Study on response of water-table aquifer under shallow, deep and high-intensity exploitation

SUN Xueyang[1,2] , LIU Ziqiang[2],LI Cheng[1,3], LIU Liangdong[2],KOU Guigui[2],LI Pengqiang[2]

(1.Key Laboratory of Mine Geological Hazards mechanism and Control,Shaanxi Institute of Geological Survey,710054,China;2.Xi'an University of Science and Technology, School of Geology and Environment, Xi'an 710054, China;3.Geological Survey Center of Shaanxi Institute of Geological Survey,710054,China)

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Abstract: The depth of coal seam buried in Yushenfu mining area is shallow, and there is inevitable contradiction between the mining activities of high strength coal seam and the protection of aquifers. Therefore, it is very important to study aquifer's response law to coal seam mining for scientific mining of coal seam in this area. Therefore, based on the present situation of 5201 working face of a mine in Shenfu mining area, this paper will study the variation law of aquifer when the mining height is 6m and the width of working face is 100m by using FLAC3D solid-liquid coupling numerical simulation method.The results show that :The maximum response range of aquifer in the inclination direction and trending direction is 393m and 964m respectively, and the maximum water level is drop 7.7m.

INTRODUCTION

The environmental protection of Jurassic coal field in Northern Shaanxi attracts much attention for the shallowly buried coal seam and fragile surface ecological environment. Once the coal mining causes the seepage and drop of the water level of the aquifer of Salawusu group, it will have a huge and irreversible impact on the ecological environment of the surface[1-3].Rational utilization of Yushenfu groundwater resources，located on the edge of the Maowusu desert, poor groundwater resources, is the key to coalfield development. The groundwater in the Salawusu group in this area is a reliable water supply base and a source of severe deterioration of the engineering geological conditions as well as a major hazard to the mine shaft abandonment and submerged equipment caused by quicksand collapse into the mine.Therefore, in this paper, the influence law of coal mining activity on the aquifer is researched by numerical simulation when the mining thickness is 6m and the width of working face is 100m, which will provide guidance for the green mining of coal resources in Shenfu Mining Area.

EXPERIMENTAL DESIGN

During the design of the model, 300m protection coal pillars are reserved for each boundary, therefore,the final size of the model is: length × width × height = 1200m × 700m × 243m, in which the thickness of coal seam is 6m, the thickness of coal seam floor is 8m, the thickness of aquifer is

8m and aquifer from the surface is 8m.The pore water pressure is applied to the aquifer,which are submersible aquifers, according to the gradient of 1×10^4pa/m. The pore water pressure at the bottom of the aquifer is 8×104pa, and the pore water pressure at the top is 0Pa. Cell division: The horizontal cell division specifications for the 20m×20m.And in the vertical direction, the division height be controlled at 15m ~ 20m depending on the thickness of the rock layer,which ensures the uniformity of model meshing. Experimental model shown in Fig.1. On the other hand, in order to more accurately simulate the variation law of aquifers after mining, the grid change ratio of loess layer below the aquifer is set to 0.8 to raise the aquifer water level Decrease depth of precision especially. During the simulation process, the pore water pressure will change when water is filled in the rock formation. So, the pore water pressure increase zone is taken as the judgment basis for the water level drop of the aquifer. Excavation process each step forward 60m, calculated 1500 times, 10 minutes to complete the excavation process. Excavation process is divided into 10 steps to complete, each step pushing forward 60m and calculated 1500 times.

Table 1. Numerical experiment generalization model of physical and mechanical parameters of coal and rock

Sequence	Lithology	Strata thickness （m）	Bulk density （KN/m^3）	Elasticity Modulus （MPa）	Compressive strength （MPa）	internal friction angle （°）	Poisson ratio	Cohesive （MPa）
1	drift-sand	8	19.2	69	0.8	30	0.31	0.069
2	Aquifer	8	19.2	69	0.8	30	0.31	0.069
3	Loess	51	16.86	1000	1.59	30.9	0.31	0.069
4	laterite	33	18.23	800	2.12	30.5	0.35	0.086
5	Sandstone	21	24.6	4000	30.0	42	0.19	3.27
6	mudstone	15	24.89	1000	20.0	28	0.13	5.8
7	Sandstone	11	24.6	4000	30.0	42	0.19	3.27
8	mudstone	1	24.89	1000	20.0	28	0.13	5.8
9	Sandstone	31	24.6	4000	30.0	42	0.19	3.27
10	Feldspar quartz sandstone	27	24.89	1000	20.0	28	0.13	5.8
11	pelitic siltstone	2	25.2	4300	74.5	43	0.18	3.67
12	mudstone	6	24.89	1000	20.0	28	0.13	5.8
13	Fine grained	16	25.0	6000	87.6	42	0.19	3.27
14	caol	5	13.5	1000	24.5	38	0.28	2.13
15	pelitic siltstone	8	25.2	4300	74.5	43	0.18	3.67

Table 2. rock stratum hydrologic parameters of numerical experiment generalizing model

lithology	**Permeability （cm/s）**	**Po rosity**	lithology	**Permeability （cm/s）**	**porosity**
drift-sand		0.3	Sandstone	1.3e-6	0.05
Aquifer	2.7e-3	0.4	Feldspar quartz sandstone	5.0e-9	0.09
Loess	8.4e-5	0.096	pelitic siltstone	2.3e-6	0.077
laterite	1.4e-6	0.103	mudstone	1.08e-9	0.05
Sandstone	1.3e-6	0.05	Fine grained sandstone	2.3e-6	0.081
mudstone	1.08e-9	0.05	caol	8.8e-6	0.07
Sandstone	1.3e-6	0.05	pelitic siltstone	2.3e-6	0.077
mudstone	1.08e-9	0.05			

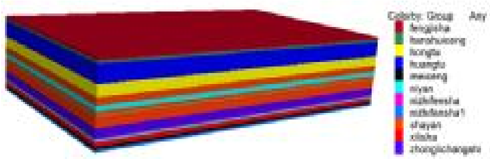
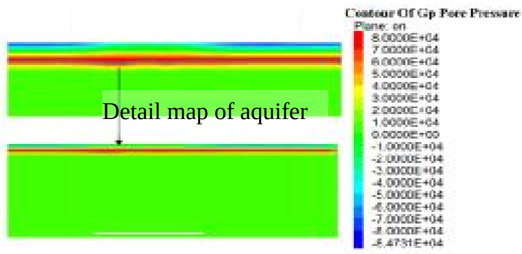


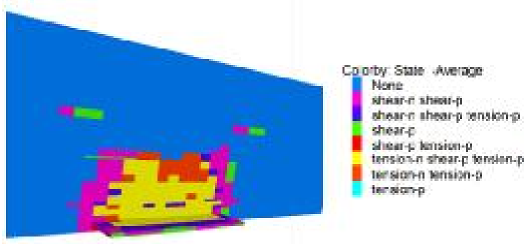
Fig.1. FLAC3D numerical simulation model diagram

EXPERIMENTAL SIMULATION

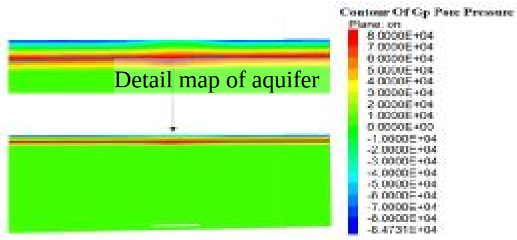
When the working face is advanced to 240m, the pore water pressure and the development of water flowing fractured zone are shown in Fig.2. The height of the plastic zone is 92m, getting the propotion of water flowing fractured zone height and caving thickness is 15.3. At this time, the distribution range of high pore water pressure in aquifers just above the goaf has been expanded in the vertical direction vertical. Based on this analysis, when the excavation started from 180m to 240m, the aquifer began to be impacted. By analyzing the Fig.2a, the area with high pore water pressure concentration is located directly above the working face and the influence length is from 92m in front of the working face to 329m behind the working face. that is the influence length on the trending direction of coal mining face is 461m. In the inclination direction of the the working face, the center position of the section analysis is made by the high pore water pressure concentrated area (section shown in Fig.2c). The total length of influence range is 173m.In the process of simulation, the pore water pressure in aquifers is a fixed value. When monitoring water level, 70000Pa pore water pressure isosurface is selected as the reference level of water level monitoring. Based on that, the maximum drawdown value of water level is 1.02m.



a. Pore water pressure distribution



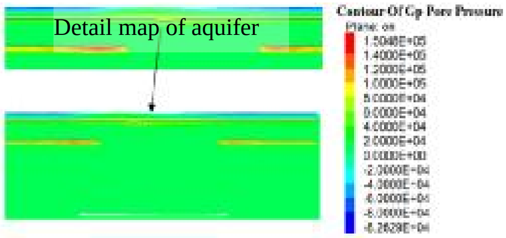
b. Plastic zone distribution



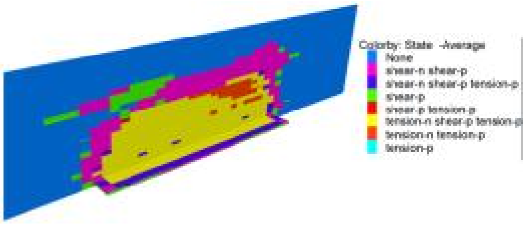
c. Distribution diagram of pore water pressure in inclination direction

Fig.2 The pore water pressure and the plastic zone distribution map of the working face pushed to 240m

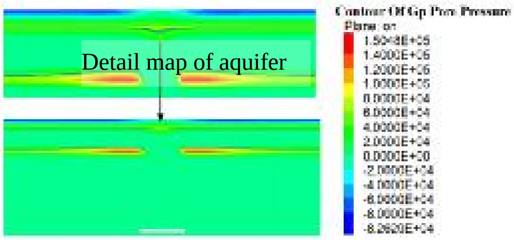
When the working face is pushed to 480m, the pore water pressure and the development of water flowing fractured zone are shown in Fig.3. The development height of the plastic zone is 162.0m, and the propotion of water flowing fractured zone height and caving thickness is 27. The image can be observed that the water flowing fractured zone is close to the aquifer. At the same time, the loess layer under the bottom of aquifer also produced the pore water pressure distribution both sides of Open-off cut and working face. The center position of the high pore water pressure concentrated area of aquifer is located to the near side of the working face. And the length of influence is 204.6m in front of the working face to 636.0m behind working face. Namely, the length of impact on the trending direction is 840.6m. The high pore water pressure area, in loess layer, is located at the rear of working face 100m to 65m in front of working face (namely,the total length is 165m), and 28m behind Open-off cut (Goaf side) to 92m in front of Open-off cut (namely,the total length 120m), which is connected with the aquifer. In the inclination direction of the the working face, the center position of the section analysis is made by the high pore water pressure concentrated area(section shown in Fig.3c). According to the analysis of figure, the response range of pore water pressure to coal seam mining extends 196m and 187m from the center to the sides of the working face, and the distribution tends to be symmetrical with the total impact length of 383m. According to the analysis of the 70000Pa pore water pressure equivalent surface, the maximum drop depth of the water level is 4.9m. The distance, between the high pore water pressure of the loess layer bottom and the 70000Pa pore water pressure equivalent surface, is 50.17m. After further comparative analysis, because mining impact on the overlying soil layer had a disturbance, changing its permeability, to increase the permeation amount of the aquifer of Salawusu group, and cause the water level further reduce.



a. Pore water pressure distribution



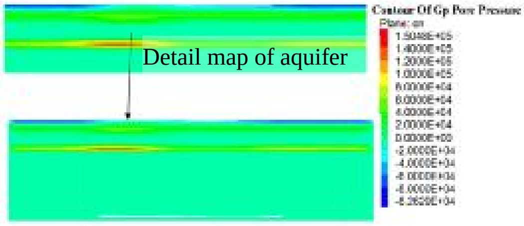
b. Plastic zone distribution



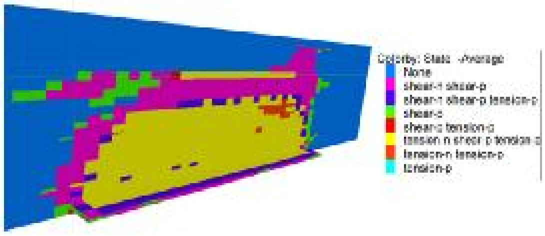
c. Distribution diagram of pore water pressure in inclination direction

Fig.3 The pore water pressure and the plastic zone distribution map of the working face to 480m

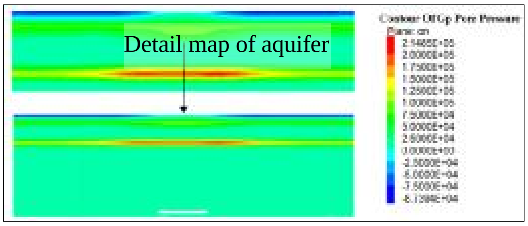
When the working face is advanced to 600m, the pore water pressure and the development of water flowing fractured zone are shown in Fig.4. The development height of the plastic zone is 164.0m, and the propotion of water flowing fractured zone height and caving thickness is 27.3. It is found by comparison that the height of the plastic zone has stabilized. The high pore water pressure zone still occurs directly above the mining face at the bottom of the loess layer, affecting 208m in front of the working face and 206.9m behind the working face, which the total length in the trending direction of working face is 414.9m. The change trend of water level in aquifer is the same as that of the high pore water pressure at the bottom of loess layer. The 70000Pa pore water pressure isosurface had a "concave shape" increase above the mining face, and the water level drop value of the aquifer was judged to be 7.7m. In the inclination direction of the the working face, the center position of the section analysis is made by the high pore water pressure concentrated area(section shown in Fig.3c). From the diagram analysis, the response range of pore water pressure to the coal seam mining is 198m and 195m from the center to the both sides of the working face. Compared with the excavation to 480m, the influence of coal mining on the SalaWusu aquifer has stabilized.



a. Pore water pressure distribution



b. Plastic zone distribution



c. Distribution diagram of pore water pressure in inclination direction

Fig.4 The pore water pressure and the plastic zone distribution map of the working face to 600m

CONCLUSION

1. When the thickness of coal seam is 6m and the width of working face is 100m, the maximum height of water flowing fractured zone development is 164.0m, the propotion of water flowing fractured zone height and caving thickness is 27.3.And the water flowing fractured zone is not conductive in aquifer. When the working face is pushed to 480m,the plastic zone tends to be stable.
2. When the coal seam is mined to 180m, the influence on the aquifer is not obvious; the pore water pressure is basically distributed in the aquifer.
3. When the coal seam is mined to 240m, pore water pressure began to show a "concave shape" growth model. The lowest point of the "concave shape " type moves along with the working face moves forward. When the working face is mined to 600m, the value of the lower concavity reaches the maximum of 7.7m.
4. In the inclination direction of the working face, the area of the aquifer affected by the coal mining

trend to be stable when the working face is pushed to the 480m, and the impact range of the excavation to 600m is 393m. In the trending direction of the working face, the influence range of coal mining on aquifer is increasing along with the continuous advancing of coal mining face. The influence range is 208m in front of working face to 156m front of Open-off cut, and the total length is 964m.

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REFERENCES

[1]FAN Li-min,MA Xiong-de,JI Rui-jun.Progress in engineering practice of water-preserved coal mining in western eco-environment frangible area[J]. Journal of China Coal Society, 2015, 40(8):1711-1717.

[2]WANG Shuang-ming, FAN Li-min,MA Xiong-de. Coal development and ecological water level protection in ecological fragile area [J]. China Mining Magazine, 2010(19):212-216.

[3] Ma Xiongde，Fan Limin，Zhang Xiaotuan，et al． Driving force analysis for water and wetlands evolution at Yushenfu mining area［J］． Journal of China Coal Society，2015，40(5) : 1126-1133．

[4] MA Liqiang，ZHANG Dongsheng，Qiao Jinli, et al.. Physical simulation of water crack distribution characteristics in overlying strata under coal mining conditions [J]. Journal of Liaoning Technical University（Natural Science）,2008,27(5):649-652.

[5] Ju Jinfeng，Xu Jialin，Zhu Weibing． Storage capacity of underground reservoir in the Chinese western water-short coalfield [J]． Journal of China Coal Society，2017，42(2) : 381 － 387．