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Subsidence control and farmland conservation by solid backfilling mining technology

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Abstract: Solid backfilling mining technology, which decreases the height of fissure zone and caving zone, and alleviates the subsidence, is a new technology for farmland conservation. Based on the situation analysis of farmland destruction in mining area, three ways for farmland protection were proposed. In order to improve the feasibility of this technology, the limited filling materials should be used to increase resources recovery ratio, and then the surplus materials could be backfilled into goaf. An index, namely farmland conservation ability, was put forward to optimize the ways for farmland conservation. At last, the Wanbei coal mine was taken as a case for farmland conservation. It was shown that 3240 t dull coal was substituted and 52 hm^2 farmland was conserved by solid backfilling mining in this coal mine.

Key words: solid backfilling; farmland conservation; mining subsidence; equivalent mining height

1 Introduction

As the essence of land, farmland quantity is significant for nation economy and people's livelihood. In China, it is explicitly stipulated in The National Land Use Planning (2006−2020) [1] that the quantity of farmland should be more than 0.1212 and 0.1203 billion hectares in 2010 and 2020 respectively. Considering the current decreasing velocity of farmland quantity, it is difficult to achieve the task. Therefore, many researchers in various fields studied protecting farmland from destruction.

The report of China's Sustainable Energy Development Strategy [2] pointed that coal resource will account for more than 50% in the production and consumption of one-time energy. Besides, coal mining causes serious ecological environment problems, such as farmland destruction, buildings' damage, geological disasters. Statistics data show that mining subsidence area is around 6×10^5 hm^2 in China and 50% of the annual increase of land supplement is for mining industry. Meanwhile, there are 15000 hm^2 farmland which was occupied by gangue hills and the increasing speed of gangue is 0.15−0.2 billion tons annually. Currently, many scholars indicated that mining subsidence, villages relocation, solid waste accumulation are the main reasons of land occupation and destruction in mining area, thus some corresponding methods like strip mining [3], overburden grouting [4] and land reclamation [5−6] are used for farmland conservation.

Solid backfilling is a new technology for mining subsidence control. By this technology, solid waste is filled in the goaf to constrain overburden strata movement, and then land subsidence decreased drastically. Based on analyzing the mechanism of farmland conservation by solid backfilling, three ways for farmland conservation which can be applied in coal enterprises are put forward. After evaluating the farmland conservation ability of different ways, the

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prospect of farmland conservation by solid backfilling technology is evaluated.

2 Solid backfilling mining technology and its mechanism of farmland conservation

2.1 Solid backfilling mining technology

Solid backfilling mining technology contains three classes: fully mechanized solid backfilling mining technology, conventional mechanized solid backfilling mining technology and roadway excavation solid backfilling mining technology. Among them, fully mechanized solid backfilling mining, whose working face layout mode is similar to fully mechanized mining (Fig. 1), is the most widely used one. Fully mechanized solid backfilling mining means that solid backfilling and coal mining are done at the same time in the working face [7]. The filling working face is deployed on one side of the goaf (i.e., at the back of mining working face), and a transportation belt, which shifts the solid material to scraper chain conveyors, is set in the headentry of working face. Two scraper chain conveyors with the same direction are set at the front and rear of hydraulic support. The rear of hydraulic one is called solid backfilling conveyor, which hangs under the horizontal rear canopy and several dropping holes are made on it. Solid backfilling conveyor is connected with the transportation belt, then solid materials can be transported to solid backfilling conveyor and fall from dropping holes, until the goaf is full of solid filling material. All the backfilling tasks can be done at the shield of horizontal tail beam (Fig. 2).

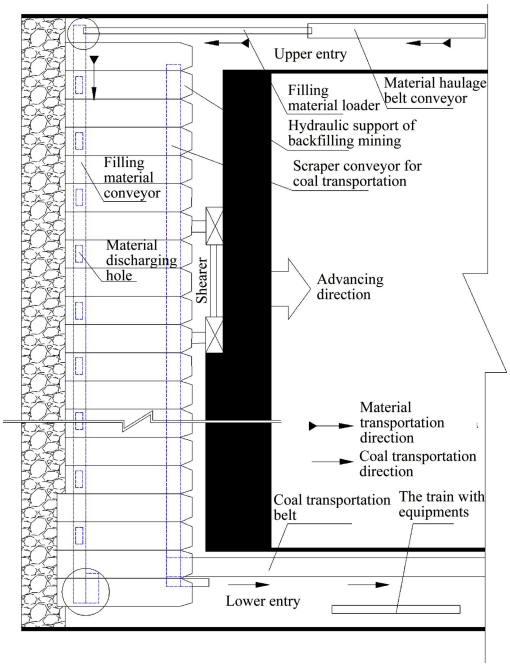


Fig. 1 Working face layout of fully mechanized mining by solid backfilling system [7]

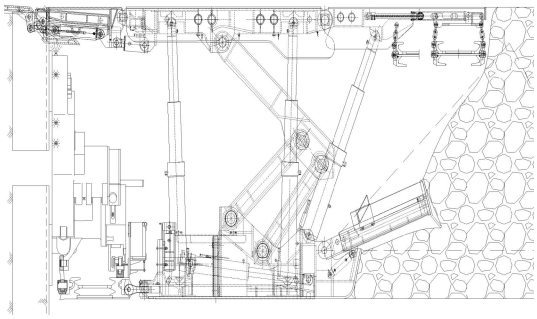


Fig. 2 New solid filling hydraulic support [7]

As shown in Fig. 1, solid filling materials fall into goaf through dropping holes on solid backfilling conveyor, and then they are compacted by the push-tamp equipment which is set at the rear of hydraulic support, finally the density and ratio of backfilling body can be increased.

2.2 Mechanism of farmland conservation

Ground deformation (including continuous and discontinuous deformation) caused by mining leads to the surface water resources and even the farmland destruction. Solid backfilling mining can efficiently reduce the ground deformation caused by mining. Meanwhile, solid backfilling technology can sharply lessen the overburden destruction extent, and then protect the surface water resources. These are the main reasons that farmland is conserved by solid backfilling technology.

Farmland subsidence, when the solid backfilling technology is used, can be evaluated by using the equivalent mining height theory [8]. Equivalent mining height is the difference between the mining height and the height of backfilling body after long time compaction and rheology by overburden strata, as shown in Fig. 3.

In the equivalent height theory, it is supposed that the subsidence basin by solid backfilling mining is the same as caving method with equivalent mining height. So the prediction of solid backfilling mining can be switched to the prediction by caving method with equivalent mining height. The subsidence prediction parameters and methods of thin coal seams could be used for it.

In the subsidence prediction of solid backfilling method, how to determine the equivalent mining height is the key. The analysis of subsidence influence factors by solid backfilling mining shows that the elements which affect the equivalent height are: thickness of coal seam, movement of roof and floor before filling, backfilling rate, prime compression of the backfilling body, residual compression of the backfilling body, etc. Then the calculation of equivalent height can be divided

in two parts:

1) The height of filling body (H_0) can be calculated with the following formula:

$$H_0=H-\Delta-\delta \quad (1)$$

where δ is the gap between the backfilling body and roof, Δ is the movement of roof and floor before filling, and H is the thickness of coal seam.

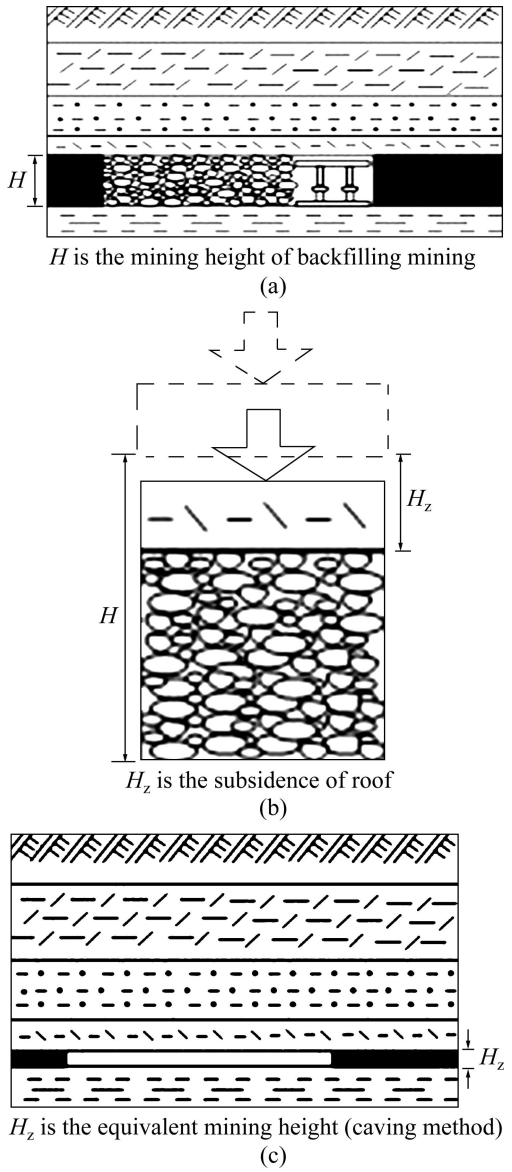
2) Equivalent height can be decided by the following formula:

$$H_z=H-H_0+\eta H_0 \quad (2)$$

where η is the residual compression rate of solid filling body.

After that, solid backfilling mining subsidence can be calculated by the equivalent mining height and strata movement parameters in the coal mines.

Similarly, the height of crooked zone, fissure zone and caving zone of solid backfilling mining are calculated by the expericence formula, which is inversed from the coal mine measurement data or from the Regulations on Coal Pillar Design and Mining Regulations Under Buildings, Water, Railways [9]. However, the mining height should be subsititued by equivalent mining height.



H is the mining height of backfilling mining
(a)

H_z is the subsidence of roof
(b)

H_z is the equivalent mining height (caving method)
(c)

Fig. 3 Equivalent mining height model of backfilling mining

3 Farmland conservation approach

Different kinds of farmland occupation and destruction by coal resources exploitation are summarized as follows:

1) Mining subsidence causes farmland reduction and quality decrease. Mining subsidence changes surface morphology, landforms and even crop's growing environment, then crops' production will decrease or even crops will die. Meanwhile, in high water level mining areas, ground subsidence causes a relative rise of groundwater level, which leads large number of farmland to be submerged by water and the area of farmland decrease directly. According to statistics datas, subsidence land caused by mining is 0.6 million hectares and increases with the speed of 53 thousand hectares per year in China, while solid backfilling mining can relieve the ground subsidence and protect the certain part of farmland from decreasing and deterioration efficiently.

2) The area of farmland decreases by gangue hills occupation. Traditional way to deal with gangue is to lift them from underground to surface, which occupies a large area of land. At the same time, gangue hills release harmful gases, acid liquid and heavy metal pollution. According to statistics data, gangue hills occupy 15 thousand hectares with the increasing speed of 400 hectares per year.

3) Village relocation occupies massive land. In China, it is a serious problem that large numbers of coals buried under buildings, water and railways, especially under the buildings. Statistics data show that, coal under buildings accounts for 63.5% of the total buried coal of 13.79 billion tons, even that in some coal mines the percentage of coal under buildings is 100%. Therefore, how to choose an efficient method to mine the buried coal is difficult for coal mines. Currently, moving out the people before mining under buildings is the main method, and large of farmland will be occupied by new buildings.

4) Surface water system is destroyed by mining subsidence. During the process of overburden rock collapse and fratures, the natural state of aquifer, water-resisting layer and surface water system will be destroyed, and then the district can not offer the comfortable water condition of crop growth. This problem is more serious in western coal mines whose ecological system is poor. However, the extent of overburden strata destruction can be reduced and surface water system can be protected efficiently by using solid

backfilling technique.

After analyzing the pattern of farmland occupation and destruction, several ways for farmland conservation by solid backfilling are given, as shown in Fig. 4.

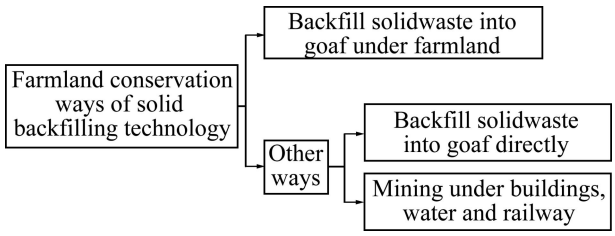


Fig. 4 Farmland conservation approach by solid backfilling mining

4 Optimization of farmland conservation approach

Solid backfilling materials are various in different coal enterprises. In general, they are gangue, coal ashes, sands, loess, industrial waste, etc. On one hand, some of these materials are kinds of resources themselves, such as gangue, loess and sands, which will raise the cost of enterprise when using the solid backfilling technology; on the other hand, the productivity of solid backfilling mining is much less than the conventional caving method. Therefore, coal mine enterprises hold the negative attitude to farmland conservation by using this technology. However, the farmland conservation needs to be implemented by coal mine enterprise. So, a new concept is proposed that the limited filling materials should be used in some complicated and difficult mining areas, such as coals under buildings, water, railways and areas with high stress to increase resources recovery ratio, which protect farmland indirectly. The surplus materials could be backfilled into goaf directly, which avoids the farmland occupation and pollution by solid waste (gangue, coal ashes).

From the analysis of the new concept, it is shown that there are many ways to protect farmland from destruction. In order to optimize the protection ways, farmland conservation ability, a new index, is defined.

Farmland conservation ability is the area of farmland conservation by using a million ton solid backfilling materials.

Obviously, farmland conservation ability is related to coal seam thickness, mining depth, filling ratio, compression ratio of the filling body, etc. To further elaborate the index value of different farmland conservation ways, a case of Wanbei coal mine is calculated.

Wanbei coal mine locates in the central of Huaibei plain with large high-quality land. The average elevation of this mine field is about 27.0 m, and the buried depth of underground water level is 2.9 m. The No.5 coal seam is the main one exploited, whose density is 1.37 t/m^3, thickness is 3.2 m, depth is 380 m, and average dip angle is 10°.

There are seven villages in Wanbei coal mine, and coal is buried under four of them: Darenjia, Wanglou, Sunyuzi and Hujiacun with the population larger than 3600. Moreover, there is another challenge to extend the upper extraction limit of coals buried under water (mainly in quaternary aquifer) in this coal mine.

For the coal mine, gangue, as the main solid waste, occupies a large number of farmland and causes serious environment pollution. Up to now, there is 2.865 million tons gangue in the mine field, and it is increased by 18% of the coal production.

After analysis of the geologic and mining conditions, and combining with subsidence monitoring results, the subsidence prediction parameters of solid backfilling are selected: subsidence coefficient 0.89, tangent of major influence angle 1.8, horizontal movement coefficient 0.24 and the displacement distance of inflection 0.1H (H is the mine depth). Then the land subsidence and deformation are evaluated by the equivalent mining height theory. The specific calculation process can be found in Ref. [10].

As the buildings and farmland should not be damaged and submerged, the subsidence and tilt deformation value should be controlled to be lower than 1 m and 20 mm/m, respectively.

The results show that when farmland conservation is implemented by solid backfilling in Wanbei coal mine: Farmland conservation ability by solid backfilling mining under farmland directly is 25 hm^2/Mt; Farmland conservation by solid backfilling mining under buildings is 12 hm^2/Mt; Farmland conservation by solid backfilling mining under water is 10.8 hm^2/Mt; Farmland conservation by dealing with gangue underground is 5.1 hm^2/Mt.

According to the new concept, solid backfilling mining should be applied to mining under buildings, and water, then surplus filling materials can be filled under farmland directly. Thus 52 hm^2 farmland in the coal mine could be conserved by this technology, and 3.24 million tons of dull coal reserves can be substituted.

5 Prospects of farmland conservation

According to statistics data, gangue in China is about from 10% to 15% of coal production. By the year 2000, more than 3 billion tons gangue have been accumulated, which occupy about 12 thousands hectares farmland. According to statistic data from Chinese Coal Industry Yearbook [11], coal production is about 17 billion tons and gangue production is 1.7−2.6 billion tons, in which 0.1 billion tons are used.

Based on the data above, it can be supposed that there are about 3.8 billion tons of gangue at present, which occupies 1×10^4 hm^2 land. The increasing speed of gangue is 0.3 billion tons per year, which occupies 800 hm^2.

It can be supposed that if 70% of the available gangue will be used for mining under buildings, 1.9 billion tons dull coals will be substituted and 3.3×10^4 hm^2 of farmland can be conserved. If all of the gangue is used for backfilling mining under farmland, 6×10^4 hm^2 acres land will be conserved. By analogy, if 70% of gangue production can be used to mining coals under buildings, water and railways or filled in the goaf directly every year, 0.15 billion tons of coals under buildings or water will be substituted and 2667 hm^2 of farmland will be conserved. If the gangue is filled in goaf directly, then 5333 hm^2 of farmland will be conserved.

6 Conclusions

1) Decreasing the height of fissure zone and caving zone, and alleviating the subsidence are the main reasons that solid backfilling technology could conserve farmland. Subsidence and deformation of farmland, height of fissure zone and caving zone can be evaluated by using equivalent theroy.

2) Three farmland conservation ways of solid backfilling mining technology are proposed: mining under buildings, water and railways, which raises the resources recovery ratio accompanied with protecting farmland indirectly; backfilling solid waste into goaf to protect farmland; and dealing with the solid waste underground to avoid its occupation and pollution to farmland.

3) The limited filling materials should be used in some complicated and difficult mining areas, such as coals under buildings, water, railways and areas with high stress to increase resources recovery ratio, which protects farmland indirectly. The surplus materials could be backfilled into goaf directly, which avoid the farmland occupation and pollution by solid waste (gangue, coal ashes).

4) Solid backfilling mining can conserve farmland efficiently. The example shows that 3240 t dull coal mine are extracted and meanwhile 52 hm^2 of farmland are conserved.

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