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Similar material and numerical simulation of strata movement laws with long wall fully mechanized gangue backfilling

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Abstract

This paper studies on strata and surface movement laws with long wall fully mechanized gangue backfilling technology by similar material simulation and numerical simulation method. The results indicate that 1) the overlying strata under the situation of mining with long wall fully mechanized gangue backfilling mainly shows a slow bending and subsidence, characterized by bending, fracturing, and bed separating, while the overlying strata develops fractured zone and bending zone only; and 2) if the compression rate of backfill is about 30%, the surface subsidence coefficient is around 0.22. In addition, this paper points out that improving the filling rate of gangue backfilling in goaf and the initial density of filling body are the main technological way to enhance the controlling effect of strata movement. Based on this point of view, four technical measures are proposed at the end.

Key words: coal mining with gangue backfilling; subsidence coefficient; density; control effect

1. Introduction

In coal mining, gangue backfilling can effectively control surface subsidence, reduce the strata pressure behavior, and dispose of the underground gangue. So it is an environment-friendly measure to regulate ground subsidence. At present, many scholars are studying problems with gangue backfilling, such as the control effect of subsidence, the characteristics of mine pressure behavior, gradation characteristics of gangue and its effect on compressibility[1-3]. However, few researches on strata movement laws which is the key problem in controlling ground surface subsidence is reported, it gives rise to a lack of theoretical guidance for predicting strata movement and deformation. Aiming at this problem, physical simulation and numeric simulation are used to study on strata and surface movement laws in coal mining with gangue backfilling.

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2. Similar material simulation

2.1. Model building

Similar material simulation has an obvious superiority over numerical simulation and filed trials in studying the moving process of overlying strata and the development law of “three zones”.

In this study, gangue backfilling working face No.7606 in Xingtai coal mine of Jinneng Group is taken as the prototype of similar material simulation. The ground elevation of working face is +85m and the elevation of the working face itself is -210m to -250m; so the average mining depth is 310m. Working face No. 7606 is 50m in width, with an advancing length of 460m, a dip angle of coal seam of 7°-10°, and a coal seam thickness of 5.4m. The immediate roof is sandy shale with a thickness of 4.5m; the main roof is fine sandstone, 2.8 m in thickness. The immediate bottom is also sandy shale, 6.69m in thickness; the main bottom is moderately fine sandstone with a thickness of 9.25m. Based on the stratigraphic column and geological report of the working face, the overlying strata is simplified (Table 1).

Table 1. Distribution and accumulated thickness of overlying strata above working face No.7606

Lithology	Accumulated thickness (m)
Surface soil	120
Shaly mid-sandstone	84
Inter-bedded fine siltstone	39
Conglomerate	18
Siltstone	33
Inter-bedded sandy shale	12
Coal	5.5
Bottom(fine sandstone)	24

Similar constants of the model are: 300 for geometric similar constant, 1.5 for bulk density similar ratio, and 450 for stress similar constant.

According to properties of the similar material and characteristics of the model, river sand and mica are selected as the aggregate material, gypsum and calcium carbonate are the cementing material while sponge is the filling material.

Model monitoring includes movement monitoring and stress monitoring.

Sixty movement monitoring points are arranged into five rows.

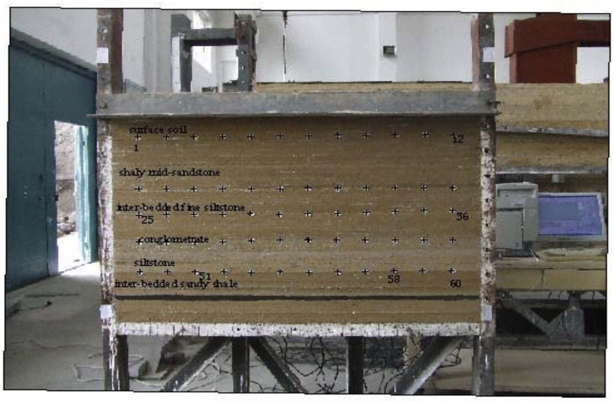

Fig. 1. Arrangement of monitoring points

Movement is monitored by the total station with an accuracy of 2″(angle) while the stress is monitored by the static resistance strain gauge TS3890.

Mining process of the model is divided into 10 times, 10 cm for each. After that, the goaf is filled with sponge whose compression ratio is known; before each mining, the movement and deformation at the monitoring points should be measured, with pictures taken and fracturing process recorded.

2.2. Analysis

According to the designed program, the mining process is simulated and the moving process of overlying strata above the working face with different advancing distances is recorded. During the simulation process of long wall mining with gangue backfilling, the whole structure of overlying strata keeps undestroyed, remains continuous as a whole. In the simulation process, only fractured zone and bending zone formed, no obvious caving zone developed. However, some minimal cracks formed near the open-off cut.

The similar material simulation in coal mining with gangue backfilling and the failure process of overlying strata are shown in Fig 2.

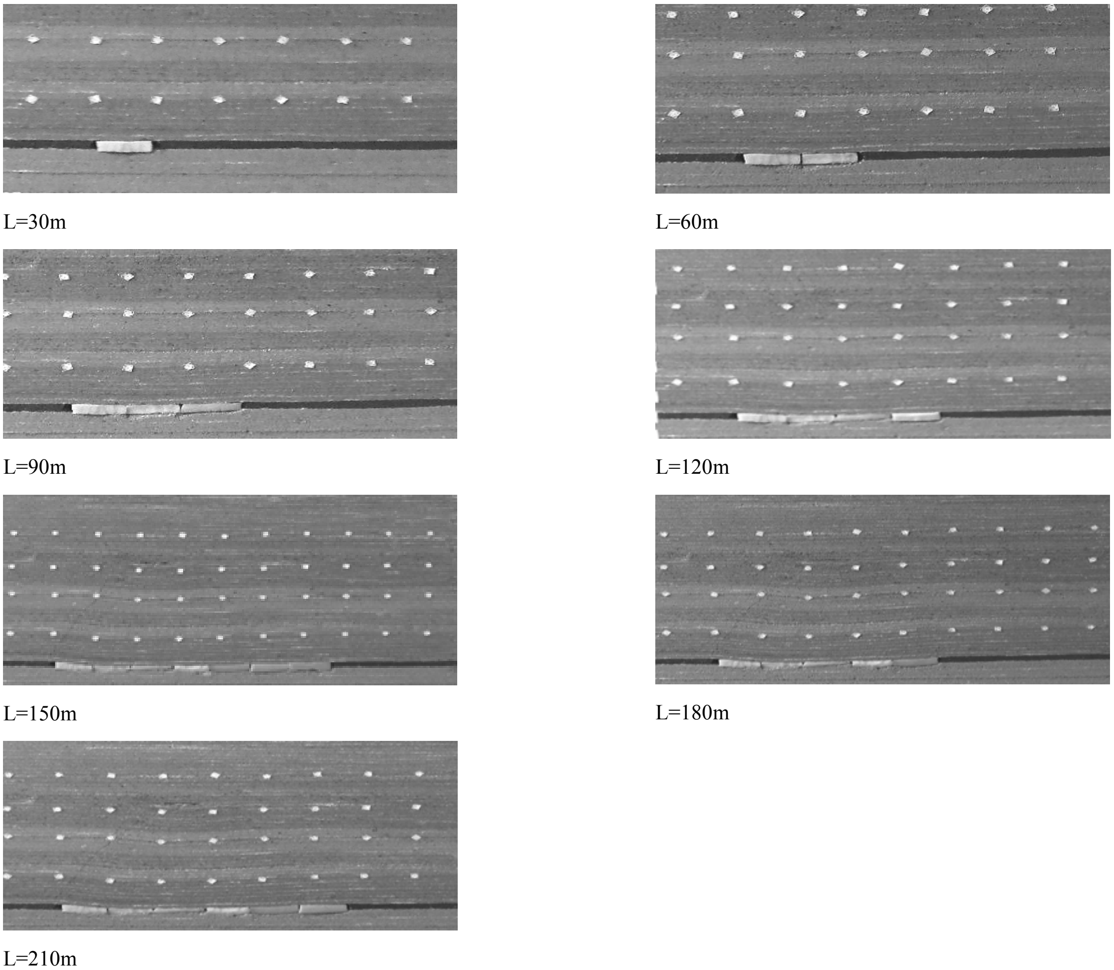

Fig. 2. Strata failure and movement of the similar material model for coal mining with gangue backfilling

When the working face has advanced for 30m, the roof has a little bend toward the filling sponge in goaf, with a subsidence of 300mm, while the positions of monitoring points in overlying strata keeps unchanged.

When the working face has advanced for 60m, the bending-induced subsidence of roof increases to 600mm, without any crack formed at the open-off cut, which is clearly different from that of mining with caving method. In caving mining, the roof shall collapse when the working face has advanced for 60m; in gangue backfilling, however, the roof has a little bend only.

When the working face has advanced for 90m, the bending-induced subsidence of roof has increased to 1000mm. In this situation, two rows of monitoring points near the coal seam move toward the goaf, with the maximum subsidence is 850mm and some minimal cracks developed at the open-off out.

When the working face has advanced for 120m, the strata above the filling zone shows an obvious bending feature with the maximum bending of the immediate roof being 1400mm.

When the working face has advanced for 150m, the strata at the open-off out becomes fractured, with the fracture angle is 75°. In addition, bed separation formed in the area above the third row of monitoring points, which is 600mm high and 38m wide.

When the working face has advanced for 180m, the height of the bed separation increases to 1100mm and the width increases to about 40m. The inner rock mass as a whole shows a bending feature and the subsidence of monitoring points of each row is in a decreasing order from top to down. In addition, the maximum compression of sponge reaches 1500mm.

With the further advancement of working face, the bed separation A1 gradually decreases and disappears because of compaction finally. Having finished mining, some results are obtained: the maximum subsidence of main roof strata above goaf is 2100mm, nearly 35% of the mining thickness; and the maximum subsidence of ground monitoring points which is right above the middle of the working face is 1305mm, about 22% of the mining thickness.

Analyzing the moving process of overlying strata in similar material model, some conclusions are made as follows:

(1) The maximum surface subsidence in coal mining with gangue backfilling is clearly less than the caving method. In this model, the maximum surface subsidence is 1402mm, with the subsidence coefficient is 0.22, which is in accordance with reference [1].

(2) The main features of strata movement in coal mining with gangue backfilling are: bending, subsidence, and fracturing; both fractured zone and bending zone develops; in the boundary area between hard rock and soft rock, bed separation forms.

3. Numerical simulation

3.1. Model building

Numerical simulation is performed by the software FLAC2D. The model is a plane strain one which is 810m long and 344m high. 300m is left for each side of the model and the middle 210m is the mining zone. The left and right boundaries are fixed in horizontal direction, while the bottom boundary is fixed in both horizontal and vertical directions. However, the top is a free surface. The model is divided into 18720 units and 19039 nodes.

Mohr-coulomb model is adopted for the overlying strata, strain-softening model for coal seam, and the harden D-Y (Double Yield) model is for filling body.

The whole advancing distance is 210m, and it is divided into 7 steps with 30m for each step, which corresponds with the similar material simulation. After a certain operation of time-stepping excavation, the goaf is filled so as to change the constitutive model of goaf units to D-Y model.

3.2. Analysis

Fig. 3 is the contrast of surface subsidence curves of mining by caving method and gangue backfilling with different compression rates of filling materials.

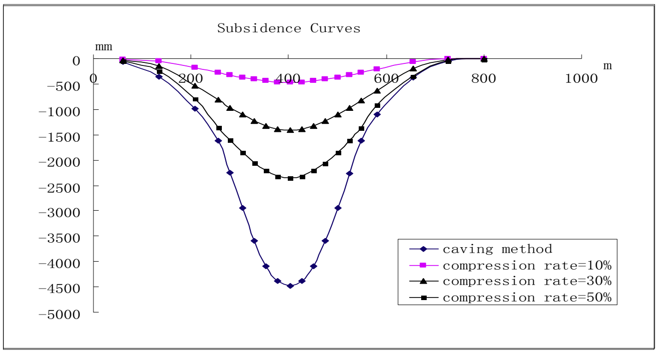

Fig. 3. Contrast of surface subsidence curves of mining by caving method and gangue backfilling with different compression rates of filling materials

In Fig 3, different compression rates of gangue backfilling results in different effects of controlling surface subsidence, that is, the smaller the compression rate is, the better the effect of controlling surface subsidence is. When the compression rate is 10%, the maximum surface subsidence is only 484mm, with the subsidence coefficient is 0.081; when the compression rate is 30%, the maximum surface subsidence is 1296mm, with the subsidence coefficient is 0.216; and when the compression rate is 50%, the maximum surface subsidence is 2456mm, with the subsidence coefficient is 0.409. When the caving method is used, the maximum surface subsidence is 4320mm, with the subsidence coefficient is 0.72.

The in-situ measured data shows that, under the condition of current gangue backfilling technique, the equivalent mining thickness after backfilling body being compressed can be controlled in the range of 20%~30% of the practical mining thickness, with the subsidence coefficient is about 0.2. The simulated result is quite close to the measured one. By comparing the surface subsidence curves resulted from gangue backfilling different in compression rate with that from caving method, it is obviously that effect of surface subsidence controlling is directly related to compression rate of the filling body.

Thus, in coal mining with gangue backfilling, some necessary measures should be taken to improve the filling rate of goaf and the initial density of filling body to decrease the compression rate and to better the control effect of strata movement. Some suggested technical measures include: (1) Ensure the roof support strength of gangue filling working face and reduce the subsidence amount of roof during the process of gangue backfilling as much as possible; (2) Optimize the gradation of gangue backfilling material and decrease its porosity; (3) Improve the gangue filling system and equipment, enhance the gangue filling rate; And (4) Better and optimize the compression-extrusion and pressure consolidation system of the gangue backfilling, improve the initial density of it.

4. Conclusions

(1) Coal mining with gangue backfilling can effectively control the overlying strata and surface movement, achieve the recycling use of solid waste, and reduce the environment pollution.

(2) The main behaviors of strata movement in coal mining with gangue backfilling are: bending, fracturing, and bed separating; in overlying strata, only fractured zone and bending zone develops.

(3) When the compression rate of backfill is about 30%, the surface subsidence coefficient is around 0.22.

(4) Four measures proposed in this paper are the main ways to improve the filling rate of goaf and initial density of gangue backfilling body and to enhance the control effect of strata movement in coal mining with gangue backfilling.

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References

[1] G. Guo, X. Miao, J. Zha, Z. Ma and Z. Zhou, Preliminary analysis of the effect of controlling mining subsidence with waste stow for long wall workface.Sciencepaper online. 11 (2008) 805-809.

[2] X. Miao and J. Zhang , Analysis of Strata Behavior in the Process of Coal Mining by Gangue Backfilling. Journal of Mining & Safety Engineering. 24 (2007) 379-382.

[3] W. Zhang, J. Zhang and J. Zhao, Research on Waste Filling Technology and Its Matching Equipment in Coal Mining. Journal of Mining & Safety Engineering. 24 (2007) 79-83.