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Model test of the overburden deformation and failure law in close distance multi-seam mining*

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Abstract Based on characteristic of the associated mining of multi-coal seam and the engineering geological characteristics of overburden, the mining impact pattern of multi-seam mining and the dynamic fracture mechanism of overburden were characterized by applying the engineering geological mechanical model test. The related strata movement parameters and influence area of multi-seam mining were obtained. the strike boundary angle is 61°, the full extraction coefficient is 0.93, the greatest subsidence angle is 81°, the horizontal movement factor is 0.38, the deviation of inflection point /mining deep is 0.11. The development height of caving zone and water flowing fractured zone of multi-seam mining were calculated, is 32 m and 81.5 m separatly. The assess of influence degree of coal layer safety mining is that, there exists the possibility of water and sand inflow when mining, some messures for mine water prevention and control should be used, and the mining thickness should be local strictly limit.

Keywords multi-seam mining, overburden failure, safety mining, engineering geological mechanical model

Introduction

In Sanjiao mine field of Shanxi Province, the No.4(No.3+No.4) and No.5 coal seams of Shanxi formation are the main coal seam for steady to mine. The interaction of different coal seams is increasingly severe. It increases the difficulty of the roadway maintenance, furthermore, in the process of fully-mechanized caving mining, the coal seam roof and floor are all mainly coal series sandstone and shale, that is, the sandstone aquifer composed the direct water-filling aquifer when mining, which is also a remarkable problem of the fully-mechanized caving mining in the area. Moreover, the overburden of the seams is composed with cracked sandstone, mudstone and coal series. It is different between the engneering geology character and the overburden failure property of this type of compositely structured overburden, which will be a advantage of groundwater hazard prevention and separated strata grouting to surface subsidence, but also may be a safety problems of mining [1,2]. Therefore, it has practical significance to determine the reasonable mine order and the arrangement of roadway that research the stress incidence of mining and the failure pattern and movement & deformation rules of overburden when mining up and below seams [3–5].

1 Geology and hydrogeology conditions

Sanjiao mine field is located in the western middle section of Luliang mountain. It is typical beam and mound loess hilly landform. The landform morphology could be divided into erosional landform and accumulation landform. The strata are of monoclinal structure in this region and from north to south with changing from westward dipping tendency to southwest. The tectonic deformation is very weak. There is no development faults and the fault throw

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does not exceed 2 m. The well-developed folds in the area is mainly broad and gentle small fold. The Jucaita graben is developed nearly east-west at the northern boundary of the area. The study area belongs to Liulin spring groundwater system, which belongs to stagnant zone.

The Shanxi formation of the middle series of Permian system is one of the main coal-bearing strata in the mining area. Its top is the K_4 sandstone of the middle Shihezi formation and its bottom is K_3 sandstone. The average depth is 40.30 m. The lithology contains greyish white and dark grey mudstone, black grey mudstone, and coal seams. The rock abundance of sandstone is about 31.94% and the pelite is about 58.64%. The coal-bearing strata distributes in the lower and middle part of the Shanxi formationin with containing 3~5 recoverable coal seams, which No.4 (or No.3+No.4) and No.5 coal seam are stable and recoverable main coal seam. The depth of the main workable coal beds is 4~8 m. This group is of the coal-bearing deposit of the terrigenous clastic sediment. The thickness variation of coal seam presents obvious rules. The general tendency is that, from north to south, thick seam changes into medium thick seam and thin seam. The coal seam roof is mainly mudstone, sandy mudstone and middle-fine sandstone. The coal seam floor is sandy mudstone and coarse clastic rocks.

The mine field is located in the northwest of Liulin spring-field. The main aquifer conditions of Shanxi formation coal seam roof are as follows.

(1) The Shanxi formation sandstone fissure confined aquifer of the middle series of Permian system is composed of K_3 and S_4~S_8 sandstone (Fig.1). The lithology is fine sandstone ~ gritstone. The lithology and thickness are all unstable. The sandstone has joints and fractures whose development is not uniform. When the formation was exposed by borehole, the water-level and water consumption has a little change. The units-inflow of pumping test is 0.002 76~0.034 7 L/(s•m). It shows that the water abundance is low.

(2) The Shihezi formation sandstone fissure confined aquifer of Permian system is composed of feldspar-quartz sandstone, quartz sandstone, siltstone, mudstone and sandy mudstone. Among them K_4 sandstone is relatively stable and its average thickness is 5.39 m. The sandstone fractures are developed. But most of fractures are packed with calcite veins and its openness and connectivity are worse. The water abundance is low for limit recharge conditions.

(3) The fractured aquifer of the bedrock weathering zone is the contact zone of different age bedrock and Quaternary. The formation is fragmental and well-developed fissure zones. Through the drillhole pumping test, the units-inflow was 0.036 L/(s•m) and the permeability coefficient was 0.006 8 m/d. The elevation of water level is about 857.85 m. It is showed HCO_3•Cl-K•Ca water type and low water abundance.

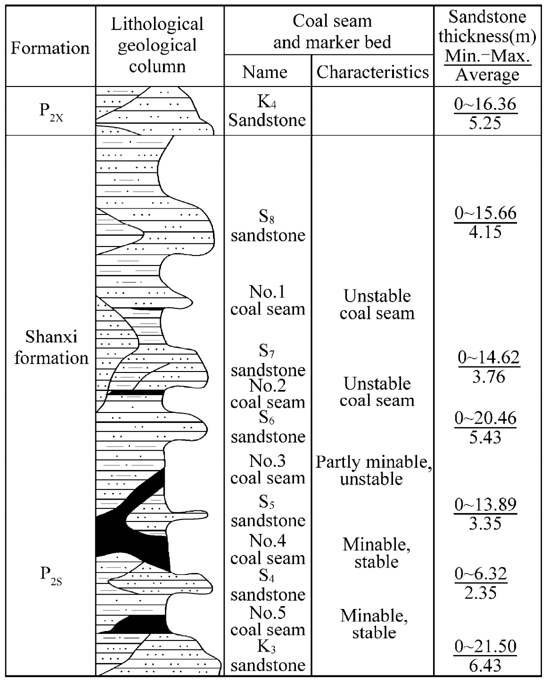

Fig.1 Sections of Shanxi formation coal seam

(4) The Quaternary alluvial-diluvial pore aquifer is composed of sand layer and sandy gravel. It is accepted mainly atmospheric precipitation penetrate and river seepage supply.

2 Engineering geological mechanical model test

2.1 Design and making of modle test

The engineering geological mechanical model test is a research method of special engineering geological state reduced scale through principle of similitude. The model needs consideration of some special geological structures, such as fault, joint, weak intercalation and so on. The essence of simulation on strata movement is that, based on the similarity principle, decrease the mine strata on certain scale, then modeled through simulating the multi fractured media rock mass with small block materials. Then the coal seams of model are simulated to mine according to the actual situation. The actual occurrence of rock and soil strata is analyzed and infered by observing the model strata movement, deformation and destruction induced by exploitation. The engineering geological mechanical model test in close distance multi-seam mining is based on the engineering geological and mining conditions of the mining area. The study of multi-seam mining, especially the influence of lower layer mining on upper layer mining and the overburden failure law of repeat mining, is the basis for preparation of the prediction method of overburden strata movement and deformation.

In this model experiment the target section is along the dip. The prototype of model is 600 m long and 300 m deep. The average buried depth is 264 m, the loose bed is 154 m thick, the overburden is 110 m thick, the No.4 (or No.3+No.4) coal seam is 4 m thick, the No.5 coal seam is 3 m thick, the average of coal seam interval is 6 m, which is on the base of drill column of engineering geological fabric. Fully mechanized sublevel caving mining according to the design mining sequence, firstly the No.4 coal seam was full mined, then the No.5 seam mined. The situation of overburden strata movement and deformation was observed after full mining upper and lower layers. The concrete parameters according to the similarity theories are provided in Table 1.

Table 1 Concrete parameters of engineering geological mechanical model

Scale	Mining method	Mining sequence	Model size	Mining height	Loading condition	Time factor	Unit weight factor	Mechanic similarity factor	Coal seam dip	Simulation direction
1/200	Fully mechanized sublevel caving mining	No.4 coal seam mining firstly, then No.5 seam	1.5 m×0.22 m×0.52 m	7 m	Deadweight and external force compensation	14.1	1.0	200	0°	Dip

When simulated bedrock, the structural body (dead weight) material used the river sand and barite powder as the aggregate, gypsum and glycerol as the cement. Because of the small density of the surface soil and coal seam, proper addition of coal powder and bentonite can reduce the density of the material. The proportioning test is the basic work of the structural body material simulation test of the engineering geological mechanical model. By repeating test on the structural body material specimen and mechanics character measurement, the material composition proportion was adjusted to reach the request of mechanics similarity.

The punctuation measurement method was used to observe the strata displacement in the model test. The punctuation was buried in the interlayer. So the displacement of the coal pillar and overlying strata of the mined-out area could be observed. As well as the interaction of each mining spaces in multi-seam mining area would be study.

With each coal seam working face mining, the stress and displacement distribution of the overlying strata would produce corresponding change. The progressive movement of the overlying strata would be analyzed by measuring the punctuation marks in the interlayer and their displacement change. Accordingly. Hereby, the movement and change law of the overlying strata would be studyed.

2.2 Model mining and observation

To explore the movement and failure law of the overlaying strata after multi-seam mining, the stress and failure condition of the rock and soil mass and each part of structure must be synthetically analyzed. According to the deformation and displacement distribution in the model, the main observation contents are as follows: the dynamic movement observation of the overlaying strata, the photographic observations and description of overburden failure and the developmental condition of the water flowing fractured zone above goaf.

After recording the initial reading data, we started to excavate and observe the model. The concrete sequence of excavation and observation was in accord with the actual mining sequence. Each excavation was completed, the corresponding measurement of dial indicator and the numeral camera measuring point would be taken once before and after the excavation. After completion of the multi-seam mining, the dial indicator was monitored sequentially and regularly.

The mode of deformation and failure in overlying strata movement is shown in Figs.2, 3.

3 Test results analysis

3.1 Overburden failure form of multi-seam mining

(1) Collapse. After each coal seam has been

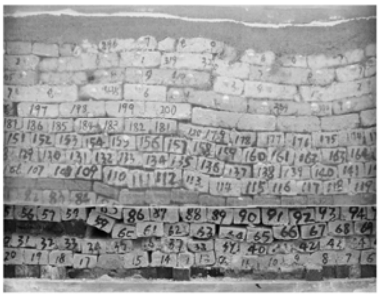

Fig.2 Overburden deformation and failure of 120 m **mining length in** No.4 **coal seam**

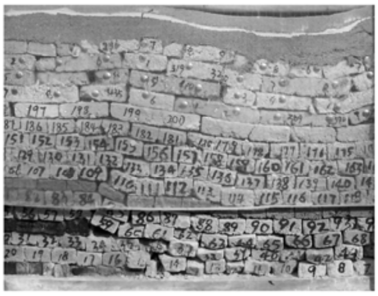

Fig.3 Overburden failure regularity of 120 m **mining length in** No.4 **coal seam and** 100 m **mining length in** No.5 **coal seam**

mined, the redistributed stress in roof strata exceed that of rockmass strength, then the rockmass cracked into block and break away from original rockmass. By measuring the model collapse height, after the No.4 coal seam has been mined, the height of caving zone is 7.0 cm (equal to the actual height of 14 m), which is 3.5 times of mining height. After the No.5 coal seam has been mined, the cumulative height of caving zone is 30.0 m.

From the photo observation during mining, it can be found that the cumulative height of failure and collapse above mined-out area is high when multi-seam mining. The main reason is that the two coal seam interval is short. After full mining, the mining width usually exceeds the first caving interval of the main roof. Otherwise, with the distortion range extending gradually, the height of collapse develops upwards. Until a certain stratum, when the tensile stress of the rock stratum is less than the allowable tensile strength of rock mass, this stratum will only take place subsidence, bending and bed separation. But the fracture failure of the stratum does not occur in the direction perpendicular to rock bedding plane. The whole continuity of strata will be kept.

(2) Bed separation. The height of bed separations changed with the mining range of work face. The bed separation was not found after No.4 coal seam full mining. When No.5 coal seam was mined, the bed separation began to develop gradually. The height and length of the bed separation showed the dynamic variation characteristics of opening and closing with mining. When the bed separation developed to the bottom of hard rock, it didn't develop upwards, the height and length of the bed separation didn't change any more because the support of hard rock. With the expanded range of mine-out areas, the bed separation level ran up continuously, and lengthened, many strata have been separated from overburden. The highest fracture height of the bed separation is 1.8 m among No.5 coal seam mining, which is located at the bottom of 15 m thick fine silty sandstone and the distance from No.4 coal seam is 80 m. When the mined-out area reached larger area under fully mechanized caving condition, the bed separation duration was short or not produce.

(3) Interlayer sliding. Took place in the interface of different rock or in weak plane. Because the structural body gravity action of each layer or the different direction and size of horizontal movement of adjacent terrane, it was to make the bedding surface or the strata on both sides of interlayer weakness zone to produce relative slip. With the development of crack in bed seperation, there are obvious interlayer sliding among the interstrata.

(4) Shear failure and plastical deformation. Mainly happened in weak strata. The repeat shear failure is mostly appeared, which take placed along the inhere fissure. It was showed from the model pictures that the immediate roof generated “V” and “\” failure.

3.2 Movement of the rock and soil layers

The uncollapse strata separated from the layer surface in prosess of subsidence. There are unelastic contact in each layer surface. Though the separated strata will close finally, it may be dislocated in the layer direction. When the separated strata developed to a certain height, the range of deformation in the strata expanded furtherly. The deformation consentration reduce, which make the layer be elastic contacted with top rockmass. The strata would be subsidented with integral deformation.

When the working face of No.5 coal seam reached a certain distance (about 45 m) from open-off cut, the strata movement began to affect the upper coal seam. With the working face advancing continuously, the overlying strata movement basin developed forward. When full mining (the size of working face is about 100 m), the subsidence of overlying strata reached the maximum. The subsidence distribution and horizontal deformation characteristics in rock strata after multi-coal seam mining are shown in Fig.4.

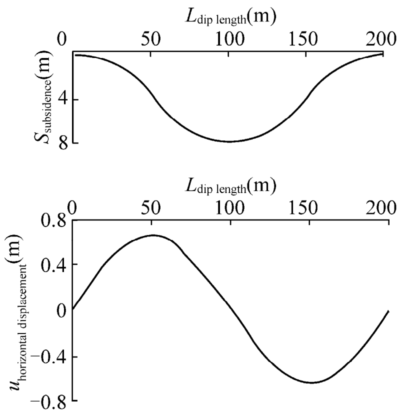

Fig.4 The subsidence distribution in rock strata after multi-coal seam mining

From the engineering geological mechanics model, following the increase of the distance away from mining area, the strata bending range increased gradually and the curvature decreased. The strata gradually trended towards gentleness and formed a single subsidence basin. The related strata movement parameters were calculated: the strike boundary angle is 61°, the full extraction coefficient is 0.93, the greatest subsidence angle is 81°, the horizontal movement factor is 0.38, the deviation of inflection point /mining deep is 0.11. The overburden caving zone height of No.5 coal seam is 32 m. The vertical displacement of strata rapidly increased. The development height of water flowing fractured zone reached the weathering zone. There was the appearance of the bed separation.

4 Conclusions

The characteristics and laws of deformation and failure in overlying strata movement were revealed by applying the engineering geological mechanical model test. The development height of caving zone and water flowing fractured zone of multi-seam mining were calculated, is 32 m and 81.5 m separatly. Meanwhile, the height of water flowing fractured zone would touch the weathering zone and the bottom aquifer of Quaternary system in various degree. So the assess of influence degree of coal layer safety mining is that, there exists the possibility of water and sand inflow when mining, some messures for mine water prevention and control should be used, and the mining thickness should be local strictly limit.

References

[1] 张改玲, 董青红, 隋旺华, 等. 红层与煤系复合结构覆岩采动破坏分析及其应用[J]. 工程地质学报, 2004, 12(1): 41−44.
Zhang Gailing, Dong Qinghong, Sui Wanghua, et al. An analysis of the failure of the compositely structured overburden with red strata and coal beds and its application[J]. Journal of Engineering Geology, 2004, 12(1): 41−44.

[2] 李全生, 张忠温, 南培珠. 多煤层开采相互采动的影响规律[J]. 煤炭学报, 2006, 31(4): 425−428.
Li Quansheng, Zhang Zhongwen, Nan Peizhu. Mining impact pattern of mutil-coal seam[J]. Journal of China Coal Society, 2006, 31(4): 425−428.

[3] 康全玉, 刘明举, 李化敏, 等. 多煤层采区岩层移动相似材料的模拟研究[J]. 焦作工学院学报, 1999, 18(2): 118−121.
Kang Quanyu, Liu Mingju, Li Huamin, et al. Similar material analog study of strata movement in multiple seam[J]. Journal of Jiaozuo Institute of Technology, 1999, 18(2): 118−121.

[4] Khare Saurabh, Rao Y V, Murthy Ch S N, et al. Multiple seam mining: A critical review[J]. Journal of Mines, Metals and Fuels, 2006, 54(12): 327−329.

[5] Charlotte A Nuttall, Paul L Younger. Hydrochemical stratification in flooded underground mines: an overlooked pitfall[J]. Journal of Contaminant Hydrology. 2004, 69: 101−114.