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Similar simulation study on overlying strata movement law of high stress and large mining length working face

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Abstract

Aiming at the problem of overlying strata movement law of large mining length working face under high stress environment in deep mining, this paper sys-tem-atically studies the movement law and failure form of overlying strata on large mining length working face by combining physical similarity simulation with three-dimensional photogrammetry. The results show that after the completion of the whole excavation process, the cumulative maximum subsidence of the surface reaches 5.4mm, the maximum subsidence value appears at 73cm from the left side of the model frame, the minimum subsidence value of the surface is 4.7mm, and the minimum subsidence value appears at 50mm from the left side of the model frame. In the process of advancing the whole working face, the maximum roof subsidence reached 15.9mm, the maximum roof subsidence ap-peared at 75cm from the left boundary of the model frame, the minimum roof subsidence was 5.4mm, and the minimum roof subsidence appeared at 44cm from the left boundary of the model frame.

Keywords

Deep mining; large mining long working face; overburden rock movement; physical similarity simulation

1. Introduction

At present, the shallow coal resources in China have been continuously exhausted, and the underground mining has shifted from shallow to deep. With the increase of buried depth, the ground stress is also increasing[1]. In order to meet the growing demand for coal, the underground mining equipment is constantly upgrading, and the working face is becoming longer and longer. The movement law of overlying strata in large mining face is obviously different from that in ordinary length working face. It is necessary to explore its movement law to guide the safe and efficient production of working face.

Many scholars at home and abroad have done a lot of research on the movement law of overlying strata in ordinary working face. Meng Xiangjun et al have proved the evolution mechanism and failure law of the structure movement of overlying strata under the thick loose layer and unequal thickness bedrock[2]. He Jiqing et al studied the overlying strata movement law of some large mining height coal seam working faces[3-5]. For deep mining, Zhao Hongbao studied the coupling evolution law of stress field and seepage field of coal body in high stress area under top coal caving mining mode, and established the model of permeability evolution law of coal body under three-dimensional stress condition[6]; Ma Shoulong et al systematically expounded the distribution characteristics of space surrounding rock structure in large dip angle stope, and established the mechanical model of space surrounding rock structure at the upper and lower ends of large dip angle working face, and obtained the qualitative relationship of technical parameters such as weighting step and support resistance of large dip angle working face[7]. Chen Yankang et al used UDEC simulation to study the development law and evolution characteristics of water-conducting fracture zones under different mining schedules, and analyzed the relationship between large energy events and the development of water-conducting fracture zones. Based on the GA-SVR algorithm, an accurate prediction method for the development height of regional water-conducting fracture zones was established[8].

For the law of overburden movement in the field, it is impossible to observe intuitively. Similar simulation is a means of making physical models in the laboratory and reflecting the law of the field through physical models, which brings great convenience to the study of overburden movement law. Wang et al studied the surface subsidence law of deep ore body partition mining in Chengchao Mine, and analyzed the variation law of surface subsidence and surrounding rock stress with mining depth in deep part mining[9]. Zhang Boyang et al used the method of similar simulation test to study the height and development form of roof water-conducting fracture zone under the influence of mining[10].

Many scholars have studied the movement law of overlying strata in the working face of deep mining, but there are few studies on the large mining face. Based on the existing research, this paper uses the similar simulation method to explore the movement law of overlying strata in the high stress large mining face and the residual deformation law of overlying strata after the end of mining, which provides a certain theoretical reference for the stability of the roof of the large mining face.

2. Experimental design

2.1. Experimental background

The coal seam exposed during the excavation of the lower trough of the 2112 working face is the II1 coal seam of the Permian Shanxi Formation. The coal (rock) layer is a single gently inclined structure, nearly east-west, inclined north, with an inclination angle of 9 ° to 20 °, with an average of 15 °. The thickness of the coal seam is 1.61~6.77m, the average coal thickness is 3.78m, the coal seam structure is simple, the local gangue is contained, the thickness is between 0.1 m~0.4m, the coal seam is affected by the sliding structure, the organization is loose, the strength is low, the coal seam is mainly powdered, the block is crossed, and the Platts hardness coefficient is less than 0.3.

The roof lithology of II1 coal seam is mainly mudstone and sandy mudstone. Among them, the mechanical samples of mudstone, sandy mudstone, carbonaceous mudstone and siltstone roof have low compressive strength and tensile strength. The compressive strength is 15.6~54.8MPa, the tensile strength is 0.4~2.39 MPa, and the previous drilling RQD statistical value is 16.2~47.9%. Most of them are unstable rock strata, which are easy to soften in water. The roof rock mass belongs to the moderately complete (grade III) and poor quality (grade IV) roof.

The lithology of the direct floor of the II1 coal seam is mainly siltstone and mudstone. The compressive strength is 25.0~35.6MPa, and the tensile strength is 1.06~1.95MPa, which is also an unstable rock stratum. There is a local false bottom, and the lithology is mudstone. It is easy to soften, expand and deform in water, and it is not easy to manage. The floor rock mass belongs to the medium complete (grade III) and poor quality (grade IV) floor. In the production, it is easy to produce roof fall, rib spalling, falling block and floor heave deformation, easy to muddy in water, and may produce bad engineering geological phenomena such as pillar sliding and sinking.

2.2. Calculation of experimental parameters

2.2.1. Geometric similarity

According to the similarity theory, the corresponding part size between the model and the prototype should be proportional, and this ratio is the geometric similarity ratio. Combined with the actual situation of the prototype and the size of the laboratory model frame and other related factors, the size of the design model is 2.5m×0.2m×0.8m (length × width × height). Therefore, the geometric similarity ratio of this physical similarity simulation experiment is :1：150. According to the geometric similarity ratio, the prototype range of the actual simulation of the model is 375m×30m×120m (length × width × height).

2.2.2. Time similar

For structural dynamics problems, in the process of changing with time, the structural model and the prototype are required to be compared at the corresponding time, and the corresponding time is required to be proportional. Therefore, the similarity ratio of the design time of this similarity simulation experiment is: 0.082.

2.2.3. Physical similitude

During the experiment, the physical and mechanical properties of the corresponding points of the model and the prototype should be similar. Therefore, the selected model material and the prototype material should be similar in cohesion, internal friction angle, uniaxial tensile strength, uniaxial compressive strength, shear strength, Poisson's ratio and load strength. The physical properties of the similar simulation experiment are designed as follows: the bulk density similarity ratio is 0.68, the stress similarity ratio is 1: 220, and the load similarity ratio is 2.015×10^{-7}.

2.3. Model making process

(1) Load the experimental frame to the similar simulation hall.
(2) The prepared similar materials such as river sand, calcium carbonate and gypsum are transported to the similar simulation hall, and the amount of materials in each layer is weighed according to the material laying layering table, and the weighed materials are numbered in plastic bags for rapid access when laying.
(3) The pre-debugged pressure box and strain gauge are taken to the similar simulation hall and connected to the computer for balance operation. After the balance is completed, the pressure box and strain gauge are placed aside for use.
(4) After the completion of the above work to load the experimental frame.
(5) Firstly, the test loading area in the experimental frame is wiped clean with cloth, and then the baffles on both sides of the experimental frame are installed. After the baffles are installed, the oil is brushed on the inside of the baffles.
(6) The similar materials prepared in advance were mixed with water in proportion. After mixing, the materials were stirred evenly and laid in layers to the experimental frame. After the layered pavement was completed, the cracks were made with saw blades and an appropriate amount of mica was sprinkled for stratification.
(7) In the process of paving the experimental frame, the pressure box and strain gauge are laid in the pre-planned position. The pressure box is laid along the coal seam floor, and the strain gauge is laid near the surrounding rock of the roadway that needs to be excavated.
(8) According to the height of the experimental design, the experimental frame is filled and dried after the experimental frame is filled. The similar materials of the experimental frame are filled and dried as shown in Figure 1.

Figure 1. Laying effect of model experimental frame

3. Experimental result analysis

3.1. Analysis of cumulative surface subsidence

In this similar simulation experiment, the number of measuring points is relatively large. Therefore, a row of measuring points at the top of the model is selected as the measuring point for observing surface subsidence, and a row of inclined measuring points at about 10 cm above the simulated coal seam is selected as the measuring point for observing roof subsidence. In the process of advancing the whole working face, there were 17 collapses, and each collapse roof had obvious subsidence.

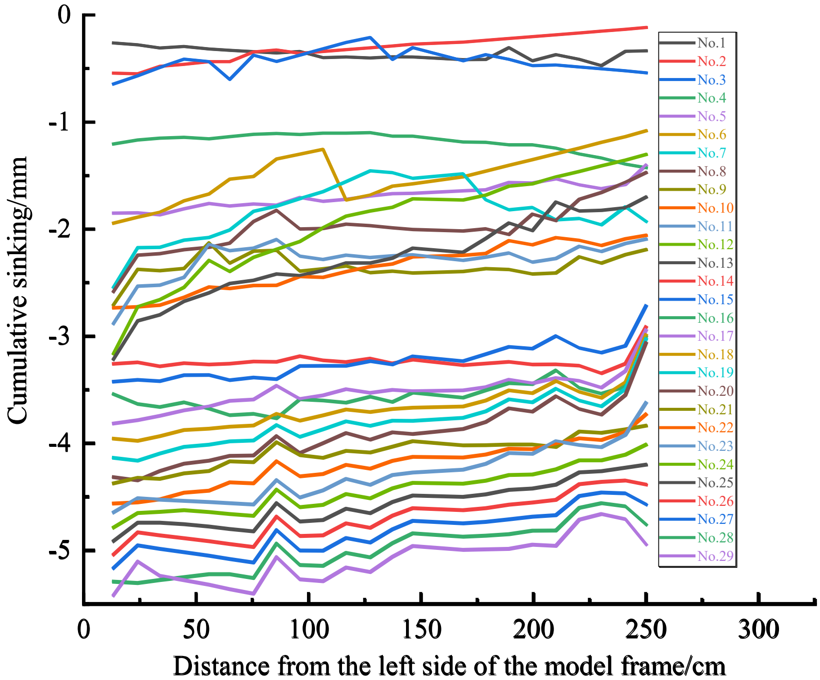

Figure 2. Cumulative subsidence curve of each excavation roof

For surface subsidence, with the continuous advancement of the working face, the surface above the whole working face has sunk to varying degrees, but some areas have bulged due to extrusion. In the 29 advancements of the working face, the overall trend of subsidence of the entire surface is increasing. Among them, the surface subsidence on the left side of the model frame is slightly larger than that on the right side of the model frame. In the process of the first 14 excavations, the ground subsidence changes little with each advance of the working face. From the 14th excavation to the 15th excavation, the ground subsidence suddenly increases a lot, and then the increase of surface subsidence remains stable. In the process of the 16th to the 29th excavation, the trend of the subsidence curve of the working face is similar. In the range of 50cm from the left side of the model frame, there are 40cm protective coal pillars in this range, so the overall subsidence of the surface is relatively small. Starting from 50cm on the left side of the model frame, the surface subsidence of the mined-out area began to increase linearly. Within the range of 150 to 200cm from the left side of the model frame, this area has been mined, and the goaf is further compacted under the action of overburden rock caving, so the subsidence of the surface in this range is relatively stable. Within the range of 210 to 250cm from the left side of the model frame, this area is a protective coal pillar area, so the surface subsidence above this area is relatively small. After the completion of the whole excavation process, the cumulative maximum subsidence of the surface reached 5.4mm, the maximum subsidence value appeared at 73cm from the left side of the model frame, the minimum subsidence value of the surface was 4.7mm, and the minimum subsidence value appeared at 50mm from the left side of the model frame.

3.2. Analysis of cumulative roof subsidence

In the process of 1 to 16 excavations of the working face, with the continuous advancement of the working face, the side away from the left boundary of the model is gradually excavated, so the roof subsidence mainly occurs in the range of 100 to 250cm from the left boundary of the model frame. With the continuous advancement of the working face, the cumulative subsidence of the roof is also increasing. In the first 15 advancements, the subsidence of the right part of the model is greater than that of the left part of the roof. However, with the continuous advancement, in the last 14 advancements, the subsidence of the left part of the model increased sharply. When excavating the left part of the model, because the right side is the goaf, and under the continuous collapse of the overlying strata, the rock in the goaf is continuously compacted, so the subsidence of the roof in the right part of the goaf is relatively small, and the subsidence curve is relatively flat. Because there are 40cm protective coal pillars on the left and right sides of the model, the roof subsidence in the range of 40cm on the left and right sides of the model is smaller than that in other areas. In the process of advancing the whole working face, the maximum roof subsidence reached 15.9mm, the maximum roof subsidence appeared at 75cm from the left boundary of the model frame, the minimum roof subsidence was 5.4mm, and the minimum roof subsidence appeared at 44cm from the left side of the model. The position is the protective coal pillar of the upper crossheading, which shows that the protective coal pillar can effectively reduce the roof subsidence. The minimum subsidence of the roof near the lower crossheading is 9.3mm, and the roof slides downward along the dip angle of the coal seam under the action of gravity. Therefore, although the lower crossheading has protective coal pillars, the subsidence value of the roof is still higher than that of the upper crossheading.

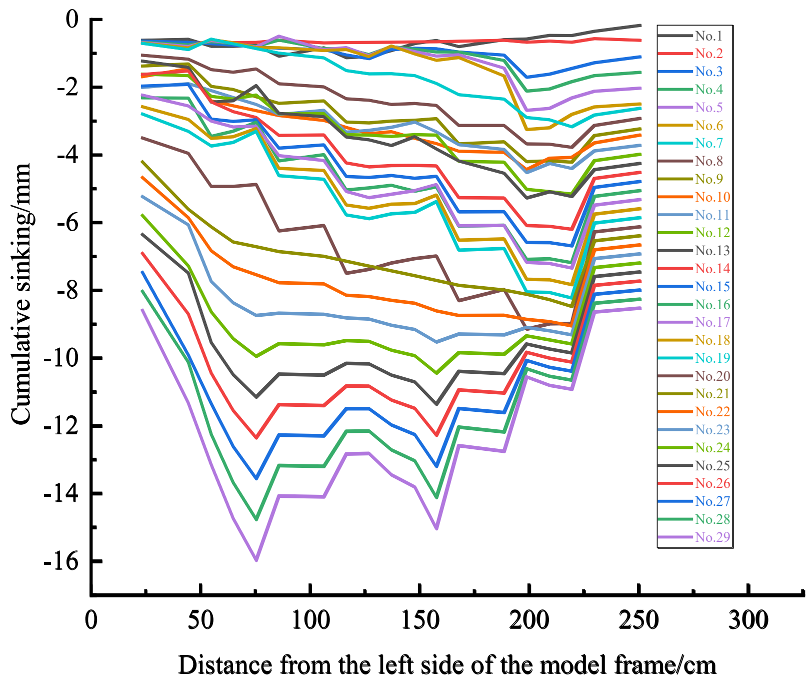

Figure 3. Cumulative subsidence curve of each excavation roof

4. Conclusion

(1) The cumulative maximum subsidence of the surface reached 5.4mm, the maximum subsidence value appeared at 73cm from the left side of the model frame, the minimum subsidence value of the surface was 4.7mm, and the minimum subsidence value appeared at 50mm from the left side of the model frame.

(2) The maximum roof subsidence reaches 15.9mm, the maximum roof subsidence occurs at 75cm from the left boundary of the model frame, the minimum roof subsidence is 5.4mm, and the minimum roof subsidence occurs at 44cm from the left boundary of the model frame.

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