

Numerical Simulation Study on The Ultimate Water Head of Artificial Dam in Coal Mine Underground Reservoir

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Abstract: In order to improve the problem of low utilization rate of groundwater in the process of coal mine production, some mining areas in northwest China use the goaf of the working face as a water storage space, and establish underground reservoirs to realize water retention mining. In order to solve the problem of the stability of the artificial dam of the underground reservoir, this paper takes the underground reservoir of the 51103 working face of Guojiawan Coal Mine as the engineering background, and uses the FLAC3D numerical simulation software to establish the artificial dam model, and the experimental results show that when the head height is 26m, the maximum tensile stress inside the dam is 1.264MPa, which is still lower than the limit of the tensile strength of the concrete, until the water pressure increases to 27m, the maximum tensile stress inside the dam is 1.290MPa, which is greater than the limit of the tensile strength of the concrete, so the ultimate head height of the artificial dam is 26m.

Keywords: Underground reservoirs; artificial dams; numerical simulation.

1. Introduction

China is a country with coal as the main energy source, and coal accounted for 57.7~63.8% of China's total energy consumption in 2015~2019. In the process of coal mining, the cracks of the roof gradually develop under the influence of mining, which conducts the aquifer and produces a large amount of mine water, resulting in a serious waste of groundwater resources. According to statistics, the amount of groundwater resources wasted in the coal mine production process in China reaches about 8 billion tons every year, and the effective utilization rate is only about 25%.^[1] With the gradual depletion of coal resources in the central and eastern parts of China, the focus of the development of China's coal resources has gradually shifted to the west. However, the climate in the western part of China is dry, the precipitation is small, and the evaporation is much greater than the precipitation, and the discharge of mine water to the surface will cause a large evaporation loss. This makes the contradiction between the development of coal resources and the shortage of water resources in the western region particularly prominent^[2]. In this regard, Academician Gu Dazhao proposed a coal mine underground reservoir with "guiding and storing use" as the core, using the goaf to store groundwater resources^[2,3]. After reviewing the relevant literature, it is found that there are few studies on the stability of artificial dams in underground reservoirs, and the stability of concrete structures is mostly focused on the stability analysis of surface reservoir dams^[4-6]. Chen yang^[7] The seepage field around the dam was simulated by a combination of numerical simulation and similar experiments, and the seepage flow around the dam was calculated. Zhang Guoen et al^[8] Through numerical simulation and other research methods, the stress of artificial retaining dams was studied. Fang Jie^[9] Through the combination of theoretical derivation, similar model experiments and numerical simulation, the stress-strain law and failure mode of the artificial dam under the action of water pressure are studied, and the seepage law

of the artificial dam and the trench site are summarized, and the comprehensive evaluation criteria for the stability of the artificial dam are summarized and analyzed according to the research results. Bai Dongyao et al^[10] Through numerical model and theoretical analysis, the vulnerable position and maximum bearing capacity of the artificial dam of the underground reservoir of Lijiahao Coal Mine under the action of water pressure were studied. Fan Fan et al^[11] The influence of confining pressure on the stability of artificial dam was studied by using FLAC3D numerical simulation software, and the results showed that low confining pressure could effectively improve the stability of the dam, but high confining pressure would promote the failure of the artificial dam. Zhi Guojun^[12] Based on the shallow burial and large mining height working face in Shendong mining area, FLAC3D numerical simulation software was used to study the development and displacement of the plastic zone of the artificial dam excavation part, and the trenching parameters of the artificial dam in Shendong mining area were reasonably designed.

2. Engineering Background

Guojiawan Jingtian is located in the northernmost part of the Loess Plateau in the northern part of Shaanxi Province, close to the Mu Us Desert on the west side, and the landform is a typical loess hilly and gully wind-sand landform, with fragile ecological environment and simple geological structure. The Guojiawan Coal Mine plans to use the goaf of the 51103 working face located in the southwest corner of the mine area as a water storage space, and use it for sewage purification, storage and water supply. The plan of the 51103 working face is shown in Figure 1, and a liaison roadway is arranged every 50m on the coal pillar of the working face section, and artificial sealing construction needs to be carried out, and the artificial dam of the underground reservoir is constructed to prevent the reservoir water from pouring into the adjacent working face through the liaison lane, and the drainage pressure of the adjacent working face is increased.

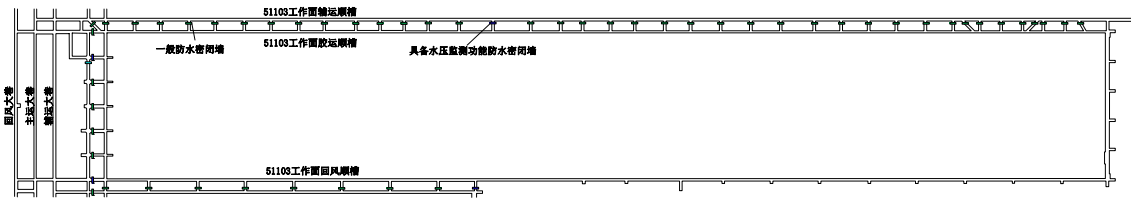


Figure 1. Schematic Diagram Of 51103 Working Face

3. Numerical Simulation

3.1. Model building

The numerical model of the artificial dam of the underground reservoir is also based on the geological conditions of the 51103 working face of Guojiawan Coal Mine in Yulin City, Shaanxi Province, with a coal seam thickness of 3m and an average buried depth of 120m, and a coarse sandstone with a thickness of 1.4m for the roof lithology. The bottom plate is mainly siltstone, with a

thickness of 11m, light gray, gray-black, argillaceous cementation, rich plant fossils, mixed with fine-grained sandstone bands, and a thin layer of medium-grained sandstone in the middle. The specific surrounding rock parameters are shown in Table 1. The cross-section of the roadway between the two working faces on the coal pillar is 5m wide and 3m high. The main structure of the artificial dam is a concrete wall, which needs to be excavated 0.5m in the surrounding rock, that is, the size of the dam is 6m wide and 4m high.

Table 1. Parameters of surrounding rock of artificial dam

Rocks Name	Thickness /m	Density /(kg·m ⁻³)	Elastic modulus quantity /GPa	Poisson ratio	Cohesion /MPa	Internal friction angle /°	Compressive strength /MPa	Tensile strength /MPa
siltstone	9.6	2650	5.8	0.24	2.0	34	29.4	1.8
grit stone	1.4	2600	5.2	0.28	1.8	32	26.4	1.5
coal rock	3	1430	3.0	0.30	1.0	30	15.8	0.8
siltstone	11	2650	5.8	0.24	2.0	34	29.4	1.8
concrete wall		2500	20	0.20	5.0	38	25	1.78

In order to ensure the accuracy of the calculation and improve the calculation speed, the size of the model is 36m, the height is 28m, and the depth of the roadway is 11m, and the grid of the area where the artificial dam is located is encrypted. Figure 2 shows that the model is siltstone, coarse sandstone, coal rock, and siltstone from top to bottom.

After the model is established, 3.1MPa vertical stress is applied to the upper part to replace the overlying rock layer load, a fixed boundary is set at the bottom of the model, and the fixed normal displacement boundary conditions are used on all four sides.

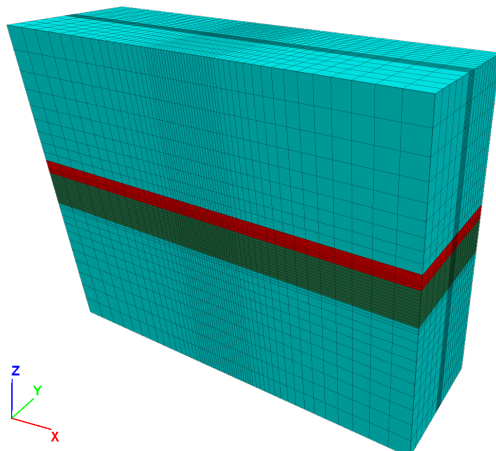


Figure 2. Numerical simulation model of artificial dam

The constitutive model selects the Moore-Coulomb model, which conforms to the actual situation and can achieve better simulation results. After the model is established, the excavation support of the roadway and the concrete wall of the artificial dam are arranged, and the water pressure is

applied on one side of the artificial dam, and the structure of the roadway and the concrete wall is shown in Figure 3 and Figure 4.

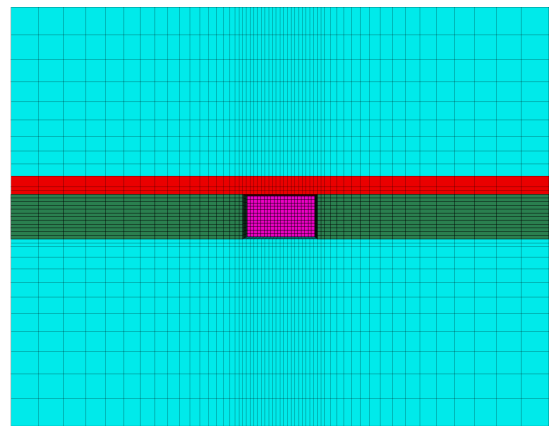


Figure 3. Excavation of the roadway and the establishment of the artificial dam

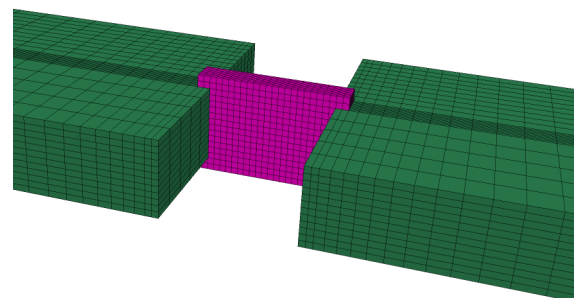


Figure 4. Schematic diagram of artificial dam and trench site

In this experiment, we aim to study the influence of different concrete wall thicknesses and different head heights on the artificial dam to carry out a reasonable design analysis of the artificial dam.

3.2. Numerical simulation results are analyzed

Fig. 5 is the minimum principal stress contour of the dam

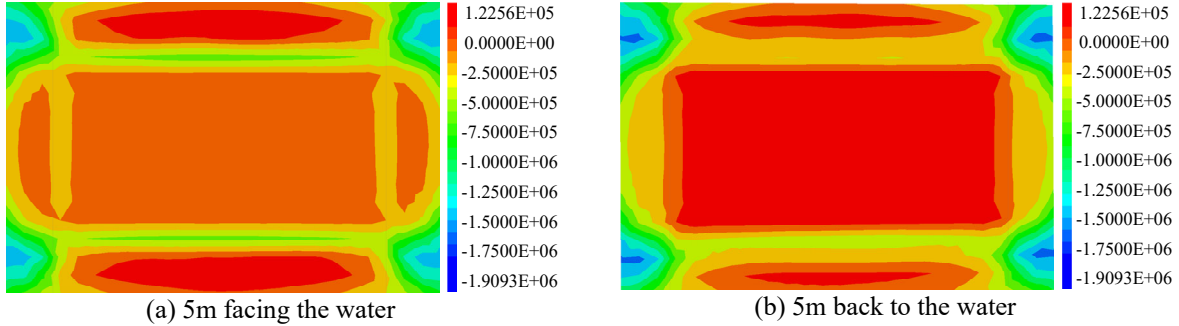


Figure 5. Diagram of the minimum principal stress of the dam at 5m water level

According to the Code for Concrete Structure Design GB50010-2010, the design value of tensile strength of C25 concrete material is 1.270MPa, and the design value of compressive strength is 11.900MPa. As shown in Figure 6, the minimum principal stress contour of the dam when the head height is 10m, it can be seen from the figure that when the water level height reaches 10m, the maximum tensile stress of the facing surface is still mainly distributed in the surrounding trench area, wherein the tensile stress of the roof trench is the largest and the dam is the largest. The center of

when the head is 5m, it can be seen from the figure that the maximum tensile stress inside the dam is mainly distributed in the four grooves of the dam headfront and the middle area of the backwater surface, wherein the maximum tensile stress of the headwater surface is located at the roof groove. As can be seen from the figure, the compressive stress of the dam is mainly distributed at the four corners of the dam.

the backwater surface is a tensile stress concentration area, which is generally circular, and gradually develops to a square in all directions, and the main compressive stress is still concentrated at the four corners of the dam. It can be seen from the numerical values that when the head height is 10m, the maximum tensile stress is 0.486MPa, which is less than the material strength limit, and according to the minimum principal stress analysis, when the head height reaches 10m, the dam still remains safe and stable.

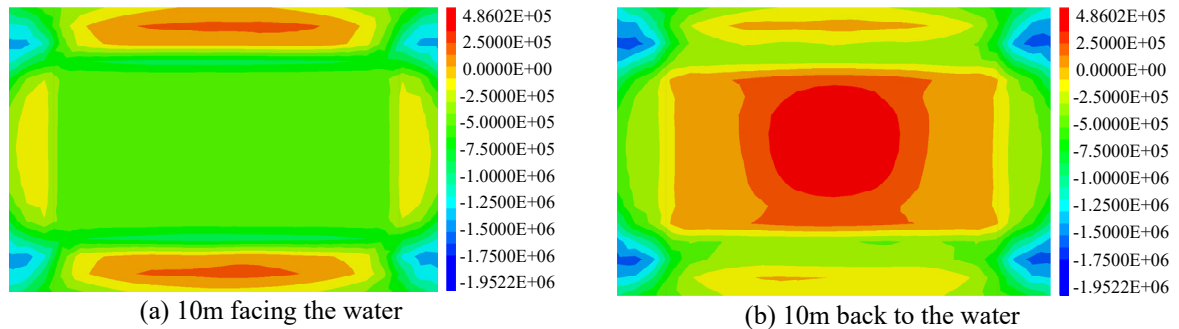


Figure 6. Diagram of the minimum principal stress of the dam at 10m water level

In order to explore the ultimate head height that the artificial dam can bear, continue to increase the water pressure, as shown in Figure 7a, when the head height is 26m, the maximum tensile stress inside the dam is 1.264MPa, which is still lower than the concrete tensile strength limit, as shown in

Figure 7b, until the water pressure increases to 27m, the maximum tensile stress inside the dam is 1.290MPa, which is greater than the concrete tensile strength limit, so the ultimate head height that the artificial dam can withstand is 26m.

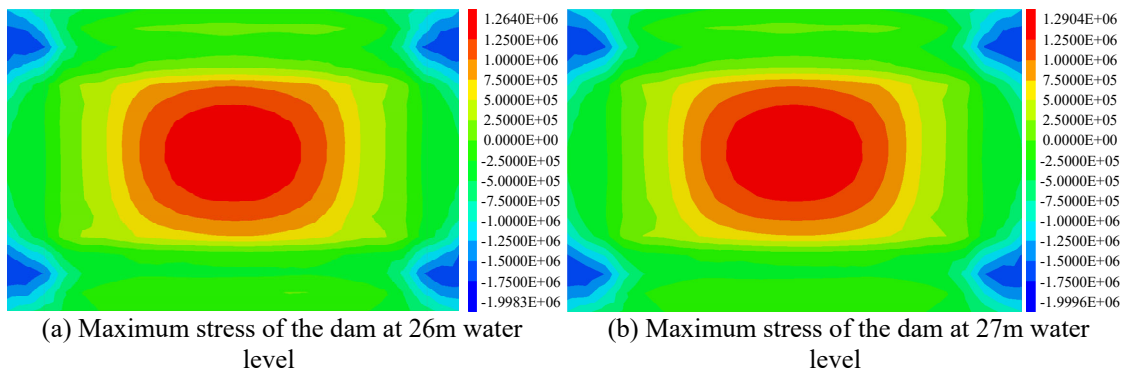


Figure 7. Maximum principal stress contour of artificial dam at 26m to 27m water level

4. Conclusion

The results show that when the head height is 26m, the maximum tensile stress inside the dam is 1.264MPa, which is still lower than the limit of concrete tensile strength, until the water pressure increases to 27m, the maximum tensile stress inside the dam is 1.290MPa, which is greater than the limit of concrete tensile strength, so the ultimate head height of the artificial dam is 26m. The results are similar to the theoretical calculations.

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