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Subsidence prediction method based on equivalent mining height theory for solid backfilling mining

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Abstract: Based on the characteristics of strata movement of solid backfilling mining technology, the surface subsidence prediction method based on the equivalent mining height theory was proposed, and the parameters selection guideline of this method was also described. While comparing the parameters of caving mining with equivalent height, the subsidence efficient can be calculated according to the mining height and bulk factor of sagging zone and fracture zone, the tangent of main influence angle of solid backfilling mining is reduced by 0.2−0.5 (while it cannot be less than 1.0). For sake of safety, offset of the inflection point is set to zero, and other parameters, such as horizontal movement coefficient and main propagation angle are equal to the corresponding parameters of caving mining with equivalent height. In the last part, a case study of solid backfilling mining subsidence prediction was described. The results show the applicability of this method and the difference of the maximum subsidence point between the prediction and the observation is less than 5%.
Key words: solid backfilling mining; mining subsidence; equivalent mining height; subsidence prediction; subsidence control

1 Introduction

Subsidence is the most common disaster in mining areas and results in lots of environmental problems, which attracts many researchers to work on this topic. Subsidence control by filling has been explored for hundreds of years, and many methods have been developed [1−6]. However, their performance on filling and subsidence control varies significantly [7−9]. To control the subsidence, an accurate subsidence prediction is crucial for designing the workface, protecting the buildings and selecting optimized mining method. At present, numerical simulation, similar material physics simulation and influence function method are the main ways to predict surface subsidence [10−12]. Among these methods, influence function method is the most widely used one in China with the parameters obtained by plenty of observations [13]. Therefore, the surface subsidence of solid backfilling mining is also predicted based on this method as caving mining except that the subsidence coefficient was decreased to reflect the effect of subsidence relief. Hereby, the subsidence control can be compared intuitively among different filling methods, such as the subsidence coefficient of sand filling and pneumatic filling is 0.05−0.55 [14]. To be specific, the subsidence coefficient depends on geological and mining conditions, filling material, filling rate and other factors [15], which causes the difficulty for determining subsidence coefficient. Hence, it is difficult to fix reasonable parameters for subsidence prediction, especially for the newly developed mining methods, such as solid backfilling mining and cement backfilling mining.

To solve this problem, the concept of equivalent mining height in solid backfilling mining was proposed. In this theory, an assumption that the subsidence basin induced by solid backfilling mining is the same as

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deformation caused by caving mining with equivalent height. Therefore, the subsidence prediction induced by solid backfilling mining can be switched to predict the deformation induced by caving mining. Then the probability integral method, which is based on influence function theory and widely used for subsidence prediction induced by caving mining in China can be applied. Besides, the equivalent mining height theory is also used for coal pressure and strata deformation analysis in solid backfilling mining technology. In this work, the parameter selection for this method was given as well. Hereby, mining subsidence of solid backfilling mining can be predicted and it will provide a reliable evidence for mining design under buildings, water bodies and railways.

2 Strata movement characteristics of solid backfilling mining

Coal exploitation breaks the stress balance of overlying strata and leads to strata movement and surface subsidence. In the process of strata and surface movement, strata in caving zones and fracture zones break, which reduces the subsidence space effectively, and stops the strata moving [15]. Compared with the caving mining method, the solid filling material occupies most of the space after mining and constrains roof subsidence when the solid backfilling mining is used. This also explains why overlying strata movement and surface subsidence can be controlled effectively by solid backfilling mining.

Based on a large number of experimental results [16], characteristics of overlying strata damage and surface movement in solid backfilling mining can be summarized as follows.

1) No obvious caving zones develop in overlying strata and only small fracture zones form in immediate roof, overlying strata bends as a whole and a tardy basin is formed. The difference of structure and morphology in the overlying strata of caving mining and solid backfilling mining is shown in Fig. 1.

2) Solid filling material is compacted slowly with bending and subsiding of overlying strata. Bearing capability of overlying strata is improved while compaction deformation decreases gradually until it stays in a stable level. There is a great difference in the process of overlying strata subsiding between solid backfilling mining and caving mining. For solid backfilling mining, overlying strata subsides slowly, but for caving mining, the overlying strata subside dramatically.

3) Characteristics of subsidence basin are similar between solid backfilling mining and caving mining method. However, the surface subsidence and

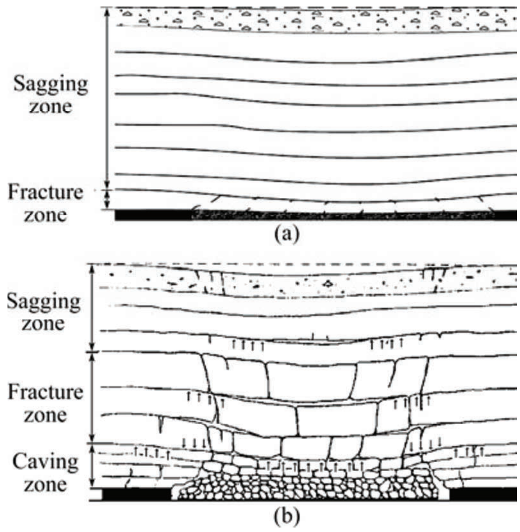

Fig. 1 Overlying rock movement and deformation of caving mining and solid backfilling mining method: (a) Solid backfilling mining; (b) Caving mining

deformation of solid backfilling mining is much smaller than caving mining. An apparent deformation and subsidence reduction can be seen for overlying strata. Moreover, uniform and unified subsidence is the most common behaviors for overlying strata of solid backfilling mining while it cannot be seen in caving mining.

3 Connotation of equivalent mining height

Mining height is the dominant factor which affects strata movement and surface deformation. For solid backfilling mining, filling material occupies the goaf and reduces the subsidence space of overlying strata. It also can be explained in this way that the subsidence is caused by mining coal with an equivalent height. To be specific, equivalent mining height is the mining height of filling working face minus the height of filling material after compaction. As shown in Fig. 2, we denote the height of solid backfilling mining as M, and the subsidence of overlying strata roof as M_e. Based on the assumption that the mining subsidence basin is same between solid backfilling mining with its mining height M and caving method with its mining height M_e. Together with the equivalent mining height model, the equation for calculating the equivalent mining height is shown in formula (1).

$$M_e=h_z+(k-k')M'h_z \tag{1}$$

where M_e is the equivalent mining height; h_z is the unfilled height in goaf; M is the mining height; k is the initial porosity of the filling material; k' is the residual porosity after compaction.