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Overlying strata movement of recovering standing pillars with solid backfilling by physical simulation

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ABSTRACT

To analyze the overlying strata movement law of recovering room mining standing pillars with solid backfilling. Physical simulation experiments with sponge and wood as the backfilling simulation material were tested. The results show that: (i) The covering-rock mechanics of the overly strata comes from "two-arch structures + hinged girder + bend beam" to "backfilling material + hinged girder + bent beam" by increasing the fill ratio from 0% to 85%, the beginning of overlying strata movement appears later and the total duration of subsidence velocity increased from zero to the highest value increases. The trend of "single polarization" of the subsidence velocity curves becomes noticeable and the velocity variation trend becomes stable. (ii) The equiponderate aeolian sand was added to improve the anti-pressure ability of the loess, and the corresponding ground processing & transportation system was designed.

1. Introduction

Chamber mining has been widely used in the Shendong mining area for many years. Until now, more than 7000 million tons in the coal pillars, which are very difficult to extract, are still used to support and protect the goaf and roof underground. Rock burst, coal spontaneous combustion, gas accumulation, aquifer depletion, groundwater contamination and subsidence of the soil caused by the oxidation and failure of pillars have become potential and enormous threats to the ecological environment in this area [1–6]. Safe and efficient extraction of the pillars is an urgent issue that needs to be addressed and has attracted the attention of many international researchers [7–11]. However, despite some advances, the majority of technical methods is still carried out by caving or strip mining. There are several disadvantages in the existing technical methods, such as damages of the ground environment and soil resources and the loss of groundwater resources.

Most studies suggest that it is easier to control rock movement and ground deformation with Mechanized Solid Backfill Mining (MSBM), thereby enabling protection of the ground environment and groundwater resources. MSBM provides a reliable and green mining technological solution for solving problems caused by the caving method [12–18]. Based on MSBM, a new method, Mechanized Solid Backfill Mining with Loess (MSBML), has been designed to recover the standing pillars, using backfill material which is the local rich loess. Compared with the caving method and other solid backfill methods, the coalfaces are surrounded by coal pillars and backfill materials (loess). In this technique, the pillars and backfilling material act as the permanent supporting body to bear the weight of the overlying rock whose overlying strata movement and fracture development law are thereby changed. In this sense, there is a far-reaching theoretical and practical need to study the overlaying strata movement laws and fracture development in MSBML.

Because of its convenience, direct observation, safety and simplicity, physical similarity simulation is used as one of the most popular and effective ways of studying the laws of overburden movement and fracture development [19,20]. In this research, wood and sponge were taken as the similar material (loess) in the model.

2. Experimental scheme of the physical simulation model

2.1. General situation of MSBML face

The MSBML consists of 2 basic systems: coal blasting and transport, similar to the blasting working face, and the MSBML transportation system of the loess (MSBML-TSL). According to the requirements of the task, the MSBML-TSL, which can carry the loess from the surface to the goaf without interruption, is separated into 4 parts: surface processing and transportation system,

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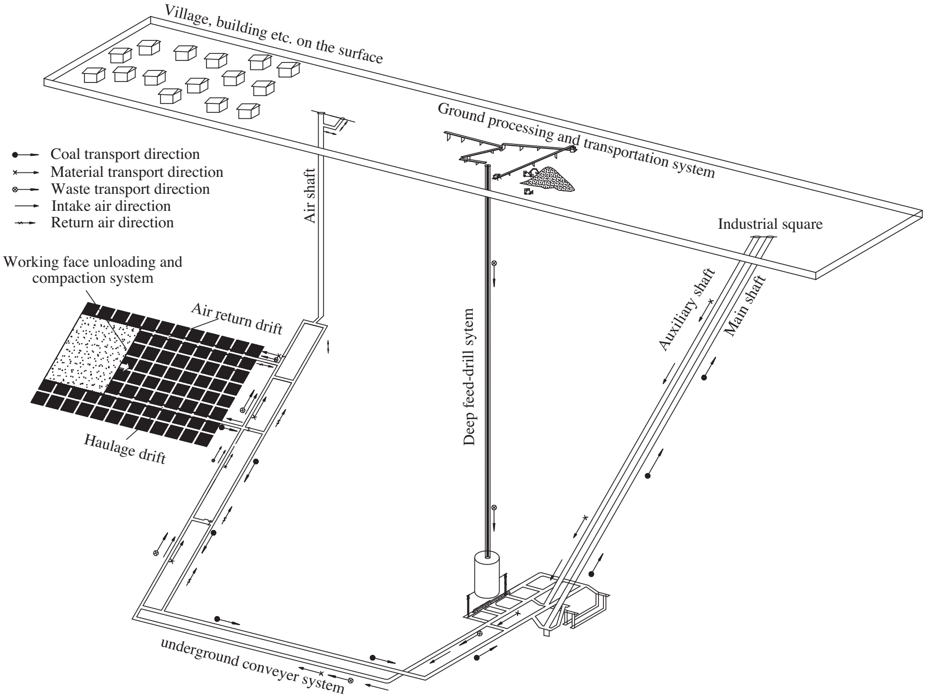
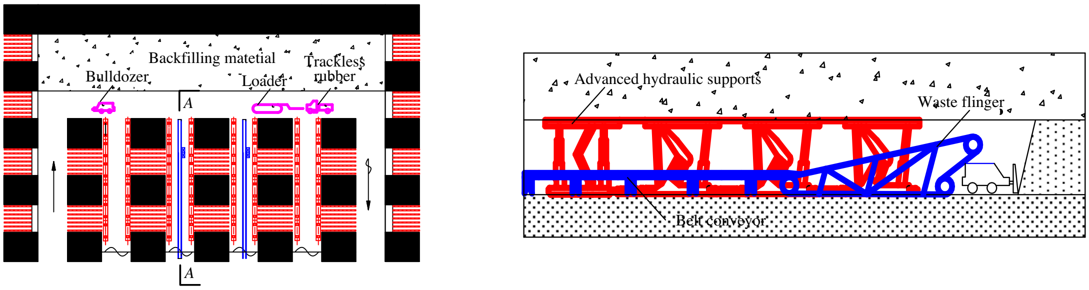


Fig. 1. Schematic plot of recovering the room mining standing pillars.



(a) Plan

(b) *A-A* section

Fig. 2. Working face unloading and compaction system.

deep feed-drill system, underground conveyer system, and working face unloading and compaction system, as shown in Fig. 1.

One mining working face (No. CT201), located in the Bandingliang coal mine area, was used as the study object. The face width and strike advance length are 48 m and 480 m respectively. The face extracts the pillars of #5–2 coal seam which has an average dip of 1.0°, an average thickness of 4.5 m and an average depth of 89.0 m. The sizes of the rooms and pillars in this region are 7.5 m by 7.5 m and 9.0 m by 9.0 m, respectively. The equipment layout of working face is shown in Fig. 2.

2.2. Model set up

From the mechanical characteristics of coal mining, the model is reduced to two dimensions whose geometric length, thickness and height are, respectively: 250.0 cm, 16.5 cm, 109.5 cm and the enrichment ratios are: 0%, 45% and 85%. The rooms are first extracted, as shown in Fig. 3, and then the pillars, the size of which is 0.09 cm × 0.09 cm, are extracted when conditions are stable. The ratio of geometric similarity, stress similarity and time similarity between the model and its prototype are 1:100, 1:167 and 1:10 respectively. Based on the above similarity parameters, the physical and mechanical parameters and strata distribution in the model are as shown in Table 1.

In order to observe the strata movement, six rows of measuring lines are arranged from the immediate roof to the overlying strata, and 2 points are used to monitor the subsidence and subsidence velocity of strata No. 6.

2.3. Simulated material design for backfilling material

Selecting the proper simulated material for loess in the goaf is the key factor in reflecting reality, both systemically and objectively. The compaction characteristics of several materials, including different kinds of sponge, rubber, softwood, and foamed plastics were tested in the laboratory. The results show that the stress–strain curve of one kind of sponge (No. 1) is similar to the stress–strain curve computed by the similarity formula relationship up to 9.0 kPa, as shown in Fig. 4. In order to reflect the real compression process of loess in the goaf and maintain the counter fill ratio, the similar material in the model is simulated by a combination of hard wood and this kind of sponge, as shown in Fig. 5. The combinations for different backfill ratio is shown in Table 2.