevation of coal seam is from +634 to +646 m, the surface elevation ranges from +810 to

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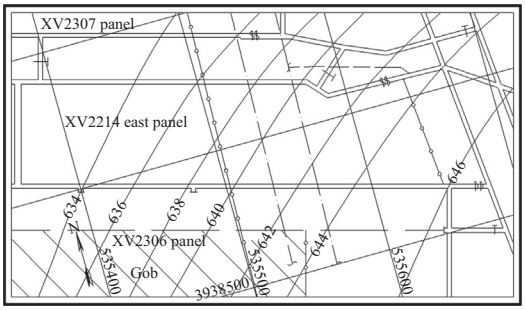

Fig. 1. Panel location where the Wongawilli strip pillar mining was employed.

+817.5 m, and the average depth of coal seam is about 174 m. The average panel length is 282 m and average panel width is 73.5 m. The seam dips 1–3°, and is 1.8–2.5 m thick with an average of 2.15 m. The roof and floor rock characteristics are shown in Table 1.

3. Wongawilli strip mining layout

3.1. Mining plan and entry layout

The XV2214 (east) panel in Wangtaipu mine is a longwall face. The mining plan employs both the strip pillar and Wongawilli mining methods in order to achieve high efficient coal mining under surface structures. Firstly, the design of strip pillar mining was determined based on the geological and mining conditions. The strip width is 25 m and the pillar width is 20 m. Secondly, the mining technology is determined. And the branch entry and rooms were driven with the continuous miner. In strip mining, two branch entries were used. In each branch entry, rooms were driven on the inside, i.e., double branch entry and single side cutting. The branch entry is 2.5 m high by 4.6 m wide. The room is 3.3 m wide and 8.8 m deep, with an inclination angle of 45° (Fig. 2).

3.2. Entry support design

The branch entry is rectangular. They were supported by a combination of roof bolts and cable bolts. The rooms were not supported (Fig. 3). The roof bolts were 20 mm in diameter by 2 m long. The anchoring portion consisted of two different types of grouting agents; one was CK2335 slow acting agent and the other was CK2360, an ultrafast grouting agent. The diameter of the hole was 30 mm.

The bolt row spacing was 1 m. Each row had 4 bolts. The cable row spacing near the solid coal side was 3 m, while near the mining side was 1 m. The distance from the cable to the solid coal side was 300 mm. The cable, made of high strength prestressed steel strand, was 15.24 mm in diameter and 6.7 m long. A K2335 quick anchoring agent and two Z2360 medium resin anchorage agents were used. The bolts used in the branch entries were 18 mm in diameter and 1.8 m long. Two anchoring agents a CK2335 and a CK2360 for drill hole diameter 28 mm were used.

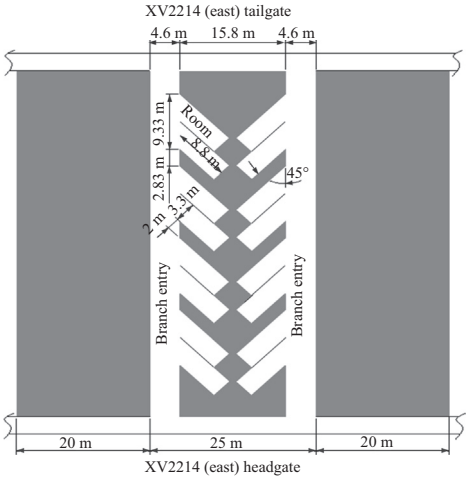

Fig. 2. Layout of Wongawilli strip pillar mining.

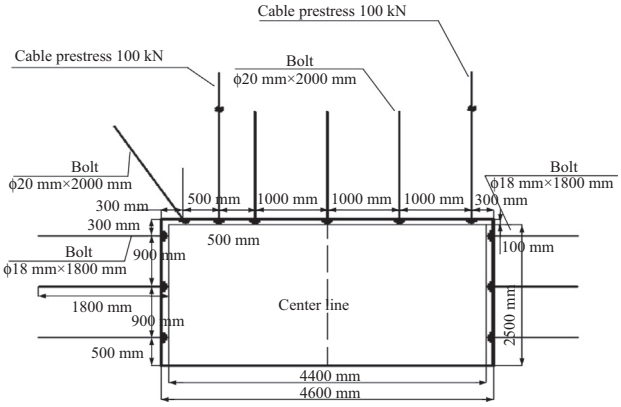

Fig. 3. Entry support of the Wongawilli method (rooms are on the right side).

3.3. Face equipment

According to the coal seam geological conditions and the equipment specifications, an intermittent face transportation mode was used, because it is more flexible and appropriate. The coal mining process is "continuous miner-shuttle car-crusher-belt conveyor". The main equipment is shown in Table 2.

3.4. Development of branch entry and retreat mining

This mining process includes branch entry development and room mining.

3.4.1. Branch entry development

The two branch entries are driven at the same time. It includes 5 steps: coal cutting, coal loading, coal transportation, coal cleaning

Table 1
Roof and floor of the coal seam.

Roof and floor	Rock	Thickness (m)	Characteristics of rock
Main roof	Limestone	9.820	Gray, blocky, thin chert layer in the upper part, well-developed fractures at the bottom, containing a large number of Reichelina, a small amount of fossils, the bottom is clayey limestone
Immediate roof			
Immediate floor	Mudstone	9.670	Light gray, top is light black blocky. The center part contains a small amount of clay. The lower part is imbedded with lumpy pyrite. At the bottom, there is a 0.15 m "Shanxi type iron"
Main floor	Limestone	20.79	Gray, slightly whitish, massive, micro fractures are well-developed, a lot of calcite veins, the top is imbedded with lumpy pyrite

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